HOLT

Physics

Solutions Manual

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Holt Physics

Teacher's Solutions Manual

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Student Edition Solutions

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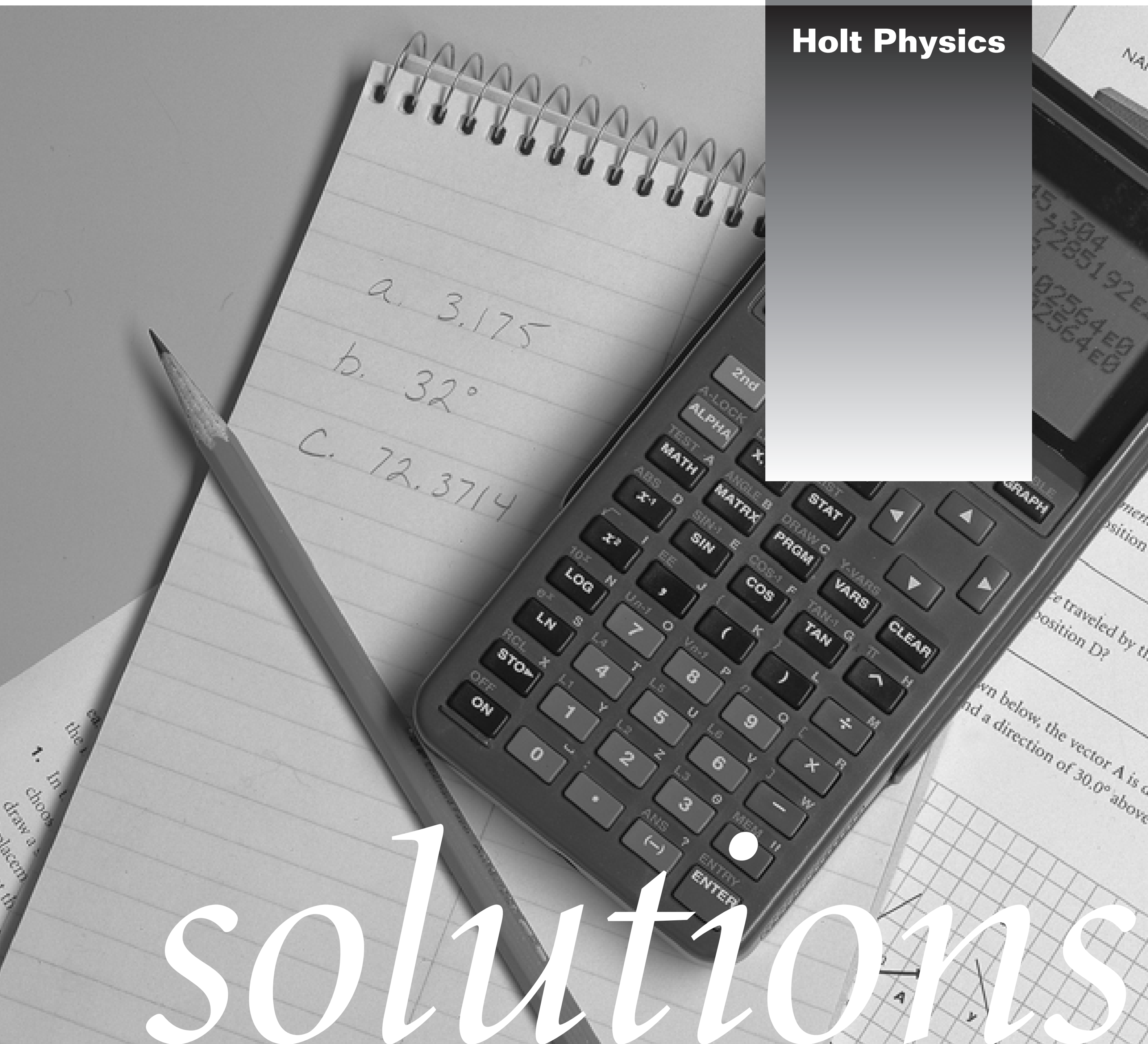
Holt Physics



solutions

The Science of Physics

The Science of Physics, Practice A

Givens	*Solutions*
1. diameter = 50 μm	$50\ \cancel{\mu m} \times \dfrac{1 \times 10^{-6}\ m}{1\ \cancel{\mu m}} = \boxed{5 \times 10^{-5}\ m}$
2. period = 1 μs	$1\ \cancel{\mu s} \times \dfrac{1 \times 10^{-6}\ s}{1\ \cancel{\mu s}} = \boxed{1 \times 10^{-6}\ s}$
3. diameter = 10 nm	**a.** $10\ \cancel{nm} \times \dfrac{1 \times 10^{-9}\ m}{1\ \cancel{nm}} = \boxed{1 \times 10^{-8}\ m}$
	b. $1 \times 10^{-8}\ \cancel{m} \times \dfrac{1\ mm}{1 \times 10^{-3}\ \cancel{m}} = \boxed{1 \times 10^{-5}\ mm}$
	c. $1 \times 10^{-8}\ \cancel{m} \times \dfrac{1\ \mu m}{1 \times 10^{-6}\ \cancel{m}} = \boxed{1 \times 10^{-2}\ \mu m}$
4. distance = 1.5×10^{11} m	$1.5 \times 10^{11}\ \cancel{m} \times \dfrac{1\ Tm}{1 \times 10^{12}\ \cancel{m}} = \boxed{1.5 \times 10^{-1}\ Tm}$
	$1.5 \times 10^{11}\ \cancel{m} \times \dfrac{1\ km}{1 \times 10^{3}\ \cancel{m}} = \boxed{1.5 \times 10^{8}\ km}$
5. mass = 1.440×10^{6} g	$1.440 \times 10^{6}\ \cancel{g} \times \dfrac{1\ kg}{1 \times 10^{3}\ \cancel{g}} = \boxed{1.440 \times 10^{3}\ kg}$

The Science of Physics, Section 2 Review

2. mass = 6.20 mg	**a.** $6.20\ \cancel{mg} \times \dfrac{1 \times 10^{-3}\ \cancel{g}}{1\ \cancel{mg}} \times \dfrac{1\ kg}{1 \times 10^{3}\ \cancel{g}} = \boxed{6.20 \times 10^{-6}\ kg}$
time = 3×10^{-9} s	**b.** $3 \times 10^{-9}\ \cancel{s} \times \dfrac{1\ ms}{1 \times 10^{-3}\ \cancel{s}} = \boxed{3 \times 10^{-6}\ ms}$
distance = 88.0 km	**c.** $88.0\ \cancel{km} \times \dfrac{1 \times 10^{3}\ m}{1\ \cancel{km}} = \boxed{8.80 \times 10^{4}\ m}$
3.	**a.** $26 \times 0.02584 = 0.67184 = \boxed{0.67}$
	b. $15.3 \div 1.1 = 13.90909091 = \boxed{14}$
	c. $782.45 - 3.5328 = 778.9172 = \boxed{778.92}$
	d. $63.258 + 734.2 = 797.458 = \boxed{797.5}$

I

Givens	*Solutions*
11. 2 dm	**a.** $2\ \cancel{\text{dm}} \times \frac{1\times10^{-1}\ \cancel{\text{m}}}{1\ \cancel{\text{dm}}} \times \frac{1\ \text{mm}}{1\times10^{-3}\ \cancel{\text{m}}} = \boxed{2\times10^{2}\ \text{mm}}$
2 h 10 min	**b.** $2\ \cancel{\text{h}} \times \frac{60\ \text{min}}{1\ \cancel{\text{h}}} = 120\ \text{min}$
	$120\ \text{min} + 10\ \text{min} = 130\ \text{min}$
	$130\ \cancel{\text{min}} \times \frac{60\ \text{s}}{1\ \cancel{\text{min}}} = \boxed{7.8\times10^{3}\ \text{s}}$
16 g	**c.** $16\ \cancel{\text{g}} \times \frac{1\ \mu\text{g}}{1\times10^{-6}\ \cancel{\text{g}}} = \boxed{1.6\times10^{7}\ \mu\text{g}}$
0.75 km	**d.** $0.75\ \cancel{\text{km}} \times \frac{1\times10^{3}\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \frac{1\ \text{cm}}{1\times10^{-2}\ \cancel{\text{m}}} = \boxed{7.5\times10^{4}\ \text{cm}}$
0.675 mg	**e.** $0.675\ \cancel{\text{mg}} \times \frac{1\times10^{-3}\ \text{g}}{1\ \cancel{\text{mg}}} = \boxed{6.75\times10^{-4}\ \text{g}}$
462 µm	**f.** $462\ \cancel{\mu\text{m}} \times \frac{1\times10^{-6}\ \cancel{\text{m}}}{1\ \cancel{\mu\text{m}}} \times \frac{1\ \text{cm}}{1\times10^{-2}\ \cancel{\text{m}}} = \boxed{4.62\times10^{-2}\ \text{cm}}$
35 km/h	**g.** $\frac{35\ \cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} \times \frac{1\times10^{3}\ \text{m}}{1\ \cancel{\text{km}}} = \boxed{9.7\ \text{m/s}}$
12. 10 rations	**a.** $10\ \cancel{\text{rations}} \times \frac{1\ \text{dekaration}}{10^{1}\ \cancel{\text{rations}}} = \boxed{1\ \text{dekaration}}$
2000 mockingbirds	**b.** $2000\ \cancel{\text{mockingbirds}} \times \frac{1\ \text{kmockingbirds}}{1\times10^{3}\ \cancel{\text{mockingbirds}}} = \boxed{2\ \text{kilomockingbirds}}$
10^{-6} phones	**c.** $10^{-6}\ \cancel{\text{phones}} \times \frac{1\ \mu\text{phone}}{10^{-6}\ \cancel{\text{phones}}} = \boxed{1\ \text{microphone}}$
10^{-9} goats	**d.** $10^{-9}\ \cancel{\text{goats}} \times \frac{1\ \text{ngoat}}{10^{-9}\ \cancel{\text{goats}}} = \boxed{1\ \text{nanogoat}}$
10^{18} miners	**e.** $10^{18}\ \cancel{\text{miners}} \times \frac{1\ \text{Eminer}}{10^{18}\ \cancel{\text{miners}}} = \boxed{1\ \text{examiner}}$
13. speed of light = 3.00×10^{8} m/s $\Delta t = 1$ h	$\frac{3.00\times10^{8}\ \cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}} \times 1\ \cancel{\text{h}} \times \frac{1\ \text{km}}{1\times10^{3}\ \cancel{\text{m}}} = \boxed{1.08\times10^{9}\ \text{km}}$
14. 1 ton = 1.000×10^{3} kg	$1.000\times10^{3}\ \cancel{\text{kg}} \times \frac{1\ \text{person}}{85\ \cancel{\text{kg}}} = \boxed{11\ \text{people}}$
mass/person = 85 kg	Note that the numerical answer, 11.8 people, must be rounded *down* to 11 people.

Givens	Solutions
20.	**a.** 756 g + 37.2 g + 0.83 g + 2.5 g = 796.53 g = $\boxed{797\text{ g}}$ **b.** $\frac{3.2\text{ m}}{3.563\text{ s}} = 0.898119562\text{ m/s} = \boxed{0.90\text{ m/s}}$ **c.** $5.67\text{ mm} \times \pi = 17.81283035\text{ mm} = \boxed{17.8\text{ mm}}$ **d.** $27.54\text{ s} - 3.8\text{ s} = 23.74\text{ s} = \boxed{23.7\text{ s}}$
21. 93.46 cm, 135.3 cm	93.46 cm + 135.3 cm = 228.76 cm = $\boxed{228.8\text{ cm}}$
22. $\ell = 38.44$ m $w = 19.5$ m	38.44 m + 38.44 m + 19.5 m + 19.5 m = 115.88 m = $\boxed{115.9\text{ m}}$
26. $s = (a + b + c) \div 2$	$r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}}$ r, a, b, c, and s all have units of L. $\text{length} = \sqrt{\frac{\text{length} \times \text{length} \times \text{length}}{\text{length}}} = \sqrt{\frac{(\text{length})^3}{\text{length}}} = \sqrt{(\text{length})^2} = \text{length}$ Thus, the equation is dimensionally consistent.
27.	$T = 2\pi \sqrt{\frac{L}{a_g}}$ Substitute the proper dimensions into the equation. $\text{time} = \sqrt{\frac{\text{length}}{[\text{length}/(\text{time})^2]}} = \sqrt{(\text{time})^2} = \text{time}$ Thus, the dimensions are consistent.
28.	$(\text{m/s})^2 \neq \text{m/s}^2 \times \text{s}$ $\text{m}^2/\text{s}^2 \neq \text{m/s}$ The dimensions are not consistent.
29.	Estimate one breath every 5 s. $70\ \cancel{\text{years}} \times \frac{365\ \cancel{\text{days}}}{1\ \cancel{\text{year}}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}} \times \frac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}} \times \frac{1\text{ breath}}{5\ \cancel{\text{s}}} = \boxed{4 \times 10^8\text{ breaths}}$
30.	Estimate one heart beat per second. $1\ \cancel{\text{day}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}} \times \frac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}} \times \frac{1\text{ beat}}{\cancel{\text{s}}} = \boxed{9 \times 10^4\text{ beats}}$
31.	Ages will vary. $17\ \cancel{\text{years}} \times \frac{365\ \cancel{\text{days}}}{1\ \cancel{\text{year}}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}} \times \frac{3600\text{ s}}{1\ \cancel{\text{h}}} = \boxed{5.4 \times 10^8\text{ s}}$
32.	Estimate a tire's radius to be 0.3 m. $50\,000\ \cancel{\text{mi}} \times \frac{1.609\ \cancel{\text{km}}}{1\ \cancel{\text{mi}}} \times \frac{10^3\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \frac{1\text{ rev}}{2\ \pi\,(0.3\ \cancel{\text{m}})} = \boxed{4 \times 10^7\text{ rev}}$

Givens	Solutions

33.

Estimate 30 balls lost per game.

$$81\ \cancel{\text{games}} \times \frac{30\text{ balls}}{1\ \cancel{\text{game}}} = \boxed{2 \times 10^3\text{ balls}}$$

I

34.

Estimate $\frac{1}{4}$ lb per burger and 800 lb per head of cattle.

$$5 \times 10^{10}\ \cancel{\text{burgers}} \times \frac{0.25\text{ lb}}{1\ \cancel{\text{burger}}} = \boxed{1 \times 10^{10}\text{ lb}}$$

$$5 \times 10^{10}\ \cancel{\text{burgers}} \times \frac{0.25\ \cancel{\text{lb}}}{1\ \cancel{\text{burger}}} \times \frac{1\text{ head}}{800\ \cancel{\text{lb}}} = \boxed{2 \times 10^7\text{ head of cattle}}$$

35. population = 8 million people

Estimate 5 people per family.

$$\frac{8\text{ million people}}{5\text{ people per family}} = 2\text{ million families}$$

Estimate that 1/5 of families have a piano.

$$\text{Number of pianos} = (2\text{ million families})\left(\frac{1}{5}\right) = 400{,}000\text{ pianos}$$

Estimate 3 tunings per day per tuner, with 200 work days per year.

Number of pianos tuned each year (per tuner) = (3)(200) = 600

$$\text{Number of tuners} = \frac{400{,}000\text{ pianos}}{600\text{ pianos/year per tuner}} = \boxed{7 \times 10^2\text{ tuners}}$$

36. diameter = 3.8 cm

$\ell = 4$ m $\quad w = 4$ m $\quad h = 3$m

Find the number of balls that can fit along the length and width.

$$4\ \cancel{\text{m}} \times \frac{1\text{ ball}}{0.038\ \cancel{\text{m}}} = 100\text{ balls}$$

Find the number that can be stacked to the ceiling.

$$3\ \cancel{\text{m}} \times \frac{1\text{ ball}}{0.038\ \cancel{\text{m}}} = 80\text{ balls}$$

Multiply all three figures to find the number of balls that can fit in the room.

$$100\text{ balls} \times 100\text{ balls} \times 80\text{ balls} = \boxed{8 \times 10^5\text{ balls}}$$

A rough estimate: divide the volume of the room by the volume of a ball.

37. $r = 3.5$ cm

a. $C = 2\pi r = 2\pi\ (3.5\text{ cm}) = \boxed{22\text{ cm}}$

$A = \pi r^2 = \pi\ (3.5\text{ cm})^2 = \boxed{38\text{ cm}^2}$

$r = 4.65$ cm

b. $C = 2\pi r = 2\pi\ (4.65\text{ cm}) = \boxed{29.2\text{ cm}}$

$A = \pi r^2 = \pi\ (4.65\text{ cm})^2 = \boxed{67.9\text{ cm}^2}$

38.

$$5 \times 10^9\ \cancel{\text{bills}} \times \frac{1\ \cancel{\text{s}}}{1\ \cancel{\text{bill}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \cancel{\text{s}}} \times \frac{1\ \cancel{\text{day}}}{14\ \cancel{\text{h}}} \times \frac{1\text{ year}}{365\ \cancel{\text{days}}} = \boxed{272\text{ years}}$$

Take the $5000. It would take 272 years to count 5 billion $1 bills.

Givens | *Solutions*

39.

$$V = 1\ \cancel{\text{quart}} \times \frac{3.786 \times 10^{-3}\ \text{m}^3}{4\ \cancel{\text{quarts}}} = 9.465 \times 10^{-4}\ \text{m}^3$$

$$V = L^3$$

$$L = \sqrt[3]{V} = \sqrt[3]{9.465 \times 10^{-4}\ \text{m}^3} = \boxed{9.818 \times 10^{-2}\ \text{m}}$$

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40. mass $= 9.00 \times 10^{-7}$ kg

density $= 918\ \text{kg/m}^3$

$r = 41.8$ cm

area $= \pi r^2$

$$\text{volume} = \frac{\text{mass}}{\text{density}} = \frac{9.00 \times 10^{-7}\ \text{kg}}{918\ \text{kg/m}^3} = 9.80 \times 10^{-10}\ \text{m}^3$$

$$\text{diameter} = \frac{\text{volume}}{\text{area}} = \frac{9.80 \times 10^{-10}\ \text{m}^3}{\pi (0.418\ \text{m})^2} = \boxed{1.79 \times 10^{-9}\ \text{m}}$$

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41. 1 cubit = 0.50 m

$V_{ark} = 300$ cubits $\times$ 50 cubits $\times$ 30 cubits

$$V_{ark} = (300\ \text{cubits})(50\ \text{cubits})(30\ \text{cubits})\left(\frac{0.50\ \text{m}}{\text{cubit}}\right)^3$$

$$V_{ark} = \boxed{6 \times 10^4\ \text{m}^3}$$

Estimate the average size of a house to be 2000 ft^2 and 10 ft tall.

$$V_{house} = (2000\ \text{ft}^2)(10\ \text{ft})\left(\frac{1\ \text{m}}{3.281\ \text{ft}}\right)^3$$

$$V_{house} = \boxed{6 \times 10^2\ \text{m}^3}$$

$$\frac{V_{ark}}{V_{house}} = \frac{6 \times 10^4\ \text{m}^3}{6 \times 10^2\ \text{m}^3} = \boxed{100}$$

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42. $d = 1.0 \times 10^{-6}$ m

$\ell = 1.0$ m

number of micrometeorites per side:

$$1.0\ \cancel{\text{m}} \times \frac{1\ \text{micrometeorite}}{1.0 \times 10^{-6}\ \cancel{\text{m}}} = 1.0 \times 10^6\ \text{micrometeorites}$$

number of micrometeorites needed to cover the moon to a depth of 1.0 m:

$$(1.0 \times 10^6\ \text{micrometeorites})^3 = 1.0 \times 10^{18}\ \text{micrometeorites}$$

$$1.0 \times 10^{18}\ \cancel{\text{micrometeorites}} \times \frac{1\ \cancel{\text{s}}}{1\ \cancel{\text{micrometeorite}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \cancel{\text{s}}} \times \frac{1\ \cancel{\text{day}}}{24\ \cancel{\text{h}}} \times \frac{1\ \text{year}}{365\ \cancel{\text{days}}} = \boxed{3.2 \times 10^{10}\ \text{years}}$$

Note that a rougher estimate can be made by dividing the volume of the 1.0 m^3 box by the volume of a micrometeorite.

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43. $V = 1.0\ \text{cm}^3$

$m = 1.0 \times 10^{-3}$ kg

$$\frac{1.0 \times 10^{-3}\ \text{kg}}{1.0\ \cancel{\text{cm}^3}} \times \frac{1\ \cancel{\text{cm}^3}}{(1 \times 10^{-2}\ \cancel{\text{m}})^3} \times 1.0\ \cancel{\text{m}^3} = \boxed{1.0 \times 10^3\ \text{kg}}$$

Givens	*Solutions*
44. density $= \rho = 1.0 \times 10^3$ kg/m^3 diameter $= 1.0$ μm	**a.** $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{1.0 \times 10^{-6}\text{ m}}{2}\right)^3 = 5.2 \times 10^{-19}\text{ m}^3$ $m = \rho V = (1.0 \times 10^3\text{ kg/m}^3)(5.2 \times 10^{-19}\text{ m}^3)(0.9) = \boxed{5 \times 10^{-16}\text{ kg}}$
$\ell = 4.0$ mm diameter $= 2r = 2.0$ mm density $= \rho = 1.0 \times 10^3$ kg/m^3	**b.** $V = \ell\pi r^2 = (4.0 \times 10^{-3}\text{m})\ (\pi)\left(\frac{2.0 \times 10^{-3}\text{ m}}{2}\right)^2 = 1.3 \times 10^{-8}\text{ m}^3$ $m = \rho V = (1.0 \times 10^3\text{ kg/m}^3)(1.3 \times 10^{-8}\text{ m}^3)(0.9) = \boxed{1 \times 10^{-5}\text{ kg}}$
45. $r = 6.03 \times 10^7$ m $m = 5.68 \times 10^{26}$ kg	**a.** $V = \frac{4}{3}\pi r^3$ density $= \frac{m}{V} = \frac{3m}{4\pi r^3}$ density $= \left(\frac{(3)(5.68 \times 10^{26}\text{ kg})}{4\pi(6.03 \times 10^7\text{ m})^3}\right)\left(\frac{10^3\text{ g}}{\text{kg}}\right)\left(\frac{1\text{ m}}{10^2\text{ cm}}\right)^3$ density $= \boxed{0.618\text{ g/cm}^3}$ **b.** surface area $= 4\pi r^2 = 4\pi(6.03 \times 10^7\text{ m})^2$ surface area $= \boxed{4.57 \times 10^{16}\text{ m}^2}$

The Science of Physics, Standardized Test Prep

5. 1 ly = 9 500 000 000 000 km $= 9.5 \times 10^{12}$ km	$9.5 \times 10^{12}\text{ km} \times \frac{10^3\text{ m}}{1\text{ km}} = \boxed{9.5 \times 10^{15}\text{ m}}$

Motion In One Dimension

Motion In One Dimension, Practice A

Givens	*Solutions*
1. $v_{avg} = 0.98$ m/s east $\Delta t = 34$ min	$\Delta x = v_{avg}\Delta t = (0.98 \text{ m/s})(34 \text{ min})(60 \text{ s/min})$ $\Delta x = 2.0 \times 10^3 \text{ m} = \boxed{2.0 \text{ km east}}$
2. $\Delta t = 15$ min $v_{avg} = 12.5$ km/h south	$\Delta x = v_{avg}\Delta t = (12.5 \text{ km/h})(15 \text{ min})\left(\frac{1 \text{ h}}{60 \text{ min}}\right)$ $\Delta x = \boxed{3.1 \text{ km}}$
3. $\Delta t = 9.5$ min $v_{avg} = 1.2$ m/s north	$\Delta x = v_{avg}\Delta t = (1.2 \text{ m/s})\ (9.5 \text{ min})(60 \text{ s/min})$ $\Delta x = \boxed{680 \text{ m north}}$
4. $v_{avg} = 48.0$ km/h east $\Delta x = 144$ km east	$\Delta t = \frac{\Delta x}{v_{avg}} = \frac{144 \text{ km}}{48.0 \text{ km/h}} = \boxed{3.00 \text{ h}}$
5. $v_{avg} = 56.0$ km/h east $\Delta x = 144$ km east	$\Delta t = \frac{\Delta x}{v_{avg}} = \frac{144 \text{ km}}{56.0 \text{ km/h}} = 2.57 \text{ h}$ time saved = 3.00 h − 2.57 h = $\boxed{0.43 \text{ h} = 25.8 \text{ min}}$
6. $\Delta x_1 = 280$ km south $v_{avg,1} = 88$ km/h south $\Delta t_2 = 24$ min $v_{avg,2} = 0$ km/h $\Delta x_3 = 210$ km south $v_{avg,3} = 75$ km/h south	**a.** $\Delta t_{tot} = \Delta t_1 + \Delta t_2 + \Delta t_3 = \frac{\Delta x_1}{v_{avg,1}} + \Delta t_2 + \frac{\Delta x_3}{v_{avg,3}}$ $\Delta t_{tot} = \left(\frac{280 \text{ km}}{88 \text{ km/h}}\right) + (24 \text{ min})\left(\frac{1 \text{ h}}{60 \text{ min}}\right) + \left(\frac{210 \text{ km}}{75 \text{ km/h}}\right)$ $\Delta t_{tot} = 3.2 \text{ h} + 0.40 \text{ h} + 2.8 \text{ h} = \boxed{6.4 \text{ h} = 6 \text{ h } 24 \text{ min}}$ **b.** $v_{avg,\,tot} = \frac{\Delta x_{tot}}{\Delta t_{tot}} = \frac{\Delta x_1 + \Delta x_2 + \Delta x_3}{\Delta t_1 + \Delta t_2 + \Delta t_3}$ $\Delta x_2 = v_{avg,2}\Delta t_2 = (0 \text{ km/h})(24 \text{ min})\left(\frac{1 \text{ h}}{60 \text{ min}}\right) = 0 \text{ km}$ $v_{avg,\,tot} = \frac{280 \text{ km} + 0 \text{ km} + 210 \text{ km}}{6.4 \text{ h}} = \frac{490 \text{ km}}{6.4 \text{ h}} = \boxed{77 \text{ km/h south}}$

Motion In One Dimension, Section 1 Review

1. $v = 3.5$ mm/s $\Delta x = 8.4$ cm	$\Delta t = \frac{\Delta x}{v} = \frac{8.4 \text{ cm}}{0.35 \text{ cm/s}} = \boxed{24 \text{ s}}$
2. $v = 1.5$ m/s $\Delta x = 9.3$ m	$\Delta t = \frac{\Delta x}{v} = \frac{9.3 \text{ m}}{1.5 \text{ m/s}} = \boxed{6.2 \text{ s}}$

Givens	Solutions
3. $\Delta x_1 = 50.0$ m south $\Delta t_1 = 20.0$ s $\Delta x_2 = 50.0$ m north $\Delta t_2 = 22.0$ s	**a.** $v_{avg,1} = \frac{\Delta x_1}{\Delta t_1} = \frac{50.0\text{ m}}{20.0\text{ s}} = \boxed{2.50\text{ m/s south}}$ **b.** $v_{avg,2} = \frac{\Delta x_2}{\Delta t_2} = \frac{50.0\text{ m}}{22.0\text{ s}} = \boxed{2.27\text{ m/s north}}$ $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = (-50.0\text{ m}) + (50.0\text{ m}) = 0.0\text{ m}$ $\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 20.0\text{ s} + 22.0\text{ s} = 42.0\text{ s}$ $v_{avg} = \frac{\Delta x_{tot}}{\Delta t_{tot}} = \frac{0.0\text{ m}}{42.0\text{ s}} = \boxed{0.0\text{ m/s}}$
4. $v_1 = 0.90$ m/s $v_2 = 1.90$ m/s $\Delta x = 780$ m	**a.** $\Delta t_1 = \frac{\Delta x}{v_1} = \frac{780\text{ m}}{0.90\text{ m/s}} = 870\text{ s}$ $\Delta t_2 = \frac{\Delta x}{v_2} = \frac{780\text{ m}}{1.90\text{ m/s}} = 410\text{ s}$ $\Delta t_1 - \Delta t_2 = 870\text{ s} - 410\text{ s} = \boxed{460\text{ s}}$
$\Delta t_1 - \Delta t_2 =$ $(5.50\text{ min})(60\text{ s/min}) =$ 3.30×10^2 s	**b.** $\Delta x_1 = v_1 \Delta t_1$ $\Delta x_2 = v_2 \Delta t_2$ $\Delta x_1 = \Delta x_2$ $v_1 \Delta t_1 = v_2 \Delta t_2$ $v_1[\Delta t_2 + (3.30 \times 10^2\text{ s})] = v_2 \Delta t_2$ $v_1 \Delta t_2 + v_1(3.30 \times 10^2\text{ s}) = v_2 \Delta t_2$ $\Delta t_2 (v_1 - v_2) = -v_1(3.30 \times 10^2\text{ s})$ $\Delta t_2 = \frac{-v_1(3.30 \times 10^2\text{ s})}{v_1 - v_2} = \frac{-(0.90\text{ m/s})(3.30 \times 10^2\text{ s})}{0.90\text{ m/s} - 1.90\text{ m/s}} = \frac{-(0.90\text{ m/s})(3.30 \times 10^2\text{ s})}{-1.00\text{ m/s}}$ $\Delta t_2 = 3.0 \times 10^2$ s $\Delta t_1 = \Delta t_2 + (3.30 \times 10^2\text{ s}) = (3.0 \times 10^2\text{ s}) + (3.30 \times 10^2\text{ s}) = 630\text{ s}$ $\Delta x_1 = v_1 \Delta t_1 = (0.90\text{ m/s})(630\text{ s}) = \boxed{570\text{ m}}$ $\Delta x_2 = v_2 \Delta t_2 = (1.90\text{ m/s})(3.0 \times 10^2\text{ s}) = \boxed{570\text{ m}}$

Motion In One Dimension, Practice B

Givens	Solutions
1. $a_{avg} = -4.1\text{ m/s}^2$ $v_i = 9.0$ m/s $v_f = 0.0$ m/s	$\Delta t = \frac{\Delta v}{a_{avg}} = \frac{v_f - v_i}{a_{avg}} = \frac{0.0\text{ m/s} - 9.0\text{ m/s}}{-4.1\text{ m/s}^2} = \frac{-9.0\text{ m/s}}{-4.1\text{ m/s}^2} = \boxed{2.2\text{ s}}$
2. $a_{avg} = 2.5\text{ m/s}^2$ $v_i = 7.0$ m/s $v_f = 12.0$ m/s	$\Delta t = \frac{\Delta v}{a_{avg}} = \frac{v_f - v_i}{a_{avg}} = \frac{12.0\text{ m/s} - 7.0\text{ m/s}}{2.5\text{ m/s}^2} = \frac{5.0\text{ m/s}}{2.5\text{ m/s}^2} = \boxed{2.0\text{ s}}$
3. $a_{avg} = -1.2\text{ m/s}^2$ $v_i = 6.5$ m/s $v_f = 0.0$ m/s	$\Delta t = \frac{v_f - v_i}{a_{avg}} = \frac{0.0\text{ m/s} - 6.5\text{ m/s}}{-1.2\text{ m/s}^2} = \frac{-6.5\text{ m/s}}{-1.2\text{ m/s}^2} = \boxed{5.4\text{ s}}$

Givens	*Solutions*
4. $v_i = -1.2$ m/s $v_f = -6.5$ m/s $\Delta t = 25$ min	$a_{avg} = \dfrac{v_f - v_i}{\Delta t} = \dfrac{-6.5 \text{ m/s} - (-1.2 \text{ m/s})}{(25 \text{ min})(60 \text{ s/min})} = \dfrac{-5.3 \text{ m/s}}{1500 \text{ s}} = \boxed{-3.5 \times 10^{-3} \text{ m/s}^2}$
5. $a_{avg} = 4.7 \times 10^{-3}$ m/s^2 $\Delta t = 5.0$ min $v_i = 1.7$ m/s	**a.** $\Delta v = a_{avg}\Delta t = (4.7 \times 10^{-3} \text{ m/s}^2)(5.0 \text{ min})(60 \text{ s/min}) = \boxed{1.4 \text{ m/s}}$ **b.** $v_f = \Delta v + v_i = 1.4 \text{ m/s} + 1.7 \text{ m/s} = \boxed{3.1 \text{ m/s}}$

I

Motion In One Dimension, Practice C

1. $v_i = 0.0$ m/s $v_f = 6.6$ m/s $\Delta t = 6.5$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0.0 \text{ m/s} + 6.6 \text{ m/s})(6.5 \text{ s}) = \boxed{21 \text{ m}}$
2. $v_i = 15.0$ m/s $v_f = 0.0$ m/s $\Delta t = 2.50$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(15.0 \text{ m/s} + 0.0 \text{ m/s})(2.50 \text{ s}) = \boxed{18.8 \text{ m}}$
3. $v_i = 21.8$ m/s $\Delta x = 99$ m $v_f = 0.0$ m/s	$\Delta t = \dfrac{2\Delta x}{v_i + v_f} = \dfrac{(2)(99 \text{ m})}{21.8 \text{ m/s} + 0.0 \text{ m/s}} = \boxed{9.1 \text{ s}}$
4. $v_i = 6.4$ m/s $\Delta x = 3.2$ km $\Delta t = 3.5$ min	$v_f = \dfrac{2\Delta x}{\Delta t} - v_i = \dfrac{(2)(3.2 \times 10^3 \text{ m})}{(3.5 \text{ min})(60 \text{ s/min})} - 6.4 \text{ m/s} = 3.0 \times 10^1 \text{ m/s} - 6.4 \text{ m/s} = \boxed{24 \text{ m/s}}$

Motion In One Dimension, Practice D

1. $v_i = 6.5$ m/s $a = 0.92$ m/s^2 $\Delta t = 3.6$ s	$v_f = v_i + a\Delta t = 6.5 \text{ m/s} + (0.92 \text{ m/s}^2)(3.6 \text{ s})$ $v_f = 6.5 \text{ m/s} + 3.3 \text{ m/s} = \boxed{9.8 \text{ m/s}}$ $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta x = (6.5 \text{ m/s})(3.6 \text{ s}) + \frac{1}{2}(0.92 \text{ m/s}^2)(3.6 \text{ s})^2$ $\Delta x = 23 \text{ m} + 6.0 \text{ m} = \boxed{29 \text{ m}}$
2. $v_i = 4.30$ m/s $a = 3.00$ m/s^2 $\Delta t = 5.00$ s	$v_f = v_i + a\Delta t = 4.30 \text{ m/s} + (3.00 \text{ m/s}^2)(5.00 \text{ s})$ $v_f = 4.30 \text{ m/s} + 15.0 \text{ m/s} = \boxed{19.3 \text{ m/s}}$ $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta x = (4.30 \text{ m/s})(5.00 \text{ s}) + \frac{1}{2}(3.00 \text{ m/s}^2)(5.00 \text{ s})^2$ $\Delta x = 21.5 \text{ m} + 37.5 \text{ m} = \boxed{59.0 \text{ m}}$

Givens | *Solutions*

3. $v_i = 0.0$ m/s

$\Delta t = 5.0$ s

$a = -1.5$ m/s^2

$v_f = v_i + a\Delta t = 0 \text{ m/s} + (-1.5 \text{ m/s}^2)(5.0 \text{ s}) = \boxed{-7.5 \text{ m/s}}$

$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(-1.5 \text{ m/s}^2)(5.0 \text{ s})^2 = -19 \text{ m}$

distance traveled = $\boxed{19 \text{ m}}$

4. $v_i = 15.0$ m/s

$a = -2.0$ m/s^2

$v_f = 10.0$ m/s

$\Delta t = \dfrac{v_f - vi}{a} = \dfrac{10.0 \text{ m/s} - 15.0 \text{ m/s}}{-2.0 \text{ m/s}^2} = \dfrac{-5.0}{-2.0} \text{ s} = \boxed{2.5 \text{ s}}$

$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$

$\Delta x = (15.0 \text{ m/s})(2.5 \text{ s}) + \frac{1}{2}(-2.0 \text{ m/s}^2)(2.5 \text{ s})^2$

$\Delta x = 38 \text{ m} + (-6.2 \text{ m}) = 32 \text{ m}$

distance traveled during braking = $\boxed{32 \text{ m}}$

Motion In One Dimension, Practice E

1. $v_i = 0$ m/s

$a = 0.500$ m/s^2

$\Delta x = 6.32$ m

$v_f = \sqrt{v_i^2 + 2a\Delta x}$

$v_f = \sqrt{(0 \text{ m/s})^2 + (2)(0.500 \text{ m/s}^2)(6.32 \text{ m})} = \sqrt{6.32 \text{ m}^2/\text{s}^2} = \pm 2.51 \text{ m/s}$

$v_f = \boxed{+2.51 \text{ m/s}}$

2. $v_i = +7.0$ m/s

$a = +0.80$ m/s^2

$\Delta x = 245$ m

a. $v_f = \sqrt{v_i^2 + 2a\Delta x}$

$v_f = \sqrt{(7.0 \text{ m/s})^2 + (2)(0.80 \text{ m/s}^2)(245 \text{ m})}$

$v_f = \sqrt{49 \text{ m}^2/\text{s}^2 + 390 \text{ m}^2/\text{s}^2} = \sqrt{440 \text{ m}^2/\text{s}^2} = \pm 21 \text{ m/s}$

$v_f = \boxed{+21 \text{ m/s}}$

$\Delta x = 125$ m

b. $v_f = \sqrt{(7.0 \text{ m/s})^2 + (2)(0.80 \text{ m/s}^2)(125 \text{ m})}$

$v_f = \sqrt{49 \text{ m}^2/\text{s}^2 + (2.0 \times 10^2 \text{ m}^2/\text{s}^2)} = \sqrt{250 \text{ m}^2/\text{s}^2}$

$v_f = \pm 16 \text{ m/s} = \boxed{+16 \text{ m/s}}$

$\Delta x = 67$ m

c. $v_f = \sqrt{(7.0 \text{ m/s})^2 + (2)(0.80 \text{ m/s}^2)(67 \text{ m})} = \sqrt{49 \text{ m}^2/\text{s}^2 + 110 \text{ m}^2/\text{s}^2}$

$v_f = \sqrt{160 \text{ m}^2/\text{s}^2} = \pm 13 \text{ m/s} = \boxed{+13 \text{ m/s}}$

3. $v_i = 0$ m/s

$a = 2.3$ m/s^2

$\Delta x = 55$ m

a. $v_f = \sqrt{v_i^2 + 2a\Delta x} = \sqrt{(0 \text{ m/s})^2 + (2)(2.3 \text{ m/s}^2)(55 \text{ m})}$

$v_f = \sqrt{250 \text{ m}^2/\text{s}^2} = \pm 16 \text{ m/s}$

car speed = $\boxed{16 \text{ m/s}}$

b. $\Delta t = \dfrac{v_f}{a} = \dfrac{16 \text{ m/s}}{2.3 \text{ m/s}^2} = \boxed{7.0 \text{ s}}$

4. $v_i = 6.5$ m/s

$v_f = 1.5$ m/s

$a = -2.7$ m/s^2

$\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{(1.5 \text{ m/s})^2 - (6.5 \text{ m/s})^2}{(2)(-2.7 \text{ m/s}^2)} = \dfrac{-40 \text{ m}^2/\text{s}^2}{-5.4 \text{ m/s}^2} = \boxed{7.4 \text{ m}}$

Givens	Solutions
5. $v_i = 0.0$ m/s $v_f = 33$ m/s $\Delta x = 240$ m	$a = \dfrac{v_f^2 - v_i^2}{2\Delta x} = \dfrac{(33\text{ m/s})^2 - (0.0\text{ m/s})^2}{(2)(240\text{ m})} = \boxed{2.3\text{ m/s}^2}$
6. $a = 0.85$ m/s^2 $v_i = 83$ km/h $v_f = 94$ km/h	$v_i = (83\text{ km/h})(10^3\text{ m/km})(1\text{ h}/3600\text{ s}) = 23\text{ m/s}$ $v_f = (94\text{ km/h})(10^3\text{ m/km})(1\text{ h}/3600\text{ s}) = 26\text{ ms}$ $\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{(26\text{ m/s})^2 - (23\text{ m/s})^2}{(2)(0.85\text{ m/s}^2)}$ $\Delta x = \dfrac{680\text{ m}^2/\text{s}^2 - 530\text{ m}^2/\text{s}^2}{(2)(0.85\text{ m/s}^2)}$ $\Delta x = \dfrac{150\text{ m}^2/\text{s}^2}{(2)(0.85\text{ m/s}^2)} = 88\text{ m}$ distance traveled = $\boxed{88\text{ m}}$

Motion In One Dimension, Section 2 Review

1. $a = +2.60$ m/s^2 $v_i = 24.6$ m/s $v_f = 26.8$ m/s	$\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{26.8\text{ m/s} - 24.6\text{ m/s}}{2.60\text{ m/s}^2}$ $\Delta t = \dfrac{2.2\text{ m/s}}{2.60\text{ m/s}^2} = \boxed{0.85\text{ s}}$
3. $v_i = 0$ m/s $v_f = 12.5$ m/s $\Delta t = 2.5$ s	**a.** $a = \dfrac{v_f - v_i}{\Delta t} = \dfrac{12.5\text{ m/s} - 0\text{ m/s}}{2.5\text{ s}} = \boxed{+5.0\text{ m/s}^2}$ **b.** $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0\text{ m/s})(2.5\text{ s}) + \frac{1}{2}(5.0\text{ m/s}^2)(2.5\text{ s})^2 = \boxed{+16\text{ m}}$ **c.** $v_{avg} = \dfrac{\Delta x}{\Delta t} = \dfrac{16\text{ m}}{2.5\text{ s}} = \boxed{+6.4\text{ m/s}}$

Motion In One Dimension, Practice F

1. $\Delta y = -239$ m $v_i = 0$ m/s $a = -3.7$ m/s^2	**a.** $v_f = \sqrt{v_i^2 + 2a\,\Delta y} = \sqrt{(0\text{ m/s})^2 + (2)(-3.7\text{ m/s}^2)(-239\text{ m})}$ $v_f = \sqrt{1.8 \times 10^3\text{ m}^2/\text{s}^2} = \pm 42\text{ m/s}$ $v_f = \boxed{-42\text{ m/s}}$ **b.** $\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{-42\text{ m/s} - 0\text{ m/s}}{-3.7\text{ m/s}^2} = \boxed{11\text{ s}}$
2. $\Delta y = -25.0$ m $v_i = 0$ m/s $a = -9.81$ m/s^2	**a.** $v_f = \sqrt{v_i^2 + 2a\Delta y} = \sqrt{(0\text{ m/s})^2 + (2)(-9.81\text{ m/s}^2)(-25.0\text{ m})}$ $v_f = \sqrt{4.90 \times 10^2\text{ m}^2/\text{s}^2} = \boxed{-22.1\text{ m/s}}$ **b.** $\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{-22.1\text{ m/s} - 0\text{ m/s}}{-9.81\text{ m/s}^2} = \boxed{2.25\text{ s}}$

Givens	Solutions
3. $v_i = +8.0$ m/s	**a.** $v_f = \sqrt{v_i^2 + 2a\Delta y} = \sqrt{(8.0\text{ m/s})^2 + (2)(-9.81\text{ m/s}^2)(0\text{ m})}$
$a = -9.81$ m/s^2	$v_f = \sqrt{64\text{ m}^2/\text{s}^2} = \pm 8.0\text{ m/s} = \boxed{-8.0\text{ m/s}}$
$\Delta y = 0$ m	**b.** $\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{-8.0\text{ m/s} - 8.0\text{ m/s}}{-9.81\text{ m/s}^2} = \dfrac{-16.0\text{ m/s}}{-9.81\text{ m/s}^2} = \boxed{1.63\text{ s}}$
4. $v_i = +6.0$ m/s	$\Delta y = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{(1.1\text{ m/s})^2 - (6.0\text{ m/s})^2}{(2)(-9.81\text{ m/s}^2)}$
$v_f = +1.1$ m/s^2	
$a = -9.81$ m/s^2	$\Delta y = \dfrac{1.2\text{ m}^2/\text{s}^2 - 36\text{ m}^2/\text{s}^2}{-19.6\text{ m/s}^2} = \dfrac{-35\text{ m}^2/\text{s}^2}{-19.6\text{ m/s}^2} = \boxed{+1.8\text{ m}}$

Motion In One Dimension, Section 3 Review

2. $v_i = 0$ m/s	$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0\text{ m/s})(1.5\text{ s}) + \frac{1}{2}(-9.81\text{ m/s}^2)(1.5\text{ s})^2$
$\Delta t = 1.5$ s	$\Delta y = 0\text{ m} + (-11\text{ m}) = -11\text{ m}$
$a = -9.81$ m/s^2	the distance to the water's surface = $\boxed{11\text{ m}}$

Motion In One Dimension, Chapter Review

7. $\Delta t = 0.530$ h	$\Delta x = v_{avg}\Delta t = (19.0\text{ km/h})(0.530\text{ h}) = \boxed{10.1\text{ km east}}$
$v_{avg} = 19.0$ km/h east	
8. $\Delta t = 2.00$ h, 9.00 min, 21.0 s	$\Delta x = v_{avg}\Delta t = (5.436\text{ m/s})\,[(2.00\text{ h})(3600\text{ s/h}) + (9.00\text{ min})(60\text{ s/min}) + 21.0\text{ s}]$
$v_{avg} = 5.436$ m/s	$\Delta x = (5.436\text{ m/s})(7200\text{ s} + 540\text{ s} + 21.0\text{ s}) = (5.436\text{ m/s})(7760\text{ s})$
	$\Delta x = 4.22 \times 10^4\text{ m} = \boxed{4.22 \times 10^1\text{ km}}$
9. $\Delta t = 5.00$ s	**a.** $\Delta x_A = \boxed{+70.0\text{ m}}$
distance between	**b.** $\Delta x_B = 70.0\text{ m} + 70.0\text{ m} = \boxed{+140.0\text{ m}}$
poles = 70.0 m	**c.** $v_{avg,A} = \dfrac{\Delta x_A}{\Delta t} = \dfrac{70.0\text{ m}}{5.0\text{ s}} = \boxed{+14\text{ m/s}}$
	d. $v_{avg,B} = \dfrac{\Delta x_B}{\Delta t} = \dfrac{140\text{ m}}{5.0\text{ s}} = \boxed{+28\text{ m/s}}$

Givens	Solutions
10. $v_1 = 80.0$ km/h	**a.** $\Delta x_1 = v_1 \Delta t_1 = (80.0 \text{ km/h})(30.0 \text{ min})(1 \text{ h}/60 \text{ min}) = 40.0 \text{ km}$
$\Delta t_1 = 30.0$ min	$\Delta x_2 = v_2 \Delta t_2 = (105 \text{ km/h})(12.0 \text{ min})(1 \text{ h}/60 \text{ min}) = 21.0 \text{ km}$
$v_2 = 105$ km/h	$\Delta x_3 = v_3 \Delta t_3 = (40.0 \text{ km/h})(45.0 \text{ min})(1 \text{ h}/60 \text{ min}) = 30.0 \text{ km}$
$\Delta t_2 = 12.0$ min	$\Delta x_4 = v_4 \Delta t_4 = (0 \text{ km/h})(15.0 \text{ min})(1 \text{ h}/60 \text{ min}) = 0 \text{ km}$
$v_3 = 40.0$ km/h	$v_{avg} = \dfrac{\Delta x_{tot}}{\Delta t_{tot}} = \dfrac{\Delta x_1 + \Delta x_2 + \Delta x_3 + \Delta x_4}{\Delta t_1 + \Delta t_2 + \Delta t_3 + \Delta t_4}$
$\Delta t_3 = 45.0$ min	$v_{avg} = \dfrac{40.0 \text{ km} + 21.0 \text{ km} + 30.0 \text{ km} + 0 \text{ km}}{(30.0 \text{ min} + 12.0 \text{ min} + 45.0 \text{ min} + 15.0 \text{ min})(1 \text{ h}/60 \text{ min})}$
$v_4 = 0$ km/h	$v_{avg} = \dfrac{91.0 \text{ km}}{(102.0 \text{ min})(1 \text{ h}/60 \text{ min})} = \boxed{53.5 \text{ km/h}}$
$\Delta t_4 = 15.0$ min	**b.** $\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 + \Delta x_4$
	$\Delta x_{tot} = 40.0 \text{ km} + 21.0 \text{ km} + 30.0 \text{ km} + 0 \text{ km} = \boxed{91.0 \text{ km}}$

Givens	Solutions
11. $v_A = 9.0$ km/h east	$\Delta x_A = v_A \Delta t = x - x_{i,A}$
$= +9.0$ km/h	$\Delta x_B = v_B \Delta t = x - x_{i,B}$
$x_{i,A} = 6.0$ km west of flagpole $= -6.0$ km	$\Delta x_A - \Delta x_B = (x - x_{i,A}) - (x - x_{i,B}) = x_{i,B} - x_{i,A}$
	$\Delta x_A - \Delta x_B = v_A \Delta t - v_B \Delta t = (v_A - v_B)\Delta t$
$v_B = 8.0$ km/h west	$\Delta t = \dfrac{x_{i,B} - x_{i,A}}{v_A - v_B} = \dfrac{5.0 \text{ km} - (-6.0 \text{ km})}{9.0 \text{ km/h} - (-8.0 \text{ km/h})} = \dfrac{11.0 \text{ km}}{17.0 \text{ km/h}}$
$= -8.0$ km/h	
$x_{i,B} = 5.0$ km east of flagpole $= +5.0$ km	$\Delta t = 0.647$ h
	$\Delta x_A = v_A \Delta t = (9.0 \text{ km/h})(0.647 \text{ h}) = 5.8 \text{ km}$
	$\Delta x_B = v_B \Delta t = (-8.0 \text{ km/h})(0.647 \text{ h}) = -5.2 \text{ km}$
x = distance from flagpole to point where runners' paths cross	for runner A, $x = \Delta x_A + x_{i,A} = 5.8 \text{ km} + (-6.0 \text{ km}) = -0.2 \text{ km}$
	$x = \boxed{0.2 \text{ km west of the flagpole}}$
	for runner B, $x = \Delta x_B + x_{i,B} = -5.2 \text{ km} + (5.0 \text{ km}) = -0.2 \text{ km}$
	$x = \boxed{0.2 \text{ km west of the flagpole}}$

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Givens	Solutions
16. $v_i = +5.0$ m/s $a_{avg} = +0.75$ m/s^2 $v_f = +8.0$ m/s	$\Delta t = \frac{\Delta v}{a_{avg}} = \frac{v_f - v_i}{a_{avg}} = \frac{8.0 \text{ m/s} - 5.0 \text{ m/s}}{0.75 \text{ m/s}^2} = \frac{3.0 \text{ m/s}}{0.75 \text{ m/s}^2}$ $\Delta t = \boxed{4.0 \text{ s}}$
17. For 0 s to 5.0 s: $v_i = -6.8$ m/s $v_f = -6.8$ m/s $\Delta t = 5.0$ s	For 0 s to 5.0 s, $a_{avg} = \frac{v_f - v_i}{\Delta t} = \frac{-6.8 \text{ m/s} - (-6.8 \text{ m/s})}{5.0 \text{ s}} = \boxed{0.0 \text{ m/s}^2}$
For 5.0 s to 15.0 s: $v_i = -6.8$ m/s $v_f = +6.8$ m/s $\Delta t = 10.0$ s	For 5.0 s to 15.0 s, $a_{avg} = \frac{v_f - v_i}{\Delta t} = \frac{6.8 \text{ m/s} - (-6.8 \text{ m/s})}{10.0 \text{ s}} = \frac{13.6 \text{ m/s}}{10.0 \text{ s}} = \boxed{+1.36 \text{ m/s}^2}$
For 0 s to 20.0 s: $v_i = -6.8$ m/s $v_f = +6.8$ m/s $\Delta t = 20.0$ s	For 0 s to 20.0 s, $a_{avg} = \frac{v_f - v_i}{\Delta t} = \frac{6.8 \text{ m/s} - (-6.8 \text{ m/s})}{20.0 \text{ s}} = \frac{13.6 \text{ m/s}}{20.0 \text{ s}} = \boxed{+0.680 \text{ m/s}^2}$
18. $v_i = 75.0$ km/h $= 21.0$ m/s $v_f = 0$ km/h $= 0$ m/s $\Delta t = 21$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(21.0 \text{ m/s} + 0 \text{ m/s})(21.0 \text{ s}) = \frac{1}{2}(21.0 \text{ m/s})(21 \text{ s})$ $\Delta x = \boxed{220 \text{ m}}$
19. $v_i = 0$ m/s $v_f = 18$ m/s $\Delta t = 12$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0 \text{ m/s} + 18 \text{ m/s})(12 \text{ s}) = \boxed{110 \text{ m}}$
20. $v_i = +7.0$ m/s $a = +0.80$ m/s^2 $\Delta t = 2.0$ s	$v_f = v_i + a\Delta t = 7.0 \text{ m/s} + (0.80 \text{ m/s}^2)(2.0 \text{ s}) = 7.0 \text{ m/s} + 1.6 \text{ m/s} = \boxed{+8.6 \text{ m/s}}$
21. $v_i = 0$ m/s $a = -3.00$ m/s^2 $\Delta t = 5.0$ s	**a.** $v_f = v_i + a\Delta t = 0 \text{ m/s} + (-3.00 \text{ m/s}^2)(5.0 \text{ s}) = \boxed{-15 \text{ m/s}}$ **b.** $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(-3.00 \text{ m/s}^2)(5.0 \text{ s})^2 = \boxed{-38 \text{ m}}$
22. $v_i = 0$ m/s $\Delta t_1 = 5.0$ s $a_1 = +1.5$ m/s^2 $\Delta t_2 = 3.0$ s $a_2 = -2.0$ m/s^2	For the first time interval, $v_f = v_i + a_1\Delta t_1 = 0 \text{ m/s} + (1.5 \text{ m/s}^2)(5.0 \text{ s}) = +7.5 \text{ m/s}$ $\Delta x_1 = v_i\Delta t_1 + \frac{1}{2}a_1\Delta t_1^2 = (0 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(1.5 \text{ m/s}^2)(5.0 \text{ s})^2 = +19 \text{ m}$ For the second time interval, $v_i = +7.5$ m/s $v_f = v_i + a_2\Delta t_2 = 7.5 \text{ m/s} + (-2.0 \text{ m/s}^2)(3.0 \text{ s}) = 7.5 \text{ m/s} - 6.0 \text{ m/s} = \boxed{+1.5 \text{ m/s}}$ $\Delta x_2 = v_i\Delta t_2 + \frac{1}{2}a_2\Delta t_2 = (7.5 \text{ m/s})(3.0 \text{ s}) + \frac{1}{2}(-2.0 \text{ m/s}^2)(3.0 \text{ s})^2 = 22 \text{ m} - 9.0 \text{ m} = +13 \text{ m}$ $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 19 \text{ m} + 13 \text{ m} = \boxed{+32 \text{ m}}$

Givens	*Solutions*
23. $a = 1.40\ \text{m/s}^2$ $v_i = 0\ \text{m/s}$ $v_f = 7.00\ \text{m/s}$	$\Delta x = \frac{v_f^2 - v_i^2}{2a} = \frac{(7.00\ \text{m/s})^2 - (0\ \text{m/s})^2}{(2)(1.40\ \text{m/s}^2)} = \frac{49.0\ \text{m}^2/\text{s}^2}{2.80\ \text{m/s}^2} = \boxed{17.5\ \text{m}}$
24. $v_i = 0\ \text{m/s}$ $a = 0.21\ \text{m/s}^2$ $\Delta x = 280\ \text{m}$	**a.** $v_f = \sqrt{v_i^2 + 2a\Delta x} = \sqrt{(0\ \text{m/s})^2 + (2)(0.21\ \text{m/s}^2)(280\ \text{m})} = \sqrt{120\ \text{m}^2/\text{s}^2} = \pm 11\ \text{m/s}$ $\boxed{v_f = 11\ \text{m/s}}$ **b.** $\Delta t = \frac{v_f - v_i}{a} = \frac{11\ \text{m/s} - 0\ \text{m/s}}{0.21\ \text{m/s}^2} = \boxed{52\ \text{s}}$
25. $v_i = +1.20\ \text{m/s}$ $a = -0.31\ \text{m/s}^2$ $\Delta x = +0.75\ \text{m}$	$v_f = \sqrt{v_i^2 + 2a\Delta x} = \sqrt{(1.20\ \text{m/s})^2 + (2)(-0.31\ \text{m/s}^2)(0.75\ \text{m})}$ $v_f = \sqrt{1.44\ \text{m}^2/\text{s}^2 - 0.46\ \text{m}^2/\text{s}^2} = \sqrt{0.98\ \text{m}^2/\text{s}^2} = \pm 0.99\ \text{m/s} = \boxed{+0.99\ \text{m/s}}$
30. $v_i = 0\ \text{m/s}$ $\Delta y = -80.0\ \text{m}$ $a = -9.81\ \text{m/s}^2$	When $v_i = 0\ \text{m/s}$, $v^2 = 2a\Delta y \qquad v = \sqrt{2a\Delta y}$ $v = \sqrt{(2)(-9.81\ \text{m/s}^2)(-80.0\ \text{m})}$ $v = \pm\sqrt{1570\ \text{m}^2/\text{s}^2}$ $v = \boxed{-39.6\ \text{m/s}}$
31. $v_i = 0\ \text{m/s}$ $a = -9.81\ \text{m/s}^2$ $\Delta y = -76.0\ \text{m}$	When $v_i = 0\ \text{m/s}$, $\Delta t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{(2)(-76.0\ \text{m})}{-9.81\ \text{m/s}^2}} = \boxed{3.94\ \text{s}}$
32. $v_{i,1} = +25\ \text{m/s}$ $v_{i,2} = 0\ \text{m/s}$ $a = -9.81\ \text{m/s}^2$ $y_{i,1} = 0\ \text{m}$ $y_{i,2} = 15\ \text{m}$ y = distance from ground to point where both balls are at the same height	$\Delta y_1 = y - y_{i,1} = v_{i,1}\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta y_2 = y - y_{i,2} = v_{i,2}\Delta t + \frac{1}{2}a\Delta t^2$ $\Delta y_1 - \Delta y_2 = (y - y_{i,1}) - (y - y_{i,2}) = y_{i,2} - y_{i,1}$ $\Delta y_1 - \Delta y_2 = (v_{i,1}\Delta t + \frac{1}{2}a\Delta t^2) - (v_{i,2}\Delta t + \frac{1}{2}a\Delta t^2) = (v_{i,1} - v_{i,2})\,\Delta t$ $\Delta y_1 - \Delta y_2 = y_{i,2} - y_{i,1} = (v_{i,1} - v_{i,2})\Delta t$ $\Delta t = \frac{y_{i,2} - y_{i,1}}{v_{i,1} - v_{i,2}} = \frac{15\ \text{m} - 0\ \text{m}}{25\ \text{m/s} - 0\ \text{m/s}} = \frac{15\ \text{m}}{25\ \text{m/s}} = \boxed{0.60\ \text{s}}$
33. $v_{avg} = 27\,800\ \text{km/h}$ $r_{earth} = 6380\ \text{km}$ $\Delta x = 320.0\ \text{km}$	circumference $= 2\pi(r_{earth} + \Delta x)$ $\Delta t = \frac{\text{circumference}}{v_{avg}} = \frac{2\pi(6380\ \text{km} + 320.0\ \text{km})}{27\,800\ \text{km/h}} = \frac{2\pi(6.70 \times 10^3\ \text{km})}{27\,800\ \text{km/h}} = \boxed{1.51\ \text{h}}$

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34.

a. For $\Delta y = 0.20$ m = maximum height of ball, $\Delta t = \boxed{0.20 \text{ s}}$

b. For $\Delta y = 0.10$ m = one-half maximum height of ball,

$\Delta t = \boxed{0.06 \text{ s as ball goes up}}$

$\Delta t = \boxed{0.34 \text{ s as ball comes down}}$

c. Estimating v from $t = 0.04$ s to $t = 0.06$ s:

$$v = \frac{\Delta x}{\Delta t} = \frac{0.10 \text{ m} - 0.07 \text{ m}}{0.06 \text{ s} - 0.04 \text{ s}} = \frac{0.03 \text{ m}}{0.02 \text{ s}} = \boxed{+2 \text{ m/s}}$$

Estimating v from $t = 0.09$ s to $t = 0.11$ s:

$$v = \frac{\Delta x}{\Delta t} = \frac{0.15 \text{ m} - 0.13 \text{ m}}{0.11 \text{ s} - 0.09 \text{ s}} = \frac{0.02 \text{ m}}{0.02 \text{ s}} = \boxed{+1 \text{ m/s}}$$

Estimating v from $t = 0.14$ s to $t = 0.16$ s:

$$v = \frac{\Delta x}{\Delta t} = \frac{0.19 \text{ m} - 0.18 \text{ m}}{0.16 \text{ s} - 0.14 \text{ s}} = \frac{0.01 \text{ m}}{0.02 \text{ s}} = \boxed{+\ 0.5 \text{ m/s}}$$

Estimating v from $t = 0.19$ s to $t = 0.21$ s:

$$v = \frac{\Delta x}{\Delta t} = \frac{0.20 \text{ m} - 0.20 \text{ m}}{0.21 \text{ s} - 0.19 \text{ s}} = \boxed{0 \text{ m/s}}$$

d. $a = \dfrac{\Delta v}{\Delta t} = \dfrac{0 \text{ m/s} - 2 \text{ m/s}}{0.20 \text{ s} - 0 \text{ s}} = \dfrac{-2 \text{ m/s}}{0.20 \text{ s}} = \boxed{-10 \text{ m/s}^2}$

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35. $\Delta x_{AB} = \Delta x_{BC} = \Delta x_{CD}$

$\Delta t_{AB} + \Delta t_{BC} + \Delta t_{CD} =$ 5.00 min

$$\Delta t_{AB} = \frac{\Delta x_{AB}}{v_{AB,avg}} = \frac{\Delta x_{AB}}{\frac{(v_B + 0)}{2}} = \frac{2\Delta x_{AB}}{v_B}$$

Because the train's velocity is constant from B to C, $\Delta t_{BC} = \dfrac{\Delta x_{BC}}{v_B}$.

$$\Delta t_{CD} = \frac{\Delta x_{CD}}{v_{CD,avg}} = \frac{\Delta x_{CD}}{\frac{(0 + v_B)}{2}} = \frac{2\Delta x_{CD}}{v_B}$$

Because $\Delta x_{AB} = \Delta x_{BC} = \Delta x_{CD}$, $\dfrac{\Delta t_{AB}}{2} = \Delta t_{BC} = \dfrac{\Delta t_{CD}}{2}$, or

$\Delta t_{AB} = \Delta t_{CD} = 2\Delta t_{BC}$.

We also know that $\Delta t_{AB} + \Delta t_{BC} + \Delta t_{CD} = 5.00$ min.

Thus, the time intervals are as follows:

a. $\Delta t_{AB} = \boxed{2.00 \text{ min}}$

b. $\Delta t_{BC} = \boxed{1.00 \text{ min}}$

c. $\Delta t_{CD} = \boxed{2.00 \text{ min}}$

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36. $\Delta y = -19.6$ m $v_{i,1} = -14.7$ m/s $v_{i,2} = +14.7$ m/s $a = -9.81$ m/s^2	**a.** $v_{f,1} = \sqrt{v_{i,1}^2 + 2a\Delta y} = \sqrt{(-14.7 \text{ m/s})^2 + (2)(-9.81 \text{ m/s}^2)(-19.6 \text{ m})}$ $v_{f,1} = \sqrt{216 \text{ m}^2/\text{s}^2 + 385 \text{ m}^2/\text{s}^2} = \sqrt{601 \text{ m}^2/\text{s}^2} = \pm 24.5 \text{ m/s} = -24.5 \text{ m/s}$ $v_{f,2} = \sqrt{v_{i,2}^2 + 2a\Delta y} = \sqrt{(14.7 \text{ m/s})^2 + (2)(-9.81 \text{ m/s}^2)(-19.6 \text{ m})}$ $v_{f,2} = \sqrt{216 \text{ m}^2/\text{s}^2 + 385 \text{ m}^2/\text{s}^2} = \sqrt{601 \text{ m}^2/\text{s}^2} = \pm 24.5 \text{ m/s} = -24.5 \text{ m/s}$ $\Delta t_1 = \frac{v_{f,1} - v_{i,1}}{a} = \frac{-24.5 \text{ m/s} - (-14.7 \text{ m/s})}{-9.81 \text{ m/s}^2} = \frac{-9.8 \text{ m/s}}{-9.81 \text{ m/s}^2} = 1.0 \text{ s}$ $\Delta t_2 = \frac{v_{f,2} - v_{i,2}}{a} = \frac{-24.5 \text{ m/s} - 14.7 \text{ m/s}}{-9.81 \text{ m/s}^2} = \frac{-39.2 \text{ m/s}}{-9.81 \text{ m/s}^2} = 4.00 \text{ s}$ difference in time $= \Delta t_2 - \Delta t_1 = 4.00 \text{ s} - 1.0 \text{ s} = \boxed{3.0 \text{ s}}$
	b. $v_{f,1} = \boxed{-24.5 \text{ m/s}}$ (See **a.**) $v_{f,2} = \boxed{-24.5 \text{ m/s}}$ (See **a.**)
$\Delta t = 0.800$ s	**c.** $\Delta y_1 = v_{i,1}\Delta t + \frac{1}{2}a\Delta t^2 = (-14.7 \text{ m/s})(0.800 \text{ s}) + \frac{1}{2}(-9.81 \text{ m/s}^2)(0.800 \text{ s})^2$ $\Delta y_1 = -11.8 \text{ m} - 3.14 \text{ m} = -14.9 \text{ m}$ $\Delta y_2 = v_{i,2}\Delta t + \frac{1}{2}a\Delta t^2 = (14.7 \text{ m/s})(0.800 \text{ s}) + \frac{1}{2}(-9.81 \text{ m/s}^2)(0.800 \text{ s})^2$ $\Delta y_2 = 11.8 \text{ m} - 3.14 \text{ m} = +8.7 \text{ m}$ distance between balls $= \Delta y_2 - \Delta y_1 = 8.7 \text{ m} - (-14.9 \text{ m}) = \boxed{23.6 \text{ m}}$
37. For the first time interval: $v_i = 0$ m/s $a = +29.4$ m/s^2 $\Delta t = 3.98$ s	While the rocket accelerates, $\Delta y_1 = v_1\Delta t + \frac{1}{2}a\Delta t^2 = (0 \text{ m/s})(3.98 \text{ s}) + \frac{1}{2}(29.4 \text{ m/s}^2)(3.98 \text{ s})^2 = +233 \text{ m}$ $v_f = v_i + a\Delta t = 0 \text{ m/s} + (29.4 \text{ m/s}^2)(3.98 \text{ s}) = +117 \text{ m/s}$
For the second time interval: $v_i = +117$ m/s $a = -9.81$ m/s^2 $v_f = 0$ m/s	After the rocket runs out of fuel, $\Delta y_2 = \frac{v_f^2 - v_i^2}{2a} = \frac{(0 \text{ m/s})^2 - (117 \text{ m/s})^2}{(2)(-9.81 \text{ m/s}^2)} = +698 \text{ m}$ total height reached by rocket $= \Delta y_1 + \Delta y_2 = 233 \text{ m} + 698 \text{ m} = \boxed{931 \text{ m}}$

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38. $v_1 = 85$ km/h $v_2 = 115$ km/h $\Delta x = 16$ km	**a.** $\Delta t_1 = \frac{\Delta x}{v_1} = \frac{16 \text{ km}}{85 \text{ km/h}} = 0.19 \text{ h}$ $\Delta t_2 = \frac{\Delta x}{v_2} = \frac{16 \text{ km}}{115 \text{ km/h}} = 0.14 \text{ h}$ The faster car arrives $\Delta t_1 - \Delta t_2 = 0.19 \text{ h} - 0.14 \text{ h} = \boxed{0.05 \text{ h}}$ earlier.
$\Delta t_1 - \Delta t_2 = 15$ min $= 0.25$ h	**b.** $\Delta x = \Delta t_1 v_1 = \Delta t_2 v_2$ $\Delta x\,(v_2 - v_1) = \Delta x v_2 - \Delta x v_1 = (\Delta t_1 v_1)v_2 - (\Delta t_2 v_2)v_1$ $\Delta x\,(v_2 - v_1) = (\Delta t_1 - \Delta t_2)v_2 v_1$ $\Delta x = (\Delta t_1 - \Delta t_2)\left(\frac{v_2 v_1}{v_2 - v_1}\right) = (0.25 \text{ h})\left(\frac{(115 \text{ km/h})(85 \text{ km/h})}{(115 \text{ km/h}) - (85 \text{ km/h})}\right)$ $\Delta x = (0.25 \text{ h})\left(\frac{(115 \text{ km/h})(85 \text{ km/h})}{(30 \text{ km/h})}\right) = \boxed{81 \text{ km}}$
39. $v_i = -1.3$ m/s $a = -9.81$ m/s^2 $\Delta t = 2.5$ s	$v_f = v_i + a\Delta t = -1.3 \text{ m/s} + (-9.81 \text{ m/s}^2)(2.5 \text{ s})$ $v_f = -1.3 \text{ m/s} - 25 \text{ m/s} = \boxed{-26 \text{ m/s}}$ $\Delta x_{kit} = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(-1.3 \text{ m/s} - 26 \text{ m/s})(2.5 \text{ s})$ $\Delta x_{kit} = \frac{1}{2}(-27 \text{ m/s})(2.5 \text{ s}) = -34 \text{ m}$ $\Delta x_{climber} = (-1.3 \text{ m/s})(2.5 \text{ s}) = -3.2 \text{ m}$ The distance between the kit and the climber is $\Delta x_{climber} - \Delta x_{kit}$. $\Delta x_{climber} - \Delta x_{kit} = -3.2 \text{ m} - (-34 \text{ m}) = \boxed{31 \text{ m}}$
40. $v_i = +0.50$ m/s $\Delta t = 2.5$ s $a = -9.81$ m/s^2	**a.** $v_f = v_i + a\Delta t = 0.50 \text{ m/s} + (-9.81 \text{ m/s}^2)(2.5 \text{ s}) = 0.50 \text{ m/s} - 25 \text{ m/s}$ $v_f = \boxed{-24 \text{ m/s}}$ **b.** $\Delta x_{fish} = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0.50 \text{ m/s} - 24 \text{ m/s})(2.5 \text{ s})$ $\Delta x_{fish} = \frac{1}{2}(-24 \text{ m/s})(2.5 \text{ s}) = -30 \text{ m}$ $\Delta x_{pelican} = (0.50 \text{ m/s})(2.5 \text{ s}) = +1.2 \text{ m}$ The distance between the fish and the pelican is $\Delta x_{pelican} - \Delta x_{fish}$. $\Delta x_{pelican} - \Delta x_{fish} = 1.2 \text{ m} - (-30 \text{ m}) = \boxed{31 \text{ m}}$
41. $v_i = 56$ km/h $v_f = 0$ m/s $a = -3.0$ m/s^2 $\Delta x_{tot} = 65$ m	For the time interval during which the ranger decelerates, $\Delta t = \frac{v_f - v_i}{a} = \frac{0 \text{ m/s} - (56 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})}{-3.0 \text{ m/s}^2} = 5.2 \text{ s}$ $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (56 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})(5.2 \text{ s}) + \frac{1}{2}(-3.0 \text{ m/s}^2)(5.2 \text{ s})^2$ $\Delta x = 81 \text{ m} - 41 \text{ m} = 4.0 \times 10^1 \text{ m}$ maximum reaction distance $= \Delta x_{tot} - \Delta x = 65 \text{ m} - (4.0 \times 10^1 \text{ m}) = 25 \text{ m}$ maximum reaction time $= \frac{\text{maximum reaction distance}}{v_i}$ maximum reaction time $= \frac{25 \text{ m}}{(56 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})} = \boxed{1.6 \text{ s}}$

42. $v_s = 30.0$ m/s

$v_{i,p} = 0$ m/s

$a_p = 2.44$ m/s^2

a. $\Delta x_s = \Delta x_p$

$\Delta x_s = v_s \Delta t$

Because $v_{i,p} = 0$ m/s,

$\Delta x_p = \frac{1}{2} a_p \Delta t^2$

$v_s \Delta t = \frac{1}{2} a_p \Delta t^2$

$$\Delta t = \frac{2v_s}{a_p} = \frac{(2)(30.0 \text{ m/s})}{2.44 \text{ m/s}^2} = \boxed{24.6 \text{ s}}$$

b. $\Delta x_s = v_s \Delta t = (30.0 \text{ m/s})(24.6 \text{ s}) = \boxed{738 \text{ m}}$

or $\Delta x_p = \frac{1}{2} a_p \Delta t^2 = \frac{1}{2}(2.44 \text{ m/s}^2)(24.6 \text{ s})^2 = \boxed{738 \text{ m}}$

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43. For Δt_1:

$v_i = 0$ m/s

$a = +13.0$ m/s^2

$v_f = v$

For Δt_2:

$a = 0$ m/s^2

v = constant velocity

$\Delta x_{tot} = +5.30 \times 10^3$ m

$\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 90.0$ s

When $v_i = 0$ m/s,

$\Delta x_1 = \frac{1}{2} a \Delta t_1^{\,2}$

$\Delta t_2 = 90.0 \text{ s} - \Delta t_1$

$\Delta x_2 = v \Delta t_2 = v(90.0 \text{ s} - \Delta t_1)$

$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = \frac{1}{2} a \Delta t_1^{\,2} + v(90.0 \text{ s} - \Delta t_1)$

$v = v_f$ during the first time interval $= a\Delta t_1$

$\Delta x_{tot} = \frac{1}{2} a \Delta t_1^{\,2} + a\Delta t_1(90.0 \text{ s} - \Delta t_1) = \frac{1}{2} a \Delta t_1^{\,2} + (90.0 \text{ s}) a \Delta t_1 - a \Delta t_1^{\,2}$

$\Delta x_{tot} = -\frac{1}{2} a \Delta t_1^{\,2} + (90.0 \text{ s}) a \Delta t_1$

$\frac{1}{2} a \Delta t_1^{\,2} - (90.0 \text{ s}) a \Delta t_1 + \Delta x_{tot} = 0$

Using the quadratic equation,

$$\Delta t_1 = \frac{(90.0 \text{ s})(a) \pm \sqrt{[-(90.0 \text{ s})(a)]^2 - 4\left(\frac{1}{2}a\right)(\Delta x_{tot})}}{2\left(\frac{1}{2}a\right)}$$

$$\Delta t_1 = \frac{(90.0 \text{ s})(13.0 \text{ m/s}^2) \pm \sqrt{[-(90.0 \text{ s})(13.0 \text{ m/s}^2)]^2 - 2(13.0 \text{ m/s})(5.30 \times 10^3 \text{ m})}}{13.0 \text{ m/s}^2}$$

$$\Delta t_1 = \frac{1170 \text{ m/s} \pm \sqrt{(1.37 \times 10^6 \text{ m}^2/\text{s}^2) - (1.38 \times 10^5 \text{ m}^2/\text{s}^2)}}{13.0 \text{ m/s}^2}$$

$$\Delta t_1 = \frac{1170 \text{ m/s} \pm \sqrt{1.23 \times 10^6 \text{ m}^2/\text{s}^2}}{13.0 \text{ m/s}^2} = \frac{1170 \text{ m/s} \pm 1110 \text{ m/s}}{13.0 \text{ m/s}^2} = \frac{60 \text{ m/s}}{13.0 \text{ m/s}^2} = \boxed{5 \text{ s}}$$

$\Delta t_2 = \Delta t_{tot} - \Delta t_1 = 90.0 \text{ s} - 5 \text{ s} = \boxed{85 \text{ s}}$

$v = a\Delta t_1 = (13.0 \text{ m/s}^2)(5 \text{ s}) = \boxed{+60 \text{ m/s}}$

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44. $\Delta x_1 = +5800$ m

$a = -7.0$ m/s^2

$v_i = +60$ m/s (see **43.**)

$v_f = 0$ m/s

a. $\Delta x_2 = \dfrac{v_f^{\,2} - v_i^2}{2a} = \dfrac{(0\text{ m/s})^2 - (60\text{ m/s})^2}{(2)(-7.0\text{ m/s}^2)} = +\,300\text{ m}$

sled's final position $= \Delta x_1 + \Delta x_2 = 5800\text{ m} + 300\text{ m} = \boxed{6100\text{ m}}$

b. $\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{0\text{ m/s} - 60\text{ m/s}}{-7.0\text{ m/s}^2} = \boxed{9\text{ s}}$

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45. $v_i = +10.0$ m/s

$v_f = -8.0$ m/s

$\Delta t = 0.012$ s

$a_{avg} = \dfrac{v_f - v_i}{\Delta t} = \dfrac{-8.0\text{ m/s} - 10.0\text{ m/s}}{0.012\text{ s}} = \boxed{-1.5 \times 10^3\text{ m/s}^2}$

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46. $v_i = -10.0$ m/s

$\Delta y = -50.0$ m

$a = -9.81$ m/s^2

a. $v_f = \sqrt{v_i^2 + 2a\Delta y} = \sqrt{(-10.0\text{ m/s})^2 + (2)(-9.81\text{ m/s}^2)(-50.0\text{ m})}$

$v_f = \sqrt{1.00 \times 10^2\text{ m}^2/\text{s}^2 + 981\text{ m}^2/\text{s}^2} = \sqrt{1081\text{ m}^2/\text{s}^2} = \pm 32.9\text{ m/s} = -32.9\text{ m/s}$

$\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{-32.9\text{ m/s} - (-10.0\text{ m/s})}{-9.81\text{ m/s}^2} = \dfrac{-22.9\text{ m/s}}{-9.81\text{ m/s}^2} = \boxed{2.33\text{ s}}$

b. $v_f = \boxed{-32.9\text{ m/s}}$ (See **a.**)

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47. $\Delta y = -50.0$ m

$v_{i,1} = +2.0$ m/s

$\Delta t_1 = \Delta t_2 + 1.0$ s

$a = -9.81$ m/s^2

a. $v_{f,1} = \sqrt{v_{i,1}^{\;2} + 2a\Delta y} = \sqrt{(2.0\text{ m/s})^2 + (2)(-9.81\text{ m/s}^2)(-50.0\text{ m})}$

$v_{f,1} = \sqrt{4.0\text{ m}^2/\text{s}^2 + 981\text{ m}^2/\text{s}^2} = \sqrt{985\text{ m}^2/\text{s}^2} = \pm 31.4\text{ m/s} = -31.4\text{ m/s}$

$\Delta t_1 = \dfrac{v_{f,1} - v_{i,1}}{a} = \dfrac{-31.4\text{ m/s} - 2.0\text{ m/s}}{-9.81\text{ m/s}^2} = \dfrac{-33.4\text{ m/s}}{-9.81\text{ m/s}^2} = \boxed{3.40\text{ s}}$

b. $\Delta t_2 = \Delta t_1 - 1.0\text{ s} = 3.40\text{ s} - 1.0\text{ s} = 2.4\text{ s}$

$\Delta y = v_{i,2}\Delta t_2 + \frac{1}{2}a\Delta t_2^{\,2}$

$v_{i,2} = \dfrac{\Delta y - \frac{1}{2}a\Delta t_2^{\,2}}{\Delta t_2} = \dfrac{-50.0\text{ m} - \frac{1}{2}(-9.81\text{ m/s}^2)(2.4\text{ s})^2}{2.4\text{ s}}$

$v_{i,2} = \dfrac{-50.0\text{ m} + 28\text{ m}}{2.4\text{ s}} = \dfrac{-22\text{ m}}{2.4\text{ s}} = \boxed{-9.2\text{ m/s}}$

c. $v_{f,1} = \boxed{-31.4\text{ m/s}}$ (See **a.**)

$v_{f,2} = v_{i,2} + a\Delta t_2 = -9.2\text{ m/s} + (-9.81\text{ m/s}^2)(2.4\text{ s})$

$v_{f,2} = -9.2\text{ m/s} - 24\text{ m/s} = \boxed{-33\text{ m/s}}$

Givens | *Solutions*

48. For the first time interval:

$v_{i,1} = +50.0$ m/s

$a_1 = +2.00$ m/s^2

$\Delta y_1 = +150$ m

For the second time interval:

$v_{i,2} = +55.7$ m/s

$v_{f,2} = 0$ m/s

$a_2 = -9.81$ m/s^2

For the trip down:

$\Delta y = -310$ m

$v_i = 0$ m/s

$a = -9.81$ m/s^2

a. $v_{f,1} = \sqrt{v_{i,1}{}^2 + 2a_1\Delta y_1} = \sqrt{(50.0 \text{ m/s})^2 + (2)(2.00 \text{ m/s}^2)(150 \text{ m})}$

$v_{f,1} = \sqrt{(2.50 \times 10^3 \text{ m}^2/\text{s}^2) + (6.0 \times 10^2 \text{ m}^2/\text{s}^2)} = \sqrt{3.10 \times 10^3 \text{ m}^2/\text{s}^2}$

$v_{f,1} = \pm 55.7 \text{ m/s} = +55.7 \text{ m/s}$

$$\Delta y_2 = \frac{v_{f,2}{}^2 - v_{i,2}{}^2}{2a_2} = \frac{(0 \text{ m/s})^2 - (55.7 \text{ m/s})^2}{(2)(-9.81 \text{ m/s}^2)} = +158 \text{ m}$$

maximum height $= \Delta y_1 + \Delta y_2 = 150 \text{ m} + 158 \text{ m} = \boxed{310 \text{ m}}$

b. For the first time interval,

$$\Delta t_{up,1} = \frac{2\Delta y_1}{v_{i,1} + v_{f,1}} = \frac{(2)(150 \text{ m})}{50.0 \text{ m/s} + 55.7 \text{ m/s}} = \frac{(2)(150 \text{ m})}{105.7 \text{ m/s}} = 2.8 \text{ s}$$

For the second time interval,

$$\Delta t_{up,2} = \frac{2\Delta y_2}{v_{i,2} + v_{f,2}} = \frac{(2)(158 \text{ m})}{55.7 \text{ m/s} + 0 \text{ m/s}} = 5.67 \text{ s}$$

$\Delta t_{up,tot} = \Delta t_{up,1} + \Delta t_{up,2} = 2.8 \text{ s} + 5.67 \text{ s} = \boxed{8.5 \text{ s}}$

c. Because $v_i = 0$ m/s, $\Delta t_{down} = \sqrt{\dfrac{2\Delta y}{a}} = \dfrac{\sqrt{(2)(-310 \text{ m})}}{-9.81 \text{ m/s}^2} = \sqrt{63 \text{ s}^2} = 7.9 \text{ s}$

$\Delta t_{tot} = \Delta t_{up,tot} + \Delta t_{down} = 8.5 \text{ s} + 7.9 \text{ s} = \boxed{16.4 \text{ s}}$

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Givens	Solutions

49. $a_1 = +5.9 \text{ m/s}^2$

$a_2 = +3.6 \text{ m/s}^2$

$\Delta t_1 = \Delta t_2 - 1.0 \text{ s}$

Because both cars are initially at rest,

a. $\Delta x_1 = \frac{1}{2} a_1 \Delta t_1^2$

$\Delta x_2 = \frac{1}{2} a_2 \Delta t_2^2$

$\Delta x_1 = \Delta x_2$

$\frac{1}{2} a_1 \Delta t_1^2 = \frac{1}{2} a_2 \Delta t_2^2$

$a_1(\Delta t_2 - 1.0 \text{ s})^2 = a_2 \Delta t_2^2$

$a_1[\Delta t_2^2 - (2.0 \text{ s})(\Delta t_2) + 1.0 \text{ s}^2] = a_2 \Delta t_2^2$

$(a_1)(\Delta t_2)^2 - a_1(2.0 \text{ s})\Delta t_2 + a_1(1.0 \text{ s}^2) = a_2 \Delta t_2^2$

$(a_1 - a_2)\Delta t_2^2 - a_1(2.0 \text{ s})\Delta t_2 + a_1(1.0 \text{ s}^2) = 0$

Using the quadratic equation,

$$\Delta t_2 = \frac{(a_1)(2.0 \text{ s}) \pm \sqrt{[-a_1(2.0 \text{ s})]^2 - 4(a_1 - a_2)a_1(1.0 \text{ s}^2)}}{2(a_1 - a_2)}$$

$a_1 - a_2 = 5.9 \text{ m/s}^2 - 3.6 \text{ m/s}^2 = 2.3 \text{ m/s}^2$

$$\Delta t_2 = \frac{(5.9 \text{ m/s}^2)(2.0 \text{ s}) \pm \sqrt{[-(5.9 \text{ m/s}^2)(2.0 \text{ s})]^2 - (4)(2.3 \text{ m/s}^2)(5.9 \text{ m/s}^2)(1.0 \text{ s}^2)}}{(2)(2.3 \text{ m/s}^2)}$$

$$\Delta t_2 = \frac{12 \text{ m/s} \pm \sqrt{140 \text{ m}^2/\text{s}^2 - 54 \text{ m}^2/\text{s}^2}}{(2)(2.3 \text{ m/s}^2)} = \frac{12 \text{ m/s} \pm \sqrt{90 \text{ m}^2/\text{s}^2}}{(2)(2.3 \text{ m/s}^2)}$$

$$\Delta t_2 = \frac{12 \text{ m/s} \pm 9 \text{ m/s}}{(2)(2.3 \text{ m/s}^2)} = \frac{21 \text{ m/s}}{(2)(2.3 \text{ m/s}^2)} = \boxed{4.6 \text{ s}}$$

$\Delta t_1 = \Delta t_2 - 1.0 \text{ s} = 4.6 \text{ s} - 1.0 \text{ s} = \boxed{3.6 \text{ s}}$

b. $\Delta x_1 = \frac{1}{2} a_1 \Delta t_1^2 = \frac{1}{2}(5.9 \text{ m/s}^2)(3.6 \text{ s})^2 = 38 \text{ m}$

or $\Delta x_2 = \frac{1}{2} a_2 \Delta t_2^2 = \frac{1}{2}(3.6 \text{ m/s}^2)(4.6 \text{ s})^2 = 38 \text{ m}$

distance both cars travel = $\boxed{38 \text{ m}}$

c. $v_1 = a_1 \Delta t_1 = (5.9 \text{ m/s}^2)(3.6 \text{ s}) = \boxed{+21 \text{ m/s}}$

$v_2 = a_2 \Delta t_2 = (3.6 \text{ m/s}^2)(4.6 \text{ s}) = \boxed{+17 \text{ m/s}}$

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50. $v_{i,1} = +25 \text{ m/s}$

$v_{i,2} = +35 \text{ m/s}$

$\Delta x_2 = \Delta x_1 + 45 \text{ m}$

$a_1 = -2.0 \text{ m/s}^2$

$v_{f,1} = 0 \text{ m/s}$

$v_{f,2} = 0 \text{ m/s}$

a. $\Delta t_1 = \dfrac{v_{f,1} - v_{i,1}}{a_1} = \dfrac{0 \text{ m/s} - 25 \text{ m/s}}{-2.0 \text{ m/s}^2} = \boxed{13 \text{ s}}$

b. $\Delta x_1 = \frac{1}{2}(v_{i,1} + v_{f,1})\Delta t_1 = \frac{1}{2}(25 \text{ m/s} + 0 \text{ m/s})(13 \text{ s}) = +163 \text{ m}$

$\Delta x_2 = \Delta x_1 + 45 \text{ m} = 163 \text{ m} + 45 \text{ m} = +208 \text{ m}$

$a_2 = \dfrac{v_{f,2}^2 - v_{i,2}^2}{2\Delta x_2} = \dfrac{(0 \text{ m/s})^2 - (35 \text{ m/s})^2}{(2)(208 \text{ m})} = \boxed{-2.9 \text{ m/s}^2}$

c. $\Delta t_2 = \dfrac{v_{f,2} - v_{i,2}}{a_2} = \dfrac{0 \text{ m/s} - 35 \text{ m/s}}{-2.9 \text{ m/s}^2} = \boxed{12 \text{ s}}$

Givens | *Solutions*

51. $\Delta x_1 = 20.0$ m

$v_1 = 4.00$ m/s

$\Delta x_2 = v_2(0.50 \text{ s}) + 20.0$ m

$$\Delta t = \frac{\Delta x_1}{v_1} = \frac{20.0 \text{ m}}{4.00 \text{ m/s}} = 5.00 \text{ s}$$

$$v_2 = \frac{\Delta x_2}{\Delta t} = \frac{v_2(0.50 \text{ s}) + 20.0 \text{ m}}{\Delta t}$$

$$v_2\Delta t = v_2(0.50 \text{ s}) + 20.0 \text{ m}$$

$$v_2(\Delta t - 0.50 \text{ s}) = 20.0 \text{ m}$$

$$v_2 = \frac{20.0 \text{ m}}{\Delta t - 0.50 \text{ s}} = \frac{20.0 \text{ m}}{(5.00 \text{ s} - 0.50 \text{ s})} = \frac{20.0 \text{ m}}{4.50 \text{ s}} = \boxed{4.44 \text{ m/s}}$$

I

Motion In One Dimension, Standardized Test Prep

4. $\Delta t = 5.2$ h

$v_{avg} = 73$ km/h south

$$\Delta x = v_{avg}\Delta t = (73 \text{ km/h})(5.2 \text{ h}) = \boxed{3.8 \times 10^2 \text{ km south}}$$

5. $\Delta t = 3.0$ s

$$\Delta x = 4.0 \text{ m} + (-4.0 \text{ m}) + (-2.0 \text{ m}) + 0.0 \text{ m} = \boxed{-2.0 \text{ m}}$$

6. $\Delta x = -2.0$ m (see **5.**)

$\Delta t = 3.0$ s

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{-2.0 \text{ m}}{3.0 \text{ s}} = \boxed{-0.67 \text{ m/s}}$$

8. $v_i = 0$ m/s

$a = 3.3 \text{ m/s}^2$

$\Delta t = 7.5$ s

$$\Delta x = v_i\Delta t + \tfrac{1}{2}a\Delta t^2$$

$$\Delta x = (0 \text{ m/s})(7.5 \text{ s}) + \tfrac{1}{2}(3.3 \text{ m/s}^2)(7.5 \text{ s})^2 = 0 \text{ m} + 93 \text{ m} = \boxed{93 \text{ m}}$$

11. $\Delta t_1 = 10.0 \text{ min} - 0 \text{ min}$

$= 10.0$ min

$\Delta t_2 = 20.0 \text{ min} - 10.0 \text{ min}$

$= 10.0$ min

$\Delta t_3 = 30.0 \text{ min} - 20.0 \text{ min}$

$= 10.0$ min

a. $\Delta x_1 = (2.4 \times 10^3 \text{ m}) - (0 \times 10^3 \text{ m}) = \boxed{+2.4 \times 10^3 \text{ m}}$

$$v_1 = \frac{\Delta x_1}{\Delta t_1} = \frac{(2.4 \times 10^3 \text{ m})}{(10.0 \text{ min})(60 \text{ s/min})} = \boxed{+4.0 \text{ m/s}}$$

b. $\Delta x_2 = (3.9 \times 10^3 \text{ m}) - (2.4 \times 10^3 \text{ m}) = \boxed{+1.5 \times 10^3 \text{ m}}$

$$v_2 = \frac{\Delta x_2}{\Delta t_2} = \frac{(1.5 \times 10^3 \text{ m})}{(10.0 \text{ min})(60 \text{ s/min})} = \boxed{+2.5 \text{ m/s}}$$

c. $\Delta x_3 = (4.8 \times 10^3 \text{ m}) - (3.9 \times 10^3 \text{ m}) = \boxed{+9 \times 10^2 \text{ m}}$

$$v_3 = \frac{\Delta x_3}{\Delta t_3} = \frac{(9 \times 10^2 \text{ m})}{(10.0 \text{ min})(60 \text{ s/min})} = \boxed{+2 \text{ m/s}}$$

d. $\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 = (2.4 \times 10^3 \text{ m}) + (1.5 \times 10^3 \text{ m}) + (9 \times 10^2 \text{ m})$

$\Delta x_{tot} = \boxed{+4.8 \times 10^3 \text{ m}}$

$$v_{avg} = \frac{\Delta x_{tot}}{\Delta t_{tot}} = \frac{\Delta x_1 + \Delta x_2 + \Delta x_3}{\Delta t_1 + \Delta t_2 + \Delta t_3} = \frac{(4.8 \times 10^3 \text{ m})}{(30.0 \text{ min})(60 \text{ s/min})}$$

$v_{avg} = \boxed{+2.7 \text{ m/s}}$

Givens	Solutions
13. $v_i = +3.0$ m/s $a_1 = +0.50$ m/s^2 $\Delta t = 7.0$ s $a_2 = -0.60$ m/s^2 $v_f = 0$ m/s	**a.** $v_f = a_1\Delta t + v_i = (0.50 \text{ m/s}^2)(7.0 \text{ s}) + 3.0 \text{ m/s} = 3.5 \text{ m/s} + 3.0 \text{ m/s} = \boxed{+6.5 \text{ m/s}}$ **b.** $\Delta t = \frac{v_f - v_i}{a_2} = \frac{0 \text{ m/s} - 3.0 \text{ m/s}}{-0.60 \text{ m/s}^2} = \boxed{5.0 \text{ s}}$
14. $v_i = 16$ m/s east $= +16$ m/s $v_f = 32$ m/s east $= +32$ m/s $\Delta t = 10.0$ s	**a.** $a = \frac{v_f - v_i}{\Delta t} = \frac{32 \text{ m/s} - 16 \text{ m/s}}{10.0 \text{ s}} = \frac{16 \text{ m/s}}{10.0 \text{ s}} = +1.6 \text{ m/s}^2 = \boxed{1.6 \text{ m/s}^2 \text{ east}}$ **b.** $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(16 \text{ m/s} + 32 \text{ m/s})(10.0 \text{ s}) = \frac{1}{2}(48 \text{ m/s})(10.0 \text{ s})$ $\Delta x = +240$ m $v_{avg} = \frac{\Delta x}{\Delta t} = \frac{240 \text{ m}}{10.0 \text{ s}} = +24 \text{ m/s} = \boxed{24 \text{ m/s east}}$ **c.** distance traveled = $\boxed{+240 \text{ m}}$ (See **b.**)
15. $v_i = +25.0$ m/s $y_i = +2.0$ m/s $a = -9.81$ m/s^2 For the trip up: $v_f = 0$ m/s	**a.** For the trip up, $\Delta t = \frac{v_f - v_i}{a} = \frac{0 \text{ m/s} - 25.0 \text{ m/s}}{-9.81 \text{ m/s}^2} = \boxed{2.55 \text{ s}}$ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (25.0 \text{ m/s})(2.55 \text{ s}) + \frac{1}{2}(-9.81 \text{ m/s}^2)(2.55 \text{ s})^2$ $\Delta y = 63.8 \text{ m} - 31.9 \text{ m} = +31.9 \text{ m}$
For the trip down: $v_i = 0$ m/s $\Delta y = (-31.9 \text{ m} - 2.0 \text{ m})$ $= -33.9$ m	**b.** For the trip down, because $v_i = 0$ m/s, $\Delta t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{(2)(-33.9 \text{ m})}{-9.81 \text{ m/s}^2}} = \sqrt{6.91 \text{ s}^2} = 2.63 \text{ s}$ total time = 2.55 s + 2.63 s = $\boxed{5.18 \text{ s}}$

Student Edition Solutions

Two-Dimensional Motion and Vectors

I

Two-Dimensional Motion and Vectors, Section 1 Review

Givens | *Solutions*

2. $\Delta x_1 = 85$ m

$d_2 = 45$ m

$\theta_2 = 30.0°$

Students should use graphical techniques. Their answers can be checked using the techniques presented in Section 2. Answers may vary.

$$\Delta x_2 = d_2(\cos \theta_2) = (45 \text{ m})(\cos 30.0°) = 39 \text{ m}$$

$$\Delta y_2 = d_2(\sin \theta_2) = (45 \text{ m})(\sin 30.0°) = 22 \text{ m}$$

$$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 85 \text{ m} + 39 \text{ m} = 124 \text{ m}$$

$$\Delta y_{tot} = \Delta y_2 = 22 \text{ m}$$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(124 \text{ m})^2 + (22 \text{ m})^2}$$

$$d = \sqrt{15\,400 \text{ m}^2 + 480 \text{ m}^2} = \sqrt{15\,900 \text{ m}^2} = \boxed{126 \text{ m}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{22 \text{ m}}{124 \text{ m}}\right) = \boxed{(1.0 \times 10^1)° \text{ above the horizontal}}$$

---

3. $v_{y,1} = 2.50 \times 10^2$ km/h

$v_2 = 75$ km/h

$\theta_2 = -45°$

Students should use graphical techniques.

$$v_{x,2} = v_2(\cos \theta_2) = (75 \text{ km/h})[\cos(-45°)] = 53 \text{ km/h}$$

$$v_{y,2} = v_2(\sin \theta_2) = (75 \text{ km/h})[\sin(-45°)] = -53 \text{ km/h}$$

$$v_{y,tot} = v_{y,1} + v_{y,2} = 2.50 \times 10^2 \text{ km/h} - 53 \text{ km/h} = 197 \text{ km/h}$$

$$v_{x,tot} = v_{s,2} = 53 \text{ km/h}$$

$$v = \sqrt{(v_{x,tot})^2 + (v_{y,tot})^2} = \sqrt{(53 \text{ km/h})^2 + (197 \text{ km/h})^2}$$

$$v = \sqrt{2800 \text{ km}^2/\text{h}^2 + 38\,800 \text{ km}^2/\text{h}^2} = \sqrt{41\,600 \text{ km}^2/\text{h}^2} = \boxed{204 \text{ km/h}}$$

$$\theta = \tan^{-1}\left(\frac{v_{y,tot}}{v_{x,tot}}\right) = \tan^{-1}\left(\frac{204 \text{ km/h}}{53 \text{ km/h}}\right) = \boxed{75° \text{ north of east}}$$

---

4. $v_{y,1} = \dfrac{2.50 \times 10^2 \text{ km/h}}{2}$

$= 125$ km/h

$v_{x,2} = 53$ km/h

$v_{y,2} = -53$ km/h

Students should use graphical techniques.

$$v_{y,dr} = v_{y,1} + v_{y,2} = 125 \text{ km/h} - 53 \text{ km/h} = 72 \text{ km/h}$$

$$v_{x,dr} = v_{x,2} = 53 \text{ km/h}$$

$$v = \sqrt{(v_{x,dr})^2 = v_{y,dr})^2} = \sqrt{(53 \text{ km/h})^2 + (72 \text{ km/h})^2}$$

$$v = \sqrt{2800 \text{ km}^2/\text{h}^2 + 5200 \text{ km}^2/\text{h}^2} = \sqrt{8.0 \times 10^3 \text{ km}^2/\text{h}^2} = \boxed{89 \text{ km/h}}$$

$$\theta = \tan^{-1}\left(\frac{v_{y,dr}}{v_{x,dr}}\right) = \tan^{-1}\left(\frac{72 \text{ km/h}}{53 \text{ km/h}}\right) = \boxed{54° \text{ north of east}}$$

Two-Dimensional Motion and Vectors, Practice A

Givens — *Solutions*

1. $\mathbf{\Delta x_1}$ = 8 km east
$\Delta x_1 = 8$ km
$\mathbf{\Delta x_2}$ = 3 km west = −3km, east
$\Delta x_2 = 3$ km
$\mathbf{\Delta x_3}$ = 12 km east
$\Delta x_3 = 12$ km
$\Delta y = 0$ km

a. $d = \Delta x_1 + \Delta x_2 + \Delta x_3 = 8\text{ km} + 3\text{ km} + 12\text{ km} = \boxed{23\text{ km}}$

b. $\mathbf{\Delta x_{tot}} = \mathbf{\Delta x_1} + \mathbf{\Delta x_2} + \mathbf{\Delta x_3} = 8\text{ km} + (-3\text{ km}) + 12\text{ km} = \boxed{17\text{ km east}}$

---

2. $\Delta x = 7.5$ m
$\Delta y = 45.0$ m

$$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(7.5\text{ m})^2 + (45.0\text{ m})^2}$$

$$d = \sqrt{56\text{ m}^2 + 2020\text{ m}^2} = \sqrt{2080\text{ m}^2} = \boxed{45.6\text{ m}}$$

Measuring direction with respect to y (north),

$$\theta = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) = \tan^{-1}\left(\frac{7.5\text{ m}}{45.0\text{ m}}\right) = \boxed{9.5^\circ\text{ east of due north}}$$

---

3. $\Delta x = 6.0$ m
$\Delta y = 14.5$ m

$$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(6.0\text{ m})^2 + (14.5\text{ m})^2}$$

$$d = \sqrt{36\text{ m}^2 + 2.10 \times 10^2\text{ m}^2} = \sqrt{246\text{ m}^2} = \boxed{15.7\text{ m}}$$

Measuring direction with respect to the length of the field (down the field),

$$\theta = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) = \tan^{-1}\left(\frac{6.0\text{ m}}{14.5\text{ m}}\right) = \boxed{22^\circ\text{ to the side of downfield}}$$

---

4. $\Delta x = 1.2$ m
$\Delta y = -1.4$ m

$$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(1.2\text{ m})^2 + (-1.4\text{ m})^2}$$

$$d = \sqrt{1.4\text{ m}^2 + 2.0\text{ m}^2} = \sqrt{3.4\text{ m}^2} = \boxed{1.8\text{ m}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\frac{-1.4\text{ m}}{1.2\text{ m}}\right) = -49^\circ = \boxed{49^\circ\text{ below the horizontal}}$$

Two-Dimensional Motion and Vectors, Practice B

1. $v = 105$ km/h
$\theta = 25^\circ$

$v_x = v(\cos\theta) = (105\text{ km/h})(\cos 25^\circ) = \boxed{95\text{ km/h}}$

---

2. $v = 105$ km/h
$\theta = 25^\circ$

$v_y = v(\sin\theta) = (105\text{ km/h})(\sin 25^\circ) = \boxed{44\text{ km/h}}$

---

3. $v = 22$ m/s
$\theta = 15^\circ$

$v_x = v(\cos\theta) = (22\text{ m/s})(\cos 15^\circ) = \boxed{21\text{ m/s}}$

$v_y = v(\sin\theta) = (22\text{ m/s})(\sin 15^\circ) = \boxed{5.7\text{ m/s}}$

---

4. $d = 5$ m
$\theta = 90^\circ$

$\Delta x = d(\cos\theta) = (5\text{ m})(\cos 90^\circ) = \boxed{0\text{ m}}$

$\Delta y = d(\sin\theta) = (5\text{ m})(\sin 90^\circ) = \boxed{5\text{ m}}$

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Givens	*Solutions*
1. $d_1 = 35$ m	$\Delta x_1 = d_1(\cos\theta_1) = (35\text{ m})(\cos 0.0°) = 35\text{ m}$
$\theta_1 = 0.0°$	$\Delta y_1 = d_1(\sin\theta_1) = (35\text{ m})(\sin 0.0°) = 0.0\text{ m}$
$d_2 = 15$ m	$\Delta x_2 = d_2(\cos\theta_2) = (15\text{ m})(\cos 25°) = 14\text{ m}$
$\theta_2 = 25°$	$\Delta y_2 = d_2(\sin\theta_2) = (15\text{ m})(\sin 25°) = 6.3\text{ m}$
	$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 35\text{ m} + 14\text{ m} = 49\text{ m}$
	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 0.0\text{ m} + 6.3\text{ m} = 6.3\text{ m}$
	$d_{tot} = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(49\text{ m})^2 + (6.3\text{ m})^2}$
	$d_{tot} = \sqrt{2400\text{ m}^2 + 40\text{ m}^2} = \sqrt{2400\text{ m}^2} = \boxed{49\text{ m}}$
	$\theta_{tot} = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{6.3\text{ m}}{49\text{ m}}\right) = \boxed{7.3° \text{ to the right of downfield}}$

2. $d_1 = 2.5$ km	$\Delta x_1 = d_1(\cos\theta_1) = (2.5\text{ km})(\cos 35°) = 2.0\text{ km}$
$\theta_1 = 35°$	$\Delta y_1 = d_1(\sin\theta_1) = (2.5\text{ km})(\sin 35°) = 1.4\text{ km}$
$d_2 = 5.2$ km	$\Delta x_2 = d_2(\cos\theta_2) = (5.2\text{ km})(\cos 22°) = 4.8\text{ km}$
$\theta_2 = 22°$	$\Delta y_2 = d_2(\sin\theta_2) = (5.2\text{ km})(\sin 22°) = 1.9\text{ km}$
	$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 2.0\text{ km} + 4.8\text{ km} = 6.8\text{ km}$
	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 1.4\text{ km} + 1.9\text{ km} = 3.3\text{ km}$
	$d_{tot} = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(6.8\text{ km})^2 + (3.3\text{ km})^2}$
	$d_{tot} = \sqrt{46\text{ km}^2 + 11\text{ km}^2} = \sqrt{57\text{ km}^2} = \boxed{7.5\text{ km}}$
	$\theta_{tot} = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{3.3\text{ km}}{6.8\text{ km}}\right) = \boxed{26° \text{ above the horizontal}}$

3. $d_1 = 8.0$ m	Measuring direction with respect to x = (east),
$\theta_1 = 90.0°$	$\Delta x_1 = d_1(\cos\theta_1) = (8.0\text{ m})(\cos 90.0°) = 0.0\text{ m}$
$d_2 = 3.5$ m	$\Delta y_1 = d_1(\sin\theta_1) = (8.0\text{ m})(\sin 90.0°) = 8.0\text{ m}$
$\theta_2 = 55°$	$\Delta x_2 = d_2(\cos\theta_2) = (3.5\text{ m})(\cos 55°) = 2.0\text{ m}$
$d_3 = 5.0$ m	$\Delta y_2 = d_2(\sin\theta_2) = (3.5\text{ m})(\sin 55°) = 2.9\text{ m}$
$\theta_3 = 0.0°$	$\Delta x_3 = d_3(\cos\theta_3) = (5.0\text{ m})(\cos 0.0°) = 5.0\text{ m}$
	$\Delta y_3 = d_3(\sin\theta_3) = (5.0\text{ m})(\sin 0.0°) = 0.0\text{ m}$
	$\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 = 0.0\text{ m} + 2.0\text{ m} + 5.0\text{ m} = 7.0\text{ m}$
	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 + \Delta y_3 = 8.0\text{ m} + 2.9\text{ m} + 0.0\text{ m} = 10.9\text{ m}$
	$d_{tot} = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(7.0\text{ m})^2 + (10.9\text{ m})^2}$
	$d_{tot} = \sqrt{49\text{ m}^2 + 119\text{ m}^2} = \sqrt{168\text{ m}^2} = \boxed{13.0\text{ m}}$
	$\theta_{tot} = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{10.9\text{ m}}{7.0\text{ m}}\right) = \boxed{57° \text{ north of east}}$

I

Givens | *Solutions*

4. $d_1 = 75$ km

$\theta_1 = -30.0°$

$d_2 = 155$ km

$\theta_2 = 60.0°$

Measuring direction with respect to y (north),

$$\Delta x_1 = d_1(\sin\theta_1) = (75 \text{ km})(\sin -30.0°) = -38 \text{ km}$$

$$\Delta y_1 = d_1(\cos\theta_1) = (75 \text{ km})(\cos -30.0°) = 65 \text{ km}$$

$$\Delta x_2 = d_2(\sin\theta_2) = (155 \text{ km})(\sin 60.0°) = 134 \text{ km}$$

$$\Delta y_2 = d_2(\cos\theta_2) = (155 \text{ km})(\cos 60.0°) = 77.5 \text{ km}$$

$$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = -38 \text{ km} + 134 \text{ km} = 96 \text{ km}$$

$$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 65 \text{ km} + 77.5 \text{ km} = 142 \text{ km}$$

$$d_{tot} = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(96 \text{ km})^2 + (142 \text{ km})^2} = \sqrt{9200 \text{ km}^2 + 20\,200 \text{ km}^2}$$

$$d_{tot} = \sqrt{29\,400 \text{ km}^2} = \boxed{171 \text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta x_{tot}}{\Delta y_{tot}}\right) = \tan^{-1}\left(\frac{96 \text{ km}}{142 \text{ km}}\right) = \boxed{34° \text{ east of north}}$$

Two-Dimensional Motion and Vectors, Section 2 Review

2. $v_x = 3.0$ m/s

$v_y = 5.0$ m/s

a. $v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{(3.0 \text{ m/s})^2 = (5.0 \text{ m/s})^2}$

$$v = \sqrt{9.0 \text{ m}^2/\text{s}^2 + 25 \text{ m}^2/\text{s}^2} = \sqrt{34 \text{ m}^2/\text{s}^2} = \boxed{5.8 \text{ m/s}}$$

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{5.0 \text{ m/s}}{3.0 \text{ m/s}}\right) = \boxed{59° \text{ downriver from its intended path}}$$

$v_x = 1.0$ m/s

$v_y = 6.0$ m/s

b. $v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{(1.0 \text{ m/s})^2 + (6.0 \text{ m/s})^2}$

$$v = \sqrt{1.0 \text{ m}^2/\text{s}^2 + 36 \text{ m}^2/\text{s}^2} = \sqrt{37 \text{ m}^2/\text{s}^2} = \boxed{6.1 \text{ m/s}}$$

$$\theta = \tan^{-1}\left(\frac{v_x}{v_y}\right) = \tan^{-1}\left(\frac{1.0 \text{ m/s}}{6.0 \text{ m/s}}\right) = \boxed{9.5° \text{ from the direction the wave is traveling}}$$

---

3. $d = 10.0$ km

$\theta = 45.0°$

a. $\Delta x = d(\cos\theta) = (10.0 \text{ km})(\cos 45.0°) = \boxed{7.07 \text{ km}}$

$\Delta y = d(\sin\theta) = (10.0 \text{ km})(\sin 45.0°) = \boxed{7.07 \text{ km}}$

$a = 2.0$ m/s^2

$\theta = 35°$

b. $a_x = a(\cos\theta) = (2.0 \text{ m/s}^2)(\cos 35°) = \boxed{1.6 \text{ m/s}^2}$

$a_y = a(\sin\theta) = (2.0 \text{ m/s}^2)(\sin 35°) = \boxed{1.1 \text{ m/s}^2}$

Two-Dimensional Motion and Vectors, Practice D

1. $\Delta y = -0.70$ m

$\Delta x = 0.25$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$v_x = \sqrt{\frac{a_y}{2\Delta y}}\,\Delta x = \sqrt{\frac{-9.81 \text{ m/s}^2}{(2)(-0.70 \text{ m})}}(0.25 \text{ m}) = \boxed{0.66 \text{ m/s}}$$

---

2. $\Delta y = -1.0$ m

$\Delta x = 2.2$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$v_x = \sqrt{\frac{a_y}{2\Delta y}}\,\Delta x = \sqrt{\frac{-9.81 \text{ m/s}^2}{(2)(-1.0 \text{ m})}}(2.2 \text{ m}) = \boxed{4.9 \text{ m/s}}$$

Givens | *Solutions*

3. $\Delta y = -5.4$ m

$\Delta x = 8.0$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$v_x = \sqrt{\frac{a_y}{2\Delta y}}\,\Delta x = \sqrt{\frac{-9.81 \text{ m/s}^2}{(2)(-5.4 \text{ m})}}\,(8.0 \text{ m}) = \boxed{7.6 \text{ m/s}}$$

---

4. $v_x = 7.6$ m/s

$\Delta y = -2.7$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$\Delta x = \sqrt{\frac{2\Delta y}{a_y}}\,v_x = \sqrt{\frac{(2)(-2.7 \text{ m})}{-9.81 \text{ m/s}^2}}\,(7.6 \text{ m/s}) = \boxed{5.6 \text{ m}}$$

Two-Dimensional Motion and Vectors, Practice E

1. $\Delta x = 4.0$ m

$\theta = 15°$

$v_i = 5.0$ m/s

$\Delta y_{max} = -2.5$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta x = v_i(\cos\theta)\Delta t$$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)} = \frac{4.0 \text{ m}}{(5.0 \text{ m/s})(\cos 15°)} = 0.83 \text{ s}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = (5.0 \text{ m/s})(\sin 15°)(0.83 \text{ s}) + \tfrac{1}{2}(-9.81 \text{ m/s}^2)(0.83 \text{ s})^2$$

$$\Delta y = 1.1 \text{ m} - 3.4 \text{ m} = \boxed{-2.3 \text{ m}}\ \boxed{\text{yes}}$$

---

2. $\Delta x = 301.5$ m

$\theta = 25.0°$

At Δy_{max}, $v_{y,f} = 0$ m/s, $\Delta t = \Delta t_{peak}$

$$v_{y,f} = v_i \sin\theta + a_y\Delta t_{peak} = 0$$

$$\Delta t_{peak} = \frac{-v_i \sin\theta}{a_y}$$

at Δx_{max}, $\Delta t_m = 2\,\Delta t_p = \dfrac{-2v_i \sin\theta}{a_y}$

$$\Delta x_{max} = v_i \cos\theta\,\Delta t_m = v_i\cos\theta\left(\frac{-2\,v_i \sin\theta}{a_y}\right) = \frac{-2\,v_i^2 \sin\theta\cos\theta}{a_y}$$

$$v_i = \sqrt{\frac{-a_y\,\Delta x_{max}}{2\sin\theta\cos\theta}}$$

$$v_{f,y}^2 = v_i^2(\sin\theta)^2 = -2a_y\Delta y_{max} = 0 \text{ at peak}$$

$$\Delta y_{max} = \frac{v_i^2(\sin\theta)^2}{-2a_y} = \left(\frac{-a_y\Delta x_{max}}{2\sin\theta\cos\theta}\right)\left(\frac{(\sin\theta)^2}{-2a_y}\right) = \frac{1}{4}\Delta x_{max}\tan\theta$$

$$\Delta y_{max} = \frac{1}{4}(301.5 \text{ m})(\tan 25.0°) = \boxed{35.1 \text{ m}}$$

---

3. $\Delta x = 42.0$ m

$\theta = 25°$

$v_i = 23.0$ m/s

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \frac{\Delta x}{v_x} = \frac{\Delta x}{v_i(\cos\theta)} = \frac{42.0 \text{ m}}{(23.0 \text{ m/s})(\cos 25°)} = \boxed{2.0 \text{ s}}$$

At maximum height, $v_{y,f} = 0$ m/s.

$$v_{y,f}^2 = v_{y,i}^2 + 2a_y\Delta y_{max} = 0$$

$$\Delta y_{max} = -\frac{v_{y,i}^2}{2a_y} = -\frac{v_i^2(\sin\theta)^2}{2a_y} = -\frac{(23.0 \text{ m/s})^2(\sin 25°)^2}{(2)(-9.81 \text{ m/s}^2)} = \boxed{4.8 \text{ m}}$$

Givens	*Solutions*

4. $\Delta x = 2.00$ m

$\Delta y = 0.55$ m

$\theta = 32.0°$

$a_y = -g = -9.81$ m/s^2

$$\Delta x = v_i(\cos\theta)\Delta t$$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = v_i(\sin\theta)\left[\frac{\Delta x}{v_i(\cos\theta)}\right] + \tfrac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right]^2$$

$$\Delta y = \Delta x(\tan\theta) + \frac{a_y\Delta x^2}{2v_i^2(\cos\theta)^2}$$

$$\Delta x(\tan\theta) - \Delta y = \frac{-a_y\Delta x^2}{2v_i^2(\cos\theta)^2}$$

$$2v_i^2(\cos\theta)^2 = \frac{-a_y\Delta x^2}{\Delta x(\tan\theta) - \Delta y}$$

$$v_i = \sqrt{\frac{-a_y\Delta x^2}{2(\cos\theta)^2[\Delta x(\tan\theta) - \Delta y]}}$$

$$v_i = \sqrt{\frac{(9.81\ \text{m/s}^2)(2.00\ \text{m})^2}{(2)(\cos 32.0°)^2[(2.00\ \text{m})(\tan 32.0°) - 0.55\ \text{m}]}}$$

$$v_i = \sqrt{\frac{(9.81\ \text{m/s}^2)(2.00\ \text{m})^2}{(2)(\cos 32.0°)^2(1.25 - 0.55\ \text{m})}} = \sqrt{\frac{(9.81\ \text{m/s}^2)(2.00\ \text{m})^2}{(2)(\cos 32.0°)^2(0.70\ \text{m})}} = \boxed{6.2\ \text{m/s}}$$

Two-Dimensional Motion and Vectors, Section 3 Review

2. $\Delta y = -125$ m

$v_x = 90.0$ m/s

$a_y = -g = -9.81$ m/s^2

$$\Delta y = \tfrac{1}{2}a_y\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{(2)(-125\ \text{m})}{-9.81\ \text{m/s}^2}} = \boxed{5.05\ \text{s}}$$

$$\Delta x = v_x\Delta t = (90.0\ \text{m/s})(5.05\ \text{s}) = \boxed{454\ \text{m}}$$

---

3. $v_x = 30.0$ m/s

$\Delta y = -200.0$ m

$a_y = -g = -9.81$ m/s^2

a. $\Delta y = \tfrac{1}{2}a_y\Delta t^2$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}}$$

$$\Delta x = v_x\Delta t = v_x\sqrt{\frac{2\Delta y}{a_y}} = (30.0\ \text{m/s})\sqrt{\frac{(2)(-200.0\ \text{m})}{-9.81\ \text{m/s}^2}} = \boxed{192\ \text{m}}$$

$v_x = 30.0$ m/s

$\Delta y = -200.0$ m

$a_y = -g = -9.81$ m/s^2

$\Delta x = 192$ m

b. $v_y = \sqrt{v_{y,i}^2 + 2a_y\Delta y} = \sqrt{(0\ \text{m/s})^2 + (2)(-9.81\ \text{m/s}^2)(-200.0\ \text{m})} = \pm 62.6\ \text{m/s} = -62.6\ \text{m/s}$

$$v_{tot} = \sqrt{v_x^2 + v_y^2} = \sqrt{(30.0\ \text{m/s})^2 + (-62.6\ \text{m/s})^2} = \sqrt{9.00\times 10^2\ \text{m}^2/\text{s}^2 + 3.92\times 10^3\ \text{m}^2/\text{s}^2}$$

$$v_{tot} = \sqrt{4820\ \text{m}^2/\text{s}^2} = \boxed{69.4\ \text{m/s}}$$

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{-62.6\ \text{m/s}}{30.0\ \text{m/s}}\right) = -64.4°$$

$$\theta = \boxed{64.4°\ \text{below the horizontal}}$$

Two-Dimensional Motion and Vectors, Practice F

Givens	*Solutions*
1. $\mathbf{v_{te}} = +15$ m/s $\mathbf{v_{bt}} = -15$ m/s	$\mathbf{v_{be}} = \mathbf{v_{bt}} + \mathbf{v_{te}} = -15 \text{ m/s} + 15 \text{ m/s} = \boxed{0 \text{ m/s}}$
2. $\mathbf{v_{aw}} = +18.0$ m/s $\mathbf{v_{sa}} = -3.5$ m/s	$\mathbf{v_{sw}} = \mathbf{v_{sa}} + \mathbf{v_{aw}} = -3.5 \text{ m/s} + 18.0 \text{ m/s}$ $\mathbf{v_{sw}} = \boxed{\text{14.5 m/s in the direction that the aircraft carrier is moving}}$
3. $\mathbf{v_{fw}} = 2.5$ m/s north $\mathbf{v_{we}} = 3.0$ m/s east	$\mathbf{v_{fe}} = \mathbf{v_{fw}} + \mathbf{v_{we}}$ $v_{tot} = \sqrt{v_{fw}^2 + v_{we}^2} = \sqrt{(2.5 \text{ m/s})^2 + (3.0 \text{ m/s})^2}$ $v_{tot} = \sqrt{6.2 \text{ m}^2/\text{s}^2 + 9.0 \text{ m}^2/\text{s}^2} = \sqrt{15.2 \text{ m}^2/\text{s}^2} = \boxed{3.90 \text{ m/s}}$ $\theta = \tan^{-1}\left(\frac{v_{fw}}{v_{we}}\right) = \tan\left(\frac{2.5 \text{ m/s}}{3.0 \text{ m/s}}\right) = \boxed{(4.0 \times 10^1)^\circ \text{ north of east}}$
4. $\mathbf{v_{tr}} = 25.0$ m/s north $\mathbf{v_{dt}} = 1.75$ m/s at 35.0° east of north	$\mathbf{v_{dr}} = \mathbf{v_{dt}} + \mathbf{v_{tr}}$ $v_{x,tot} = v_{x,dt} = (1.75 \text{ m/s})(\sin 35.0^\circ) = 1.00 \text{ m/s}$ $v_{y,dt} = (1.75 \text{ m/s})(\cos 35.0^\circ) = 1.43 \text{ m/s}$ $v_{y,tot} = v_{tr} + v_{y,dt} = 25.0 \text{ m/s} + 1.43 \text{ m/s} = 26.4 \text{ m/s}$ $v_{tot} = \sqrt{(v_{x,tot})^2 + (v_{y,tot})^2} = \sqrt{(1.00 \text{ m/s})^2 + (26.4 \text{ m/s})^2}$ $v_{tot} = \sqrt{1.00 \text{ m}^2/\text{s}^2 + 697 \text{ m}^2/\text{s}^2} = \sqrt{698 \text{ m}^2/\text{s}^2} = \boxed{26.4 \text{ m/s}}$ $\theta = \tan^{-1}\left(\frac{v_{x,tot}}{v_{y,tot}}\right) = \tan^{-1}\left(\frac{1.00 \text{ m/s}}{26.4 \text{ m/s}}\right) = \boxed{2.17^\circ \text{ east of north}}$

Two-Dimensional Motion and Vectors, Section 4 Review

1. $\mathbf{v_{wg}} = -9$ m/s $\mathbf{v_{bg}} = 1$ m/s	$\mathbf{v_{bw}} = \mathbf{v_{bg}} + \mathbf{v_{gw}} = \mathbf{v_{bg}} - \mathbf{v_{wg}} = (1 \text{ m/s}) - (-9 \text{ m/s}) = 1 \text{ m/s} + 9 \text{ m/s}$ $\mathbf{v_{bw}} = \boxed{\text{10 m/s in the opposite direction}}$
2. $\mathbf{v_{bw}} = 0.15$ m/s north $\mathbf{v_{we}} = 1.50$ m/s east	$\mathbf{v_{be}} = \mathbf{v_{bw}} + \mathbf{v_{we}}$ $v_{tot} = \sqrt{v_{bw}^2 + v_{we}^2} = \sqrt{(0.15 \text{ m/s})^2 + (1.50 \text{ m/s})^2}$ $v_{tot} = \sqrt{0.022 \text{ m}^2/\text{s}^2 + 2.25 \text{ m}^2/\text{s}^2} = \sqrt{2.27 \text{ m}^2/\text{s}^2} = \boxed{1.51 \text{ m/s}}$ $\theta = \tan^{-1}\left(\frac{v_{bw}}{v_{we}}\right) = \tan^{-1}\left(\frac{0.15 \text{ m/s}}{1.50 \text{ m/s}}\right) = \boxed{5.7^\circ \text{ north of east}}$

Givens | *Solutions*

I

6. $A = 3.00$ units (u)

$B = -4.00$ units (u)

Students should use graphical techniques.

a. $A + B = \sqrt{A^2 + B^2} = \sqrt{(3.00\text{ u})^2 + (-4.00\text{ u})^2}$

$A + B = \sqrt{9.00\text{ u}^2 + 16.0\text{ u}^2} = \sqrt{25.0\text{ u}^2} = \boxed{5.00\text{ units}}$

$\theta = \tan^{-1}\left(\frac{B}{A}\right) = \tan^{-1}\left(\frac{-4.00\text{ u}}{3.00\text{ u}}\right) = \boxed{53.1° \text{ below the positive } x\text{-axis}}$

b. $A - B = \sqrt{A^2 + (-B)^2} = \sqrt{(3.00\text{ u})^2 + (4.00\text{ u})^2}$

$A - B = \sqrt{9.00\text{ u}^2 + 16.0\text{ u}^2} = \sqrt{25.0\text{ u}^2} = \boxed{5.00\text{ units}}$

$\theta = \tan^{-1}\left(\frac{-B}{A}\right) = \tan^{-1}\left(\frac{4.00\text{ u}}{3.00\text{ u}}\right) = \boxed{53.1° \text{ above the positive } x\text{-axis}}$

c. $A + 2B = \sqrt{A^2 + (2B)^2} = \sqrt{(3.00\text{ u})^2 + (-8.00\text{ u})^2}$

$A + 2B = \sqrt{9.00\text{ u}^2 + 64.0\text{ u}^2} = \sqrt{73.0\text{ u}^2} = \boxed{8.54\text{ units}}$

$\theta = \tan^{-1}\left(\frac{2B}{A}\right) = \tan^{-1}\left(\frac{-8.00\text{ u}}{3.00\text{ u}}\right) = \boxed{69.4° \text{ below the positive } x\text{-axis}}$

d. $B - A = \sqrt{B^2 + (-A)^2} = \sqrt{(-4.00\text{ u})^2 + (-3.00\text{ u})^2} = \boxed{5.00\text{ units}}$

$\theta = \tan^{-1}\left(\frac{B}{-A}\right) = \tan^{-1}\left(\frac{-4.00\text{ u}}{-3.00\text{ u}}\right) = 53.1° \text{ below the negative } x\text{-axis}$

or $\boxed{127° \text{ clockwise from the positive } x\text{-axis}}$

---

7. $A = 3.00$ m

$B = 3.00$ m

$\theta = 30.0°$

Students should use graphical techniques.

$A_x = A(\cos\theta) = (3.00\text{ m})(\cos 30.0°) = 2.60\text{ m}$

$A_y = A(\sin\theta) = (3.00\text{ m})(\sin 30.0°) = 1.50\text{ m}$

a. $A + B = \sqrt{A_x{}^2 + (A_y + B)^2} = \sqrt{(2.60\text{ m})^2 + (4.50\text{ m})^2}$

$A + B = \sqrt{6.76\text{ m}^2 + 20.2\text{ m}^2} = \sqrt{27.0\text{ m}^2} = \boxed{5.20\text{ m}}$

$\theta = \tan^{-1}\left(\frac{A_y + B}{A_x}\right) = \tan^{-1}\left(\frac{4.50\text{ m}}{2.60\text{ m}}\right) = \boxed{60.0° \text{ above the positive } x\text{-axis}}$

b. $A - B = \sqrt{A_x{}^2 + (A_y - B)^2} = \sqrt{(2.60\text{ m})^2 + (-1.50\text{ m})^2}$

$A - B = \sqrt{6.76\text{ m}^2 + 2.25\text{ m}^2} = \sqrt{9.01\text{ m}^2} = \boxed{3.00\text{ m}}$

$\theta = \tan^{-1}\left(\frac{A_y - B}{A_x}\right) = \tan^{-1}\left(\frac{-1.50\text{ m}}{2.60\text{ m}}\right) = \boxed{30.0° \text{ below the positive } x\text{-axis}}$

Givens	*Solutions*

c. $B - A = \sqrt{(B - A_y)^2 + (-A_x)^2} = \sqrt{(1.50\text{ m})^2 + (-2.60\text{ m})^2}$

$B - A = \boxed{3.00\text{ m}}$

$\theta = \tan^{-1}\left(\dfrac{B - A_y}{-A_x}\right) = \tan^{-1}\left(\dfrac{1.50\text{ m}}{-2.60\text{ m}}\right) = 30.0°$ above the negative x-axis

or $\boxed{150° \text{ counterclockwise from the positive } x\text{-axis}}$

d. $A - 2B = \sqrt{A_x^2 + (A_y - 2B)^2} = \sqrt{(2.60\text{ m})^2 + (-4.50\text{ m})^2} = \boxed{5.20\text{ m}}$

$\theta = \tan^{-1}\left(\dfrac{A_y - 2B}{A_x}\right) = \tan^{-1}\left(\dfrac{-4.50\text{ m}}{2.60\text{ m}}\right) = \boxed{60.0° \text{ below the positive } x\text{-axis}}$

---

8. $\Delta y_1 = -3.50$ m

$d_2 = 8.20$ m

$\theta_2 = 30.0°$

$\Delta x_3 = -15.0$ m

Students should use graphical techniques.

$\Delta x_2 = d_2(\cos\theta_2) = (8.20\text{ m})(\cos 30.0°) = 7.10\text{ m}$

$\Delta y_2 = d_2(\sin\theta_2) = (8.20\text{ m})(\sin 30.0°) = 4.10\text{ m}$

$\Delta x_{tot} = \Delta x_2 + \Delta x_3 = 7.10\text{ m} - 15.0\text{ m} = -7.9\text{ m}$

$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -3.50\text{ m} + 4.10\text{ m} = 0.60\text{ m}$

$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(-7.9\text{ m})^2 + (0.60\text{ m})^2}$

$d = \sqrt{62\text{ m}^2 + 0.36\text{ m}^2} = \sqrt{62\text{ m}^2} = \boxed{7.9\text{ m}}$

$\theta = \tan^{-1}\left(\dfrac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\dfrac{0.60\text{ m}}{-7.9\text{ m}}\right) = \boxed{4.3° \text{ north of west}}$

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9. $\Delta x = -8.00$ m

$\Delta y = 13.0$ m

Students should use graphical techniques.

$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(-8.00\text{ m})^2 + (13.0\text{ m})^2}$

$d = \sqrt{64.0\text{ m}^2 + 169\text{ m}^2} = \sqrt{233\text{ m}^2} = \boxed{15.3\text{ m}}$

$\theta = \tan^{-1}\left(\dfrac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\dfrac{13.0\text{ m}}{-8.00\text{ m}}\right) = \boxed{58.4° \text{ south of east}}$

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21. $\Delta \mathbf{x_1}$ = 3 blocks west = −3 blocks east

$\Delta \mathbf{y}$ = 4 blocks north

$\Delta \mathbf{x_2}$ = 6 blocks east

a. $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = -3\text{ blocks} + 6\text{ blocks} = 3\text{ blocks}$

$\Delta y_{tot} = \Delta y = 4\text{ blocks}$

$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(3\text{ blocks})^2 + (4\text{ blocks})^2}$

$d = \sqrt{9\text{ blocks}^2 + 16\text{ blocks}^2} = \sqrt{25\text{ blocks}^2} = \boxed{5\text{ blocks}}$

$\theta = \tan^{-1}\left(\dfrac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\dfrac{4\text{ blocks}}{3\text{ blocks}}\right) = \boxed{53° \text{ north of east}}$

b. distance traveled = 3 blocks + 4 blocks + 6 blocks = $\boxed{13\text{ blocks}}$

Givens	*Solutions*
22. $\Delta y_1 = -10.0$ yards	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -10.0 \text{ yards} + 50.0 \text{ yards} = 40.0 \text{ yards}$
$\Delta x = 15.0$ yards	$\Delta x_{tot} = \Delta x = 15.0$ yards
$\Delta y_2 = 50.0$ yards	$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(15.0 \text{ yards})^2 + (40.0 \text{ yards})^2}$
	$d = \sqrt{225 \text{ yards}^2 + 1.60 \times 10^3 \text{ yards}^2} = \sqrt{1820 \text{ yards}^2} = \boxed{42.7 \text{ yards}}$

23. $\Delta y_1 = -40.0$ m	**Case 1:** $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -40.0 \text{ m} - 20.0 \text{ m} = -60.0 \text{ m}$
$\Delta x = \pm 15.0$ m	$\Delta x_{tot} = \Delta x = +15.0$ m
$\Delta y_2 = \pm 20.0$ m	$d = \sqrt{(\Delta y_{tot})^2 + (\Delta x_{tot})^2} = \sqrt{(-60.0 \text{ m})^2 + (15.0 \text{ m})^2}$
	$d = \sqrt{3.60 \times 10^3 \text{ m}^2 + 225 \text{ m}^2} = \sqrt{3820 \text{ m}^2} = \boxed{61.8 \text{ m}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{-60.0 \text{ m}}{15.0 \text{ m}}\right) = \boxed{76.0° \text{ south of east}}$
	Case 2: $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -40.0 \text{ m} + 20.0 \text{ m} = -20.0 \text{ m}$
	$\Delta x_{tot} = \Delta x = +15.0$ m
	$d = \sqrt{(\Delta y_{tot})^2 +)\Delta x_{tot})^2} = \sqrt{(-20.0 \text{ m})^2 + (15.0 \text{ m})^2}$
	$d = \sqrt{4.00 \times 10^2 \text{ m}^2 + 225 \text{ m}^2} = \sqrt{625 \text{ m}^2} = \boxed{25.0 \text{ m}}$
	$\Delta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta_{tot}}\right) = \tan^{-1}\left(\frac{-20.0 \text{ m}}{15.0 \text{ m}}\right) = \boxed{53.1° \text{ south of east}}$
	Case 3: $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -40.0 \text{ m} - 20.0 \text{ m} = -60.0 \text{ m}$
	$\Delta x_{tot} = \Delta x = -15.0$ m
	$d = \sqrt{(\Delta y_{tot})^2 + (\Delta x_{tot})^2} = \sqrt{(-60.0 \text{ m})^2 + (-15.0 \text{ m})^2}$
	$d = \boxed{61.8 \text{ m}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{-60.0 \text{ m}}{-15.0 \text{ m}}\right) = \boxed{76.0° \text{ south of west}}$
	Case 4: $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = -40.0 \text{ m} + 20.0 \text{ m} = -20.0 \text{ m}$
	$\Delta x_{tot} = \Delta x = -15.0$ m
	$d = \sqrt{(\Delta y_{tot})^2 + (\Delta x_{tot})^2} = \sqrt{(-20.0 \text{ m})^2 + (-15.0 \text{ m})^2}$
	$d = \boxed{25.0 \text{ m}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{-20.0 \text{ m}}{-15.0 \text{ m}}\right) = \boxed{53.1° \text{ south of west}}$

24. $d = 110.0$ m	$\Delta x = d(\cos\theta) = (110.0 \text{ m})[\cos(-10.0°)] = \boxed{108 \text{ m}}$
$\Delta = -10.0°$	$\Delta x = d(\sin\theta) = (110.0 \text{ m})[\sin(-10.0°)] = \boxed{-19.1 \text{ m}}$

25. $\theta = 25.0°$	$\Delta x = d(\cos\theta) = (3.10 \text{ km})(\cos 25.0°) = \boxed{2.81 \text{ km east}}$
$d = 3.10$ km	$\Delta y = d(\sin\theta) = (3.10 \text{ km})(\sin 25.0°) = \boxed{1.31 \text{ km north}}$

Givens	*Solutions*
26. $d_1 = 100.0$ m	$\Delta x_{tot} = d_1 - d_3 \cos \theta_1 - d_4 \cos \theta_2$
$d_2 = 300.0$ m	$\Delta x_{tot} = 100.0 \text{ m} - (150.0 \text{ m})(\cos 30.0°) - (200.0 \text{ m})(\cos 60.0°)$
$d_3 = 150.0$ m	$\Delta x_{tot} = 100.0 \text{ m} - 1.30 \times 10^2 \text{ m} - 1.00 \times 10^2 \text{ m} = -1.30 \times 10^2 \text{ m}$
$d_4 = 200.0$ m	$\Delta y_{tot} = -d_2 - d_3 \sin \theta_1 + d_4 \sin \theta_2$
$\theta_1 = 30.0°$	$\Delta y_{tot} = -300.0 \text{ m} - (150.0 \text{ m})(\sin 30.0°) + (200.0 \text{ m})(\sin 60.0°)$
$\theta_2 = 60.0°$	$\Delta y_{tot} = -300.0 \text{ m} - 75.0 \text{ m} + 173 \text{ m} = -202 \text{ m}$
	$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(1.30 \times 10^2 \text{ m})^2 + (-202 \text{ m})^2}$
	$d = \sqrt{16\,900 \text{ m}^2 + 40\,800 \text{ m}^2} = \sqrt{57700 \text{ m}^2} = \boxed{2.40 \times 10^2 \text{ m}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{-202 \text{ m}}{-1.30 \times 10^2 \text{ m}}\right) = \boxed{57.2° \text{ south of west}}$

31. $\Delta y = -0.809$ m	$\Delta t = \frac{\Delta x}{v_x}$
$\Delta x = 18.3$ m	$\Delta y = \frac{1}{2} a_y \Delta t^2 = \frac{1}{2} a_y \left(\frac{\Delta x}{v_x}\right)^2$
$a_y = -g = -9.81 \text{ m/s}^2$	$v_x = \sqrt{\frac{a_y}{2\Delta y}} \Delta x = \sqrt{\frac{-9.81 \text{ m/s}^2}{(2)(-0.809 \text{ m})}}(18.3 \text{ m}) = \boxed{45.1 \text{ m/s}}$

32. $v_x = 18$ m/s	$\Delta y = \frac{1}{2} a_y \Delta t^2$
$\Delta y = -52$ m	$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{(2)(-52 \text{ m})}{-9.81 \text{ m/s}^2}} = \boxed{3.3 \text{ s}}$
$a_y = -g = -9.81 \text{ m/s}^2$	When the stone hits the water,
	$v_y = a_y \Delta t = (-9.81 \text{ m/s})(3.3 \text{ s}) = -32 \text{ m/s}$
	$v_{tot} = \sqrt{v_x^2 + v_y^2} = \sqrt{(18 \text{ m/s})^2 + (-32 \text{ m/s})^2}$
	$v_{tot} = \sqrt{320 \text{ m}^2/\text{s}^2 + 1000 \text{ m}^2/\text{s}^2} = \sqrt{1300 \text{ m}^2/\text{s}^2} = \boxed{36 \text{ m/s}}$

33. $v_{x,s} = 15$ m/s	$\Delta y = \frac{1}{2} a_y \Delta t^2$
$v_{x,o} = 26$ m/s	$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{2(-5.0 \text{ m})}{-9.81 \text{ m/s}^2}} = 1.0 \text{ s}$
$\Delta y = -5.0$ m	$\Delta x_s = v_{x,s} \Delta t = (15 \text{ m/s})(1.0 \text{ s}) = 15 \text{ m}$
$a_y = -g = -9.81 \text{ m/s}^2$	$\Delta x_o = v_{x,o} \Delta t = (26 \text{ m/s})(1.0 \text{ s}) = 26 \text{ m}$
	$\Delta x_o - \Delta x_s = 26 \text{ m} - 15 \text{ m} = \boxed{11 \text{ m}}$

34. $v_i = 1.70 \times 10^3$ m/s	**a.** $\Delta y = v_i(\sin \theta)\Delta t + \frac{1}{2} a_y \Delta t^2 = v_i(\sin \theta) + \frac{1}{2} a_y \Delta t = 0$
$\theta = 55.0°$	$\Delta t = -\frac{2v_i(\sin \theta)}{a_y} = -\frac{(2)(1.70 \times 10^3 \text{ m/s})(\sin 55.0°)}{-9.81 \text{ m/s}^2} = 284 \text{ s}$
$a_y = -g = -9.81 \text{ m/s}^2$	$\Delta x = v_i(\cos \theta)\Delta t = (1.70 \times 10^3 \text{ m/s})(\cos 55.0°)(284 \text{ s}) = \boxed{2.77 \times 10^5 \text{ m}}$
	b. $\Delta t = \boxed{284 \text{ s}}$ (See **a.**)

Givens	Solutions

35. $\Delta x = 36.0$ m

$v_i = 20.0$ m/s

$\theta = 53°$

$\Delta y_{bar} = 3.05$ m

$a_y = -g = -9.81\ \mathrm{m/s^2}$

a. $\Delta x = v_i(\cos\theta)\Delta t$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)} = \frac{36.0\ \mathrm{m}}{(20.0\ \mathrm{m/s})(\cos 53°)} = 3.0\ \mathrm{s}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = (20.0\ \mathrm{m/s})(\sin 53°)(3.0\ \mathrm{s}) + \tfrac{1}{2}(-9.81\ \mathrm{m/s^2})(3.0\ \mathrm{s})^2$$

$$\Delta y = 48\ \mathrm{m} - 44\ \mathrm{m} = 4\ \mathrm{m}$$

$$\Delta y = \Delta y_{bar} = 4\ \mathrm{m} - 3.05\ \mathrm{m} = 1\ \mathrm{m}$$

$\boxed{\text{The ball clears the goal by 1 m.}}$

b. $v_{y,f} = v_i(\sin\theta) + a_y\Delta t = (20.0\ \mathrm{m/s})(\sin 53°) + (-9.81\ \mathrm{m/s^2})(3.0\ \mathrm{s})$

$v_{x,f} = 16\ \mathrm{m/s} - 29\ \mathrm{m/s} = -13\ \mathrm{m/s}$

The velocity of the ball as it passes over the crossbar is negative; therefore, the ball is falling.

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36. $\Delta y = -1.00$ m

$\Delta x = 5.00$ m

$\theta = 45.0°$

$v = 2.00$ m/s

$\Delta t = 0.329$ s

$a_y = -g = -9.81\ \mathrm{m/s^2}$

Find the initial velocity of the water when shot at rest horizontally 1 m above the ground.

$$\Delta y = \tfrac{1}{2}a_y\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}}$$

$$\Delta x = v_x\Delta t$$

$$v_x = \frac{\Delta x}{\Delta t} = \frac{\Delta x}{\sqrt{\frac{2\Delta y}{a_y}}} = \frac{5.00\ \mathrm{m}}{\sqrt{\frac{(2)(-1.00\ \mathrm{m})}{-9.81\ \mathrm{m/s^2}}}} = 11.1\ \mathrm{m/s}$$

Find how far the water will go if it is shot horizontally 1 m above the ground while the child is sliding down the slide.

$$v_{x,\,tot} = v_x + v(\cos\theta)$$

$$\Delta x = v_{x,\,tot}\Delta t = [v_x + v(\cos\theta)]\Delta t = [11.1\ \mathrm{m/s} + (2.00\ \mathrm{m/s})(\cos 45.0°)](0.329\ \mathrm{s})$$

$$\Delta x = [11.1\ \mathrm{m/s} + 1.41\ \mathrm{m/s}](0.329\ \mathrm{s}) = (12.5\ \mathrm{m/s})(0.329\ \mathrm{s}) = \boxed{4.11\ \mathrm{m}}$$

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37. $\Delta x_1 = 2.50 \times 10^3$ m

$\Delta x_2 = 6.10 \times 10^2$ m

$\Delta y_{mountain} = 1.80 \times 10^3$ m

$v_i = 2.50 \times 10^2$ m/s

$\theta = 75.0°$

$a_y = -g = -9.81\ \mathrm{m/s^2}$

For projectile's full flight,

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \tfrac{1}{2}a_y\Delta t = 0$$

$$v_i(\sin\theta) + \tfrac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right] = 0$$

$$\Delta x = -\frac{2v_i^2(\sin\theta)(\cos\theta)}{a_y} = -\frac{(2)(2.50\times10^2\ \mathrm{m/s})^2(\sin 75.0°)(\cos 75.0°)}{-9.81\ \mathrm{m/s^2}} = 3190\ \mathrm{m}$$

Distance between projectile and ship $= \Delta x - \Delta x_1 - \Delta x_2$

$= 3190\ \mathrm{m} - 2.50 \times 10^3\ \mathrm{m} - 6.10 \times 10^2\ \mathrm{m} = \boxed{80\ \mathrm{m}}$

For projectile's flight to the mountain,

$$\Delta t' = \frac{\Delta x_i}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t' + \tfrac{1}{2}a_y\Delta t'^2 = v_i(\sin\theta)\left[\frac{\Delta x_1}{v_i(\cos\theta)}\right] + \tfrac{1}{2}a_y\left[\frac{\Delta x_1}{v_i(\cos\theta)}\right]^2$$

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$$\Delta y = \Delta x_1(\tan\theta) + \frac{a_y \Delta x_1^2}{2v_i^2(\cos\theta)^2}$$

$$\Delta y = (2.50 \times 10^3 \text{ m})(\tan 75.0°) + \frac{(-9.81 \text{ m/s}^2)(2.50 \times 10^3 \text{ m})^2}{(2)(2.50 \times 10^2 \text{ m/s})^2 (\cos 75.0°)^2}$$

$$\Delta y = 9330 \text{ m} - 7320 = 2010 \text{ m}$$

distance above peak $= \Delta y - \Delta y_{mountain} = 2010 \text{ m} - 1.80 \times 10^3 \text{ m} = \boxed{210 \text{ m}}$

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43. $\mathbf{v_{re}} = 1.50$ m/s east

$\mathbf{v_{br}} = 10.0$ m/s north

$\Delta x = 325$ m

a. $\mathbf{v_{be}} = \mathbf{v_{br}} + \mathbf{v_{re}}$

$$v_{be} = \sqrt{v_{br}^2 + v_{re}^2} = \sqrt{(10.0 \text{ m/s})^2 + (1.50 \text{ m/s})^2}$$

$$v_{be} = \sqrt{1.00 \times 10^2 \text{ m}^2/\text{s}^2 + 2.25 \text{ m}^2/\text{s}^2} = \sqrt{102 \text{ m}^2/\text{s}^2} = \boxed{10.1 \text{ m/s}}$$

$$\theta = \tan^{-1}\left(\frac{v_{re}}{v_{br}}\right) = \tan^{-1}\left(\frac{1.50 \text{ m/s}}{10.0 \text{ m/s}}\right) = \boxed{8.53° \text{ east of north}}$$

b. $\Delta t = \dfrac{\Delta x}{v_{br}} = \dfrac{325 \text{ m}}{10.0 \text{ m/s}} = 32.5 \text{ s}$

$$\Delta y = v_{re}\Delta t = (1.50 \text{ m/s})(32.5 \text{ s}) = \boxed{48.8 \text{ m}}$$

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44. $\mathbf{v_{we}} = 50.0$ km/h south

$v_{aw} = 205$ km/h

$\mathbf{v_{ae}}$ is directed due west

a. $\mathbf{v_{aw}} = \mathbf{v_{ae}} + (-\mathbf{v_{we}})$ $\qquad \dfrac{v_{we}}{v_{aw}} = \sin\theta$

$$\theta = \sin^{-1}\left(\frac{v_{we}}{v_{aw}}\right) = \sin^{-1}\left(\frac{50.0 \text{ km/h}}{205 \text{ km/h}}\right) = \boxed{14.1° \text{ north of west}}$$

b. $v_{aw}^2 = v_{ae}^2 + v_{we}^2$

$$v_{ae} = \sqrt{v_{aw}^2 - v_{we}^2} = \sqrt{(205 \text{ km/h})^2 - (50.0 \text{ km/h})^2}$$

$$v_{ae} = \sqrt{4.20 \times 10^4 \text{ km}^2/\text{h}^2 - 2.50 \times 10^3 \text{ km}^2/\text{h}^2}$$

$$v_{ae} = \sqrt{3.95 \times 10^4 \text{ km}^2/\text{h}^2} = \boxed{199 \text{ km/h}}$$

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45. $\Delta x = 1.5$ km

$v_{re} = 5.0$ km/h

$v_{br} = 12$ km/h

The boat's velocity in the x direction is greatest when the boat moves directly across the river with respect to the river.

$$\Delta t_{min} = \frac{\Delta x}{v_{br}} = \frac{1.5 \text{ km}}{(12 \text{ km/h})(1 \text{ h}/60 \text{ min})} = \boxed{7.5 \text{ min}}$$

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46. $\mathbf{v_{re}} = 3.75$ m/s downstream

$v_{sr} = 9.50$ m/s

$\mathbf{v_{se}}$ is directed across the river

a. $\mathbf{v_{sr}} = \mathbf{v_{se}} + (-\mathbf{v_{re}})$ $\qquad \dfrac{v_{re}}{v_{sr}} = \sin\theta$

$$\theta = \sin^{-1}\left(\frac{3.75 \text{ m/s}}{9.50 \text{ m/s}}\right) = \boxed{23.2° \text{ upstream from straight across}}$$

b. $v_{sr}^2 = v_{se}^2 + v_{re}^2$

$$v_{se} = \sqrt{v_{sr}^2 - v_{re}^2} = \sqrt{(9.50 \text{ m/s})^2 - (3.75 \text{ m/s})^2}$$

$$v_{se} = \sqrt{90.2 \text{ m}^2/\text{s}^2 - 14.1 \text{ m}^2/\text{s}^2} = \sqrt{76.1 \text{ m}^2/\text{s}^2} = 8.72 \text{ m/s}$$

$$\mathbf{v_{se}} = \boxed{8.72 \text{ m/s directly across the river}}$$

Givens	Solutions

47. $\Delta y = 21.0\text{ m} - 1.0\text{ m} = 20.0\text{ m}$

$\Delta x = 130.0\text{ m}$

$\theta = 35.0°$

$a_y = -g = -9.81\text{ m/s}^2$

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a. $\Delta x = v_i \cos\theta\,\Delta t \qquad \Delta t = \dfrac{\Delta x}{v_i \cos\theta}$

$$\Delta y = v_i \sin\theta\,\Delta t + \tfrac{1}{2}a_y(\Delta t)^2$$

$$\Delta y = v_i \sin\theta\left(\frac{\Delta x}{v_i\cos\theta}\right) + \tfrac{1}{2}a_y\left(\frac{\Delta x}{v_i\cos\theta}\right)^2$$

$$\Delta y = \Delta x\tan\theta + \frac{a_y(\Delta x)^2}{2\,v_i^2\cos^2\theta}$$

$$v_i^2 = \frac{a_y(\Delta x)^2}{2\cos^2\theta\,(\Delta y - \Delta x\tan\theta)}$$

$$v_i = \frac{\Delta x}{\cos\theta}\sqrt{\frac{a_y}{2(\Delta y - \Delta x\tan\theta)}}$$

$$v_i = \frac{130.0\text{ m}}{\cos 35.0°}\sqrt{\frac{(-9.81\text{ m/s}^2)}{2[(20.0\text{ m}) - (130.0\text{ m})(\tan 35.0°)]}}$$

$$v_i = \boxed{41.7\text{ m/s}}$$

b. $\Delta t = \dfrac{\Delta x}{v_i\cos\theta} = \dfrac{130.0\text{ m}}{(41.7\text{ m/s})\,(\cos 35.0°)}$

$$\Delta t = \boxed{3.81\text{ s}}$$

c. $v_{y,f} = v_i\sin\theta + a_y\,\Delta t = (41.7\text{ m/s})(\sin 35.0°) + (-9.81\text{ m/s}^2)(3.81\text{ s})$

$$v_{y,f} = 23.9\text{ m/s} - 37.4\text{ m/s} = \boxed{-13.5\text{ m/s}}$$

$$v_{x,f} = v_i\cos\theta = (41.7\text{ m/s})\,(\cos 35.0°) = \boxed{34.2\text{ m/s}}$$

$$v_f = \sqrt{1170\text{ m}^2/\text{s}^2 + 182\text{ m}^2/\text{s}^2} = \sqrt{1350\text{ m}^2/\text{s}^2} = \boxed{36.7\text{ m/s}}$$

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48. $\Delta x = 12\text{ m}$

$\theta = 15°$

$a_y = -g = -9.81\text{ m/s}^2$

a. $\Delta x = v_i(\cos\theta)\Delta t$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \tfrac{1}{2}a_y\Delta t = 0$$

$$v_i(\sin\theta) + \tfrac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right] = 0$$

$$2v_i^2(\sin\theta)(\cos\theta) = -a_y\Delta x$$

$$v_i = \sqrt{\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{(9.81\text{ m/s}^2)(12\text{ m})}{(2)(\sin 15°)(\cos 15°)}} = \boxed{15\text{ m/s}}$$

b. $\Delta t = \dfrac{\Delta x}{v_i(\cos\theta)} = \dfrac{12\text{ m}}{(15\text{ m/s})(\cos 15°)} = 0.83\text{ s}$

$$v_{y,f} = v_i(\sin\theta) + a_y\Delta t = (15\text{ m/s})(\sin 15°) + (-9.81\text{ m/s}^2)(0.83\text{ s})$$

$$v_{y,f} = 3.9\text{ m/s} - 8.1\text{ m/s} = -4.2\text{ m/s}$$

$$v_{x,f} = v_x = v_i(\cos\theta) = (15\text{ m/s})(\cos 15°) = 14\text{ m/s}$$

$$v_f = \sqrt{(v_{x,f})^2 + (v_{y,f})^2} = \sqrt{(14\text{ m/s})^2 + (-4.2\text{ m/s})^2}$$

$$v_f = \sqrt{2.0\times 10^2\text{ m}^2/\text{s}^2 + 18\text{ m}^2/\text{s}^2} = \sqrt{220\text{ m}^2/\text{s}^2} = \boxed{15\text{ m/s}}$$

Givens	Solutions

49. $\Delta x = 10.00$ m

$\theta = 45.0°$

$\Delta y = 3.05\text{ m} - 2.00\text{ m} = 1.05$ m

$a_y = -g = -9.81\text{ m/s}^2$

See the solution to problem **47** for a derivation of the following equation.

$$v_i = \sqrt{\frac{a_y \Delta x^2}{2(\cos\theta)^2[(\Delta y - \Delta x \tan\theta)]}} = \sqrt{\frac{(-9.81\text{ m/s}^2)(10.00\text{ m})^2}{(2)(\cos 45.0°)^2[1.05\text{ m} - (10.00\text{ m})(\tan 45.0°)]}}$$

$$v_i = \sqrt{\frac{(-9.81\text{ m/s}^2)(10.00\text{ m})^2}{(2)(\cos 45.0°)^2(1.05\text{ m} - 10.00\text{ m})}} = \sqrt{\frac{(-9.81\text{ m/s}^2)(10.00\text{ m})^2}{(2)(\cos 45.0°)^2(-8.95\text{ m})}} = \boxed{10.5\text{ m/s}}$$

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50. $\Delta x = 20.0$ m

$\Delta t = 50.0$ s

$v_{pe} = \pm 0.500$ m/s

$$v_{eg} = \frac{\Delta x}{\Delta t} = \frac{20.0\text{ m}}{50.0\text{ s}} = 0.400\text{ m/s}$$

$\mathbf{v_{pg}} = \mathbf{v_{pe}} + \mathbf{v_{eg}}$

a. Going up:

$v_{pg} = v_{pe} + v_{eg} = 0.500\text{ m/s} + 0.400\text{ m/s} = 0.900\text{ m/s}$

$$\Delta t_{up} = \frac{\Delta x}{v_{pg}} = \frac{20.0\text{ m}}{0.900\text{ m/s}} = \boxed{22.2\text{ s}}$$

b. Going down:

$v_{pg} = -v_{pe} + v_{eg} = -0.500\text{ m/s} + 0.400\text{ m/s} = -0.100\text{ m/s}$

$$\Delta t_{down} = \frac{-\Delta x}{v_{pg}} = \frac{-20.0\text{ m}}{-0.100\text{ m/s}} = \boxed{2.00 \times 10^2\text{ s}}$$

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51. $\Delta y = -1.00$ m

$\Delta x = 1.20$ m

$a_y = -g = -9.81\text{ m/s}^2$

a. $\Delta x = v_x \Delta t$ $\qquad$ $\Delta t = \dfrac{\Delta x}{v_x}$

$$\Delta y = \tfrac{1}{2}a_y \Delta t^2 = \tfrac{1}{2}a_y\left(\frac{\Delta x}{v_x}\right)^2 = \frac{a_y \Delta x^2}{2v_x^{\,2}}$$

$$v_x = \sqrt{\frac{a_y \Delta x^2}{2\Delta y}} = \sqrt{\frac{-(9.81\text{ m/s}^2)(1.20\text{ m})^2}{(2)(-1.00\text{ m})}} = \boxed{2.66\text{ m/s}}$$

b. The ball's velocity vector makes a 45° angle with the horizontal when $v_x = v_y$.

$v_x = v_{y,f} = a_y \Delta t$ $\qquad$ $\Delta t = \dfrac{v_x}{a_y}$

$$\Delta y = \tfrac{1}{2}a_y \Delta t^2 = \tfrac{1}{2}a_y\left(\frac{v_x}{a_y}\right)^2 = \frac{v_x^{\,2}}{2a_y}$$

$$\Delta y = \frac{(2.66\text{ m/s})^2}{(2)(-9.81\text{ m/s}^2)} = -\,0.361\text{ m}$$

$h = 1.00\text{ m} - 0.361\text{ m} = \boxed{0.64\text{ m}}$

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52. $v_1 = 40.0$ km/h

$v_2 = 60.0$ km/h

$\Delta x_i = 125$ m

For lead car:

$\Delta x_{tot} = v_1 \Delta t + \Delta x_i$

For chasing car:

$\Delta x_{tot} = v_2 \Delta t$

$v_2 \Delta t = v_1 \Delta t + \Delta x_i$

$$\Delta t = \frac{\Delta x_i}{v_2 - v_1} = \frac{(125\text{ m})(10^{-3}\text{ km/m})}{(60.0\text{ km/h} - 40.0\text{ km/h})(1\text{ h}/3600\text{ s})}$$

$$\Delta t = \frac{125 \times 10^{-3}\text{ km}}{(20.0\text{ km/h})(1\text{ h}/3600\text{ s})} = \boxed{22.5\text{ s}}$$

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Givens	Solutions
53. $\theta = 60.0°$ $v_1 = 41.0$ km/h $v_2 = 25.0$ km/h $\Delta t_1 = 3.00$ h $\Delta t = 4.50$ h	$d_1 = v_1\Delta t = (41.0 \text{ km/h})(3.00 \text{ h}) = 123 \text{ km}$ $\Delta x_1 = d_1(\cos\theta) = (123 \text{ km})(\cos 60.0°) = 61.5 \text{ km}$ $\Delta y_1 = d_1(\sin\theta) = (123 \text{ km})(\sin 60.0°) = 107 \text{ km}$ $\Delta t_2 = \Delta t - \Delta t_1 = 4.50 \text{ h} - 3.00 \text{ h} = 1.50 \text{ h}$ $\Delta y_2 = v_2\Delta t_2 = (25.0 \text{ km/h})(1.50 \text{ h}) = 37.5 \text{ km}$ $\Delta x_{tot} = \Delta x_1 = 61.5 \text{ km}$ $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 107 \text{ km} + 37.5 \text{ km} = 144 \text{ km}$ $d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(61.5 \text{ km})^2 + (144 \text{ km})^2}$ $d = \sqrt{3780 \text{ km}^2 + 20\,700 \text{ km}^2} = \sqrt{24\,500 \text{ km}^2} = \boxed{157 \text{ km}}$
54. $v_{bw} = \pm 7.5$ m/s $v_{we} = 1.5$ m/s $\Delta x_d = 250$ m $\Delta x_u = -250$ m	$\mathbf{v_{be}} = \mathbf{v_{bw}} + \mathbf{v_{we}}$ Going downstream: $v_{be,d} = 7.5 \text{ m/s} + 1.5 \text{ m/s} = 9.0 \text{ m/s}$ Going upstream: $v_{be,u} = -7.5 \text{ m/s} + 1.5 \text{ m/s} = -6.0 \text{ m/s}$ $\Delta t = \dfrac{\Delta x_d}{v_{be,d}} + \dfrac{\Delta x_u}{v_{be,u}} = \dfrac{250 \text{ m}}{9.0 \text{ m/s}} + \dfrac{-250 \text{ m}}{-6.0 \text{ m/s}} = 28 \text{ s} + 42 \text{ s} = \boxed{7.0 \times 10^1 \text{ s}}$
55. $\theta = -24.0°$ $a = 4.00$ m/s^2 $d = 50.0$ m $\Delta y = -30.0$ m $a_y = -g = -9.81$ m/s^2	**a.** $d = \frac{1}{2}a\Delta t^2$ $\Delta t_1 = \sqrt{\dfrac{2d}{a}} = \sqrt{\dfrac{(2)(50.0 \text{ m})}{4.00 \text{ m/s}^2}} = 5.00 \text{ s}$ $v_i = a\Delta t_1 = (4.00 \text{ m/s}^2)(5.00 \text{ s}) = 20.0 \text{ m/s}$ $v_{y,f} = \sqrt{v_i^2(\sin\theta)^2 + 2a_y\Delta y} = \sqrt{(20.0 \text{ m/s})^2[\sin(-24.0°)]^2 + (2)(-9.81 \text{ m/s}^2)(-30.0 \text{ m})}$ $v_{y,f} = \sqrt{66.2 \text{ m}^2/\text{s}^2 + 589 \text{ m}^2/\text{s}^2} = \sqrt{655 \text{ m}^2/\text{s}^2} = \pm 25.6 \text{ m/s} = -25.6 \text{ m/s}$ $v_{y,f} = v_i(\sin\theta) + a_y\Delta t_2$ $\Delta t_2 = \dfrac{v_{y,f} - v_i(\sin\theta)}{a_y} = \dfrac{-25.6 \text{ m/s} - (20.0 \text{ m/s})(\sin -24.0°)}{-9.81 \text{ m/s}^2}$ $\Delta t_2 = \dfrac{-25.6 \text{ m/s} + 8.13 \text{ m/s}}{-9.81 \text{ m/s}^2} = \dfrac{-17.5 \text{ m/s}}{-9.81 \text{ m/s}^2} = 1.78 \text{ s}$ $\Delta x = v_i(\cos\theta)\Delta t_2 = (20.0 \text{ m/s})[\cos(-24.0°)](1.78 \text{ s}) = \boxed{32.5 \text{ m}}$ **b.** $\Delta t_2 = \boxed{1.78 \text{ s}}$ (See **a.**)

Givens	*Solutions*

56. $\theta = 34°$

$\Delta x = 240$ m

$a_y = -g = -9.81$ m/s^2

a. $\Delta x = v_i(\cos\theta)\Delta t$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \tfrac{1}{2}a_y\Delta t = 0$$

$$v_i(\sin\theta) + \tfrac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right] = v_i^2(\sin\theta) + \frac{a_y\Delta x}{2(\cos\theta)} = 0$$

$$v_i = \sqrt{\frac{-a_y\Delta x}{2(\cos\theta)(\sin\theta)}} = \sqrt{\frac{(9.81\text{ m/s}^2)(240\text{ m})}{(2)(\cos 34°)(\sin 34°)}} = \boxed{5.0\times10^1\text{ m/s}}$$

b. $$\Delta y_{max} = \frac{v_{y,f}^2 - v_{y,i}^2}{2a_y}$$

Because $v_{y,f} = 0$ m/s,

$$\Delta y_{max} = \frac{-v_i^2(\sin\theta)^2}{2a_y} = \frac{-(5.0\times10^1\text{ m/s})^2(\sin 34°)^2}{(2)(-9.81\text{ m/s}^2)}$$

$$\Delta y_{max} = \boxed{4.0\times10^1\text{ m}}$$

$$v_i(\sin\theta)\left[\frac{\Delta x}{2v_i(\cos\theta)}\right] + \frac{1}{2}a_y\left[\frac{\Delta x}{2v_i(\cos\theta)}\right]^2$$

$$\Delta y_{max} = \frac{\Delta x}{2}(\tan\theta) + \frac{a_y\Delta x^2}{8\,v_i^2(\cos\theta)^2}$$

$$\Delta y_{max} = \frac{(240\text{ m})(\tan 34°)}{2} + \frac{(-9.81\text{ m/s}^2)(240\text{ m})^2}{(8)(5.0\times10^1\text{ m/s})^2(\cos 34°)}$$

$$\Delta y_{max} = 81\text{ m} - 41\text{ m} = \boxed{4.0\times10^1\text{ m}}$$

---

57. $\mathbf{v_{ce}} = 50.0$ km/h east

$\theta = 60.0°$

a. $v_{ce} = v_{rc}(\sin\theta)$

$$v_{rc} = \frac{v_{ce}}{(\sin\theta)} = \frac{50.0\text{ km/h}}{(\sin 60.0°)} = 57.7\text{ km/h}$$

$\mathbf{v_{rc}} = \boxed{\text{57.7 km/h at 60.0° west of the vertical}}$

b. $v_{re} = v_{rc}(\cos\theta) = (57.7\text{ km/h})(\cos 60.0°) = 28.8$ km/h

$\mathbf{v_{re}} = \boxed{\text{28.8 km/h straight down}}$

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58. $\Delta t_{walk} = 30.0$ s

$\Delta t_{stand} = 20.0$ s

$$v_{pe} = \frac{L}{\Delta t_{walk}} = \frac{L}{30.0\text{ s}}$$

$$v_{eg} = \frac{L}{\Delta t_{stand}} = \frac{L}{20.0\text{ s}}$$

$\mathbf{v_{pg}} = \mathbf{v_{pe}} + \mathbf{v_{eg}}$

$v_{pg} = v_{pe} + v_{eg}$

$$v_{pg} = \frac{L}{30.0\text{ s}} + \frac{L}{20.0\text{ s}} = \frac{2L+3L}{60.0\text{ s}} = \frac{5L}{60.0\text{ s}}$$

$$\frac{L}{\Delta t} = \frac{5L}{60.0\text{ s}}$$

$$\Delta t = \frac{60.0\text{ s}}{5} = \boxed{12.0\text{ s}}$$

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59. $\Delta x_{Earth} = 3.0$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta y = v_i(\sin\theta)\Delta t + \frac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \frac{1}{2}a_y\Delta t = 0$$

$$\Delta t = -\frac{2v_i(\sin\theta)}{a_y}$$

$$\Delta x_{Earth} = v_i(\cos\theta)\Delta t = v_i(\cos\theta)\left[-\frac{2v_i(\sin\theta)}{a_y}\right]$$

$$\Delta x_{Earth} = -\frac{2v_i^2(\cos\theta)(\sin\theta)}{a_y} = \frac{2v_i^2(\cos\theta)(\sin\theta)}{g}$$

Because v_i and θ are the same for all locations,

$$\Delta x_{Earth} = \frac{k}{g}, \text{ where } k = 2v_i^2(\cos\theta)(\sin\theta)$$

$$k = g\Delta x_{Earth} = \left(\frac{g}{6}\right)\Delta x_{moon} = (0.38g)\Delta x_{Mars}$$

$$\Delta x_{moon} = 6\Delta x_{Earth} = (6)(3.0\text{ m}) = \boxed{18\text{ m}}$$

$$\Delta x_{Mars} = \frac{\Delta x_{Earth}}{0.38} = \frac{3.0\text{ m}}{0.38} = \boxed{7.9\text{ m}}$$

---

60. $v_x = 10.0$ m/s

$\theta = 60.0°$

$a_y = -g = -9.81$ m/s^2

The observer on the ground sees the ball rise vertically, which indicates that the x-component of the ball's velocity is equal and opposite the velocity of the train.

$$v_x = v_i(\cos\theta)$$

$$v_i = \frac{v_x}{(\cos\theta)} = \frac{10.0\text{ m/s}}{(\cos 60.0°)} = 20.0\text{ m/s}$$

At maximum height, $v_y = 0$, so

$$\Delta y_{max} = \frac{v_{y,f}^2 - v_{y,i}^2}{2a_y} = \frac{-v_i^2(\sin\theta)^2}{2a_y}$$

$$\Delta y_{max} = \frac{-(20.0\text{ m/s})^2(\sin 60.0°)^2}{(2)(-9.81\text{ m/s}^2)} = \boxed{15.3\text{ m}}$$

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61. $v_i = 18.0$ m/s

$\theta = 35.0°$

$\Delta x_i = 18.0$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta y = v_i(\sin\theta)\Delta t + \frac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \frac{1}{2}a_y\Delta t = 0$$

$$\Delta t = \frac{-2v_i(\sin\theta)}{a_y} = \frac{-2(18.0\text{ m/s})(\sin 35.0°)}{-9.81\text{ m/s}^2} = 2.10\text{ s}$$

$$\Delta x = v_i(\cos\theta)\Delta t = (18.0\text{ m/s})(\cos 35.0°)(2.10\text{ s}) = 31.0\text{ m}$$

$$\Delta x_{run} = \Delta x - \Delta x_i = 31.0\text{ m} - 18.0\text{ m} = 13.0\text{ m}$$

$$v_{run} = \frac{\Delta x_{run}}{\Delta t} = \frac{13.0\text{ m}}{2.10\text{ s}} = \boxed{6.19\text{ m/s downfield}}$$

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62. $\theta = 53°$

$v_i = 75$ m/s

$\Delta t = 25$ s

$a = 25$ m/s^2

$$a_y = a(\sin\theta) = (25\text{ m/s}^2)(\sin 53°) = 2.0\times 10^1\text{ m/s}^2$$

$$\Delta y = v_i(\sin\theta)\Delta t + \frac{1}{2}a_y\Delta t^2 = (75\text{ m/s})(\sin 53°)(25\text{ s}) + \frac{1}{2}(2.0\times 10^1\text{ m/s}^2)(25\text{ s})^2$$

$$\Delta y = 1500\text{ m} + 6200\text{ m} = 7700\text{ m}$$

$$v_f = v_i + a\Delta t = 75\text{ m/s} + (25\text{ m/s}^2)(25\text{ s}) = 75\text{ m/s} + 620\text{ m/s} = 7.0\times 10^2\text{ m/s}$$

Givens | *Solutions*

For the motion of the rocket after the boosters quit:

$v_i = v_f = 7.0 \times 10^2$ m/s

$\theta = 53°$

$a_y = -g = -9.81$ m/s^2

$v_{y,f} = v_i(\sin\theta) + a_y\Delta t = 0$

$$\Delta t = \frac{-v_i(\sin\theta)}{a_y} = \frac{-(7.0\times10^2\text{ m/s})(\sin 53°)}{-9.81\text{ m/s}^2} = 57\text{ s}$$

$$\Delta y = v_i(\sin\theta)\Delta t + \tfrac{1}{2}a_y\Delta t^2 = (7.0\times10^2\text{ m/s})(\sin 53°)(57\text{ s}) + \tfrac{1}{2}(-9.81\text{ m/s}^2)(57\text{ s})^2$$

$\Delta y = 32\,000$ m $- 16\,000$ m $= 16\,000$ m

a. $\Delta y_{total} = 7700\text{ m} + 16\,000\text{ m} = \boxed{2.4\times10^4\text{ m}}$

b. $\Delta y = +\tfrac{1}{2}a_y\Delta t^2$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{(2)(-24\,000\text{ m})}{-9.81\text{ m/s}^2}} = 7.0\times10^1\text{ s}$$

$\Delta t_{total} = 25\text{ s} + 57\text{ s} + 7.0\times10^1\text{ s} = \boxed{152\text{ s}}$

c. $a_x = a(\cos\theta)$

$$\Delta x = v_i(\cos\theta)\Delta t + \tfrac{1}{2}a_x\Delta t^2 = v_i(\cos\theta)\Delta t + \tfrac{1}{2}a(\cos\theta)\Delta t^2$$

$$\Delta x = (75\text{ m/s})(\cos 53°)(25\text{ s}) + \tfrac{1}{2}(25\text{ m/s}^2)(\cos 53°)(25\text{ s})^2$$

$\Delta x = (1.1\times10^3\text{ m}) + (4.7\times10^3\text{ m}) = 5.8\times10^3$ m

$v_i = 7.0\times10^2$ m/s

$\theta = 53°$

After the rockets quit:

$\Delta t = 57\text{ s} + 7.0\times10^1\text{ s} = 127$ s

$\Delta x = v_i(\cos\theta)\Delta t = (7.0\times10^1\text{ m/s})(\cos 53°)(127\text{ s}) = 5.4\times10^4$ m

$\Delta x_{tot} = (5.8\times10^3\text{ m}) + (5.4\times10^4\text{ m}) = \boxed{6.0\times10^4\text{ m}}$

Two-Dimensional Motion and Vectors, Standardized Test Prep

5. $\mathbf{v_{br}} = 5.0$ m/s east

$\mathbf{v_{re}} = 5.0$ m/s south

$\mathbf{v_{be}} = \mathbf{v_{br}} + \mathbf{v_{re}}$

$$v_{be} = \sqrt{v_{br}^2 + v_{re}^2} = \sqrt{(5.0\text{ m/s})^2 + (5.0\text{ m/s})^2}$$

$$v_{be} = \sqrt{25\text{ m}^2/\text{s}^2 + 25\text{ m}^2/\text{s}^2} = \boxed{7.1\text{ m/s}}$$

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6. $\Delta x = 125$ m

$v_{br} = 5.0$ m/s

$$\Delta t = \frac{\Delta x}{v_{br}} = \frac{125\text{ m}}{5.0\text{ m/s}} = \boxed{25\text{ s}}$$

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7. $\mathbf{v_{ap}} = 165$ km/h south

$= -165$ km/h north

$\mathbf{v_{pe}} = 145$ km/h north

$\mathbf{v_{ae}} = \mathbf{v_{ap}} + \mathbf{v_{pe}}$

$\mathbf{v_{ae}} = -165\text{ km/h north} + 145\text{ km/h north} = -20\text{ km/h north} = \boxed{20\text{ km/h south}}$

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Givens	*Solutions*
8. $\Delta x = 6.00$ m $\Delta y = -5.40$ m	$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(6.00\text{ m})^2 + (-5.40\text{ m})^2}$ $d = \sqrt{36.0\text{ m}^2 + 29.2\text{ m}^2} = \sqrt{65.2\text{ m}^2} = \boxed{8.07\text{ m}}$ $\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\frac{-5.40\text{ m}}{6.00\text{ m}}\right) = \boxed{42.0° \text{ south of east}}$
12. $v_{f,x} = v_x = 3.0$ m/s $\Delta y = -1.5$ m $g = -9.81\text{ m/s}^2$ $a_y = -g$	$v_{f,y} = \sqrt{2a_y\Delta y} = \sqrt{-2g\Delta y} = \sqrt{(-2)(9.81\text{ m/s}^2)(-1.5\text{ m})} = 5.4\text{ m/s}^2$ $v_f = \sqrt{v_{fx}{}^2 + v_{fy}{}^2} = \sqrt{(3.0\text{ m/s})^2 + (5.4\text{ m/s})^2} = \boxed{6.2\text{ m/s}}$
14. $d = 41.1$ m $\theta = 40.0°$	$\Delta x = d(\cos\theta) = (41.1\text{ m})(\cos 40.0°) = \boxed{31.5\text{ m}}$ $\Delta y = d(\sin\theta) = (41.1\text{ m})(\sin 40.0°) = \boxed{26.4\text{ m}}$
15. $\Delta t = 3.00$ s $\theta = 30.0°$ $a_y = -g = -9.81\text{ m/s}^2$	$\Delta y = v_i(\sin\theta)\Delta t + \frac{1}{2}a_y\Delta t^2 = v_i(\sin\theta) + \frac{1}{2}a_y\Delta t = 0$ $v_i = \frac{-a_y\Delta t}{2(\sin\theta)} = \frac{(9.81\text{ m/s}^2)(3.00\text{ s})}{(2)(\sin 30.0°)} = \boxed{29.4\text{ m/s}}$
16. $v_i = 25.0$ m/s $\theta = 45.0°$ $\Delta x = 50.0$ m $a_y = -g = -9.81\text{ m/s}^2$	$\Delta x = v_i(\cos\theta)\Delta t$ $\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$ $\Delta y = v_i(\sin\theta)\Delta t + \frac{1}{2}a_y\Delta t^2 = v_i(\sin\theta)\left[\frac{\Delta x}{v_i(\cos\theta)}\right] + \frac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right]^2$ $\Delta y = \Delta x(\tan\theta) + \frac{a_y\Delta x^2}{2v_i^2(\cos\theta)^2} = (50.0\text{ m})(\tan 45.0°) + \frac{(-9.81\text{ m/s}^2)(50.0\text{ m})^2}{(2)(25.0\text{ m/s})^2(\cos 45.0)^2}$ $\Delta y = 50.0\text{ m} - 39.2\text{ m} = \boxed{10.8\text{ m}}$

Forces and the Laws of Motion

Forces and the Laws of Motion, Practice B

Givens — *Solutions*

1. $F = 70.0$ N

$\theta = +30.0°$

$F_x = F(\cos\theta) = (70.0\text{ N})(\cos 30.0°) = \boxed{60.6\text{ N}}$

$F_y = F(\sin\theta) = (70.0\text{ N})(\sin 30.0°) = \boxed{35.0\text{ N}}$

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2. $F_y = -2.25$ N

$F_x = 1.05$ N

$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(1.05\text{ N})^2 + (-2.25\text{ N})^2}$

$F_{net} = \sqrt{1.10\text{ N}^2 + 5.06\text{ N}^2} = \sqrt{6.16\text{ N}^2} = \boxed{2.48\text{ N}}$

$\theta = \tan^{-1}\left(\frac{F_x}{F_y}\right) = \tan^{-1}\left(\frac{1.05\text{ N}}{-2.25\text{ N}}\right)$

$\theta = \boxed{25.0°\text{ counterclockwise from straight down}}$

---

3. $\mathbf{F_{wind}} = 452$ N north

$\mathbf{F_{water}} = 325$ N west

$F_x = F_{water} = -325$ N

$F_y = F_{wind} = 452$ N

$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(-325\text{ N})^2 + (452\text{ N})^2}$

$F_{net} = \sqrt{1.06 \times 10^5\text{ N}^2 + 2.04 \times 10^5\text{ N}^2} = \sqrt{3.10 \times 10^5\text{ N}^2}$

$F_{net} = \boxed{557\text{ N}}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{452\text{ N}}{-325\text{ N}}\right) = -54.3°$

$\theta = \boxed{54.3°\text{ north of west, or }35.7°\text{ west of north}}$

Forces and the Laws of Motion, Section 2 Review

3. $F_y = 130.0$ N

$F_x = 4500.0$ N

$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(4500.0\text{ N})^2 + (130.0\text{ N})^2}$

$F_{net} = \sqrt{2.025 \times 10^7\text{ N}^2 + 1.690 \times 10^4\text{ N}^2} = \sqrt{2.027 \times 10^7\text{ N}^2} = \boxed{4502\text{ N}}$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{130.0\text{ N}}{4500.0\text{ N}}\right) = \boxed{1.655°\text{ forward of the side}}$

Forces and the Laws of Motion, Practice C

1. $\mathbf{F_{net}} = 7.0$ N forward

$m = 3.2$ kg

$\mathbf{a} = \frac{\mathbf{F_{net}}}{m} = \frac{7.0\text{ N}}{3.2\text{ kg}} = \boxed{2.2\text{ m/s}^2\text{ forward}}$

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2. $\mathbf{F_{net}} = 390$ N north

$m = 270$ kg

$\mathbf{a} = \frac{\mathbf{F_{net}}}{m} = \frac{390\text{ N}}{270\text{ kg}} = \boxed{1.4\text{ m/s}^2\text{ north}}$

Forces and the Laws of Motion, Practice C

Givens	*Solutions*
3. $\mathbf{F_{net}} = 6.75 \times 10^3$ N east $m = 1.50 \times 10^3$ kg	$\mathbf{a} = \dfrac{\mathbf{F_{net}}}{m} = \dfrac{6.75 \times 10^3 \text{ N east}}{1.50 \times 10^3 \text{ kg}} = \boxed{4.50 \text{ m/s}^2 \text{ east}}$
4. $\mathbf{F_{net}} = 13.5$ N to the right $\mathbf{a} = 6.5$ m/s^2 to the right	$m = \dfrac{\mathbf{F_{net}}}{\mathbf{a}} = \dfrac{F_{net}}{a} = \dfrac{13.5 \text{ N}}{6.5 \text{ m/s}^2} = \boxed{2.1 \text{ kg}}$
5. $m = 2.0$ kg $\Delta x = 85$ cm $\Delta t = 0.50$ s	$\Delta x = \frac{1}{2}a(\Delta t)^2$ $a = \dfrac{2\Delta x}{\Delta t^2} = \dfrac{(2)(0.85 \text{ m})}{(0.50 \text{ s})^2} = 6.8 \text{ m/s}^2$ $F_{net} = ma = (2.0 \text{ kg})(6.8 \text{ m/s}^2) = \boxed{14 \text{ N}}$

Forces and the Laws of Motion, Section 3 Review

1. $m = 6.0$ kg $a = 2.0$ m/s^2	**a.** $F_{net} = ma = (6.0 \text{ kg})(2.0 \text{ m/s}^2) = \boxed{12 \text{ N}}$
$m = 4.0$ kg	**b.** $a = \dfrac{F_{net}}{m} = \dfrac{12 \text{ N}}{4.0 \text{ kg}} = \boxed{3.0 \text{ m/s}^2}$
4. $\mathbf{F_y} = 390$ N, north $\mathbf{F_x} = 180$ N, east $m = 270$ kg	$F_{net} = \sqrt{F_x^2 + F_y^2} = \sqrt{(180 \text{ N})^2 + (390 \text{ N})^2}$ $F_{net} = \sqrt{3.2 \times 10^4 \text{ N}^2 + 1.5 \times 10^5 \text{ N}^2} = \sqrt{1.8 \times 10^5 \text{ N}^2} = 420 \text{ N}$ $\theta = \tan^{-1}\left(\dfrac{F_y}{F_x}\right) = \tan^{-1}\left(\dfrac{390 \text{ N}}{180 \text{ N}}\right)$ $\theta = \boxed{65° \text{ north of east}}$ $a = \dfrac{F_{net}}{m} = \dfrac{420 \text{ N}}{270 \text{ kg}} = \boxed{1.6 \text{ m/s}^2}$

Forces and the Laws of Motion, Practice D

1. $F_k = 53$ N $m = 24$ kg $g = 9.81$ m/s^2	$\mu_k = \dfrac{F_k}{F_n} = \dfrac{F_k}{mg} = \dfrac{53 \text{ N}}{(24 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{0.23}$
2. $m = 25$ kg $F_{s,\,max} = 165$ N $F_k = 127$ N $g = 9.81$ m/s^2	**a.** $\mu_s = \dfrac{F_{s,max}}{F_n} = \dfrac{F_{s,max}}{mg} = \dfrac{165 \text{ N}}{(25 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{0.67}$ **b.** $\mu_k = \dfrac{F_k}{F_n} = \dfrac{F_k}{mg} = \dfrac{127 \text{ N}}{(25 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{0.52}$

Givens | *Solutions*

I

3. $m = 145$ kg, $\mu_s = 0.61$, $\mu_k = 0.47$, $g = 9.81$ m/s^2

a. $F_{s,max} = \mu_s F_n = \mu_s mg = (0.61)(145 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{8.7 \times 10^2 \text{ N}}$

$F_k = \mu_k F_n = \mu_k mg = (0.47)(145 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{6.7 \times 10^2 \text{ N}}$

$m = 15$ kg, $\mu_s = 0.74$, $\mu_k = 0.57$, $g = 9.81$ m/s^2

b. $F_{s,max} = \mu_s F_n = \mu_s mg = (0.74)(15 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{1.1 \times 10^2 \text{ N}}$

$F_k = \mu_k F_n = \mu_k mg = (0.57)(15 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{84 \text{ N}}$

$m = 250$ kg, $\mu_s = 0.4$, $\mu_k = 0.2$, $g = 9.81$ m/s^2

c. $F_{s,max} = \mu_s F_n = \mu_s mg = (0.4)(250 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{1 \times 10^3 \text{ N}}$

$F_k = \mu_k F_n = \mu_k mg = (0.2)(250 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{5 \times 10^2 \text{ N}}$

$m = 0.55$ kg, $\mu_s = 0.9$, $\mu_k = 0.4$, $g = 9.81$ m/s^2

d. $F_{s,max} = \mu_s F_n = \mu_s mg = (0.9)(0.55 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{5 \text{ N}}$

$F_k = \mu_k F_n = \mu_k mg = (0.4)(0.55 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{2 \text{ N}}$

Forces and the Laws of Motion, Practice E

1. $\mathbf{F_{applied}} = 185$ N at 25.0° above the horizontal, $m = 35.0$ kg, $\mu_k = 0.27$, $g = 9.81$ m/s^2

$F_{applied,\,x} = F_{applied}(\cos\,\theta)$

$F_{applied,\,y} = F_{applied}(\sin\,\theta)$

$F_{y,\,net} = \Sigma F_y = F_n + F_{applied,\,y} - F_g = 0$

$F_n = F_g - F_{applied,\,y} = mg - F_{applied}(\sin\,\theta)$

$F_n = (35.0 \text{ kg})(9.81 \text{ m/s}^2) - (185 \text{ N})(\sin 25.0°) = 343 \text{ N} - 78.2 \text{ N} = 265 \text{ N}$

$F_k = \mu_k F_n = (0.27)(265 \text{ N}) = 72 \text{ N}$

$F_{x,\,net} = \Sigma F_x = F_{applied,\,x} - F_k = F_{applied}(\cos\,\theta) - F_k$

$F_{x,\,net} = (185 \text{ N})(\cos 25.0°) - 72 \text{ N} = 168 \text{ N} - 72 \text{ N} = 96 \text{ N}$

$$a_x = \frac{F_{x,net}}{m} = \frac{96 \text{ N}}{35.0 \text{ kg}} = 2.7 \text{ m/s}^2$$

$\mathbf{a} = \mathbf{a_x} = \boxed{2.7 \text{ m/s}^2 \text{ in the positive } x \text{ direction}}$

---

2. $\theta_1 = 12.0°$, $\theta_2 = 25.0°$, $F_{applied} = 185$ N, $m = 35.0$ kg, $\mu_k = 0.27$, $g = 9.81$ m/s^2

$F_{g,y} = mg(\cos\,\theta_1) = (35.0 \text{ kg})(9.81 \text{ m/s}^2)(\cos 12.0°) = 336 \text{ N}$

$F_{g,x} = mg(\sin\,\theta_1) = (35.0 \text{ kg})(9.81 \text{ m/s}^2)(\sin 12.0°) = 71.4 \text{ N}$

$F_{applied,x} = F_{applied}(\cos\,\theta_2) = (185 \text{ N})(\cos 25.0°) = 168 \text{ N}$

$F_{applied,y} = F_{applied}(\sin\,\theta_2) = (185 \text{ N})(\sin 25.0°) = 78.2 \text{ N}$

$F_{y,net} = \Sigma F_y = F_n + F_{applied,y} - F_{g,y} = 0$

$F_n = F_{g,y} - F_{applied,y} = 336 \text{ N} - 78.2 \text{ N} = 258 \text{ N}$

$F_k = \mu_k F_n = (0.27)(258 \text{ N}) = 7.0 \times 10^1 \text{ N}$

$F_{x,net} = \Sigma F_x = F_{applied,x} - F_k - F_{g,x} = ma_x$

$$a_x = \frac{F_{applied,x} - F_k - F_{g,x}}{m}$$

Givens | *Solutions*

$$a_x = \frac{168\text{ N} - 7.0\times10^1\text{ N} - 71.4\text{ N}}{35.0\text{ kg}} = \frac{27\text{ N}}{35.0\text{ kg}} = 0.77\text{ m/s}^2$$

$\mathbf{a} = \mathbf{a_x} = \boxed{0.77\text{ m/s}^2\text{ up the ramp}}$

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3. $m = 75.0$ kg

$\theta = 25.0°$

$a_x = 3.60$ m/s^2

$g = 9.81$ m/s^2

a. $F_{x,net} = ma_x = F_{g,x} - F_k$

$F_{g,x} = mg(\sin\theta)$

$F_k = F_{g,x} - ma_x = mg(\sin\theta) - ma_x$

$F_k = (75.0\text{ kg})(9.81\text{ m/s}^2)(\sin 25.0°) - (75.0\text{ kg})(3.60\text{ m/s}^2)$

$F_k = 311\text{ N} - 2.70\times10^2\text{ N} = 41\text{ N}$

$F_n = F_{g,y} = mg(\cos\theta) = (75.0\text{ kg})(9.81\text{ m/s}^2)(\cos 25.0°) = 667\text{ N}$

$$\mu_k = \frac{F_k}{F_n} = \frac{41\text{ N}}{667\text{ N}} = \boxed{0.061}$$

$m = 175$ kg

$\mu_k = 0.061$

b. $F_{x,net} = F_{g,x} - F_k = mg\sin\theta - \mu_k F_n$

$F_n = F_{g,y} = mg\cos\theta$

$$a_x = \frac{F_{x,net}}{m} = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m} = g\sin\theta - \mu_k g\cos\theta$$

$a_x = g(\sin\theta - \mu_k\cos\theta) = 9.81\text{ m/s}^2\,[\sin 25.0° - (0.061)(\cos 25.0°)]$

$a_x = 9.81\text{ m/s}^2\,(0.423 - 0.055) = (9.81\text{ m/s}^2)(0.368) = 3.61\text{ m/s}^2$

$\mathbf{a} = \mathbf{a_x} = \boxed{3.61\text{ m/s}^2\text{ down the ramp}}$

---

4. $F_g = 325$ N

$F_{applied} = 425$ N

$\theta = -35.2°$

$F_{x,net} = F_{applied,x} - F_k = 0$

$F_k = F_{applied,x} = F_{applied}(\cos\theta) = (425\text{ N})[\cos(-35.2°)] = 347\text{ N}$

$F_{y,net} = F_n + F_{applied,y} - F_g = 0$

$F_n = F_g - F_{applied,y} = F_g - F_{applied}(\sin\theta)$

$F_n = 325\text{ N} - (425\text{ N})[\sin(-35.2°)] = 325\text{ N} + 245\text{ N} = 5.70\times10^2\text{ N}$

$$\mu_k = \frac{F_k}{F_n} = \frac{347\text{ N}}{5.70\times10^2\text{ N}} = \boxed{0.609}$$

Forces and the Laws of Motion, Section 4 Review

2. $m = 2.26$ kg

$g = 9.81$ m/s^2

a. $F_g = \frac{1}{6}mg = \frac{1}{6}(2.26\text{ kg})(9.81\text{ m/s}^2) = \boxed{3.70\text{ N}}$

b. $F_g = (2.64)mg = (2.64)(2.26\text{ kg})(9.81\text{ m/s}^2) = \boxed{58.5\text{ N}}$

---

3. $m = 2.0$ kg

$\theta = 60.0°$

$g = 9.81$ m/s^2

a. $F_{x,net} = F(\cos\theta) - mg(\sin\theta) = 0$

$$F = \frac{mg(\sin\theta)}{\cos\theta} = \frac{(2.0\text{ kg})(9.81\text{ m/s}^2)(\sin 60.0°)}{\cos 60.0°} = \boxed{34\text{ N}}$$

b. $F_{y,net} = F_n - F(\sin\theta) - mg(\cos\theta) = 0$

$F_n = F(\sin\theta) + mg(\cos\theta) = (34\text{ N})(\sin 60.0°) + (2.0\text{ kg})(9.81\text{ m/s}^2)(\cos 60.0°)$

$F_n = 29\text{ N} + 9.8\text{ N} = \boxed{39\text{ N}}$

Givens | *Solutions*

4. $m = 55$ kg

$F_{s,\,max} = 198$ N

$F_k = 175$ N

$g = 9.81$ m/s^2

$$\mu_s = \frac{F_{s,max}}{F_n} = \frac{F_{s,max}}{mg} = \frac{198 \text{ N}}{(55 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{0.37}$$

$$\mu_k = \frac{F_k}{F_n} = \frac{F_k}{mg} = \frac{175 \text{ N}}{(55 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{0.32}$$

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Forces and the Laws of Motion, Chapter Review

10. $F_{x,1} = 950$ N

$F_{x,2} = -1520$ N

$F_{y,1} = 5120$ N

$F_{y,2} = -4050$ N

$$F_{x,net} = F_{x,1} + F_{x,2} = 950 \text{ N} + (-1520 \text{ N}) = -570 \text{ N}$$

$$F_{y,net} = F_{y,1} + F_{y,2} = 5120 \text{ N} + (-4050 \text{ N}) = 1070 \text{ N}$$

$$F_{net} = \sqrt{(F_{x,net})^2 + (F_{y,net})^2} = \sqrt{(-570 \text{ N})^2 + (1070 \text{ N})^2}$$

$$F_{net} = \sqrt{3.2 \times 10^5 \text{ N}^2 + 1.14 \times 10^6 \text{ N}^2} = \sqrt{1.46 \times 10^6 \text{ N}^2} = \boxed{1.21 \times 10^3 \text{ N}}$$

$$\theta = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right) = \tan^{-1}\left(\frac{1070 \text{ N}}{-570 \text{ N}}\right) = -62°$$

$\theta = \boxed{\text{62° above the 1520 N force}}$

---

11. $F_1 + F_2 = 334$ N

$-F_1 + F_2 = -106$ N

b.
$$\begin{array}{r} F_1 + F_2 = \quad 334 \text{ N} \\ +(-F_1 + F_2) = (-106 \text{ N}) \\ \hline 2F_2 = 228 \text{ N} \end{array}$$

$F_2 = 114$ N $\qquad F_1 + 114 \text{ N} = 334$ N $\qquad F_1 = 220$ N

$\mathbf{F_1} = \boxed{\text{220 N right for the first situation and left for the second}}$

$\mathbf{F_2} = \boxed{\text{114 N right for both situations}}$

---

12. $F = 5$ N

$\theta = 37°$

$$F_x = F(\cos\theta) = (5 \text{ N})(\cos 37°) = \boxed{4 \text{ N}}$$

$$F_y = F(\sin\theta) = (5 \text{ N})(\sin 37°) = \boxed{3 \text{ N}}$$

---

20. $m = 24.3$ kg

$F_{net} = 85.5$ N

$$a = \frac{F_{net}}{m} = \frac{85.5 \text{ N}}{24.3 \text{ kg}} = \boxed{3.52 \text{ m/s}^2}$$

---

21. $m = 25$ kg

$a = 2.2$ m/s^2

$$F_{net} = ma = (25 \text{ kg})(2.2 \text{ m/s}^2) = 55 \text{ N}$$

$\mathbf{F_{net}} = \boxed{\text{55 N to the right}}$

Givens | *Solutions*

I

22. $F_1 = 380$ N
$\theta_1 = 30.0°$
$F_2 = 450$ N
$\theta_2 = -10.0°$

a. $F_{1,x} = F_1(\sin\theta_1) = (380 \text{ N})(\sin 30.0°) = 190 \text{ N}$

$F_{1,y} = F_1(\cos\theta_1) = (380 \text{ N})(\cos 30.0°) = 330 \text{ N}$

$F_{2,x} = F_2(\sin\theta_2) = (450 \text{ N})[\sin(-10.0°)] = -78 \text{ N}$

$F_{2,y} = F_2(\cos\theta_2) = (450 \text{ N})[\cos(-10.0°)] = 440 \text{ N}$

$F_{y,net} = F_{1,y} + F_{2,y} = 330 \text{ N} + 440 \text{ N} = 770 \text{ N}$

$F_{x,net} = F_{1,x} + F_{2,x} = 190 \text{ N} - 78 \text{ N} = 110 \text{ N}$

$F_{net} = \sqrt{(F_{x,net})^2 + (F_{y,net})^2} = \sqrt{(110 \text{ N})^2 + (770 \text{ N})^2}$

$F_{net} = \sqrt{1.2 \times 10^4 \text{ N}^2 + 5.9 \times 10^5 \text{ N}^2} = \sqrt{6.0 \times 10^5 \text{ N}^2} = \boxed{770 \text{ N}}$

$\theta = \tan^{-1}\left(\frac{F_{x,net}}{F_{y,net}}\right) = \tan^{-1}\left(\frac{110 \text{ N}}{770 \text{ N}}\right) = \boxed{8.1° \text{ to the right of forward}}$

$m = 3200$ kg

b. $a = \frac{F_{net}}{m} = \frac{770 \text{ N}}{3200 \text{ kg}} = 0.24 \text{ m/s}^2$

$\mathbf{a_{net}} = \boxed{0.24 \text{ m/s}^2 \text{ at } 8.1° \text{ to the right of forward}}$

---

24. $m = 0.150$ kg
$v_i = 20.0$ m/s
$g = 9.81 \text{ m/s}^2$

a. $F_{net} = -mg = -(0.150 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{-1.47 \text{ N}}$

b. same as part **a.**

---

26. $m = 5.5$ kg
$g = 9.81 \text{ m/s}^2$

a. $F_n = mg = (5.5 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{54 \text{ N}}$

$\theta = 12°$

b. $F_n = mg(\cos\theta) = (5.5 \text{ kg})(9.81 \text{ m/s}^2)(\cos 12°) = \boxed{53 \text{ N}}$

$\theta = 25°$

c. $F_n = mg(\cos\theta) = (5.5 \text{ kg})(9.81 \text{ m/s}^2)(\cos 25°) = \boxed{49 \text{ N}}$

$\theta = 45°$

d. $F_n = mg(\cos\theta) = (5.5 \text{ kg})(9.81 \text{ m/s}^2)(\cos 45°) = \boxed{38 \text{ N}}$

---

29. $m = 5.4$ kg
$\theta = 15°$
$g = 9.81 \text{ m/s}^2$

$F_n = mg(\cos\theta) = (5.4 \text{ kg})(9.81 \text{ m/s}^2)(\cos 15°) = \boxed{51 \text{ N}}$

---

35. $m = 95$ kg
$F_{s,max} = 650$ N
$F_k = 560$ N
$g = 9.81 \text{ m/s}^2$

$F_n = F_g = mg = (95 \text{ kg})(9.81 \text{ m/s}^2) = 930 \text{ N}$

$\mu_s = \frac{F_{s,max}}{F_n} = \frac{650 \text{ N}}{930 \text{ N}} = \boxed{0.70}$

$\mu_k = \frac{F_k}{F_n} = \frac{560 \text{ N}}{930 \text{ N}} = \boxed{0.60}$

---

36. $\theta = 30.0°$
$a = 1.20 \text{ m/s}^2$
$g = 9.81 \text{ m/s}^2$

$F_n = mg(\cos\theta)$

$mg(\sin\theta) - F_k = ma_x$, where $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$

$mg(\sin\theta) - \mu_k mg(\cos\theta) = ma_x$

$\mu_k = \frac{mg(\sin\theta) - ma_x}{mg(\cos\theta)} = \frac{\sin\theta}{\cos\theta} - \frac{a_x}{g(\cos\theta)} = \tan\theta - \frac{a_x}{g(\cos\theta)}$

$\mu_k = (\tan 30.0°) - \frac{1.20 \text{ m/s}^2}{(9.81 \text{ m/s}^2)(\cos 30.0°)} = 0.577 - 0.141 = \boxed{0.436}$

Givens | *Solutions*

37. $m = 4.00$ kg

$F_{applied} = 85.0$ N

$\theta = 55.0°$

$a_x = 6.00 \text{ m/s}^2$

$g = 9.81 \text{ m/s}^2$

$F_{applied,x} = F_{applied}(\cos\theta) = (85.0 \text{ N})(\cos 55.0°) = 48.8 \text{ N}$

$F_{applied,y} = F_{applied}(\sin\theta) = (85.0 \text{ N})(\sin 55.0°) = 69.6 \text{ N}$

$F_n = F_{applied,y} - mg = 69.6 \text{ N} - (4.00 \text{ kg})(9.81 \text{ m/s}^2) = 69.6 \text{ N} - 39.2 \text{ N} = 30.4 \text{ N}$

$ma_x = F_{applied,x} - F_k = F_{applied,x} - \mu_k F_n$

$$\mu_k = \frac{F_{applied,x} - ma_x}{F_n} = \frac{48.8 \text{ N} - (4.00 \text{ kg})(6.00 \text{ m/s}^2)}{30.4 \text{ N}}$$

$$\mu_k = \frac{48.8 \text{ N} - 24.0 \text{ N}}{30.4 \text{ N}} = \frac{24.8 \text{ N}}{30.4 \text{ N}} = \boxed{0.816}$$

---

38. $F_{applied} = 185.0$ N

$\theta = 25.0°$

$m = 35.0$ kg

$\mu_k = 0.450$

$g = 9.81 \text{ m/s}^2$

$F_{applied,x} = F_{applied}(\cos\theta) = (185.0 \text{ N})(\cos 25.0°) = 168 \text{ N}$

$F_{applied,y} = F_{applied}(\sin\theta) = (185.0 \text{ N})(\sin 25.0°) = 78.2 \text{ N}$

$F_{y,net} = F_n + F_{applied,y} - mg = 0$

$F_n = mg - F_{applied,y} = (35.0 \text{ kg})(9.81 \text{ m/s}^2) - 78.2 \text{ N} = 343 \text{ N} - 78.2 \text{ N} = 265 \text{ N}$

$F_k = \mu_k F_n = (0.450)(265 \text{ N}) = 119 \text{ N}$

$F_{x,net} = ma_x = F_{applied,x} - F_k$

$$a_x = \frac{F_{x,net}}{m} = \frac{168 \text{ N} - 119 \text{ N}}{35.0 \text{ kg}} = \frac{49 \text{ N}}{35.0 \text{ kg}} = 1.4 \text{ m/s}^2$$

$\mathbf{a} = \mathbf{a_x} = \boxed{1.4 \text{ m/s}^2 \text{ down the aisle}}$

---

39. $F_g = 925$ N

$F_{applied} = 325$ N

$\theta = 25.0°$

$\mu_k = 0.25$

$g = 9.81 \text{ m/s}^2$

$F_{applied,x} = F_{applied}(\cos\theta) = (325 \text{ N})(\cos 25.0°) = 295 \text{ N}$

$F_{applied,y} = F_{applied}(\sin\theta) = (325 \text{ N})(\sin 25.0°) = 137 \text{ N}$

$F_{y,net} = F_n + F_{applied,y} - F_g = 0$

$F_n = F_g - F_{applied,y} = 925 \text{ N} - 137 \text{ N} = 788 \text{ N}$

$F_k = \mu_k F_n = (0.25)(788 \text{ N}) = 2.0 \times 10^2 \text{ N}$

$F_{x,net} = ma_x = F_{applied,x} - F_k = 295 \text{ N} - 2.0 \times 10^2 \text{ N} = 95 \text{ N}$

$$m = \frac{F_g}{g} = \frac{925 \text{ N}}{9.81 \text{ m/s}^2} = 94.3 \text{ kg}$$

$$a_x = \frac{F_{x,net}}{m} = \frac{95 \text{ N}}{94.3 \text{ kg}} = \boxed{1.0 \text{ m/s}^2}$$

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40. $m = 6.0$ kg

$\theta = 30.0°$

$g = 9.81 \text{ m/s}^2$

$$F_n = \frac{mg}{\cos\theta} = \frac{(6.0 \text{ kg})(9.81 \text{ m/s}^2)}{\cos 30.0°} = \boxed{68 \text{ N}}$$

$F = F_n \sin\theta = (68 \text{ N})(\sin 30.0°) = \boxed{34 \text{ N}}$

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41. $m = 2.0$ kg

$\Delta x = 8.0 \times 10^{-1}$ m

$\Delta t = 0.50$ s

$v_i = 0$ m/s

Because $v_i = 0$ m/s,

$\Delta x = \frac{1}{2}a\Delta t^2$

$$a = \frac{2\Delta x}{\Delta t^2} = \frac{(2)(0.80 \text{ m})}{(0.50 \text{ s})^2} = 6.4 \text{ m/s}^2$$

$F_{net} = ma = (2.0 \text{ kg})(6.4 \text{ m/s}^2) = 13 \text{ N}$

$\mathbf{F_{net}} = \boxed{13 \text{ N down the incline}}$

Givens	*Solutions*
42. $m = 2.26$ kg $\Delta y = -1.5$ m $g = 9.81$ m/s^2	**b.** $F_g = mg = (2.26 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{22.2 \text{ N}}$
43. $m = 5.0$ kg $a = 3.0$ m/s^2 $g = 9.81$ m/s^2	$F_T - F_g = ma$ $F_T = ma + F_g = ma + mg$ $F_T = (5.0 \text{ kg})(3.0 \text{ m/s}^2) + (5.0 \text{ kg})(9.81 \text{ m/s}^2) = 15 \text{ N} + 49 \text{ N} = 64 \text{ N}$ $\mathbf{F_T} = \boxed{64 \text{ N upward}}$
44. $m = 3.46$ kg $g = 9.81$ m/s^2	**b.** $F_g = mg = (3.46 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{33.9 \text{ N}}$
45. $F_1 = 2.10 \times 10^3$ N $F_2 = -1.80 \times 10^3$ N $m = 1200$ kg	**a.** $F_{net} = F_1 + F_2 = 2.10 \times 10^3 \text{ N} + (-1.80 \times 10^3 \text{ N})$ $F_{net} = 3.02 \times 10^2 \text{ N}$ $a_{net} = \dfrac{F_{net}}{m} = \dfrac{3.02 \times 10^2 \text{ N}}{1200 \text{ kg}} = 0.25 \text{ m/s}^2$ $\mathbf{a_{net}} = \boxed{0.25 \text{ m/s}^2 \text{ forward}}$
$\Delta t = 12$ s $v_i = 0$ m/s	**b.** $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0 \text{ m/s})(12 \text{ s}) + \frac{1}{2}(0.25 \text{ m/s}^2)(12 \text{ s})^2$ $\Delta x = \boxed{18 \text{ m}}$ **c.** $v_f = a\Delta t + v_i = (0.25 \text{ m/s}^2)(12 \text{ s}) + 0 \text{ m/s}$ $v_f = \boxed{3.0 \text{ m/s}}$
46. $v_i = 7.0$ m/s $\mu_k = 0.050$ $F_g = 645$ N $g = 9.81$ m/s^2 $v_f = 0$ m/s	$F_k = \mu_k F_n = (0.050)(645 \text{ N}) = 32 \text{ N}$ $m = \dfrac{F_g}{g} = \dfrac{645 \text{ N}}{9.81 \text{ m/s}^2} = 65.7 \text{ kg}$ $a = \dfrac{-F_k}{m} = \dfrac{-32 \text{ N}}{65.7 \text{ kg}} = -0.49 \text{ m/s}^2$ $\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{(0 \text{ m/s})^2 - (7.0 \text{ m/s})^2}{(2)(-0.49 \text{ m/s}^2)}$ $\Delta x = \boxed{5.0 \times 10^1 \text{ m}}$

Givens	*Solutions*

47. $F_g = 319$ N

$F_{applied} = 485$ N

$\theta = -35°$

$\mu_k = 0.57$

$\Delta x = 4.00$ m

$g = 9.81$ m/s^2

$v_i = 0$ m/s

a. $F_{applied,\,x} = F_{applied}(\cos\theta) = (485\text{ N})[\cos(-35°)] = 4.0 \times 10^2$ N

$F_{applied,y} = F_{applied}(\sin\theta) = (485\text{ N})[\sin(-35°)] = -2.8 \times 10^2$ N

$F_{y,net} = F_n + F_{applied,y} - F_g = 0$

$F_n = F_g - F_{applied,y} = 319\text{ N} - (-2.8 \times 10^2\text{ N}) = 6.0 \times 10^2$ N

$F_k = \mu_k F_n = (0.57)(6.0 \times 10^2\text{ N}) = 3.4 \times 10^2$ N

$F_{x,net} = ma_x = F_{applied,x} - F_k = 4.0 \times 10^2\text{ N} - 3.4 \times 10^2\text{ N} = 6 \times 10^1$ N

$$m = \frac{F_g}{g} = \frac{319\text{ N}}{9.81\text{ m/s}^2} = 32.5\text{ kg}$$

$$a_x = \frac{F_{x,net}}{m} = \frac{6 \times 10^1\text{ N}}{32.5\text{ kg}} = 2\text{ m/s}^2$$

$$\Delta x = v_i\Delta t + \tfrac{1}{2}a_x\Delta t^2$$

Because $v_i = 0$ m/s,

$$\Delta t = \sqrt{\frac{2\Delta x}{a_x}} = \sqrt{\frac{(2)(4.00\text{ m})}{2\text{ m/s}^2}} = \boxed{2\text{ s}}$$

$\mu_k = 0.75$

b. $F_k = \mu_k F_n = (0.75)(6.0 \times 10^2\text{ N}) = 4.5 \times 10^2$ N

$\boxed{F_k > F_{applied,x}\text{; the box will not move}}$

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48. $m = 3.00$ kg

$\theta = 30.0°$

$\Delta x = 2.00$ m

$\Delta t = 1.50$ s

$g = 9.81$ m/s^2

$v_i = 0$ m/s

a. $\Delta x = v_i\Delta t + \tfrac{1}{2}a\Delta t^2$

Because $v_i = 0$ m/s,

$$a = \frac{2\Delta x}{\Delta t^2} = \frac{(2)(2.00\text{ m})}{(1.50\text{ s})^2} = \boxed{1.78\text{ m/s}^2}$$

b. $F_{g,x} = mg(\sin\theta) = (3.00\text{ kg})(9.81\text{ m/s}^2)(\sin 30.0°) = 14.7$ N

$F_{g,y} = mg(\cos\theta) = (3.00\text{ kg})(9.81\text{ m/s}^2)(\cos 30.0°) = 25.5$ N

$F_n = F_{g,y} = 25.5$ N

$ma_x = F_{g,x} - F_k = F_{g,x} - \mu_k F_n$

$$\mu_k = \frac{F_{g,x} - ma_x}{F_n} = \frac{14.7\text{ N} - (3.00\text{ kg})(1.78\text{ m/s}^2)}{25.5\text{ N}}$$

$$\mu_k = \frac{14.7\text{ N} - 5.34\text{ N}}{25.5\text{ N}} = \frac{9.4\text{ N}}{25.5\text{ N}} = \boxed{0.37}$$

c. $F_k = \mu_k F_n = (0.37)(25.5\text{ N}) = \boxed{9.4\text{ N}}$

d. $v_f^2 = v_i^2 + 2a_x\Delta x$

$$v_f = \sqrt{v_i^2 + 2a_x\Delta x} = \sqrt{(0\text{ m/s})^2 + (2)(1.78\text{ m/s}^2)(2.00\text{ m})} = \boxed{2.67\text{ m/s}}$$

---

49. $v_i = 12.0$ m/s

$\Delta t = 5.00$ s

$v_f = 6.00$ m/s

$v_f = v_i + a\Delta t$

$$a = \frac{v_f - v_i}{\Delta t} = \frac{6.00\text{ m/s} - 12.0\text{ m/s}}{5.00\text{ s}} = \frac{-6.0\text{ m/s}}{5.00\text{ s}}$$

$a = \boxed{-1.2\text{ m/s}^2}$

$F_k = -ma$

$$\mu_k = \frac{F_k}{F_n} = \frac{-ma}{mg} = \frac{-a}{g} = \frac{1.2\text{ m/s}^2}{9.8\text{ m/s}^2} = \boxed{0.12}$$

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Givens | *Solutions*

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50. $F_g = 8820$ N

$v_i = 35$ m/s

$\Delta x = 1100$ m

$g = 9.81$ m/s^2

$$m = \frac{F_g}{g} = \frac{8820 \text{ N}}{9.81 \text{ m/s}^2} = 899 \text{ kg}$$

$$v_f^2 = v_i^2 + 2a\Delta x = 0$$

$$a = \frac{-v_i^2}{2\Delta x} = \frac{-(35 \text{ m/s})^2}{(2)(1100 \text{ m})} = -0.56 \text{ m/s}^2$$

$$F_{net} = ma = (899 \text{ kg})(-0.56 \text{ m/s}^2) = \boxed{-5.0 \times 10^2 \text{ N}}$$

---

51. $m_{car} = 1250$ kg

$m_{trailer} = 325$ kg

$a = 2.15$ m/s^2

a. $F_{net} = m_{car}a = (1250 \text{ kg})(2.15 \text{ m/s}^2) = 2690$ N

$\mathbf{F_{net}} = \boxed{2690 \text{ N forward}}$

b. $F_{net} = m_{trailer}a = (325 \text{ kg})(2.15 \text{ m/s}^2) = 699$ N

$\mathbf{F_{net}} = \boxed{699 \text{ N forward}}$

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52. $m = 3.00$ kg

$\theta = 35.0°$

$\mu_s = 0.300$

$g = 9.81$ m/s^2

$$F_{s,\,max} = \mu_s F_n$$

$$mg(\sin\theta) = \mu_s[F + mg(\cos\theta)]$$

$$F = \frac{mg(\sin\theta) - \mu_s mg(\cos\theta)}{\mu_s} = \frac{mg[\sin\theta - \mu_s(\cos\theta)]}{\mu_s}$$

$$F = \frac{(3.00 \text{ kg})(9.81 \text{ m/s}^2)[\sin 35.0° - 0.300(\cos 35.0°)]}{0.300}$$

$$F = \frac{(3.00 \text{ kg})(9.81 \text{ m/s}^2)(0.574 - 0.246)}{0.300} = \frac{(3.00 \text{ kg})(9.81 \text{ m/s}^2)(0.328)}{0.300}$$

$$F = \boxed{32.2 \text{ N}}$$

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53. $m = 64.0$ kg

At $t = 0.00$ s, $v = 0.00$ m/s. At $t = 0.50$ s, $v = 0.100$ m/s.

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{0.100 \text{ m/s} - 0.00 \text{ m/s}}{0.50 \text{ s} - 0.00 \text{ s}} = 0.20 \text{ m/s}^2$$

$$F = ma = (64.0 \text{ kg})(0.20 \text{ m/s}^2) = \boxed{13 \text{ N}}$$

At $t = 0.50$ s, $v = 0.100$ m/s. At $t = 1.00$ s, $v = 0.200$ m/s.

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{0.200 \text{ m/s} - 0.100 \text{ m/s}}{1.00 \text{ s} - 0.50 \text{ s}} = 0.20 \text{ m/s}^2$$

$$F = ma = (64.0 \text{ kg})(0.20 \text{ m/s}^2) = \boxed{13 \text{ N}}$$

At $t = 1.00$ s, $v = 0.200$ m/s. At $t = 1.50$ s, $v = 0.200$ m/s.

$a = 0$ m/s^2; therefore, $F = \boxed{0 \text{ N}}$

At $t = 1.50$ s, $v = 0.200$ m/s. At $t = 2.00$ s, $v = 0.00$ m/s.

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{0.00 \text{ m/s} - 0.200 \text{ m/s}}{2.00 \text{ s} - 1.50 \text{ s}} = -0.40 \text{ m/s}^2$$

$$F = ma = (64.0 \text{ kg})(-0.40 \text{ m/s}^2) = \boxed{-26 \text{ N}}$$

Givens — *Solutions*

54. $F_{applied} = 3.00 \times 10^2$ N

$F_g = 1.22 \times 10^4$ N

$g = 9.81$ m/s^2

$F_{net} = F_{applied} - F_g \sin\theta = 0$

$$\sin\theta = \frac{F_{applied}}{F_g}$$

$$\theta = \sin^{-1}\left(\frac{F_{applied}}{F_g}\right) = \sin^{-1}\left(\frac{3.00 \times 10^2 \text{ N}}{1.22 \times 10^4 \text{ N}}\right)$$

$$\theta = \boxed{1.41°}$$

Forces and the Laws of Motion, Standardized Test Prep

3. $F_{x,1} = 82$ N

$F_{x,2} = -115$ N

$F_{y,1} = 565$ N

$F_{y,2} = -236$ N

$F_{x,net} = F_{x,1} + F_{x,2} = 82 \text{ N} - 115 \text{ N} = -33$ N

$F_{y,net} = F_{y,1} + F_{y,2} = 565 \text{ N} - 236 \text{ N} = 329$ N

$$F_{net} = \sqrt{(F_{x,net})^2 + (F_{y,net})^2} = \sqrt{(-33 \text{ N})^2 + (329 \text{ N})^2}$$

$$F_{net} = \sqrt{1.09 \times 10^3 \text{ N}^2 + 1.08 \times 10^5 \text{ N}^2} = \sqrt{1.09 \times 10^5 \text{ N}^2} = \boxed{3.30 \times 10^2 \text{ N}}$$

$$\theta = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right) = \tan^{-1}\left(\frac{329 \text{ N}}{-33 \text{ N}}\right) = -84° \text{ above negative } x\text{-axis}$$

$$\theta = 180.0° - 84° = \boxed{96° \text{ counterclockwise from the positive } x\text{-axis}}$$

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5. $m = 1.5 \times 10^7$ kg

$F_{net} = 7.5 \times 10^5$ N

$v_f = 85$ km/h

$v_i = 0$ km/h

$$a = \frac{F_{net}}{m} = \frac{7.5 \times 10^5 \text{ N}}{1.5 \times 10^7 \text{ kg}} = 5.0 \times 10^{-2} \text{ m/s}^2$$

$$\Delta t = \frac{v_f - v_i}{a} = \frac{(85 \text{ km/h} - 0 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})}{5.0 \times 10^{-2} \text{ m/s}^2}$$

$$\Delta t = \boxed{4.7 \times 10^2 \text{ s}}$$

6.

Apply Newton's second law to find an expression for the acceleration of the truck.

$ma = F_f = \mu_k F_n = \mu_k mg$

$a = \mu_k g$

Because the acceleration of the truck does not depend on the mass of the truck, the stopping distance will be Δx regardless of the mass of the truck.

7.

$$v_f = \sqrt{v_i^2 + 2a\Delta x} = 0$$

$$a = \frac{-v_i^2}{2\Delta x}$$

The acceleration will be the same regardless of the intial velocity.

$a_1 = a_2 = \mu_k g$ (see **6.**)

$$\frac{-v_{i,1}^2}{2\Delta x} = \frac{-v_{i,2}^2}{2\Delta x_2}$$

$$\Delta x_2 = \frac{v_{i,2}^2 \Delta x}{v_{i,1}^2} \text{ where } v_{i,2} = \tfrac{1}{2} v_{i,1}$$

$$\Delta x_2 = \frac{\left(\tfrac{1}{2} v_{i,1}\right)^2 \Delta x}{v_{i,1}^2} = \boxed{\tfrac{1}{4}\Delta x}$$

Givens / Solutions

10. $m = 3.00$ kg

$\Delta y = -176.4$ m

$F_w = 12.0$ N

$a_y = -g = -9.81$ m/s^2

Because the ball is dropped, $v_i = 0$ m/s

$$\Delta y = \frac{1}{2}a_y\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \sqrt{\frac{(2)(-176.4 \text{ m})}{-9.81 \text{ m/s}^2}} = \boxed{6.00 \text{ s}}$$

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11. $m = 3.00$ kg

$F_w = 23.0$ N

$\Delta t = 6.00$ s (see **10.**)

$$a_x = \frac{F_w}{m} = \frac{12.0 \text{ N}}{3.00 \text{ kg}} = 4.00 \text{ m/s}^2$$

$$\Delta x = \frac{1}{2}a_x\Delta t^2 = \frac{1}{2}(4.00 \text{ m/s}^2)(6.00 \text{ s})^2 = \boxed{72.0 \text{ m}}$$

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12. $a_y = -g = -9.81$ m/s^2

$\Delta t = 6.00$ s (see **10.**)

$a_x = 4.00$ m/s^2 (see **11.**)

$$v_y = a_y\Delta t = (-9.81 \text{ m/s}^2)(6.00 \text{ s}) = -58.9 \text{ m/s}$$

$$v_x = a_x\Delta t = (4.00 \text{ m/s}^2)(6.00 \text{ s}) = 24.0 \text{ m/s}$$

$$v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{(24.0 \text{ m/s})^2 + (-58.9 \text{ m/s})^2}$$

$$v = \sqrt{576 \text{ m}^2/\text{s}^2 + 3470 \text{ m}^2/\text{s}^2} = \sqrt{4050 \text{ m}^2/\text{s}^2} = \boxed{63.6 \text{ m/s}}$$

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16. $m = 10.0$ kg

$F = 15.0$ N

$\theta = 45.0°$

$\mu_k = 0.040$

$g = 9.81$ m/s^2

$$F_{net,y} = F_n + F\sin\theta - mg = 0$$

$$F_n = mg - F\sin\theta$$

$$F_{net,x} = F\cos\theta - F_k = F\cos\theta - \mu_k F_n$$

$$F_{net,x} = F\cos\theta - \mu_k(mg - F\sin\theta)$$

$$a_x = \frac{F_{net,x}}{m} = \frac{F\cos\theta - \mu_k(mg - F\sin\theta)}{m}$$

$$a_x = \frac{(15.0 \text{ N})(\cos 45.0°) - (0.040)[(10.0 \text{ kg})(9.81 \text{ m/s}^2) - (15.0 \text{ N})(\sin 45.0°)]}{10.0 \text{ kg}}$$

$$a_x = \frac{10.6 \text{ N} - (0.040)(98.1 \text{ N} - 10.6 \text{ N})}{10.0 \text{ kg}} = \frac{10.6 \text{ N} - (0.040)(87.5 \text{ N})}{10.0 \text{ kg}}$$

$$a_x = \frac{10.6 \text{ N} - 3.5 \text{ N}}{10.0 \text{ kg}} = \frac{7.1 \text{ N}}{10.0 \text{ kg}} = 0.71 \text{ m/s}^2$$

$$a = a_x = \boxed{0.71 \text{ m/s}^2}$$

Work and Energy

Work and Energy, Practice A

Givens | *Solutions*

1. $F_{net} = 5.00 \times 10^3$ N, $d = 3.00$ km, $\theta = 0°$

$$W_{net} = F_{net}d(\cos\theta) = (5.00 \times 10^3 \text{ N})(3.00 \times 10^3 \text{ m})(\cos 0°) = \boxed{1.50 \times 10^7 \text{ J}}$$

2. $d = 2.00$ m, $\theta = 0°$, $F_{net} = 350$ N

$$W_{net} = F_{net}d(\cos\theta) = (350 \text{ N})(2.00 \text{ m})(\cos 0°) = \boxed{7.0 \times 10^2 \text{ J}}$$

3. $F = 35$ N, $\theta = 25°$, $d = 50.0$ m

$$W = Fd(\cos\theta) = (35 \text{ N})(50.0 \text{ m})(\cos 25°) = \boxed{1.6 \times 10^3 \text{ J}}$$

4. $W = 2.0$ J, $m = 180$ g, $g = 9.81 \text{ m/s}^2$, $\theta = 0°$

$$d = \frac{W}{F(\cos\theta)} = \frac{W}{mg(\cos\theta)} = \frac{2.0 \text{ J}}{(0.18 \text{ kg})(9.81 \text{ m/s}^2)(\cos 0°)} = \boxed{1.1 \text{ m}}$$

Work and Energy, Section 1 Review

3. $F_g = 1.50 \times 10^3$ N, $F_{applied} = 345$ N, $\theta = 0°$, $d = 24.0$ m, $\mu_k = 0.220$

a. $W_1 = F_{applied}d(\cos\theta) = (345 \text{ N})(24.0 \text{ m})(\cos 0°) = \boxed{8.28 \times 10^3 \text{ J}}$

b. $W_2 = F_kd(\cos\theta) = -F_g\mu_kd(\cos\theta)$

$W_2 = -(1.50 \times 10^3 \text{ N})(0.220)(24.0 \text{ m})(\cos 0°) = \boxed{-7.92 \times 10^3 \text{ J}}$

c. $W_{net} = W_1 + W_2 = 8.28 \times 10^3 \text{ J} + (-7.92 \times 10^3 \text{ J}) = \boxed{3.6 \times 10^2 \text{ J}}$

4. $m = 0.075$ kg, $F_k = 0.350$ N, $g = 9.81 \text{ m/s}^2$, $d = 1.32$ m, $\theta = 0°$

$$W_{net} = F_{net}d(\cos\theta) = (F_g - F_k)d(\cos\theta) = (mg - F_k)d(\cos\theta)$$

$$W_{net} = [(0.075 \text{ kg})(9.81 \text{ m/s}^2) - 0.350 \text{ N}](1.33 \text{ m})(\cos 0°)$$

$$W_{net} = (0.74 \text{ N} - 0.350 \text{ N})(1.32 \text{ m}) = (0.39 \text{ N})(1.32 \text{ m}) = \boxed{0.51 \text{ J}}$$

Work and Energy, Practice B

1. $m = 8.0 \times 10^4$ kg, $KE = 1.1 \times 10^9$ J

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{(2)(1.1 \times 10^9 \text{ J})}{8.0 \times 10^4 \text{ kg}}} = \boxed{1.7 \times 10^2 \text{ m/s}}$$

Givens	Solutions
2. $m = 0.145$ kg $KE = 109$ J	$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{(2)(109\text{ J})}{0.145\text{ kg}}} = \boxed{38.8\text{ m/s}}$
3. $m_1 = 3.0$ g $v_1 = 40.0$ m/s $m_2 = 6.0$ g $v_2 = 40.0$ m/s	$KE_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}(3.0 \times 10^{-3}\text{ kg})(40.0\text{ m/s})^2 = 2.4\text{ J}$ $KE_2 = \frac{1}{2}m_2v_2^2 = \frac{1}{2}(6.0 \times 10^{-3}\text{ kg})(40.0\text{ m/s})^2 = 4.8\text{ J}$ $\frac{KE_2}{KE_1} = \frac{4.8\text{ J}}{2.4\text{ J}} = \boxed{\frac{2}{1}}$
4. $m_1 = 3.0$ g $v_1 = 40.0$ m/s $m_2 = 3.0$ g $v_2 = 80.0$ m/s	$KE_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}(3.0 \times 10^{-3}\text{ kg})(40.0\text{ m/s})^2 = \boxed{2.4\text{ J}}$ $KE_2 = \frac{1}{2}m_2v_2^2 = \frac{1}{2}(3.0 \times 10^{-3}\text{ kg})(80.0\text{ m/s})^2 = \boxed{9.6\text{ J}}$ $\frac{KE_1}{KE_2} = \frac{2.4\text{ J}}{9.6\text{ J}} = \boxed{\frac{1}{4}}$
5. $KE = 4.32 \times 10^5$ J $v = 23$ m/s	$m = \frac{2\,KE}{v^2} = \frac{(2)(4.32 \times 10^5\text{ J})}{(23\text{ m/s})^2} = \boxed{1.6 \times 10^3\text{ kg}}$

Work and Energy, Practice C

Givens	Solutions
1. $F_{net} = 45$ N $KE_f = 352$ J $KE_i = 0$ J $\theta = 0°$	$W_{net} = \Delta KE = KE_f - KE_i$ $W_{net} = F_{net}\,d(\cos\theta)$ $d = \frac{KE_f - KE_i}{F_{net}(\cos\theta)} = \frac{352\text{ J} - 0\text{ J}}{(45\text{ N})(\cos 0°)} = \frac{352\text{ J}}{45\text{ N}} = \boxed{7.8\text{ m}}$
2. $m = 2.0 \times 10^3$ kg $F_1 = 1140$ N $F_2 = 950$ N $v_f = 2.0$ m/s $v_i = 0$ m/s $\theta = 0°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = F_{net}d(\cos\theta) = (F_1 - F_2)d(\cos\theta)$ $d = \frac{\frac{1}{2}m(v_f^2 - v_i^2)}{(F_1 - F_2)(\cos\theta)} = \frac{(2.0 \times 10^3\text{ kg})[(2.0\text{ m/s})^2 - (0\text{ m/s})^2]}{(2)(1140\text{ N} - 950\text{ N})(\cos 0°)}$ $d = \frac{(2.0 \times 10^3\text{ kg})(4.0\text{ m}^2/\text{s}^2)}{(2)(190\text{ N})} = \boxed{21\text{ m}}$
3. $m = 2.1 \times 10^3$ kg $\theta = 20.0°$ $F_k = 4.0 \times 10^3$ N $g = 9.81\text{ m/s}^2$ $v_f = 3.8$ m/s $v_i = 0$ m/s $\theta' = 0°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = F_{net}\,d(\cos\theta')$ $F_{net} = mg(\sin\theta) - F_k$ $[mg(\sin\theta) - F_k]d(\cos\theta') = \frac{1}{2}m(v_f^2 - v_i^2)$ Simplify the equation by noting that $v_i = 0$ m/s and $\theta' = 0$. $d = \frac{\frac{1}{2}mv_f^2}{mg(\sin\theta) - F_k} = \frac{(2.1 \times 10^3\text{ kg})(3.8\text{ m/s})^2}{(2)[(2.1 \times 10^3\text{ kg})(9.81\text{ m/s}^2)(\sin 20.0°) - 4.0 \times 10^3\text{ N}]}$ $d = \frac{(2.1 \times 10^3\text{ kg})(3.8\text{ m/s})^2}{(2)(7.0 \times 10^3\text{ N} - 4.0 \times 10^3\text{ N})} = \frac{(2.1 \times 10^3\text{ kg})(3.8\text{ m/s})^2}{(2)(3.0 \times 10^3\text{ N})} = \boxed{5.1\text{ m}}$

Givens	Solutions
4. $m = 75$ kg $d = 4.5$ m $v_f = 6.0$ m/s $v_i = 0$ m/s $\theta = 0°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = F_{net}d(\cos\theta)$ $F_{net} = \dfrac{\frac{1}{2}m(v_f^2 - v_i^2)}{d(\cos\theta)} = \dfrac{(75\text{ kg})[(6.0\text{ m/s})^2 - (0\text{ m/s})^2]}{(2)(4.5\text{ m})(\cos 0°)} = \dfrac{(75\text{ kg})(36\text{ m}^2/\text{s}^2)}{(2)(4.5\text{ m})}$ $F_{net} = \boxed{3.0 \times 10^2\text{ N}}$

I

Work and Energy, Practice D

1. $k = 5.2$ N/m $x = 3.57\text{ m} - 2.45\text{ m} = 1.12\text{ m}$	$PE = \frac{1}{2}kx^2 = \frac{1}{2}(5.2\text{ N/m})(1.12\text{ m})^2 = \boxed{3.3\text{ J}}$
2. $k = 51.0$ N/m $x = 0.150\text{ m} - 0.115\text{ m} = 0.035\text{ m}$	$PE = \frac{1}{2}kx^2 = \frac{1}{2}(51.0\text{ N/m})(0.035\text{ m})^2 = \boxed{3.1 \times 10^{-2}\text{ J}}$
3. $m = 40.0$ kg $h_1 = 2.00$ m $g = 9.81\text{ m/s}^2$	**a.** $PE_1 = mgh_1 = (40.0\text{ kg})(9.81\text{ m/s}^2)(2.00\text{ m}) = \boxed{785\text{ J}}$ **b.** $h_2 = (2.00\text{ m})(1 - \cos 30.0°) = (2.00\text{ m})(1 - 0.866)$ $h_2 = (2.00\text{ m})(0.134) = 0.268\text{ m}$ $PE_2 = mgh_2$ $PE_2 = (40.0\text{ kg})(9.81\text{ m/s}^2)(0.268\text{ m}) = \boxed{105\text{ J}}$ **c.** $h_3 = 2.00\text{ m} - 2.00\text{ m} = 0.00\text{ m}$ $PE_3 = mgh_3$ $PE_3 = (40.0\text{ kg})(9.81\text{ m/s}^2)(0.00\text{ m}) = \boxed{0.00\text{ J}}$

Work and Energy, Section 2 Review

1. $v = 42$ cm/s $m = 50.0$ g	$KE = \frac{1}{2}mv^2 = \frac{1}{2}(50.0 \times 10^{-3}\text{ kg})(0.42\text{ m/s})^2 = \boxed{4.4 \times 10^{-3}\text{ J}}$
2. $m = 0.75$ kg $d = 1.2$ m $\mu_k = 0.34$ $v_f = 0$ m/s $g = 9.81\text{ m/s}^2$ $\theta = 180°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = F_{net}d(\cos\theta) = F_k d(\cos\theta) = \mu_k mgd(\cos\theta)$ $\mu_k mgd(\cos\theta) = \frac{1}{2}m(v_f^2 - v_i^2)$ $v_i = \sqrt{v_f^2 - 2\mu_k gd(\cos\theta)} = \sqrt{(0\text{ m/s})^2 - (2)(0.34)(9.81\text{ m/s}^2)(1.2\text{ m})(\cos 180°)}$ $v_i = \sqrt{(2)(0.34)(9.81\text{ m/s}^2)(1.2\text{ m})} = \boxed{2.8\text{ m/s}}$

Givens | *Solutions*

3. $h = 21.0$ cm

$g = 9.81$ m/s^2

$m = 30.0$ g

$PE_g = mgh = (30.0 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2)(0.210\text{ m}) = \boxed{6.18 \times 10^{-2}\text{ J}}$

I

Work and Energy, Practice E

1. $v_i = 18.0$ m/s

$m = 2.00$ kg

$h_i = 5.40$ m

$g = 9.81$ m/s^2

$PE_i + KE_i = KE_f$

$mgh_i + \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh_i + v_i^2} = \sqrt{(2)(9.81\text{ m/s}^2)(5.40\text{ m}) + (18.0\text{ m/s})^2}$

$v_f = \sqrt{106\text{ m}^2/\text{s}^2 + 324\text{ m}^2/\text{s}^2} = \sqrt{4.30 \times 10^2\text{ m}^2/\text{s}^2} = 20.7\text{ m/s} = \boxed{20.7\text{ m/s}}$

2. $F_g = 755$ N

$h_i = 10.0$ m

$h_f = 5.00$ m

$g = 9.81$ m/s^2

$PE_i = PE_f + KE_f$

$mgh_i = mgh_f + \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh_i - 2gh_f} = \sqrt{(2)(9.81\text{ m/s}^2)(10.0\text{ m}) - (2)(9.81\text{ m/s}^2)(5.00\text{ m})}$

$v_f = \sqrt{196\text{ m}^2/\text{s}^2 - 98.1\text{ m}^2/\text{s}^2} = \sqrt{98\text{ m}^2/\text{s}^2} = 9.90\text{ m/s}$

diver speed at 5 m = v_f = $\boxed{9.9\text{ m/s}}$

$h_f = 0$ m

$PE_i = KE_f$

$mgh_i = \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh_i} = \sqrt{(2)(9.81\text{ m/s}^2)(10.0\text{ m})} = 14.0\text{ m/s}$

diver speed at 0 m = v_f = $\boxed{14.0\text{ m/s}}$

3. $h_i = 10.0$ m

$g = 9.81$ m/s^2

$v_i = 2.00$ m/s

$PE_i + KE_i = KE_f$

$mgh_i + \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh_i + v_i^2} = \sqrt{(2)(9.81\text{ m/s}^2)(10.0\text{ m}) + (2.00\text{ m/s})^2}$

$v_f = \sqrt{196\text{ m}^2/\text{s}^2 + 4.00\text{ m}^2/\text{s}^2} = \sqrt{2.00 \times 10^2\text{ m}^2/\text{s}^2} = 14.1\text{ m/s} = \boxed{14.1\text{ m/s}}$

4. $v_i = 2.2$ m/s

$g = 9.81$ m/s^2

$KE_i = PE_f$

$\frac{1}{2}mv_i^2 = mgh_f$

$h_f = \frac{v_i^2}{2g} = \frac{(2.2\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)} = \boxed{0.25\text{ m}}$

Givens | *Solutions*

5. $v_f = 1.9$ m/s

$g = 9.81$ m/s^2

$PE_i = KE_f$

$mgh_i = \frac{1}{2}mv_f^2$

$h_i = \frac{v_f^2}{2g} = \frac{(1.9 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = \boxed{0.18 \text{ m}}$

I

Work and Energy, Section 3 Review

1. $x = -8.00$ cm

$k = 80.0$ N/m

$g = 9.81$ m/s^2

$m = 50.0$ g

Taking the compressed spring as the zero level, $h = -x = 8.00$ cm.

$PE_{elastic,i} = PE_{g,f} + KE_f$

$\frac{1}{2}kx^2 = mgh + \frac{1}{2}mv_f^2$

$$v_f = \sqrt{\frac{kx^2}{m} - 2gh} = \sqrt{\frac{(80.0 \text{ N/m})(-0.0800 \text{ m})^2}{(50.0 \times 10^{-3} \text{ kg})} - (2)(9.81 \text{ m/s}^2)(0.0800 \text{ m})}$$

$$v_f = \sqrt{10.2 \text{ m}^2/\text{s}^2 - 1.57 \text{ m}^2/\text{s}^2} = \sqrt{8.6 \text{ m}^2/\text{s}^2} = \boxed{2.93 \text{ m/s}}$$

Work and Energy, Practice F

1. $m_{elevator} = 1.0 \times 10^3$ kg

$m_{load} = 800.0$ kg

$F_k = 4.0 \times 10^3$ N

$v = 3.00$ m/s

$g = 9.81$ m/s^2

$m = m_{elevator} + m_{load} = 1.0 \times 10^3 \text{ kg} + 800.0 \text{ kg} = 1.8 \times 10^3$ kg

$P = Fv = (F_g + F_k)v = (mg + F_k)v$

$P = [(1.8 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2) + 4.0 \times 10^3 \text{ N}](3.00 \text{ m/s})$

$P = (1.8 \times 10^4 \text{ N} + 4.0 \times 10^3 \text{ N})(3.00 \text{ m/s})$

$P = (2.2 \times 10^4 \text{ N})(3.00 \text{ m/s}) = 6.6 \times 10^4 \text{ W} = \boxed{66 \text{ kW}}$

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2. $m = 1.50 \times 10^3$ kg

$v_f = 18.0$ m/s

$v_i = 0$ m/s

$\Delta t = 12.0$ s

$F_r = 400.0$ N

For $v_i = 0$ m/s,

$\Delta x = \frac{1}{2}v_f\Delta t \qquad a = \frac{v_f}{\Delta t}$

$$P = \frac{W}{\Delta t} = \frac{F\Delta x}{\Delta t} = \frac{(ma + F_r)\Delta x}{\Delta t} = \frac{\left(\frac{mv_f}{\Delta t} + F_r\right)\left(\frac{1}{2}v_f\Delta t\right)}{\Delta t}$$

$$P = \frac{\left[\frac{(1.50 \times 10^3 \text{ kg})(18.0 \text{ m/s})}{12.0 \text{ s}} + 400.0 \text{ N}\right]\left[\frac{1}{2}(18.0 \text{ m/s})(12.0 \text{ s})\right]}{12.0 \text{ s}}$$

$$P = \frac{(2250 \text{ N} + 400.0 \text{ N})(18.0 \text{ m/s})(12.0 \text{ s})}{(2)(12.0 \text{ s})}$$

$$P = \frac{(2650 \text{ N})(18.0 \text{ m/s})}{2} = \boxed{2.38 \times 10^4 \text{ W, or } 23.8 \text{ kW}}$$

I

Givens	*Solutions*

3. $m = 2.66 \times 10^7$ kg

$P = 2.00$ kW

$d = 2.00$ km

$g = 9.81$ m/s

$$\Delta t = \frac{W}{P} = \frac{mgd}{P} = \frac{(2.66 \times 10^7 \text{ kg})(9.81 \text{ m/s}^2)(2.00 \times 10^3 \text{ m})}{2.00 \times 10^3 \text{ W}} = \boxed{2.61 \times 10^8 \text{ s}}$$

or $(2.61 \times 10^8 \text{ s})(1 \text{ h}/3600 \text{ s})(1 \text{ day}/24 \text{ h})(1 \text{ year}/365.25 \text{ days}) = \boxed{8.27 \text{ years}}$

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4. $P = 19$ kW

$W = 6.8 \times 10^7$ J

$$\Delta t = \frac{W}{P} = \frac{6.8 \times 10^7 \text{ J}}{19 \times 10^3 \text{ W}} = \boxed{3.6 \times 10^3 \text{ s}}$$

or $(3.6 \times 10^3 \text{ s})(1 \text{ h}/3600 \text{ s}) = \boxed{1.0 \text{ h}}$

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5. $m = 1.50 \times 10^3$ kg

$v_f = 10.0$ m/s

$v_i = 0$ m/s

$\Delta t = 3.00$ s

a. $W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}m\,(v_f^2 - v_i^2)$

$W_{net} = \frac{1}{2}(1.50 \times 10^3 \text{ kg})[(10.0 \text{ m/s})^2 - (0 \text{ m/s})^2]$

$W = W_{net} = \boxed{7.50 \times 10^4 \text{ J}}$

b. $P = \dfrac{W}{\Delta t} = \dfrac{7.50 \times 10^4 \text{ J}}{3.00 \text{ s}} = \boxed{2.50 \times 10^4 \text{ W or } 25.0 \text{ kW}}$

Work and Energy, Section 4 Review

1. $m = 50.0$ kg

$h = 5.00$ m

$P = 200.0$ W

$g = 9.81$ m/s^2

$$\Delta t = \frac{W}{P} = \frac{mgh}{P} = \frac{(50.0 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m})}{200.0 \text{ W}} = \boxed{12.3 \text{ s}}$$

$W = mgh = (50.0 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m}) = \boxed{2.45 \times 10^3 \text{ J}}$

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2. $m = 50.0$ kg

$h = 5.00$ m

$v = 1.25$ m/s

$g = 9.81$ m/s

$P = Fv = mgv = (50.0 \text{ kg})(9.81 \text{ m/s}^2)(1.25 \text{ m/s}) = \boxed{613 \text{ W}}$

$W = mgh = (50.0 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m}) = \boxed{2.45 \times 10^3 \text{ J}}$

Work and Energy, Chapter Review

7. $m = 4.5$ kg

$d_1 = 1.2$ m

$d_2 = 7.3$ m

$g = 9.81$ m/s^2

$\theta_1 = 0°$

$\theta_2 = 90°$

$W_{person} = F_g[d_1(\cos\theta_1) + d_2(\cos\theta_2)]$

$W_{person} = mg[d_1(\cos 0°) + d_2(\cos 90°)] = mgd_1$

$W_{person} = (4.5 \text{ kg})(9.81 \text{ m/s}^2)(1.2 \text{ m}) = \boxed{53 \text{ J}}$

$W_{gravity} = -F_g[d_1(\cos\theta_1) + d_2(\cos\theta_2)]$

$W_{gravity} = -mg[d_1(\cos 0°) + d_2(\cos 90°)] = -mgd_1$

$W_{gravity} = -(4.5 \text{ kg})(9.81 \text{ m/s}^2)(1.2 \text{ m}) = \boxed{-53 \text{ J}}$

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8. $m = 8.0 \times 10^3$ kg

$a_{net} = 1.0$ m/s^2

$d = 30.0$ m

$\theta = 0°$

$W_{net} = F_{net}d(\cos\theta) = ma_{net}d(\cos\theta) = (8.0 \times 10^3 \text{ kg})(1.0 \text{ m/s}^2)(30.0 \text{ m})(\cos 0°)$

$W = \boxed{2.4 \times 10^5 \text{ J}}$

Givens	Solutions
9. $F = 475$ N $\theta = 0°$ $d = 10.0$ cm	$W = Fd(\cos\theta) = (475\text{ N})(0.100\text{ m})(\cos 0°) = \boxed{47.5\text{ J}}$
10. $F_g = 70.0$ N $F_{applied} = 40.0$ N $d = 253$ m $\theta = 52.0°$	**a.** $W_1 = F_{applied}d(\cos\theta) = (40.0\text{ N})(253\text{ m})(\cos 52.0°) = \boxed{6.23 \times 10^3\text{ J}}$ **b.** Because the bag's speed is constant, $F_k = -F_{applied}(\cos\theta)$. $W_2 = F_k d = -F_{applied}(\cos\theta)d = -(40.0\text{ N})(\cos 52.0°)(253\text{ m}) = \boxed{-6.23 \times 10^3\text{ J}}$ **c.** $\mu_k = \frac{F_k}{F_n} = \frac{-F_{x,applied}(\cos\theta)}{-F_g + F_{y,applied}} = \frac{-(40.0\text{ N})(\cos 52.0°)}{-70.0\text{ N} + (40.0\text{ N})(\sin 52.0)} = \boxed{0.640}$
14. $v_1 = 5.0$ m/s $v_2 = 25.0$ m/s	$KE_1 = \frac{1}{2}mv_1^2 \qquad KE_2 = \frac{1}{2}mv_2^2$ $\frac{KE_1}{KE_2} = \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{v_1^2}{v_2^2} = \frac{(5.0\text{ m/s})^2}{(25.0\text{ m/s})^2} = \frac{25}{625} = \boxed{\frac{1}{25}}$
16. Scenario 1: $v_1 = 50.0$ km/h $\Delta x_1 = 35$ m Scenario 2: $v_2 = 100.0$ km/h	Assuming that the cars skid to a stop, $\Delta KE = KE_i$ $KE_1 = \frac{1}{2}mv_1^2 = \frac{1}{2}m(50.0\text{ km/h})^2 = m(1.25 \times 10^3\text{ km}^2/\text{h}^2)$ $KE_2 = \frac{1}{2}mv_2^2 = \frac{1}{2}m(100.0\text{ km/h})^2 = m(5.000 \times 10^3\text{ km}^2/\text{h}^2)$ The work done by the brakes is given by: $W_{brake} = F_{brake}d$ Assuming that the braking force is the same for either speed: $W_1 = F_{brake}(35\text{ m})$ $W_2 = F_{brake}\Delta x_2$ The work required to stop the vehicle is equal to the initial Kinetic Energy (Work—Kinetic Energy Theorem). Take the ratio of one to the other to get: $\frac{\Delta KE_2}{\Delta KE_1} = \frac{W_2}{W_1}$ $\frac{\text{m}(5.000 \times 10^3\text{ km}^2/\text{h}^2)}{\text{m}(1.25 \times 10^3\text{ km}^2/\text{h}^2)} = \frac{F_{brake}\Delta x_2}{F_{brake}(35\text{ m})}$ $\frac{5.000 \times 10^3\text{ km}^2/\text{h}^2}{1.25 \times 10^3\text{ km}^2/\text{h}^2} = \frac{4}{1} = \frac{\Delta x_2}{35\text{ m}}$ $\Delta x_2 = 4(35\text{ m}) = \boxed{140\text{ m}}$
19. $m = 1250$ kg $v = 11$ m/s	$KE = \frac{1}{2}mv^2 = \frac{1}{2}(1250\text{ kg})(11\text{ m/s})^2 = \boxed{7.6 \times 10^4\text{ J}}$
20. $m = 0.55$ g $KE = 7.6 \times 10^4$ J	$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{(2)(7.6 \times 10^4\text{ J})}{0.55 \times 10^{-3}\text{ kg}}} = \boxed{1.7 \times 10^4\text{ m/s}}$

Givens	Solutions

21. $m = 50.0$ kg, $F_r = 1500$ N, $d = 5.0$ m, $g = 9.81$ m/s^2, $KE_f = 0$ J, $\theta = 180°$

$W_{net} = \Delta KE = KE_f - KE_i = -KE_i$

The diver's kinetic energy at the water's surface equals the gravitational potential energy associated with the diver on the diving board relative to the water's surface.

$KE_i = PE_g = mgh$ $\qquad W_{net} = F_{net}d(\cos\theta) = F_r d(\cos\theta)$

$$h = \frac{F_r d(\cos\theta)}{-mg} = \frac{(1500\text{ N})(5.0\text{ m})(\cos 180°)}{-(50.0\text{ kg})(9.81\text{ m/s}^2)} = 15\text{ m}$$

total distance $= h + d = 15\text{ m} + 5.0\text{ m} = \boxed{2.0 \times 10^1\text{ m}}$

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22. $v_i = 4.0$ m/s, $v_f = 0$ m/s, $\theta = 25°$, $m = 20.0$ kg, $\mu_k = 0.20$, $g = 9.81$ m/s^2, $\theta' = 180°$

$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$W_{net} = F_{net}d(\cos\theta')$

$F_{net} = mg(\sin\theta) + F_k = mg(\sin\theta) + \mu_k mg(\cos\theta)$

$W_{net} = mg[\sin\theta + \mu_k(\cos\theta)]d(\cos\theta')$

$$d = \frac{\frac{1}{2}m(v_f^2 - v_i^2)}{mg[\sin\theta + \mu_k(\cos\theta)](\cos\theta')} = \frac{v_f^2 + v_i^2}{2\,g[\sin\theta + \mu_k(\cos\theta)](\cos\theta')}$$

$$d = \frac{(0\text{ m/s})^2 - (4.0\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)[\sin 25° + (0.20)(\cos 25°)](\cos 180°)}$$

$$d = \frac{-16\text{ m}^2/\text{s}^2}{-(2)(9.81\text{ m/s}^2)(0.42 + 0.18)} = \frac{8.0\text{ m}^2/\text{s}^2}{(9.81\text{ m/s}^2)(0.60)} = \boxed{1.4\text{ m}}$$

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23. $h_A = 10.0$ m, $m = 55$ kg, $h_B = 0$ m

a. $PE_A = mgh_A = (55\text{ kg})(9.81\text{ m/s}^2)(10.0\text{ m}) = \boxed{5.4 \times 10^3\text{ J}}$

$PE_B = mgh_B = (55\text{ kg})(9.81\text{ m/s}^2)(0\text{ m}) = \boxed{0\text{ J}}$

$\Delta PE = PE_A - PE_B = 5400\text{ J} - 0\text{ J} = \boxed{5.4 \times 10^3\text{ J}}$

$h_A = 0$ m, $h_B = -10.0$ m

b. $PE_A = mgh_A = (55\text{ kg})(9.81\text{ m/s}^2)(0\text{ m}) = \boxed{0\text{ J}}$

$PE_B = mgh_B = (55\text{ kg})(9.81\text{ m/s}^2)(-10.0\text{ m}) = \boxed{-5.4 \times 10^3\text{ J}}$

$\Delta PE = PE_A - PE_B = 0 - (-5400\text{ J}) = \boxed{5.4 \times 10^3\text{ J}}$

$h_A = 5.0$ m, $h_B = -5.0$ m

c. $PE_A = mgh_A = (55\text{ kg})(9.81\text{ m/s}^2)(5.0\text{ m}) = \boxed{2.7 \times 10^3\text{ J}}$

$PE_B = mgh_B = (55\text{ kg})(9.81\text{ m/s}^2)(-5.0\text{ m}) = \boxed{-2.7 \times 10^3\text{ J}}$

$\Delta PE = PE_A - PE_B = 2700\text{ J} - (-2700\text{ J}) = \boxed{5.4 \times 10^3\text{ J}}$

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24. $m = 2.00$ kg, $h_1 = 1.00$ m, $h_2 = 3.00$ m, $h_3 = 0$ m

a. $PE = mg(-h_1) = (2.00\text{ kg})(9.81\text{ m/s}^2)(-1.00\text{ m}) = \boxed{-19.6\text{ J}}$

b. $PE = mg(h_2 - h_1) = (2.00\text{ kg})(9.81\text{ m/s}^2)(3.00\text{ m} - 1.00\text{ m})$

$PE = (2.00\text{ kg})(9.81\text{ m/s}^2)(2.00\text{ m}) = \boxed{39.2\text{ J}}$

c. $PE = mgh_3 = (2.00\text{ kg})(9.81\text{ m/s}^2)(0\text{ m}) = \boxed{0\text{ J}}$

Givens	Solutions
25. $k = 500.0$ N/m $x_1 = 4.00$ cm $x_2 = -3.00$ cm $x_3 = 0$ cm	**a.** $PE = \frac{1}{2}kx_1^2 = \frac{1}{2}(500.0 \text{ N/m})(0.0400 \text{ m})^2 = \boxed{0.400 \text{ J}}$ **b.** $PE = \frac{1}{2}kx_2^2 = \frac{1}{2}(500.0 \text{ N/m})(-0.0300 \text{ m})^2 = \boxed{0.225 \text{ J}}$ **c.** $PE = \frac{1}{2}kx_3^2 = \frac{1}{2}(500.0 \text{ N/m})(0 \text{ m})^2 = \boxed{0 \text{ J}}$
33. $m = 50.0$ kg $h = 7.34$ m $g = 9.81$ m/s^2	$PE_i = KE_f$ $mgh = \frac{1}{2}mv_f^2$ $v_f = \sqrt{2gh} = \sqrt{(2)(9.81 \text{ m/s}^2)(7.34 \text{ m})} = \boxed{12.0 \text{ m/s}}$
34. $h = 30.0$ m $v_i = 0$ m/s $\theta = 37.0°$	**a.** $PE_i = KE_f$ $mgh_i = \frac{1}{2}mv_f^2$ $v_f = \sqrt{2gh_i} = \sqrt{2gh(1 - \cos\theta)} = \sqrt{(2)(9.81 \text{ m/s}^2)(30.0 \text{ m})(1 - \cos 37.0°)}$ $v_f = \sqrt{(2)(9.81 \text{ m/s}^2)(30.0 \text{ m})(1 - 0.799)}$ $v_f = \sqrt{(2)(9.81 \text{ m/s}^2)(30.0 \text{ m})(0.201)} = \boxed{10.9 \text{ m/s}}$
$v_i = 4.00$ m/s	**b.** $PE_i + KE_i = KE_f$ $mgh_i + \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2$ $v_f = \sqrt{2gh_i + v_i^2} = \sqrt{(2)(9.81 \text{ m/s}^2)(30.0 \text{ m})(0.201) + (4.00 \text{ m/s})^2}$ $v_f = \sqrt{118 \text{ m}^2/\text{s}^2 + 16.0 \text{ m}^2/\text{s}^2} = \sqrt{134 \text{ m}^2/\text{s}^2} = \boxed{11.6 \text{ m/s}}$
35. $P = 50.0$ hp $W = 6.40 \times 10^5$ J 1 hp = 746 W	$\Delta t = \frac{W}{P} = \frac{6.40 \times 10^5 \text{ J}}{(50.0 \text{ hp})(746 \text{ W/hp})} = \boxed{17.2 \text{ s}}$
36. rate of flow $= \frac{m}{\Delta t}$ $= 1.2 \times 10^6$ kg/s $d = 50.0$ m $g = 9.81$ m/s^2	$P = \frac{W}{\Delta t} = \frac{Fd}{\Delta t} = \frac{mgd}{\Delta t} = \frac{m}{\Delta t}gd$ $P = (1.2 \times 10^6 \text{ kg/s})(9.81 \text{ m/s}^2)(50.0 \text{ m}) = \boxed{5.9 \times 10^8 \text{ W}}$
37. $m = 215$ g $h_A = 30.0$ cm $h_B = 0$ cm $h_C = \frac{2}{3}(30.0 \text{ cm})$ $g = 9.81$ m/s^2	**a.** $PE_A = mgh_A = (215 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)(0.300 \text{ m}) = \boxed{0.633 \text{ J}}$ **b.** $KE_B = PE_A = \boxed{0.633 \text{ J}}$ **c.** $KE_B = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2KE_B}{m}} = \sqrt{\frac{(2)(0.633 \text{ J})}{215 \times 10^{-3} \text{ kg}}} = \boxed{2.43 \text{ m/s}}$ **d.** $PE_C = mgh_C = (215 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)(\frac{2}{3})(0.300 \text{ m}) = \boxed{0.422 \text{ J}}$ $KE_C = KE_B - PE_C = 0.633 \text{ J} - 0.422 \text{ J} = \boxed{0.211 \text{ J}}$

Givens | *Solutions*

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38. $F_g = 700.0$ N

$d = 25.0$ cm

$F_{upward} = (2)(355 \text{ N})$

$KE_i = 0$ J

$g = 9.81 \text{ m/s}^2$

$\theta = 0°$

$$W_{net} = \Delta KE = KE_f - KE_i = KE_f = \tfrac{1}{2}mv_f^2 = \tfrac{1}{2}\left(\frac{F_g}{g}\right)v_f^2$$

$$W_{net} = F_{net}d(\cos\theta) = (F_{upward} - F_g)d(\cos\theta)$$

$$\tfrac{1}{2}\left(\frac{F_g}{g}\right)v_f^2 = (F_{upward} - F_g)d(\cos\theta)$$

$$v_f = \sqrt{\frac{2g(F_{upward} - F_g)d(\cos\theta)}{F_g}}$$

$$v_f = \sqrt{\frac{(2)(9.81 \text{ m/s}^2)[(2)(355 \text{ N}) - 700.0 \text{ N}](0.250 \text{ m})(\cos 0°)}{700.0 \text{ N}}}$$

$$v_f = \sqrt{\frac{(2)(9.81 \text{ m/s}^2)(7.10 \times 10^2 \text{ N} - 700.0 \text{ N})(0.250 \text{ m})}{700.0 \text{ N}}}$$

$$v_f = \sqrt{\frac{(2)(9.81 \text{ m/s}^2)(1.0 \times 10^1 \text{ N})(0.250 \text{ m})}{700.0 \text{ N}}} = \boxed{0.265 \text{ m/s}}$$

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39. $m = 50.0$ kg

$v_i = 10.0$ m/s

$v_f = 1.0$ m/s

$g = 9.81 \text{ m/s}^2$

$$KE_i = PE_f + KE_f$$

$$\tfrac{1}{2}mv_i^2 = mgh + \tfrac{1}{2}mv_f^2$$

$$h = \frac{v_i^2 - v_f^2}{2g} = \frac{(10.0 \text{ m/s})^2 - (1.0 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = \frac{1.00 \times 10^2 \text{ m}^2/\text{s}^2 - 1.0 \text{ m}^2/\text{s}^2}{(2)(9.81 \text{ m/s}^2)}$$

$$h = \frac{99 \text{ m}^2/\text{s}^2}{(2)(9.81 \text{ m/s}^2)} = \boxed{5.0 \text{ m}}$$

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40. $F_g = 80.0$ N

$d = 20.0$ m

$\theta = 30.0°$

$F_{applied} = 115$ N

$\mu_k = 0.22$

$g = 9.81 \text{ m/s}^2$

$\theta' = 0°$

$$W_{net} = \Delta KE$$

$$W_{net} = F_{net}d\,(\cos\theta') = F_{net}d$$

$$\Delta KE = F_{net}d = (F_{applied} - F_k - F_{g,d})d = [F_{applied} - \mu_k F_g(\cos\theta) - F_g(\sin\theta)]d$$

$$\Delta KE = [115 \text{ N} - (0.22)(80.0 \text{ N})(\cos 30.0°) - (80.0 \text{ N})(\sin 30.0°)](20.0 \text{ m})$$

$$\Delta KE = (115 \text{ N} - 15 \text{ N} - 40.0 \text{ N})(20.0 \text{ m}) = (6.0 \times 10^1 \text{ N})(20.0 \text{ m})$$

$$\Delta KE = \boxed{1.2 \times 10^3 \text{ J}}$$

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41. $m_{tot} = 130.0$ kg

$h_J = 5.0$ m

$\theta = 30.0°$

$m_J = 50.0$ kg

$g = 9.81 \text{ m/s}^2$

For the first half of the swing,

$$PE_i = KE_f$$

$$m_{tot}gh = \tfrac{1}{2}m_{tot}v_f^2$$

$$v_f = \sqrt{2gh} = \sqrt{2gh_J(1 - \sin\theta)} = \sqrt{(2)(9.81 \text{ m/s}^2)(5.0 \text{ m})(1 - \sin 30.0°)}$$

$$v_f = \sqrt{(2)(9.81 \text{ m/s}^2)(5.0 \text{ m})(1 - 0.500)} = \sqrt{(2)(9.81 \text{ m/s}^2)(5.0 \text{ m})(0.500)}$$

$$v_f = 7.0 \text{ m/s}$$

For the second half of the swing,

$$KE_T = \tfrac{1}{2}m_Tv_f^2 = \tfrac{1}{2}(m_{tot} - m_J)v_f^2 = \tfrac{1}{2}(130.0 \text{ kg} - 50.0 \text{ kg})(7.0 \text{ m/s})^2$$

$$KE_T = \tfrac{1}{2}(80.0 \text{ kg})(7.0 \text{ m/s})^2 = 2.0 \times 10^3 \text{ J}$$

$$KE_T = PE_f = m_Tgh_f$$

$$h_f = \frac{KE_T}{m_Tg} = \frac{2.0 \times 10^3 \text{ J}}{(80.0 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{2.5 \text{ m}}$$

Givens | *Solutions*

I

42. $m = 0.250$ kg

$k = 5.00 \times 10^3$ N/m

$x = -0.100$ m

$g = 9.81$ m/s^2

$PE_{elastic,i} = PE_{g,f}$

$\frac{1}{2}kx^2 = mgh$

$$h = \frac{kx^2}{2mg} = \frac{(5.00 \times 10^3 \text{ N/m})(-0.100 \text{ m})^2}{(2)(0.250 \text{ kg})(9.81 \text{ m/s}^2)} = \boxed{10.2 \text{ m}}$$

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44. $m = 0.60$ kg

$v_A = 2.0$ m/s

$KE_B = 7.5$ J

a. $KE_A = \frac{1}{2}mv_A{}^2 = \frac{1}{2}(0.60 \text{ kg})(2.0 \text{ m/s})^2 = \boxed{1.2 \text{ J}}$

b. $KE_B = \frac{1}{2}mv_B{}^2$

$$v_B = \sqrt{\frac{2KE_B}{m}} = \sqrt{\frac{(2)(7.5 \text{ J})}{0.60 \text{ kg}}} = \boxed{5.0 \text{ m/s}}$$

c. $W_{net} = \Delta KE = KE_B - KE_A = 7.5 \text{ J} - 1.2 \text{ J} = \boxed{6.3 \text{ J}}$

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45. $m = 5.0$ kg

$d = 2.5$ m

$\theta = 30.0°$

$\Delta t = 2.0$ s

$g = 9.81$ m/s^2

$\theta' = 0°$

$v_i = 0$ m/s

a. $W_{gravity} = F_{g,d}d(\cos \theta') = F_{g,d}d = mg(\sin \theta)d$

$W_{gravity} = (5.0 \text{ kg})(9.81 \text{ m/s}^2)(\sin 30.0°)(2.5 \text{ m}) = \boxed{61 \text{ J}}$

b. $W_{friction} = \Delta ME = KE_f - PE_i = \frac{1}{2}mv_f{}^2 - mgh_i$

$d = \Delta x = \frac{1}{2}(v_i + v_f)\Delta t$

$$v_f = \frac{2d}{\Delta t} - v_i = \frac{2d}{\Delta t}$$

$h_i = d(\sin \theta)$

$$\Delta ME = \frac{1}{2}m\left(\frac{2d}{\Delta t}\right)^2 - mgd(\sin \theta)$$

$$\Delta ME = \frac{1}{2}(5.0 \text{ kg})\left[\frac{(2)(2.5 \text{ m})}{2.0 \text{ s}}\right]^2 - (5.0 \text{ kg})(9.81 \text{ m/s}^2)(2.5 \text{ m})(\sin 30.0°)$$

$\Delta ME = W_{friction} = 16 \text{ J} - 61 \text{ J} = \boxed{-45 \text{ J}}$

$\theta' = 90°$

c. $W_{normal} = F_n d(\cos \theta') mg(\cos \theta) d(\cos \theta')$

$\cos \theta' = \cos 90° = 0$, so

$W_{normal} = \boxed{0 \text{ J}}$

Givens	Solutions

46. $m = 70.0$ kg, $\theta = 35°$, $\theta' = 0°$, $d = 60.0$ m, $g = 9.81$ m/s^2

$W = Fd(\cos\theta') = Fd(\cos 0°) = Fd = mg(\sin\theta)d$

$W = (70.0\text{ kg})(9.81\text{ m/s}^2)(\sin 35°)(60.0\text{ m}) = \boxed{2.4 \times 10^4\text{ J}}$

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47. $h_1 = 50.0$ m, $h_2 = 10.0$ m, $g = 9.81$ m/s^2, $\theta = 45.0°$, $v_i = 0$ m/s

a. $PE_i = PE_f + KE_f$

$mgh_1 = mgh_2 + \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh_1 - 2gh_2} = \sqrt{2g(h_1 - h_2)} = \sqrt{(2)(9.81\text{ m/s}^2)(50.0\text{ m} - 10.0\text{ m})}$

$v_f = \sqrt{(2)(9.81\text{ m/s}^2)(40.0\text{ m})} = \boxed{28.0\text{ m/s}}$

b. At the acrobat's highest point, $v_y = 0$ m/s and $v_x = (28.0\text{ m/s})(\cos 45.0°)$.

$PE_i = PE_f + KE_f$

$mgh_1 = mgh_f + \frac{1}{2}mv_{f,x}^2$

$$h_f = \frac{gh_1 - v_{f,x}^2}{g} = \frac{(9.81\text{ m/s}^2)(50.0\text{ m}) - [(28.0\text{ m/s})(\cos 45.0°)]^2}{9.81\text{ m/s}^2}$$

$$h_f = \frac{4.90 \times 10^2\text{ m}^2/\text{s}^2 - 196\text{ m}^2/\text{s}^2}{9.81\text{ m/s}^2} = \frac{294\text{ m}^2/\text{s}^2}{9.81\text{ m/s}^2} = \boxed{30.0\text{ m above the ground}}$$

48. $m = 10.0$ kg, $d_1 = 3.00$ m, $\theta = 30.0°$, $d_2 = 5.00$ m, $v_i = 0$, $g = 9.81$ m/s^2

a. For slide down ramp,

$PE_i = KE_f$

$mgh = \frac{1}{2}mv_f^2$

$vf = \sqrt{2gh} = \sqrt{2gd_1(\sin\theta)}$

$v_f = \sqrt{(2)(9.81\text{ m/s}^2)(3.00\text{ m})(\sin 30.0°)} = \boxed{5.42\text{ m/s}}$

$KE_f = 0$ J, $\theta' = 180°$

b. For horizontal slide across floor,

$W_{net} = \Delta KE = KE_f - KE_i = -KE_i$

$W_{net} = F_k d_2(\cos\theta')$

$= \mu_k mgd_2(\cos\theta')$

KE_i of horizontal slide equals $KE_f = PE_i$ of slide down ramp.

$-PE_i = -mgd_1(\sin\theta) = \mu_k mgd_2(\cos\theta')$

$$\mu_k = \frac{-d_1(\sin\theta)}{d_2(\cos\theta')} = \frac{-(3.00\text{ m})(\sin 30.0°)}{(5.00\text{ m})(\cos 180°)} = \boxed{0.300}$$

$KE_f = 0$ J

c. $\Delta ME = KE_f - PE_i = -PE_i = -mgh = -mgd_1(\sin\theta)$

$\Delta ME = -(10.0\text{ kg})(9.81\text{ m/s}^2)(3.00\text{ m})(\sin 30.0°) = \boxed{-147\text{ J}}$

Givens	Solutions

49. $k = 105$ N/m, $m = 2.00$ kg, $x = -0.100$ m, $d = 0.250$ m, $g = 9.81$ m/s^2, $KE_f = 0$ J, $\theta = 180°$

$$W_{net} = \Delta KE = KE_f - KE_i = -KE_i = -PE_g = -\tfrac{1}{2}kx^2$$

$$W_{net} = F_k d(\cos\theta) = \mu_k mgd(\cos\theta) - \mu_k mgd$$

$$\tfrac{1}{2}kx^2 = \mu_k mgd$$

$$\mu_k = \frac{kx^2}{2mgd} = \frac{(105\text{ N/m})(-0.100\text{ m})^2}{(2)(2.00\text{ kg})(9.81\text{ m/s}^2)(0.250\text{ m})} = \boxed{0.107}$$

50. $m = 5.0$ kg, $\theta = 30.0°$, $\theta' = 0°$, $d = 3.0$ m, $\mu_k = 0.30$, $g = 9.81$ m/s^2

a. Because v is constant,

$$F_{y,\,net} = F(\sin\theta) - \mu_k F_n - mg = 0$$

$$F_{x,\,net} = F(\cos\theta) - F_n = 0$$

$$F_n = F(\cos\theta)$$

$$F(\sin\theta) - \mu_k F_n = mg$$

$$F(\sin\theta) - \mu_k F(\cos\theta) = mg$$

$$F = \frac{mg}{\sin\theta - \mu_k(\cos\theta)}$$

Upward component of F is parallel and in the same direction as motion, so

$$W = F(\sin\theta)d = \left(\frac{mg(\sin\theta)d}{\sin\theta - \mu_k(\cos\theta)}\right) = \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\sin 30.0°)(3.0\text{ m})}{\sin 30.0° - (0.30)(\cos 30.0°)}$$

$$W = \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\sin 30.0°)(3.0\text{ m})}{0.500 - 0.26}$$

$$= \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\sin 30.0°)(3.0\text{ m})}{0.24}$$

$$W = \boxed{3.1 \times 10^2\text{ J}}$$

$\theta' = 180°$

b. $W_g = F_g d(\cos\theta') = -mgd = -(5.0\text{ kg})(9.81\text{ m/s}^2)(3.0\text{ m}) = \boxed{-150\text{ J}}$

c. $$F_n = F(\cos\theta) = \left(\frac{mg}{\sin\theta - \mu_k(\cos\theta)}\right)(\cos\theta) = \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\cos 30.0°)}{\sin 30.0° - (0.30)(\cos 30.0°)}$$

$$F_n = \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\cos 30.0°)}{0.500 - 0.26} = \frac{(5.0\text{ kg})(9.81\text{ m/s}^2)(\cos 30.0°)}{0.24}$$

$$F_n = \boxed{1.8 \times 10^2\text{ N}}$$

51. $m = 25$ kg

$L = 2.0$ m

$\theta = 30.0°$

$g = 9.81$ m/s^2

a. $h = L(1 - \cos\theta) = (2.0 \text{ m})(1 - \cos 30.0°) = (2.0 \text{ m})(1 - 0.866) = (2.0 \text{ m})(0.134)$

$PE_{max} = mgh = mgL(1 - \cos\theta) = (25 \text{ kg})(9.81 \text{ m/s}^2)(2.0 \text{ m})(0.134)$

$PE_{max} = \boxed{66 \text{ J}}$

b. $PE_i = KE_f$

$mgh = \frac{1}{2}mv_f^2$

$v_f = \sqrt{2gh} = \sqrt{(2)(9.81 \text{ m/s}^2)(2.0 \text{ m})(1 - \cos 30.0°)}$

$v_f = \sqrt{(2)(9.81 \text{ m/s}^2)(2.0 \text{ m})(0.134)} = \boxed{2.3 \text{ m/s}}$

c. $ME = PE_i + KE_i = 66 \text{ J} + 0 \text{ J} = \boxed{66 \text{ J}}$

$v_f = 2.00$ m/s

d. $\Delta ME = KE_f - PE_i = \frac{1}{2}mv_f^2 - PE_i = \frac{1}{2}(25 \text{ kg})(2.00 \text{ m/s})^2 - 66 \text{ J}$

$\Delta ME = (5.0 \times 10^1 \text{ J}) - 66 \text{ J} = \boxed{-16 \text{ J}}$

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52. $m = 522$ g

$h_2 = 1.25$ m

$v_i = 0$ m/s

$g = 9.81$ m/s^2

$\Delta x = 1.00$ m

a. $PE_i = PE_f + KE_f$

$mgh = mgh_2 + \frac{1}{2}mv^2$

$h = h_2 + \dfrac{v^2}{2g}$

Choosing the point where the ball leaves the track as the origin of a coordinate system,

$\Delta x = v\Delta t$, therefore $\Delta t = \dfrac{\Delta x}{v}$

$\Delta y = -\frac{1}{2}g\Delta t^2$

At $\Delta y = -1.25$ m (ground level),

$$\Delta y = -\frac{1}{2}g\left(\frac{\Delta x}{v}\right)^2$$

$$v = \sqrt{\frac{-g\Delta x^2}{2\Delta y}} = \sqrt{\frac{-(9.81 \text{ m/s}^2)(1.00 \text{ m})^2}{(2)(-1.25 \text{ m})}} = 1.98 \text{ m/s}$$

$$h = h_2 + \frac{v^2}{2g} = 1.25 \text{ m} + \frac{(1.98 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = 1.25 \text{ m} + 0.200 \text{ m}$$

$h = \boxed{1.45 \text{ m}}$

b. $v = \boxed{1.98 \text{ m/s}}$ (See **a.**)

c. $KE_f = PE_i$

$\frac{1}{2}mv_f^2 = mgh$

$v_f = \sqrt{2gh} = \sqrt{(2)(9.81 \text{ m/s}^2)(1.45 \text{ m})} = \boxed{5.33 \text{ m/s}}$

Givens	*Solutions*
3. $ME_i = 600$ mJ	At $\Delta t = 6.0$ s, $ME_f = 500$ mJ $\Delta ME = ME_f - ME_i = 500\text{ mJ} - 600\text{ mJ} = \boxed{-100\text{ mJ}}$
4. $m = 75$ g	At $\Delta t = 4.5$ s, $KE = 350$ mJ $KE = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{(2)(350\times10^{-3}\text{ J})}{75\times10^{-3}\text{ kg}}} = \boxed{3.1\text{ m/s}}$
5. $m = 75$ g $g = 9.81\text{ m/s}^2$	$PE_{max} = 600\text{ mJ} = mgh_{max}$ $h_{max} = \frac{PE_{max}}{mg} = \frac{600\times10^{-3}\text{ J}}{(75\times10^{-3}\text{ kg})(9.81\text{ m/s}^2)} = \boxed{0.82\text{ m}}$
6. $m = 2.50\times10^3$ kg $W_{net} = 5.0$ kJ $d = 25.0$ m $v_i = 0$ m/s $\theta = 0°$	$W_{net} = \Delta KE = KE_f - KE_i$ Because $v_i = 0$ m/s, $KE_i = 0$ J, and $W_{net} = KE_f = \frac{1}{2}mv_f^2$. $v_f = \sqrt{\frac{2W_{net}}{m}} = \sqrt{\frac{(2)(5.0\times10^3\text{ J})}{2.50\times10^3\text{ kg}}} = \boxed{2.0\text{ m/s}}$
7. $m = 70.0$ kg $v_i = 4.0$ m/s $v_f = 0$ m/s	$\Delta ME = KE_f - KE_i$ $\Delta ME = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}m(v_f^2 - v_i^2)$ $\Delta ME = \frac{1}{2}(70.0\text{ kg})[(0\text{ m/s})^2 - (4.0\text{ m/s})^2] = \boxed{-5.6\times10^2\text{ J}}$
8. $m = 70.0$ kg $\mu_k = 0.70$ $g = 9.81\text{ m/s}^2$ $\theta = 180.0°$	$W = \Delta ME = -5.6\times10^2$ J $d = \frac{W}{F_k(\cos\theta)} = \frac{W}{F_n\mu_k(\cos\theta)} = \frac{W}{mg\mu_k(\cos\theta)}$ $d = \frac{-5.6\times10^2\text{ J}}{(70.0\text{ kg})(9.81\text{ m/s}^2)(0.70)(\cos 180°)} = \boxed{1.2\text{ m}}$
9. $k = 250$ N/m $m_p = 0.075$ kg $x_1 = 0.12$ m $x_2 = 0.18$ m	$PE\ Ratio = \frac{PE_{elastic2}}{PE_{elastic1}} = \frac{\frac{1}{2}kx_2^2}{\frac{1}{2}kx_1^2}$ $PE\ Ratio = \frac{x_2^2}{x_1^2}$ $PE\ Ratio = \frac{(0.18\text{ m})^2}{(0.12\text{ m})^2} = \left(\frac{3}{2}\right)^2 = \boxed{\frac{9}{4}}$

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Givens	Solutions
10. $k = 250$ N/m $m_p = 0.075$ kg $x_1 = 0.12$ m $x_2 = 0.18$ m	Since F_g is negligible, and the $PE_{elastic}$ will be converted into KE. KE_2:KE_1 will provide the velocity ratios. $KE\ Ratio = \frac{KE_2}{KE_1} = \frac{\frac{1}{2}mv_2^2}{\frac{1}{2}mv_1^2} = \frac{v_2^2}{v_1^2}$ $KE\ Ratio = PE\ Ratio = \frac{v_2^2}{v_1^2}$ $\frac{v_2}{v_1} = \sqrt{PE\ Ratio} = \sqrt{\frac{9}{4}}$ $\boxed{\frac{v_2}{v_1} = \frac{3}{2}}$
11. $m = 66.0$ kg $\Delta t = 44.0$ s $h = 14.0$ m $g = 9.81$ m/s2	Find PE_{gained} $PE = mgh = (66.0 \text{ kg})(9.81 \text{ m/s}^2)(14.0 \text{ m})$ $W = PE = 9.06 \times 10^3$ J $P = \frac{W}{\Delta t} = \frac{9.06 \times 10^3 \text{ J}}{44.0 \text{ s}} = \boxed{206 \text{ W}}$
12. $m = 75.0$ kg $g = 9.81$ m/s^2 $h = 1.00$ m	$PE_i = KE_f$ $mgh = \frac{1}{2}mv_f^2$ $v_f^2 = \frac{2mgh}{m} = 2gh$ $v_f = \boxed{\sqrt{2gh}}$
13. $m = 75.0$ kg $g = 9.81$ m/s^2 $h = 1.00$ m	$v_f = \sqrt{2gh} = \sqrt{2(9.81 \text{ m/s}^2)(1.00 \text{ m})} = \sqrt{19.6 \text{ m}^2/\text{s}^2}$ $v_f = \boxed{4.4 \text{ m/s}}$
14. $m = 5.0$ kg $h = 25.0$ m $g = 9.81$ m/s^2	$W_{gravity} = \Delta PE_g = mgh = (5.0 \text{ kg})(9.81 \text{ m/s}^2)(25.0 \text{ m}) = \boxed{1.2 \times 10^3 \text{ J}}$
15.	$\Delta KE = W_{gravity} = \boxed{1.2 \times 10^3 \text{ J}}$
16. $v_i = 17$ m/s	$\Delta KE = KE_f - KE_i$ $KE_f = \Delta KE + KE_i = \Delta KE + \frac{1}{2}mv_i^2 = 1200 \text{ J} + \frac{1}{2}(5.0 \text{ kg})(17 \text{ m/s})^2$ $KE_f = 1200 \text{ J} + 720 \text{ J} = \boxed{1.9 \times 10^3 \text{ J}}$

Givens | *Solutions*

17. $\theta = 10.5°$

$d_1 = 200.0$ m

$\mu k = 0.075$

$g = 9.81$ m/s^2

$KE_{1,i} = 0$ J

$KE_{2,f} = 0$ J

For downhill slide,

$W_{net,1} = \Delta KE_1 = KE_{1,f} - KE_{1,i} = KE_{1,f}$

$W_{net,1} = F_{net,1} d_1(\cos\theta')$

$F_{net,1} = mg(\sin\theta) - F_k = mg(\sin\theta) - \mu_k mg(\cos\theta)$

Because $F_{net,1}$ is parallel to and in the forward direction to d_1, $\theta' = 0°$, and

$W_{net,1} = mgd_1[\sin\theta - \mu_k(\cos\theta)]$

For horizontal slide,

$W_{net,2} = \Delta KE_2 = KE_{2,f} - KE_{2,i} = -KE_{2,i}$

$W_{net,2} = F_{net,2} d_2(\cos\theta') = F_k d_2(\cos\theta') = \mu_k mgd_2(\cos\theta')$

Because $F_{net,2}$ is parallel to and in the backward direction to d_2, $\theta' = 180°$, and $W_{net,2} = -\mu_k mgd_2$

For the entire ride,

$mgd_1[\sin\theta - \mu_k(\cos\theta)] = KE_{1,f} - \mu_k mgd_2 = -KE_{2,i}$

Because $KE_{1,f} = KE_{2,i}$, $mgd_1[\sin\theta - \mu_k(\cos\theta)] = \mu_k mgd_2$

$$d_2 = \frac{d_1[\sin\theta - \mu_k(\cos\theta)]}{\mu_k}$$

$$d_2 = \frac{(200.0\text{ m})[(\sin 10.5°) - (0.075)(\cos 10.5°)]}{0.075} = \frac{(200.0\text{ m})(0.182 - 0.074)}{0.075}$$

$$d_2 = \frac{(200.0\text{ m})(0.108)}{0.075} = \boxed{290\text{ m}}$$

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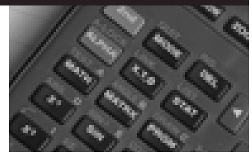
Student Edition Solutions



Momentum and Collisions

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Momentum and Collisions, Practice A

Givens	*Solutions*
1. $m = 146$ kg $\mathbf{v} = 17$ m/s south	$\mathbf{p} = m\mathbf{v} = (146 \text{ kg})(17 \text{ m/s south})$ $\mathbf{p} = \boxed{2.5 \times 10^3 \text{ kg•m/s to the south}}$
2. $m_1 = 21$ kg $m_2 = 5.9$ kg $\mathbf{v} = 4.5$ m/s to the northwest	**a.** $\mathbf{p_{tot}} = m_{tot}\mathbf{v} = (m_1 + m_2)\mathbf{v} = (21 \text{ kg} + 5.9 \text{ kg})(4.5 \text{ m/s})$ $\mathbf{p_{tot}} = (27 \text{ kg})(4.5 \text{ m/s}) = \boxed{1.2 \times 10^2 \text{ kg•m/s to the northwest}}$ **b.** $\mathbf{p_1} = m_1\mathbf{v} = (21 \text{ kg})(4.5 \text{ m/s}) = \boxed{94 \text{ kg•m/s to the northwest}}$ **c.** $\mathbf{p_2} = m_2\mathbf{v} = (5.9 \text{ kg})(4.5 \text{ m/s}) = \boxed{27 \text{ kg•m/s to the northwest}}$
3. $m = 1210$ kg $\mathbf{p} = 5.6 \times 10^4$ kg•m/s to the east	$\mathbf{v} = \dfrac{\mathbf{p}}{m} = \dfrac{5.6 \times 10^4 \text{ kg•m/s}}{1210 \text{ kg}} = \boxed{46 \text{ m/s to the east}}$

Momentum and Collisions, Practice B

Givens	*Solutions*
1. $m = 0.50$ kg $\mathbf{v_i} = 15$ m/s to the right $\Delta t = 0.020$ s $\mathbf{v_f} = 0$ m/s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(0.50 \text{ kg})(0 \text{ m/s}) - (0.50 \text{ kg})(15 \text{ m/s})}{0.020 \text{ s}}$ to the right $\mathbf{F} = -3.8 \times 10^2$ N to the right $\mathbf{F} = \boxed{3.8 \times 10^2 \text{ N to the left}}$
2. $m = 82$ kg $\Delta y = -3.0$ m $\Delta t = 0.55$ s $\mathbf{v_i} = 0$ m/s $a = -9.81$ m/s^2	$v_f = \pm\sqrt{2a\Delta y} = \pm\sqrt{(2)(-9.81 \text{ m/s}^2)(-3.0 \text{ m})} = \pm 7.7 \text{ m/s} = -7.7 \text{ m/s}$ For the time the man is in the water, $\mathbf{v_i} = 7.7$ m/s downward $= -7.7$ m/s $\mathbf{v_f} = 0$ m/s $\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(82 \text{ kg})(0 \text{ m/s}) - (82 \text{ kg})(-7.7 \text{ m/s})}{0.55 \text{ s}} = 1.1 \times 10^3 \text{ N}$ $\mathbf{F} = \boxed{1.1 \times 10^3 \text{ N upward}}$
3. $m = 0.40$ kg $\mathbf{v_i} = 18$ m/s to the north $= +18$ m/s $\mathbf{v_f} = 22$ m/s to the south $= -22$ m/s	$\Delta\mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i} = (0.40 \text{ kg})(-22 \text{ m/s}) - (0.40 \text{ kg})(18 \text{ m/s})$ $\Delta\mathbf{p} = -8.8 \text{ kg•m/s} - 7.2 \text{ kg•m/s} = -16.0 \text{ kg•m/s}$ $\Delta\mathbf{p} = \boxed{16 \text{ kg•m/s to the south}}$

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Givens	Solutions

4. $m = 0.50$ kg

$\mathbf{F_1} = 3.00$ N to the right

$\Delta t_1 = 1.50$ s

$\mathbf{v_{i,1}} = 0$ m/s

$\mathbf{F_2} = 4.00$ N to the left $= -4.00$ N

$\Delta t_2 = 3.00$ s

$\mathbf{v_{i,2}} = 9.0$ m/s to the right

a. $$\mathbf{v_{f,1}} = \frac{\mathbf{F_1}\Delta t_1 + m\mathbf{v_{i,1}}}{m} = \frac{(3.00\text{ N})(1.50\text{ s}) + (0.50\text{ kg})(0\text{ m/s})}{0.50\text{ kg}}$$

$$\mathbf{v_{f,1}} = 9.0\text{ m/s} = \boxed{9.0\text{ m/s to the right}}$$

b. $$\mathbf{v_{f,2}} = \frac{\mathbf{F_2}\Delta t_2 + m\mathbf{v_{i,2}}}{m} = \frac{(-4.00\text{ N})(3.00\text{ s}) + (0.50\text{ kg})(9.0\text{ m/s})}{0.50\text{ kg}}$$

$$\mathbf{v_{f,2}} = \frac{-12.0\text{ kg}\bullet\text{m/s} + 4.5\text{ kg}\bullet\text{m/s}}{0.50\text{ kg}} = \frac{-7.5\text{ kg}\bullet\text{m/s}}{0.50\text{ kg}} = -15\text{ m/s}$$

$$\mathbf{v_{f,2}} = \boxed{15\text{ m/s to the left}}$$

Momentum and Collisions, Practice C

1. $m = 2240$ kg

$\mathbf{v_i} = 20.0$ m/s to the west, $v_i = -20.0$ m/s

$\mathbf{v_f} = 0$

$\mathbf{F} = 8410$ N to the east, $F = +8410$ N

a. $$\Delta t = \frac{\Delta \mathbf{p}}{\mathbf{F}} = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\mathbf{F}}$$

$$\Delta t = \frac{(2240\text{ kg})(0) - (2240\text{ kg})(-20.0\text{ m/s})}{(8410\text{ N})} = \frac{44\,800\text{ kg}\bullet\text{m/s}}{8410\text{ kg}\bullet\text{m/s}^2}$$

$$\Delta t = \boxed{5.33\text{ s}}$$

b. $$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t$$

$$\Delta x = \tfrac{1}{2}(-20.0\text{ m/s} - 0)(5.33\text{ s})$$

$$\Delta x = \boxed{-53.3\text{ m or }53.3\text{ m to the west}}$$

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2. $m = 2500$ kg

$\mathbf{v_i} = 20.0$ m/s to the north $= +20.0$ m/s

$\mathbf{F} = 6250$ N to the south $= -6250$ N

$\Delta t = 2.50$ s

a. $$\mathbf{v_f} = \frac{\mathbf{F}\Delta t + m\mathbf{v_i}}{m} = \frac{(-6250\text{ N})(2.50\text{ s}) + (2500\text{ kg})(20.0\text{ m/s})}{2500\text{ kg}}$$

$$\mathbf{v_f} = \frac{(-1.56 \times 10^4\text{ kg}\bullet\text{m/s}) + (5.0 \times 10^4\text{ kg}\bullet\text{m/s})}{2500\text{ kg}} = \frac{3.4 \times 10^4\text{ kg}\bullet\text{m/s}}{2500\text{ kg}}$$

$$\mathbf{v_f} = 14\text{ m/s} = \boxed{14\text{ m/s to the north}}$$

b. $$\Delta\mathbf{x} = \tfrac{1}{2}(\mathbf{v_i} + \mathbf{v_f})(\Delta t) = \tfrac{1}{2}(20.0\text{ m/s} + 14\text{ m/s})(2.50\text{ s})$$

$$\Delta\mathbf{x} = \tfrac{1}{2}(34\text{ m/s})(2.50\text{ s}) = \boxed{42\text{ m to the north}}$$

$\mathbf{v_f} = 0$ m/s

c. $$\Delta t = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\mathbf{F}} = \frac{(2500\text{ kg})(0\text{ m/s}) - (2500\text{ kg})(20.0\text{ m/s})}{-6250\text{ N}} = \boxed{8.0\text{ s}}$$

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3. $m = 3250$ kg

$\mathbf{v_i} = 20.0$ m/s to the west $= -20.0$ m/s

$\mathbf{v_f} = 0$ m/s

$\Delta t = 5.33$ s

a. $$\mathbf{F} = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \frac{(3250\text{ kg})(0\text{ m/s}) - (3250\text{ kg})(-20.0\text{ m/s})}{5.33\text{ s}}$$

$$\mathbf{F} = 1.22 \times 10^4\text{ N} = \boxed{1.22 \times 10^4\text{ N to the east}}$$

b. $$\Delta\mathbf{x} = \tfrac{1}{2}(\mathbf{v_i} + \mathbf{v_f})(\Delta t) = \tfrac{1}{2}(-20.0\text{ m/s} + 0\text{ m/s})(5.33\text{ s}) = -53.3\text{ m}$$

$$\Delta\mathbf{x} = \boxed{53.3\text{ m to the west}}$$

Momentum and Collisions, Section 1 Review

Givens | *Solutions*

2. $m_1 = 0.145$ kg

$m_2 = 3.00$ g

$v_2 = 1.50 \times 10^3$ m/s

a. $m_1v_1 = m_2v_2$

$$v_1 = \frac{m_2v_2}{m_1} = \frac{(3.00 \times 10^{-3}\text{ kg})(1.50 \times 10^3\text{ m/s})}{(0.145\text{ kg})} = \boxed{31.0\text{ m/s}}$$

b. $KE_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}(0.145\text{ kg})(31.0\text{ m/s})^2 = 69.7\text{ J}$

$KE_2 = \frac{1}{2}m_2v_2^2 = \frac{1}{2}(3.00 \times 10^{-3}\text{ kg})(1.50 \times 10^3\text{ m/s})^2 = 3380\text{ J}$

$\boxed{KE_2 > KE_1}$ The bullet has greater kinetic energy.

3. $m = 0.42$ kg

$\mathbf{v_i} = 12$ m/s downfield

$\mathbf{v_f} = 18$ m/s downfield

$\Delta t = 0.020$ s

a. $\Delta\mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i} = (0.42\text{ kg})(18\text{ m/s}) - (0.42\text{ kg})(12\text{ m/s})$

$\Delta\mathbf{p} = 7.6\text{ kg•m/s} - 5.0\text{ kg•m/s} = \boxed{2.6\text{ kg•m/s downfield}}$

b. $$\mathbf{F} = \frac{\Delta\mathbf{p}}{\Delta t} = \frac{2.6\text{ kg•m/s}}{0.020\text{ s}} = \boxed{1.3 \times 10^2\text{ N downfield}}$$

Momentum and Collisions, Practice D

1. $m_1 = 63.0$ kg

$m_2 = 10.0$ kg

$v_{2,i} = 0$ m/s

$v_{2,f} = 12.0$ m/s

$v_{1,i} = 0$ m/s

$$v_{1,f} = \frac{m_1v_{1,i} + m_2v_{2,i} - m_2v_{2,f}}{m_1}$$

$$v_{1,f} = \frac{(63.0\text{ kg})(0\text{ m/s}) + (10.0\text{ kg})(0\text{ m/s}) - (10.0\text{ kg})(12.0\text{ m/s})}{63.0\text{ kg}} = -1.90\text{ m/s}$$

astronaut speed = $\boxed{1.90\text{ m/s}}$

2. $m_1 = 85.0$ kg

$m_2 = 135.0$ kg

$\mathbf{v_{1,i}} = 4.30$ m/s to the west $= -4.30$ m/s

$\mathbf{v_{2,i}} = 0$ m/s

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(85.0\text{ kg})(-4.30\text{ m/s}) + (135.0\text{ kg})(0\text{ m/s})}{85.0\text{ kg} + 135.0\text{ kg}}$$

$$\mathbf{v_f} = \frac{(85.0\text{ kg})(-4.30\text{ m/s})}{220.0\text{ kg}} = -1.66\text{ m/s} = \boxed{1.66\text{ m/s to the west}}$$

3. $m_1 = 0.50$ kg

$v_{1,i} = 12.0$ m/s

$v_{2,i} = 0$ m/s

$m_2 = 0.50$ kg

$v_{1,f} = 0$ m/s

a. $$v_{2,f} = \frac{m_1v_{1,i} + m_2v_{2,i} - m_1v_{1,f}}{m_2}$$

$m_1 = m_2$

$v_{2,f} = v_{1,i} + v_{2,i} - v_{1,f} = 12.0\text{ m/s} + 0\text{ m/s} - 0\text{ m/s} = \boxed{12.0\text{ m/s}}$

$v_{1,f} = 2.4$ m/s

b. $v_{2,f} = v_{1,i} + v_{2,i} - v_{1,f} = 12.0\text{ m/s} + 0\text{ m/s} - 2.4\text{ m/s} = \boxed{9.6\text{ m/s}}$

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Givens	*Solutions*
4. $m_1 = 2.0$ kg $+ m_b$ $m_2 = 8.0$ kg $v_{2,i} = 0$ m/s $v_{2,f} = 3.0$ m/s $v_{1,i} = 0$ m/s $v_{1,f} = -0.60$ m/s	$m_i v_{1,i} + m_2 v_{2,i} = m_1 v_{1,f} + m_2 v_{2,f}$ $(2.0 \text{ kg} + m_b)(0 \text{ m/s}) + (8.0 \text{ kg})(0 \text{ m/s}) = (2.0 \text{ kg} + m_b)(-0.60 \text{ m/s}) + (8.0 \text{ kg})(3.0 \text{ m/s})$ $(2.0 \text{ kg} + m_b)(0.60 \text{ m/s}) = (8.0 \text{ kg})(3.0 \text{ m/s})$ $m_b = \frac{24 \text{ kg} \bullet \text{m/s} - 1.2 \text{ kg} \bullet \text{m/s}}{0.60 \text{ m/s}} = \frac{23 \text{ kg} \bullet \text{m/s}}{0.60 \text{ m/s}}$ $m_b = \boxed{38 \text{ kg}}$

Momentum and Collisions, Section 2 Review

1. $m_1 = 44$ kg $\quad m_2 = 22$ kg

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{1,f}} = 3.5$ m/s backward $= -3.5$ m/s

a. $$\mathbf{v_{2,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$$

$$\mathbf{v_{2,f}} = \frac{(44 \text{ kg})(0 \text{ m/s}) + (22 \text{ kg})(0 \text{ m/s}) - (44 \text{ kg})(-3.5 \text{ m/s})}{22 \text{ kg}} = \boxed{7.0 \text{ m/s forward}}$$

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{2,i}} = 4.6$ m/s to the right $= +4.6$ m/s

c. $$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(44 \text{ kg})(0 \text{ m/s}) + (22 \text{ kg})(4.6 \text{ m/s})}{44 \text{ kg} + 22 \text{ kg}}$$

$$\mathbf{v_f} = \frac{(22 \text{ kg})(4.6 \text{ m/s})}{66 \text{ kg}} = \boxed{1.5 \text{ m/s to the right}}$$

3. $m_1 = 215$ g

$v_{1,i} = 55.0$ m/s

$v_{2,i} = 0$ m/s

$m_2 = 46$ g

$v_{1,f} = 42.0$ m/s

$$v_{2,f} = \frac{m_1 v_{1,i} + m_2 v_{2,i} - m_1 v_{1,f}}{m_2}$$

$$v_{2,f} = \frac{(0.215 \text{ kg})(55.0 \text{ m/s}) + (0.046 \text{ kg})(0 \text{ m/s}) - (0.215 \text{ kg})(42.0 \text{ m/s})}{0.046 \text{ kg}}$$

$$v_{2,f} = \frac{11.8 \text{ kg}\bullet\text{m/s} - 9.03 \text{ kg}\bullet\text{m/s}}{0.046 \text{ kg}} = \frac{2.8 \text{ kg}\bullet\text{m/s}}{0.046 \text{ kg}} = \boxed{61 \text{ m/s}}$$

Momentum and Collisions, Practice E

1. $m_1 = 1500$ kg

$\mathbf{v_{1,i}} = 15.0$ m/s to the south $= -15.0$ m/s

$m_2 = 4500$ kg

$\mathbf{v_{2,i}} = 0$ m/s

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(1500 \text{ kg})(-15.0 \text{ m/s}) + (4500 \text{ kg})(0 \text{ m/s})}{1500 \text{ kg} + 4500 \text{ kg}}$$

$$\mathbf{v_f} = \frac{(1500 \text{ kg})(-15.0 \text{ m/s})}{6.0 \times 10^3 \text{ kg}} = -3.8 \text{ m/s} = \boxed{3.8 \text{ m/s to the south}}$$

2. $m_1 = 9.0$ kg

$m_2 = 18.0$ kg

$v_{2,i} = 0$ m/s

$v_{1,i} = 5.5$ m/s

$$v_f = \frac{m_1 v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(9.0 \text{ kg})(5.5 \text{ m/s}) + (18.0 \text{ kg})(0 \text{ m/s})}{9.0 \text{ kg} + 18.0 \text{ kg}}$$

$$v_f = \frac{(9.0 \text{ kg})(5.5 \text{ m/s})}{27.0 \text{ kg}} = \boxed{1.8 \text{ m/s}}$$

3. $m_1 = 1.50 \times 10^4$ kg

$\mathbf{v_{1,i}} = 7.00$ m/s north

$m_2 = m_1 = m$

$\mathbf{v_{2,i}} = 1.50$ m/s north

$$\mathbf{v_f} = \frac{(m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}})}{m_1 + m_2} = \frac{m(\mathbf{v_{1,i}} + \mathbf{v_{2,i}})}{2m} = \tfrac{1}{2}(\mathbf{v_{1,i}} + \mathbf{v_{2,i}})$$

$$\mathbf{v_f} = \tfrac{1}{2}(7.00 \text{ m/s north} + 1.50 \text{ m/s north})$$

$$\mathbf{v_f} = \boxed{4.25 \text{ m/s to the north}}$$

Givens	Solutions
4. $m_1 = 22$ kg $m_2 = 9.0$ kg $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_f} = 3.0$ m/s to the right	$\mathbf{v_{1,i}} = \frac{(m_1 + m_2)\mathbf{v_f} - m_2\mathbf{v_{2,i}}}{m_1} = \frac{(22 \text{ kg} + 9.0 \text{ kg})(3.0 \text{ m/s}) - (9.0 \text{ kg})(0 \text{ m/s})}{22 \text{ kg}}$ $\mathbf{v_{1,i}} = \frac{(31 \text{ kg})(3.0 \text{ m/s})}{22 \text{ kg}} = \boxed{4.2 \text{ m/s to the right}}$
5. $m_1 = 47.4$ kg $v_{1,i} = 4.20$ m/s $v_{2,i} = 0$ m/s $v_f = 3.95$ m/s	**a.** $m_2 = \frac{m_1 v_f - m_1 v_{1,i}}{v_{2,i} - v_f} = \frac{(47.4 \text{ kg})(3.95 \text{ m/s}) - (47.4 \text{ kg})(4.20 \text{ m/s})}{0 \text{ m/s} - 3.95 \text{ m/s}}$ $m_2 = \frac{187 \text{ kg•m/s} - 199 \text{ kg•m/s}}{-3.95 \text{ m/s}} = \frac{-12 \text{ kg•m/s}}{-3.95 \text{ m/s}} = \boxed{3.0 \text{ kg}}$
$v_f = 5.00$ m/s	**b.** $v_{1,i} = \frac{(m_1 + m_2)v_f - m_2 v_{2,i}}{m_1} = \frac{(47.4 \text{ kg} + 3.0 \text{ kg})(5.00 \text{ m/s}) - (3.0 \text{ kg})(0 \text{ m/s})}{47.4 \text{ kg}}$ $v_{1,i} = \frac{(50.4 \text{ kg})(5.00 \text{ m/s})}{47.4 \text{ kg}} = \boxed{5.32 \text{ m/s}}$

Momentum and Collisions, Practice F

Givens	Solutions
1. $m_1 = 0.25$ kg $\mathbf{v_{1,i}} = 12$ m/s to the west $= -12$ m/s $m_2 = 6.8$ kg $\mathbf{v_{2,i}} = 0$ m/s	**a.** $\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(0.25 \text{ kg})(-12 \text{ m/s}) + (6.8 \text{ kg})(0 \text{ m/s})}{0.25 \text{ kg} + 6.8 \text{ kg}}$ $\mathbf{v_f} = \frac{(0.25 \text{ kg})(-12 \text{ m/s})}{7.0 \text{ kg}} = -0.43 \text{ m/s} = \boxed{0.43 \text{ m/s to the west}}$ **b.** $\Delta KE = KE_f - KE_i$ $KE_i = \frac{1}{2}m_1 v_{1,i}^2 + \frac{1}{2}m_2 v_{2,i}^2 = \frac{1}{2}(0.25 \text{ kg})(-12 \text{ m/s})^2 + \frac{1}{2}(6.8 \text{ kg})(0 \text{ m/s})^2$ $KE_i = 18 \text{ J} + 0 \text{ J} = 18 \text{ J}$ $KE_f = \frac{1}{2}(m_1 + m_2)v_f^2 = \frac{1}{2}(0.25 \text{ kg} + 6.8 \text{ kg})(-0.43 \text{ m/s})^2$ $KE_f = \frac{1}{2}(7.0 \text{ kg})(-0.43 \text{ m/s})^2 = 0.65 \text{ J}$ $\Delta KE = KE_f - KE_i = 0.65 \text{ J} - 18 \text{ J} = -17 \text{ J}$ The kinetic energy decreases by $\boxed{17 \text{ J}}$.
2. $m_1 = 0.40$ kg $\mathbf{v_{1,i}} = 8.5$ m/s to the south $= -8.5$ m/s $m_2 = 0.15$ kg $\mathbf{v_{2,i}} = 0$ m/s	**a.** $\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(0.40 \text{ kg})(-8.5 \text{ m/s}) + (0.15 \text{ kg})(0 \text{ m/s})}{0.40 \text{ kg} + 0.15 \text{ kg}}$ $\mathbf{v_f} = \frac{(0.40 \text{ kg})(-8.5 \text{ m/s})}{0.55 \text{ kg}} = -6.2 \text{ m/s} = \boxed{6.2 \text{ m/s to the south}}$ **b.** $\Delta KE = KE_f - KE_i$ $KE_i = \frac{1}{2}m_1 v_{1,i}^2 + \frac{1}{2}m_2 v_{2,i}^2 = \frac{1}{2}(0.40 \text{ kg})(-8.5 \text{ m/s})^2 + \frac{1}{2}(0.15 \text{ kg})(0 \text{ m/s})^2$ $KE_i = 14 \text{ J} + 0 \text{ J} = 14 \text{ J}$ $KE_f = \frac{1}{2}(m_1 + m_2)v_f^2 = \frac{1}{2}(0.40 \text{ kg} + 0.15 \text{ kg})(-6.2 \text{ m/s})^2$ $KE_f = \frac{1}{2}(0.55 \text{ kg})(-6.2 \text{ m/s})^2 = 11 \text{ J}$ $\Delta KE = KE_f - KE_i = 11 \text{ J} - 14 \text{ J} = -3 \text{ J}$ The kinetic energy decreases by $\boxed{3 \text{ J}}$.

Givens | *Solutions*

3. $m_1 = 56$ kg

$\mathbf{v_{1,i}} = 4.0$ m/s to the north $= +4.0$ m/s

$m_2 = 65$ kg

$\mathbf{v_{2,i}} = 12.0$ m/s to the south $= -12.0$ m/s

a. $$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(56\text{ kg})(4.0\text{ m/s}) + (65\text{ kg})(-12.0\text{ m/s})}{56\text{ kg} + 65\text{ kg}}$$

$$\mathbf{v_f} = \frac{220\text{ kg•m/s} - 780\text{ kg•m/s}}{121\text{ kg}} = \frac{-560\text{ kg•m/s}}{121\text{ kg}} = -4.6\text{ m/s}$$

$$\mathbf{v_f} = \boxed{4.6\text{ m/s to the south}}$$

b. $\Delta KE = KE_f - KE_i$

$KE_i = \frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}(56\text{ kg})(4.0\text{ m/s})^2 + \frac{1}{2}(65\text{ kg})(-12.0\text{ m/s})^2$

$KE_i = 450\text{ J} + 4700\text{ J} = 5200\text{ J}$

$KE_f = \frac{1}{2}(m_1 + m_2)v_f^2 = \frac{1}{2}(56\text{ kg} + 65\text{ kg})(-4.6\text{ m/s})^2$

$KE_f = \frac{1}{2}(121\text{ kg})(-4.6\text{ m/s})^2 = 1300\text{ J}$

$\Delta KE = KE_f - KE_i = 1300\text{ J} - 5200\text{ J} = -3900\text{ J}$

The kinetic energy decreases by $\boxed{3.9 \times 10^3\text{ J}}$.

Momentum and Collisions, Practice G

1. $m_1 = 0.015$ kg

$\mathbf{v_{1,i}} = 22.5$ cm/s to the right $= +22.5$ cm/s

$m_2 = 0.015$ kg

$\mathbf{v_{2,i}} = 18.0$ cm/s to the left $= -18.0$ cm/s

$\mathbf{v_{1,f}} = 18.0$ cm/s to the left $= -18.0$ cm/s

a. $$\mathbf{v_{2,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$$

$m_1 = m_2$

$\mathbf{v_{2,f}} = \mathbf{v_{1,i}} + \mathbf{v_{2,i}} - \mathbf{v_{1,f}} = 22.5\text{ cm/s} + (-18.0\text{ cm/s}) - (-18.0\text{ cm/s})$

$\mathbf{v_{2,f}} = 22.5\text{ cm/s} = \boxed{22.5\text{ cm/s to the right}}$

b. $KE_i = \frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2$

$KE_i = \frac{1}{2}(0.015\text{ kg})(0.225\text{ m/s})^2 + \frac{1}{2}(0.015\text{ kg})(-0.180\text{ m/s})^2$

$KE_i = 3.8 \times 10^{-4}\text{ J} + 2.4 \times 10^{-4}\text{ J} = \boxed{6.2 \times 10^{-4}\text{ J}}$

$KE_f = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$KE_f = \frac{1}{2}(0.015\text{ kg})(-0.180\text{ m/s})^2 + \frac{1}{2}(0.015\text{ kg})(0.225\text{ m/s})^2$

$KE_f = 2.4 \times 10^{-4}\text{ J} + 3.8 \times 10^{-4}\text{ J} = \boxed{6.2 \times 10^{-4}\text{ J}}$

---

2. $m_1 = 16.0$ kg

$\mathbf{v_{1,i}} = 12.5$ m/s to the left, $v_{1,i} = -12.5$ m/s

$m_2 = 14.0$ kg

$\mathbf{v_{2,i}} = 16.0$ m/s to the right, $v_{2,i} = 16.0$ m/s

$\mathbf{v_{2,f}} = 14.4$ m/s to the left, $v_{1,f} = -14.4$ m/s

a. $$\mathbf{v_{1,f}} = \frac{(m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_2\mathbf{v_{2,f}})}{m_1}$$

$$v_{1,f} = \frac{(16.0\text{ kg})(-12.5\text{ m/s}) + (14.0\text{ kg})(16.0\text{ m/s}) - (14.0\text{ kg})(-14.4\text{ m/s})}{16.0\text{ kg}}$$

$$v_{1,f} = \frac{-200\text{ kg•m/s} + 224\text{ kg•m/s} + 202\text{ kg•m/s}}{16.0\text{ kg}} = 14.1\text{ m/s}$$

$$v_{1,f} = \boxed{14.1\text{ m/s to the right}}$$

Givens | *Solutions*

b. $KE_i = \frac{1}{2}m_1 v_{1,i}^2 + \frac{1}{2}m_2 v_{2,i}^2$

$KE_i = \frac{1}{2}(16.0 \text{ kg})(-12.5 \text{ m/s})^2 + \frac{1}{2}(14.0 \text{ kg})(16.0 \text{ m/s})^2$

$KE_i = 1.25 \times 10^3 \text{ J} + 1.79 \times 10^3 \text{ J} = \boxed{3.04 \times 10^3 \text{ J}}$

$KE_f = \frac{1}{2}m_1 v_{1,f}^2 + \frac{1}{2}m_2 v_{2,f}^2$

$KE_f = \frac{1}{2}(16.0 \text{ kg})(14.1 \text{ m/s})^2 + \frac{1}{2}(14.0 \text{ kg})(-14.4 \text{ m/s})^2$

$KE_f = 1.59 \times 10^3 \text{ J} + 1.45 \times 10^3 \text{ J} = \boxed{3.04 \times 10^3 \text{ J}}$

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3. $m_1 = 4.0$ kg

$\mathbf{v_{1,i}} = 8.0$ m/s to the right

$m_2 = 4.0$ kg

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{1,f}} = 0$ m/s

a. $\mathbf{v_{2,f}} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$

$m_1 = m_2$

$\mathbf{v_{2,f}} = \mathbf{v_{1,i}} + \mathbf{v_{2,i}} - \mathbf{v_{1,f}} = 8.0 \text{ m/s} + 0 \text{ m/s} - 0 \text{ m/s}$

$\mathbf{v_{2,f}} = 8.0 \text{ m/s} = \boxed{8.0 \text{ m/s to the right}}$

b. $KE_i = \frac{1}{2}m_1 v_{1,i}^2 + \frac{1}{2}m_2 v_{2,i}^2$

$KE_i = \frac{1}{2}(4.0 \text{ kg})(8.0 \text{ m/s})^2 + \frac{1}{2}(4.0 \text{ kg})(0 \text{ m/s})^2$

$KE_i = 130 \text{ J} + 0 \text{ J} = \boxed{1.3 \times 10^2 \text{ J}}$

$KE_f = \frac{1}{2}m_1 v_{1,f}^2 + \frac{1}{2}m_2 v_{2,f}^2$

$KE_f = \frac{1}{2}(4.0 \text{ kg})(0 \text{ m/s})^2 + \frac{1}{2}(4.0 \text{ kg})(8.0 \text{ m/s})^2$

$KE_f = 0 \text{ J} + 130 \text{ J} = \boxed{1.3 \times 10^2 \text{ J}}$

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4. $m_1 = 25.0$ kg

$\mathbf{v_{1,\,i}} = 5.00$ m/s to the right

$m_2 = 35.0$ kg

$\mathbf{v_{1,\,f}} = 1.50$ m/s to the right

$\mathbf{v_{2,\,f}} = 4.50$ m/s to the right

a. $\mathbf{v_{2,\,i}} = \dfrac{m_i\mathbf{v_{1,\,f}} + m_2\mathbf{v_{2,\,f}} - m_1\mathbf{v_{1,\,i}}}{m_2}$

$\mathbf{v_{2,\,i}} = \dfrac{(25.0 \text{ kg})(1.50 \text{ m/s}) + (35.0 \text{ kg})(4.50 \text{ m/s}) - (25.0 \text{ kg})(5.00 \text{ m/s})}{35.0 \text{ kg}}$

$\mathbf{v_{2,\,i}} = \dfrac{37.5 \text{ kg•m/s} + 158 \text{ kg•m/s} - 125 \text{ kg•m/s}}{35.0 \text{ kg}} = \dfrac{7.0 \times 10^1 \text{ kg•m/s}}{35.0 \text{ kg}}$

$\mathbf{v_{2,\,i}} = 2.0 \text{ m/s} = \boxed{2.0 \text{ m/s to the right}}$

b. $KE_i = \frac{1}{2}m_i v_{1,\,i}^2 + \frac{1}{2}m_2 v_{2,\,i}^2$

$KE_i = \frac{1}{2}(25.0 \text{ kg})(5.00 \text{ m/s})^2 + \frac{1}{2}(35.0 \text{ kg})(2.0 \text{ m/s})^2$

$KE_i = 312 \text{ J} + 7.0 \times 10^1 \text{ J} = \boxed{382 \text{ J}}$

$KE_f = \frac{1}{2}m_1 v_{1,\,f}^2 + \frac{1}{2}m_2 v_{2,\,f}^2$

$KE_f = \frac{1}{2}(25.0 \text{ kg})(1.50 \text{ m/s})^2 + \frac{1}{2}(35.0 \text{ kg})(4.50 \text{ m/s})^2$

$KE_f = 28.1 \text{ J} + 354 \text{ J} = \boxed{382 \text{ J}}$

Momentum and Collisions, Section 3 Review

Givens | *Solutions*

I

2. $m_1 = 95.0$ kg

$\mathbf{v_{1,i}} = 5.0$ m/s to the south, $v_{1,i} = -5.0$ m/s

$m_2 = 90.0$ kg

$\mathbf{v_{2,i}} = 3.0$ m/s to the north, $v_{2,i} = 3.0$ m/s

a. $\mathbf{v_f} = \dfrac{(m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}})}{m_1 + m_2}$

$v_f = \dfrac{(95.0 \text{ kg})(-5.0 \text{ m/s}) + (90.0 \text{ kg})(3.0 \text{ m/s})}{95.0 \text{ kg} + 90.0 \text{ kg}}$

$v_f = \dfrac{-480 \text{ kg}\bullet\text{m/s} + 270 \text{ kg}\bullet\text{m/s}}{185 \text{ kg}} = \dfrac{-210 \text{ kg}\bullet\text{m/s}}{185 \text{ kg}} = -1.1 \text{ m/s}$

$v_f = \boxed{1.1 \text{ m/s to the south}}$

b. $\Delta KE = KE_f - KE_i$

$KE_i = \frac{1}{2}m_1 v_{1,i}{}^2 + \frac{1}{2}m_2 v_{2,i}{}^2 = \frac{1}{2}(95.0 \text{ kg})(-5.0 \text{ m/s})^2 + \frac{1}{2}(90.0 \text{ kg})(3.0 \text{ m/s})^2$

$KE_i = 1200 \text{ J} + 400 \text{ J} = 1600 \text{ J}$

$KE_f = \frac{1}{2}m_f v_{1,f}{}^2 = \frac{1}{2}(m_1 + m_2)v_{1,f}{}^2 = \frac{1}{2}(95.0 \text{ kg} + 90.0 \text{ kg})(1.1 \text{ m/s})^2$

$KE_f = \frac{1}{2}(185 \text{ kg})(1.2 \text{ m}^2/\text{s}^2) = 220 \text{ J}$

$\Delta KE = KE_f - KE_i = 220 \text{ J} - 1600 \text{ J} = -1400 \text{ J}$

$\boxed{\text{The kinetic energy decreases by } 1.4 \times 10^3 \text{ J.}}$

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3. $m_1 = m_2 = 0.40$ kg

$v_{1,i} = 0$ m/s

$v_{2,i} = 3.5$ m/s

$v_{2,f} = 0$ m/s

a. $v_{1,f} = \dfrac{m_1 v_{1,i} + m_2 v_{2,i} - m_2 v_{2,f}}{m_1}$

$m_1 = m_2$

$v_{1,f} = v_{1,i} + v_{2,i} - v_{2,f} = 0 \text{ m/s} + 3.5 \text{ m/s} - 0 \text{ m/s} = \boxed{3.5 \text{ m/s}}$

b. $KE_{1,i} = \frac{1}{2}m_1 v_{1,i}{}^2 = \frac{1}{2}(0.40 \text{ kg})(0 \text{ m/s})^2 = \boxed{0 \text{ J}}$

c. $KE_{2,f} = \frac{1}{2}m_2 v_{2,f}{}^2 = \frac{1}{2}(0.40 \text{ kg})(0 \text{ m/s})^2 = \boxed{0 \text{ J}}$

Momentum and Collisions, Chapter Review

11. $m = 1.67 \times 10^{-27}$ kg

$\mathbf{v} = 5.00 \times 10^6$ m/s straight up

a. $\mathbf{p} = m\mathbf{v} = (1.67 \times 10^{-27} \text{ kg})(5.00 \times 10^6 \text{ m/s}) = \boxed{8.35 \times 10^{-21} \text{ kg}\bullet\text{m/s upward}}$

$m = 15.0$ g

$\mathbf{v} = 325$ m/s to the right

b. $\mathbf{p} = m\mathbf{v} = (15.0 \times 10^{-3} \text{ kg})(325 \text{ m/s}) = \boxed{4.88 \text{ kg}\bullet\text{m/s to the right}}$

$m = 75.0$ kg

$\mathbf{v} = 10.0$ m/s southwest

c. $\mathbf{p} = m\mathbf{v} = (75.0 \text{ kg})(10.0 \text{ m/s}) = \boxed{7.50 \times 10^2 \text{ kg}\bullet\text{m/s to the southwest}}$

$m = 5.98 \times 10^{24}$ kg

$\mathbf{v} = 2.98 \times 10^4$ m/s forward

d. $\mathbf{p} = m\mathbf{v} = (5.98 \times 10^{24} \text{ kg})(2.98 \times 10^4 \text{ m/s}) = \boxed{1.78 \times 10^{29} \text{ kg}\bullet\text{m/s forward}}$

Givens	*Solutions*

12. $m_1 = 2.5$ kg

$\mathbf{v_i} = 8.5$ m/s to the left $= -8.5$ m/s

$\mathbf{v_f} = 7.5$ m/s to the right $= +7.5$ m/s

$\Delta t = 0.25$ s

$$\mathbf{F} = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \frac{(2.5\text{ kg})(7.5\text{ m/s}) - (2.5\text{ kg})(-8.5\text{ m/s})}{0.25\text{ s}}$$

$$\mathbf{F} = \frac{19\text{ kg•m/s} + 21\text{ kg•m/s}}{0.25\text{ s}} = \frac{4.0 \times 10^1\text{ kg•m/s}}{0.25\text{ s}} = \boxed{160\text{ N to the right}}$$

13. $m = 0.55$ kg

$v_i = 0$ m/s

$v_f = 8.0$ m/s

$\Delta t = 0.25$ s

$$F = \frac{mv_f - mv_i}{\Delta t} = \frac{(0.55\text{ kg})(8.0\text{ m/s}) - (0.55\text{ kg})(0\text{ m/s})}{0.25\text{ s}} = \frac{4.4\text{ kg•m/s}}{0.25\text{ s}}$$

$$F = \boxed{18\text{ N}}$$

14. $m = 0.15$ kg

$v_i = 26$ m/s

$v_f = 0$ m/s

$F = -390$ N

$$\Delta t = \frac{mv_f - mv_i}{F} = \frac{(0.15\text{ kg})(0\text{ m/s}) - (0.15\text{ kg})(26\text{ m/s})}{-390\text{ N}}$$

$$\Delta t = \frac{-(0.15\text{ kg})(26\text{ m/s})}{-390\text{ N}} = \boxed{0.010\text{ s}}$$

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}(26.0\text{ m/s} + 0\text{ m/s})(0.010\text{ s}) = \boxed{0.13\text{ m}}$$

22. $m_1 = 65.0$ kg

$\mathbf{v_{1,i}} = 2.50$ m/s forward

$m_2 = 0.150$ kg

$\mathbf{v_{2,i}} = 2.50$ m/s forward

$\mathbf{v_{2,f}} = 32.0$ m/s forward

a. $$\mathbf{v_{1,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_2\mathbf{v_{2,f}}}{m_1}$$

$$\mathbf{v_{1,f}} = \frac{(65.0\text{ kg})(2.50\text{ m/s}) + (0.150\text{ kg})(2.50\text{ m/s}) - (0.150\text{ kg})(32.0\text{ m/s})}{65.0\text{ kg}}$$

$$\mathbf{v_{1,f}} = \frac{162\text{ kg•m/s} + 0.375\text{ kg•m/s} - 4.80\text{ kg•m/s}}{65.0\text{ kg}} = \frac{162\text{ kg•m/s} - 4.42\text{ kg•m/s}}{65.0\text{ kg}}$$

$$\mathbf{v_{1,f}} = \frac{158\text{ kg•m/s}}{65.0\text{ kg}} = \boxed{2.43\text{ m/s forward}}$$

$m_1 = 60.0$ kg

$\mathbf{v_{1,i}} = 0$ m/s

$m_2 = 0.150$ kg

$\mathbf{v_{2,i}} = 32.0$ m/s forward

b. $$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(60.0\text{ kg})(0\text{ m/s}) + (0.150\text{ kg})(32.0\text{ m/s})}{60.0\text{ kg} + 0.150\text{ kg}}$$

$$\mathbf{v_f} = \frac{(0.150\text{ kg})(32.0\text{ m/s})}{60.2\text{ kg}} = \boxed{7.97 \times 10^{-2}\text{ m/s forward}}$$

23. $m_1 = 55$ kg

$m_2 = 0.057$ kg

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{2,f}} = 36$ m/s to the north

Because the initial momentum is zero,

$$m_1\mathbf{v_{1,f}} = -m_2\mathbf{v_{2,f}}$$

$$\mathbf{v_{1,f}} = \frac{-m_2\mathbf{v_{2,f}}}{m_1} = \frac{-(0.057\text{ kg})(36\text{ m/s})}{55\text{ kg}} = -0.037\text{ m/s}$$

$$\mathbf{v_{1,f}} = \boxed{0.037\text{ m/s to the south}}$$

Givens *Solutions*

28. $m_1 = 4.0$ kg

$m_2 = 3.0$ kg

$v_{1,i} = 5.0$ m/s

$v_{2,i} = -4.0$ m/s

$$v_f = \frac{m_1 v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(4.0 \text{ kg})(5.0 \text{ m/s}) + (3.0 \text{ kg})(-4.0 \text{ m/s})}{4.0 \text{ kg} + 3.0 \text{ kg}}$$

$$v_f = \frac{2.0 \times 10^1 \text{ kg•m/s} + (-12 \text{ kg•m/s})}{7.0 \text{ kg}} = \frac{8 \text{ kg•m/s}}{7.0 \text{ kg}} = \boxed{1 \text{ m/s}}$$

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29. $m_1 = 1.20$ kg

$v_{1,i} = 5.00$ m/s

$m_2 = 0.800$ kg

$v_{2,i} = 0$ m/s

$$v_f = \frac{m_1 v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(1.20 \text{ kg})(5.00 \text{ m/s}) + (0.800 \text{ kg})(0 \text{ m/s})}{1.20 \text{ kg} + 0.800 \text{ kg}}$$

$$v_f = \frac{(1.20 \text{ kg})(5.00 \text{ m/s})}{2.00 \text{ kg}} = \boxed{3.00 \text{ m/s}}$$

30. $m_1 = 2.00 \times 10^4$ kg

$v_{1,i} = 3.00$ m/s

$m_2 = 2m_1$

$v_{2,i} = 1.20$ m/s

a. $$v_f = \frac{m_1 v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(2.00 \times 10^4 \text{ kg})(3.00 \text{ m/s}) + (2)(2.00 \times 10^4 \text{ kg})(1.20 \text{ m/s})}{(2.00 \times 10^4 \text{ kg}) + (2)(2.00 \times 10^4 \text{ kg})}$$

$$v_f = \frac{6.00 \times 10^4 \text{ kg•m/s} + 4.80 \times 10^4 \text{ kg•m/s}}{6.00 \times 10^4 \text{ kg}}$$

$$v_f = \frac{10.80 \times 10^4 \text{ kg•m/s}}{6.00 \times 10^4 \text{ kg}} = \boxed{1.80 \text{ m/s}}$$

b. $\Delta KE = KE_f - KE_i$

$$KE_i = \tfrac{1}{2} m_1 v_{1,i}^2 + \tfrac{1}{2} m_2 v_{2,i}^2 = \tfrac{1}{2}(2.00 \times 10^4 \text{ kg})(3.00 \text{ m/s})^2 + \tfrac{1}{2}(2)(2.00 \times 10^4 \text{ kg})(1.20 \text{ m/s})^2$$

$$KE_i = 9.00 \times 10^4 \text{ J} + 2.88 \times 10^4 \text{ J} = 11.88 \times 10^4 \text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(2.00 \times 10^4 \text{ kg} + 4.00 \times 10^4 \text{ kg})(1.80 \text{ m/s})^2 = 9.72 \times 10^4 \text{ J}$$

$$\Delta KE = KE_f - KE_i = 9.72 \times 10^4 \text{ J} - 11.88 \times 10^4 \text{ J} = -2.16 \times 10^4 \text{ J}$$

The kinetic energy decreases by $\boxed{2.16 \times 10^4 \text{ J}}$.

31. $m_1 = 88$ kg

$\mathbf{v_{1,i}} = 5.0$ m/s to the east $= +5.0$ m/s

$m_2 = 97$ kg

$\mathbf{v_{2,i}} = 3.0$ m/s to the west $= -3.0$ m/s

a. $$\mathbf{v_f} = \frac{m_1 \mathbf{v_{1,i}} + m_2 \mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(88 \text{ kg})(5.0 \text{ m/s}) + (97 \text{ kg})(-3.0 \text{ m/s})}{88 \text{ kg} + 97 \text{ kg}}$$

$$\mathbf{v_f} = \frac{440 \text{ kg•m/s} - 290 \text{ kg•m/s}}{185 \text{ kg}} = \frac{150 \text{ kg•m/s}}{185 \text{ kg}} = \boxed{0.81 \text{ m/s to the east}}$$

b. $\Delta KE = KE_f - KE_i$

$$KE_i = \tfrac{1}{2} m_1 v_{1,i}^2 + \tfrac{1}{2} m_2 v_{2,i}^2 = \tfrac{1}{2}(88 \text{ kg})(5.0 \text{ m/s})^2 + \tfrac{1}{2}(97 \text{ kg})(-3.0 \text{ m/s})^2$$

$$KE_i = 1100 \text{ J} + 440 \text{ J} = 1.5 \times 10^3 \text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(88 \text{ kg} + 97 \text{ kg})(0.81 \text{ m/s})^2 = \tfrac{1}{2}(185 \text{ kg})(0.81 \text{ m/s})^2 = 61 \text{ J}$$

$$\Delta KE = KE_f - KE_i = 61 \text{ J} - 1.5 \times 10^3 \text{ J} = -1.4 \times 10^3 \text{ J}$$

The kinetic energy decreases by $\boxed{1.4 \times 10^3 \text{ J}}$.

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32. $m_1 = 5.0$ g $\mathbf{v_{1,i}}$ = 25.0 cm/s to the right = +25.0 cm/s $m_2 = 15.0$ g $\mathbf{v_{2,i}}$ = 0 m/s $\mathbf{v_{1,f}}$ = 12.5 cm/s to the left = −12.5 cm/s	**a.** $\mathbf{v_{2,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$ $\mathbf{v_{2,f}} = \frac{(5.0\text{ g})(25.0\text{ cm/s}) + (15.0\text{ g})(0\text{ m/s}) - (5.0\text{ g})(-12.5\text{ cm/s})}{15.0\text{ g}}$ $\mathbf{v_{2,f}} = \frac{120\text{ g}\bullet\text{cm/s} + 62\text{ g}\bullet\text{cm/s}}{15.0\text{ g}} = \frac{180\text{ g}\bullet\text{cm/s}}{15.0\text{ g}} = 12\text{ cm/s}$ $\mathbf{v_{2,f}} = \boxed{12\text{ cm/s to the right}}$ **b.** $\Delta KE_2 = KE_{2,f} - KE_{2,i} = \frac{1}{2}m_2v_{2,f}^2 - \frac{1}{2}m_2v_{2,i}^2$ $\Delta KE_2 = \frac{1}{2}(15.0 \times 10^{-3}\text{ kg})(0.12\text{ m/s})^2 - \frac{1}{2}(15.0 \times 10^{-3}\text{ kg})(0\text{ m/s})^2$ $\Delta KE_2 = \boxed{1.1 \times 10^{-4}\text{ J}}$
33. $v_{1,i} = 4.0$ m/s $v_{2,i} = 0$ m/s $m_1 = m_2$ $v_{1,f} = 0$ m/s	$v_{2,f} = \frac{m_1v_{1,i} + m_2v_{2,i} - m_1v_{1,f}}{m_2}$ $m_1 = m_2$ $v_{2,f} = v_{1,i} + v_{2,i} - v_{1,f} = 4.0\text{ m/s} + 0\text{ m/s} - 0\text{ m/s} = \boxed{4.0\text{ m/s}}$
34. $m_1 = 25.0$ g $\mathbf{v_{1,i}}$ = 20.0 cm/s to the right $m_2 = 10.0$ g $\mathbf{v_{2,i}}$ = 15.0 cm/s to the right $\mathbf{v_{2,f}}$ = 22.1 cm/s to the right	$\mathbf{v_{1,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_2\mathbf{v_{2,f}}}{m_1}$ $\mathbf{v_{1,f}} = \frac{(25.0\text{ g})(20.0\text{ cm/s}) + (10.0\text{ g})(15.0\text{ cm/s}) - (10.0\text{ g})(22.1\text{ cm/s})}{25.0\text{ g}}$ $\mathbf{v_{1,f}} = \frac{5.00 \times 10^2\text{ g}\bullet\text{cm/s} + 1.50 \times 10^2\text{ g}\bullet\text{cm/s} - 2.21 \times 10^2\text{ g}\bullet\text{cm/s}}{25.0\text{ g}}$ $\mathbf{v_{1,f}} = \frac{429\text{ g}\bullet\text{cm/s}}{25.0\text{ g}} = \boxed{17.2\text{ cm/s to the right}}$
35. $m = 0.147$ kg $\mathbf{p}$ = 6.17 kg•m/s toward second base	$\mathbf{v} = \frac{\mathbf{p}}{m} = \frac{6.17\text{ kg}\bullet\text{m/s}}{0.147\text{ kg}} = \boxed{42.0\text{ m/s toward second base}}$
36. $KE = 150$ J $p = 30.0$ kg•m/s	$KE = \frac{1}{2}mv^2$ $m = \frac{p}{v}$ $KE = \frac{1}{2}\left(\frac{p}{v}\right)v^2 = \frac{pv}{2}$ $v = \frac{2KE}{p} = \frac{(2)(150\text{ J})}{30.0\text{ kg}\bullet\text{m/s}} = \boxed{1.0 \times 10^1\text{ m/s}}$ $m = \frac{p}{v} = \frac{30.0\text{ kg}\bullet\text{m/s}}{1.0 \times 10^1\text{ m/s}} = \boxed{3.0\text{ kg}}$

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37. $m = 0.10$ kg

$\mathbf{v_i} = 15.0$ m/s straight up

$a = -9.81$ m/s^2

a. At its maximum height, $\mathbf{v} = 0$ m/s.

$$\mathbf{p} = m\mathbf{v} = (0.10 \text{ kg})(0 \text{ m/s}) = \boxed{0.0 \text{ kg•m/s}}$$

b. Halfway to its maximum height (where $v_f = 0$ m/s),

$$\Delta y = \left(\frac{1}{2}\right)\left(\frac{v_f^2 - v_i^2}{2a}\right) = \frac{(0 \text{ m/s})^2 - (15.0 \text{ m/s})^2}{(4)(-9.81 \text{ m/s}^2)} = 5.73 \text{ m}$$

Now let $\mathbf{v_f}$ represent the velocity at $\Delta y = 5.73$ m.

$$v_f = \pm\sqrt{v_i^2 + 2a\Delta x} = \pm\sqrt{(15.0 \text{ m/s})^2 + (2)(-9.81 \text{ m/s}^2)(5.73 \text{ m})}$$

$$v_f = \pm\sqrt{225 \text{ m}^2/\text{s}^2 - 112 \text{ m}^2/\text{s}^2} = \pm\sqrt{113 \text{ m}^2/\text{s}^2} = \pm 10.6 \text{ m/s}$$

$\mathbf{v_f} = 10.6$ m/s upward

$$\mathbf{p} = m\mathbf{v_f} = (0.10 \text{ kg})(10.6 \text{ m/s}) = \boxed{1.1 \text{ kg•m/s upward}}$$

---

38. $m_1 = 3.00$ kg

$v_{2,i} = 0$ m/s

$v_f = \frac{1}{3}v_{1,i}$, or $v_{1,i} = 3v_f$

$$m_1v_{1,i} + m_2v_{2,i} = m_1v_f + m_2v_f$$

$$m_2(v_{2,i} - v_f) = m_1v_f - m_1v_{1,i}$$

$$m_2 = \frac{m_1v_f - m_1v_{1,i}}{v_{2,i} - v_f}, \text{ where } v_{2,i} = 0 \text{ m/s}$$

$$m_2 = \frac{m_1v_f - m_1(3v_f)}{-v_f} = -(m_1 - 3m_1) = -m_1 + 3m_1$$

$$m_2 = 2m_1 = (2)(3.00 \text{ kg}) = \boxed{6.00 \text{ kg}}$$

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39. $m_1 = 5.5$ g

$m_2 = 22.6$ g

$v_{2,i} = 0$ m/s

$\Delta y = -1.5$ m

$\Delta x = 2.5$ m

$a = -9.81$ m/s^2

For an initial downward speed of zero,

$$\Delta y = \tfrac{1}{2}a\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{a}}$$

$$v_f = \frac{\Delta x}{\Delta t} = \frac{\Delta x}{\sqrt{\frac{2\Delta y}{a}}} = \Delta x\sqrt{\frac{a}{2\Delta y}}$$

$$v_f = (2.5 \text{ m})\sqrt{\frac{-9.81 \text{ m/s}^2}{(2)(-1.5 \text{ m})}} = 4.5 \text{ m/s}$$

$$v_{1,i} = \frac{(m_1 + m_2)v_f - m_2v_{2,i}}{m_1}$$

$$v_{1,i} = \frac{(5.5 \text{ g} + 22.6 \text{ g})(1 \text{ kg}/10^3 \text{ g})(4.5 \text{ m/s}) - (22.6 \times 10^{-3} \text{ kg})(0 \text{ m/s})}{5.5 \times 10^{-3} \text{ kg}}$$

$$v_{1,i} = \frac{(28.1 \times 10^{-3} \text{ kg})(4.5 \text{ m/s})}{5.5 \times 10^{-3} \text{ kg}} = \boxed{23 \text{ m/s}}$$

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40. Givens:

$m_1 = \dfrac{730\text{ N}}{9.81\text{m/s}^2}$

$R = 5.0$ m

$m_2 = 2.6$ kg

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{2,f}} = 5.0$ m/s to the north

Solutions:

Because the initial momentum is zero,

$$\mathbf{v_{1,f}} = \frac{-m_2\mathbf{v_{2,f}}}{m_1} = \frac{-(2.6\text{ kg})(5.0\text{ m/s})}{\left(\dfrac{730\text{ N}}{9.81\text{ m/s}^2}\right)} = -0.17\text{ m/s} = 0.17\text{ m/s to the south}$$

$$\Delta t = \frac{\Delta\mathbf{x}}{\mathbf{v_{1,f}}} = \frac{-R}{v_{1,f}} = \frac{-5.0\text{ m}}{-0.17\text{ m/s}} = \boxed{29\text{ s}}$$

---

41. Givens:

$m = 0.025$ kg

$v_i = 18.0$ m/s

$\Delta t = 5.0 \times 10^{-4}$ s

$v_f = 10.0$ m/s

Solutions:

$$F = \frac{mv_f - mv_i}{\Delta t} = \frac{(0.025\text{ kg})(10.0\text{ m/s}) - (0.025\text{ kg})(18.0\text{ m/s})}{5.0\times 10^{-4}\text{ s}}$$

$$F = \frac{0.25\text{ kg}\bullet\text{m/s} - 0.45\text{ kg}\bullet\text{m/s}}{5.0\times 10^{-4}\text{ s}} = \frac{-0.20\text{ kg}\bullet\text{m/s}}{5.0\times 10^{-4}\text{ s}} = -4.0\times 10^2\text{ N}$$

magnitude of the force = $\boxed{4.0\times 10^2\text{ N}}$

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42. Givens:

$m_1 = 1550$ kg

$\mathbf{v_{1,i}} = 10.0$ m/s to the south $= -10.0$ m/s

$m_2 = 2550$ kg

$\mathbf{v_f} = 5.22$ m/s to the north $= +5.22$ m/s

Solutions:

$$\mathbf{v_{2,i}} = \frac{(m_1 + m_2)\mathbf{v_f} - m_1\mathbf{v_{1,i}}}{m_2} = \frac{(1550\text{ kg} + 2550\text{ kg})(5.22\text{ m/s}) - (1550\text{ kg})(-10.0\text{ m/s})}{2550\text{ kg}}$$

$$\mathbf{v_{2,i}} = \frac{(4.10\times 10^3\text{ kg})(5.22\text{ m/s}) - (1550\text{ kg})(-10.0\text{ m/s})}{2550\text{ kg}}$$

$$\mathbf{v_{2,i}} = \frac{2.14\times 10^4\text{ kg}\bullet\text{m/s} + 1.55\times 10^4\text{ kg}\bullet\text{m/s}}{2550\text{ kg}} = \frac{3.69\times 10^4\text{ kg}\bullet\text{m/s}}{2550\text{ kg}}$$

$\mathbf{v_{2,i}} = 14.5$ m/s = $\boxed{14.5\text{ m/s to the north}}$

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43. Givens:

$m_1 = 52.0$ g

$m_2 = 153$ g

$v_{1,i} = 0$ m/s

$v_{2,i} = 0$ m/s

$v_{1,f} = 2.00$ m/s

$g = 9.81$ m/s^2

Solutions:

Because the initial momentum is zero,

$$v_{2,f} = \frac{-m_1v_{1,f}}{m_2} = \frac{-(52.0\text{ g})(2.00\text{ m/s})}{153\text{ g}} = -0.680\text{ m/s}$$

$KE_i = PE_f$

$\frac{1}{2}mv_{2,f}{}^2 = mgh$

$$h = \frac{v_{2,f}{}^2}{2g} = \frac{(-0.680\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)} = \boxed{2.36\times 10^{-2}\text{ m} = 2.36\text{ cm}}$$

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44. Givens:

$m_1 = 85.0$ kg

$m_2 = 0.500$ kg

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{2,f}} = 20.0$ m/s away from ship $= -20.0$ m/s

$\Delta x = 30.0$ m

Solutions:

Because the initial momentum is zero,

$$\mathbf{v_{1,f}} = \frac{-m_2\mathbf{v_{2,f}}}{m_1} = \frac{-(0.500\text{ kg})(-20.0\text{ m/s})}{85.0\text{ kg}} = 0.118\text{ m/s toward the ship}$$

$$\Delta t = \frac{\Delta x}{v_{1,f}} = \frac{30.0\text{ m}}{0.118\text{ m/s}} = \boxed{254\text{ s}}$$

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45. $m_1 = 2250$ kg
$v_{1,i} = 10.0$ m/s
$m_2 = 2750$ kg
$v_{2,i} = 0$ m/s
$d = 2.50$ m
$\theta = 180°$
$g = 9.81$ m/s^2

$$v_f = \frac{m_i v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(2250\text{ kg})(10.0\text{ m/s}) + (2750\text{ kg})(0\text{ m/s})}{2250\text{ kg} + 2750\text{ kg}}$$

$$v_f = \frac{(2250\text{ kg})(10.0\text{ m/s})}{5.00 \times 10^3\text{ kg}} = 4.50\text{ m/s}$$

From the work-kinetic energy theorem,

$$W_{net} = \Delta KE = KE_f - KE_i = \tfrac{1}{2}(m_1 + m_2)(v_f')^2 - \tfrac{1}{2}(m_1 + m_2)(v_i')^2$$

where

$v_i' = 4.50$ m/s $\quad v_f' = 0$ m/s

$$W_{net} = W_{friction} = F_k d(\cos\theta) = (m_1 + m_2)g\mu_k d(\cos\theta)$$

$$(m_1 + m_2)g\mu_k d(\cos\theta) = \tfrac{1}{2}(m_1 + m_2)[(v_f')^2 - (v_i')^2]$$

$$\mu_k = \frac{(v_f')^2 - (v_i')^2}{2\,gd(\cos\theta)} = \frac{(0\text{ m/s})^2 - (4.50\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)(2.50\text{ m})(\cos 180°)} = \frac{-(4.50\text{ m/s})^2}{-(2)(9.81\text{ m/s}^2)(2.50\text{ m})}$$

$$\mu_k = \boxed{0.413}$$

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46. $\mathbf{F} = 2.5$ N to the right
$m = 1.5$ kg
$\Delta t = 0.50$ s
$\mathbf{v_i} = 0$ m/s

a. $$\mathbf{v_f} = \frac{\mathbf{F}\Delta t + m\mathbf{v_i}}{m} = \frac{(2.5\text{ N})(0.50\text{ s}) + (1.5\text{ kg})(0\text{ m/s})}{1.5\text{ kg}}$$

$$\mathbf{v_f} = 0.83\text{ m/s}\ \boxed{0.83\text{ m/s to the right}}$$

$\mathbf{v_i} = 2.0$ m/s to the left
$= -2.0$ m/s

b. $$\mathbf{v_f} = \frac{\mathbf{F}\Delta t + m\mathbf{v_i}}{m} = \frac{(2.5\text{ N})(0.50\text{ s}) + (1.5\text{ kg})(-2.0\text{ m/s})}{1.5\text{ kg}}$$

$$\mathbf{v_f} = \frac{1.2\text{ N}\bullet\text{s} + (-3.0\text{ kg}\bullet\text{m/s})}{1.5\text{ kg}} = \frac{-1.8\text{ kg}\bullet\text{m/s}}{1.5\text{ kg}} = -1.2\text{ m/s}$$

$$\mathbf{v_f} = \boxed{1.2\text{ m/s to the left}}$$

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47. $m_1 = m_2$
$v_{1,i} = 22$ cm/s
$v_{2,i} = -22$ cm/s

Because $m_1 = m_2$, $v_{2,f} = v_{1,i} + v_{2,i} - v_{1,f}$.

Because kinetic energy is conserved and the two masses are equal,

$$\tfrac{1}{2}v_{1,i}^2 + \tfrac{1}{2}v_{2,i}^2 = \tfrac{1}{2}v_{1,f}^2 + \tfrac{1}{2}v_{2,f}^2$$

$$v_{1,i}^2 + v_{2,i}^2 = v_{1,f}^2 + v_{2,f}^2$$

$$v_{1,i}^2 + v_{2,i}^2 = v_{1,f}^2 + (v_{1,i} + v_{2,i} - v_{1,f})^2$$

$$(22\text{ cm/s})^2 + (-22\text{ cm/s})^2 = v_{1,f}^2 + (22\text{ cm/s} - 22\text{ cm/s} - v_{1,f})^2$$

$$480\text{ cm}^2/\text{s}^2 + 480\text{ cm}^2/\text{s}^2 = 2v_{1,f}^2$$

$$v_{1,f} = \pm\sqrt{480\text{ cm}^2/\text{s}^2} = \pm 22\text{ cm/s}$$

Because m_1 cannot pass through m_2, it follows that $v_{1,f}$ is opposite $v_{1,i}$.

$$v_{1,f} = \boxed{-22\text{ cm/s}}$$

$$v_{2,f} = v_{1,i} + v_{2,i} - v_{1,f}$$

$$v_{2,f} = 22\text{ cm/s} + (-22\text{ cm/s}) - (-22\text{ cm/s}) = \boxed{22\text{ cm/s}}$$

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48. $m_1 = 7.50$ kg

$\Delta y = -3.00$ m

$m_2 = 5.98 \times 10^{24}$ kg

$v_{1,i} = 0$ m/s

$v_{2,i} = 0$ m/s

$a = -9.81$ m/s^2

a. $v_{1,f} = \pm\sqrt{2a\Delta y} = \pm\sqrt{(2)(-9.81 \text{ m/s}^2)(-3.00 \text{ m})} = \pm 7.67 \text{ m/s} = -7.67 \text{ m/s}$

Because the initial momentum is zero,

$m_1 v_{1,f} = -m_2 v_{2,f}$

$$v_{2,f} = \frac{-m_1 v_{1,f}}{m_2} = \frac{-(7.50 \text{ kg})(-7.67 \text{ m/s})}{5.98 \times 10^{24} \text{ kg}} = \boxed{9.62 \times 10^{-24} \text{ m/s}}$$

49. $m = 55$ kg

$\Delta y = -5.0$ m

$\Delta t = 0.30$ s

$\mathbf{v_i} = 0$ m/s

$a = -9.81$ m/s^2

$\mathbf{v_i} = 9.9$ m/s downward $= -9.9$ m/s

$\mathbf{v_f} = 0$ m/s

a. $v_f = \pm\sqrt{2a\Delta y} = \pm\sqrt{(2)(-9.81 \text{ m/s}^2)(-5.0 \text{ m})} = \pm 9.9 \text{ m/s}$

$\mathbf{v_f} = -9.9 \text{ m/s} = \boxed{9.9 \text{ m/s downward}}$

b. $$\mathbf{F} = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \frac{(55 \text{ kg})(0 \text{ m/s}) - (55 \text{ kg})(-9.9 \text{ m/s})}{0.30 \text{ s}}$$

$\mathbf{F} = 1.8 \times 10^3 \text{ N} = \boxed{1.8 \times 10^3 \text{ N upward}}$

50. $m_{nuc} = 17.0 \times 10^{-27}$ kg

$m_1 = 5.0 \times 10^{-27}$ kg

$m_2 = 8.4 \times 10^{-27}$ kg

$\mathbf{v_{nuc,i}} = 0$ m/s

$\mathbf{v_{1,f}} = 6.0 \times 10^6$ m/s along the positive y-axis

$\mathbf{v_{2,f}} = 4.0 \times 10^6$ m/s along the positive x-axis

$m_3 = m_{nuc} - (m_1 + m_2) = (17.0 \times 10^{-27} \text{ kg}) - [(5.0 \times 10^{-27} \text{ kg}) + (8.4 \times 10^{-27} \text{ kg})]$

$m_3 = 3.6 \times 10^{-27}$ kg

$p_1 = m_1 v_{1,f} = (5.0 \times 10^{-27} \text{ kg})(6.0 \times 10^6 \text{ m/s}) = 3.0 \times 10^{-20} \text{ kg•m/s}$

$p_2 = m_2 v_{2,f} = (8.4 \times 10^{-27} \text{ kg})(4.0 \times 10^6 \text{ m/s}) = 3.4 \times 10^{-20} \text{ kg•m/s}$

Because the initial momentum is zero, the final momentum must also equal zero.

$\mathbf{p_1} + \mathbf{p_2} + \mathbf{p_3} = 0$ kg•m/s

$\mathbf{p_3} = -(\mathbf{p_1} + \mathbf{p_2})$

Because $\mathbf{p_1}$ and $\mathbf{p_2}$ are along the y-axis and the x-axis, respectively, the magnitude of $\mathbf{p_3}$ can be found by using the Pythagorean theorem.

$p_3 = \sqrt{p_1^2 + p_2^2} = \sqrt{(3.0 \times 10^{-20} \text{ kg•m/s})^2 + (3.4 \times 10^{-20} \text{ kg•m/s})^2}$

$p_3 = \sqrt{(9.0 \times 10^{-40} \text{ kg}^2\text{•m}^2/\text{s}^2) + (1.2 \times 10^{-39} \text{ kg}^2\text{•m}^2/\text{s}^2)}$

$p_3 = \sqrt{(21 \times 10^{-40} \text{ kg}^2\text{•m}^2/\text{s}^2)} = 4.6 \times 10^{-20} \text{ kg•m/s}$

$$v_{3,f} = \frac{p_3}{m_3} = \frac{4.6 \times 10^{-20} \text{ kg•m/s}}{3.6 \times 10^{-27} \text{ kg}} = \boxed{1.3 \times 10^7 \text{ m/s}}$$

Because $\mathbf{p_{1,2}}$ is between the positive x-axis and the positive y-axis and because $\mathbf{p_3} = -\mathbf{p_{1,2}}$, $\mathbf{p_3}$ must be between the negative x-axis and the negative y-axis.

$$\tan\theta = \frac{p_1}{p_2}$$

$$\theta = \tan^{-1}\left(\frac{p_1}{p_2}\right) = \tan^{-1}\left(\frac{3.0}{3.4}\right) = \boxed{41° \text{ below the negative } x\text{-axis}}$$

I

I

Givens	*Solutions*
3. $m = 0.148$ kg $\mathbf{v} = 35$ m/s toward home plate	$\mathbf{p} = m\mathbf{v} = (0.148\text{ kg})(35\text{ m/s}) = \boxed{5.2\text{ kg}\bullet\text{m/s toward home plate}}$
4. $m_1 = 1.5$ kg $\mathbf{v_{1,i}} = 3.0$ m/s to the right $m_2 = 1.5$ kg $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{1,f}} = 0.5$ m/s to the right	**a.** $\mathbf{v_{2,f}} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$ $m_1 = m_2$ $\mathbf{v_{2,f}} = \mathbf{v_{1,i}} + \mathbf{v_{2,i}} - \mathbf{v_{1,f}}$ $\mathbf{v_{2,f}} = 3.0\text{ m/s} + 0\text{ m/s} - 0.5\text{ m/s} = \boxed{2.5\text{ m/s to the right}}$
5. $\mathbf{v_{1,f}} = 0$ m/s	$\mathbf{v_{2,f}} = \mathbf{v_{1,i}} + \mathbf{v_{2,i}} - \mathbf{v_{1,f}} = 3.0\text{ m/s} + 0\text{ m/s} - 0\text{ m/s} = \boxed{3.0\text{ m/s to the right}}$
8. $m_1 = m_2$ $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 5.00$ m/s to the right $\mathbf{v_{2,f}} = 0$ m/s	$\mathbf{v_{1,f}} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_2\mathbf{v_{2,f}}}{m_1}$ $m_1 = m_2$ $\mathbf{v_{1,f}} = \mathbf{v_{1,i}} + \mathbf{v_{2,i}} - \mathbf{v_{2,f}} = 0\text{ m/s} + 5.00\text{ m/s} - 0\text{ m/s}$ $\mathbf{v_{1,f}} = \boxed{5.00\text{ m/s to the right}}$
9. $m_1 = 0.400$ kg $\mathbf{v_{1,i}} = 3.50$ cm/s right, $v_{1,i} = 3.50$ cm/s $m_2 = 0.600$ kg $\mathbf{v_{2,i}} = 0$ $\mathbf{v_{1,f}} = 0.07$ cm/s left, $v_{1,f} = -0.70$ cm/s	$\mathbf{v_{2,f}} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$ $v_{2,f} = \dfrac{(0.400\text{ kg})(3.50\text{ cm/s}) + (0.600\text{ kg})(0) - (0.400\text{ kg})(-0.70\text{ cm/s})}{0.600\text{ kg}}$ $v_{2,f} = \dfrac{1.40\text{ kg}\bullet\text{cm/s} + 0.28\text{ kg}\bullet\text{cm/s}}{0.600\text{ kg}} = \dfrac{1.68\text{ kg}\bullet\text{cm/s}}{0.600\text{ kg}} = 2.80\text{ cm/s}$ $\mathbf{v_{2,f}} = \boxed{2.80\text{ cm/s to the right}}$
10. $m_1 = 0.400$ kg $v_{1,f} = -0.70 \times 10^{-2}$ m/s $m_2 = 0.600$ kg $v_{2,f} = 2.80 \times 10^{-2}$ m/s	$KE_f = \frac{1}{2}m_1v_{1,f}{}^2 + \frac{1}{2}m_2v_{2,f}{}^2$ $KE_f = \frac{1}{2}(0.400\text{ kg})(-0.70 \times 10^{-2}\text{ m/s})^2 + \frac{1}{2}(0.600\text{ kg})(2.80 \times 10^{-2}\text{ m/s})^2$ $KE_f = 9.8 \times 10^{-6}\text{ kg}\bullet\text{m}^2/\text{s}^2 + 2.35 \times 10^{-4}\text{ kg}\bullet\text{m}^2/\text{s}^2$ $KE_f = \boxed{2.45 \times 10^{-4}\text{ J}}$
13. $m_1 = 8.0$ g $m_2 = 2.5$ kg $v_{2,i} = 0$ m/s $h = 6.0$ cm $g = 9.81\text{ m/s}^2$	$KE_i = PE_f$ $\frac{1}{2}mv_f{}^2 = mgh$ $v_f = \sqrt{2gh} = \sqrt{(2)(9.81\text{ m/s}^2)(0.060\text{ m})} = 1.1\text{ m/s}$ $v_{1,i} = \dfrac{(m_1 + m_2)v_f - m_2v_{2,i}}{m_1} = \dfrac{(0.0080\text{ kg} + 2.5\text{ kg})(1.1\text{ m/s}) - (2.5\text{ kg})(0\text{ m/s})}{0.0080\text{ kg}}$ $v_{1,i} = \dfrac{(2.5\text{ kg})(1.1\text{ m/s})}{0.0080\text{ kg}} = \boxed{340\text{ m/s}}$

Givens | *Solutions*

14. $m_1 = 8.0\ \text{g} = 0.0080\ \text{kg}$

$m_2 = 2.5\ \text{kg}$

$g = 9.81\ \text{m/s}^2$

$h = 6.0\ \text{cm} = 0.060\ \text{m}$

$KE_{lowest} = KE_i = PE_f = mgh$

$KE_{lowest} = (m_1 + m_2)gh$

$KE_{lowest} = (0.0080\ \text{kg} + 2.5\ \text{kg})(9.81\ \text{m/s}^2)(0.060\text{m})$

$KE_{lowest} = \boxed{1.5\ \text{J}}$

I

Circular Motion and Gravitation

Circular Motion and Gravitation, Practice A

Givens	*Solutions*
1. $a_c = 3.0 \text{ m/s}^2$ $r = 2.1 \text{ m}$	$v_t = \sqrt{a_c r} = \sqrt{(3.0 \text{ m/s}^2)(2.1 \text{ m})} = \boxed{2.5 \text{ m/s}}$
2. $a_c = 250 \text{ m/s}^2$ $r = 0.50 \text{ m}$	$v_t = \sqrt{a_c r} = \sqrt{(250 \text{ m/s}^2)(0.50 \text{ m})} = \boxed{11 \text{ m/s}}$
3. $r = 1.5 \text{ m}$ $v_t = 1.5 \text{ m/s}$	$a_c = \frac{v_t^2}{r} = \frac{(1.5 \text{ m/s})^2}{1.5 \text{ m}} = \boxed{1.5 \text{ m/s}^2}$
4. $a_c = 15.4 \text{ m/s}^2$ $v_t = 30.0 \text{ m/s}$	$r = \frac{v_t^2}{a_c} = \frac{(30.0 \text{ m/s})^2}{15.4 \text{ m/s}^2} = \boxed{58.4 \text{ m}}$

Circular Motion and Gravitation, Practice B

1. $r = 2.10 \text{ m}$ $v_t = 2.50 \text{ m/s}$ $F_c = 88.0 \text{ N}$	$m = F_c \frac{r}{v_t^2} = (88.0 \text{ N}) \frac{(2.10 \text{ m})}{(2.50 \text{ m/s})^2} = \boxed{29.6 \text{ kg}}$
2. $v_t = 13.2 \text{ m/s}$ $F_c = 377 \text{ N}$ $m = 86.5 \text{ kg}$	$r = \frac{m v_t^2}{F_c} = \frac{(86.5 \text{ kg})(13.2 \text{ m/s})^2}{377 \text{ N}} = \boxed{40.0 \text{ m}}$
3. $r = 1.50 \text{ m}$ $v_t = 1.80 \text{ m/s}$ $m = 18.5 \text{ kg}$	$F_c = \frac{m v_t^2}{r} = \frac{(18.5 \text{ kg})(1.80 \text{ m/s})^2}{1.50 \text{ m}} = \boxed{40.0 \text{ N}}$
4. $m = 905 \text{ kg}$ $r = \frac{3.25 \text{ km}}{2\pi}$ $F_c = 2140 \text{ N}$	$v_t = \sqrt{\frac{r F_c}{m}} = \sqrt{\left(\frac{3.25 \times 10^3 \text{ m}}{2\pi}\right)\left(\frac{2140 \text{ N}}{905 \text{ kg}}\right)} = \boxed{35.0 \text{ m/s}}$

Circular Motion and Gravitation, Section 1 Review

I

Givens	*Solutions*
2. $r = 12$ m $a_c = 17$ m/s^2	$v_t = \sqrt{a_c r} = \sqrt{(17 \text{ m/s}^2)(12 \text{ m})} = \boxed{14 \text{ m/s}}$
5. $m = 90.0$ kg $r = 11.5$ m $v_t = 13.2$ m/s	$F_c = \dfrac{m v_t^2}{r} = \dfrac{(90.0 \text{ kg})(13.2 \text{ m/s})^2}{11.5 \text{ m}} = \boxed{1360 \text{ N}}$

Circular Motion and Gravitation, Practice C

1. $m_1 = m_2 = 0.800$ kg

$F_g = 8.92 \times 10^{-11}$ N

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{G\, m_1 m_2}{F_g}} = \sqrt{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(0.800 \text{ kg})(0.800 \text{ kg})}{8.92 \times 10^{-11} \text{ N}}}$$

$$r = \boxed{0.692 \text{ m}}$$

2. $m_1 = 6.4 \times 10^{23}$ kg

$m_2 = 9.6 \times 10^{15}$ kg

$F_g = 4.6 \times 10^{15}$ N

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{G\, m_1 m_2}{F_g}} = \sqrt{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(6.4 \times 10^{23} \text{ kg})(9.6 \times 10^{15} \text{ kg})}{4.6 \times 10^{15} \text{ N}}}$$

$$r = \boxed{9.4 \times 10^6 \text{ m} = 9.4 \times 10^3 \text{ km}}$$

3. $m_1 = 66.5$ kg

$m_2 = 5.97 \times 10^{24}$ kg

$r = 6.38 \times 10^6$ m

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

a. $$F_g = G\frac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(66.5 \text{ kg})(5.97 \times 10^{24} \text{ kg})}{(6.38 \times 10^6 \text{ m})^2} = \boxed{651 \text{ N}}$$

$m_2 = 6.42 \times 10^{23}$ kg

$r = 3.40 \times 10^6$ m

b. $$F_g = G\frac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(66.5 \text{ kg})(6.42 \times 10^{23} \text{ kg})}{(3.40 \times 10^6 \text{ m})^2} = \boxed{246 \text{ N}}$$

$m_2 = 1.25 \times 10^{22}$ kg

$r = 1.20 \times 10^6$ m

c. $$F_g = G\frac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(66.5 \text{ kg})(1.25 \times 10^{22} \text{ kg})}{(1.20 \times 10^6 \text{ m})^2} = \boxed{38.5 \text{ N}}$$

Givens	*Solutions*
3. $m_E = 5.97 \times 10^{24}$ kg $r_E = 6.38 \times 10^6$ m $m = 65.0$ kg $G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$	**a.** $F_g = G\dfrac{mm_E}{r_E^2}$ $F_g = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)\dfrac{(65.0\text{ kg})(5.97 \times 10^{24}\text{ kg})}{(6.38 \times 10^6\text{ m})^2} = \boxed{636\text{ N}}$
$m_E = 5.97 \times 10^{24}$ kg $r = 7.38 \times 10^6$ m $m = 65.0$ kg	**b.** $F_g = G\dfrac{mm_E}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)\dfrac{(65.0\text{ kg})(5.97 \times 10^{24}\text{ kg})}{(7.38 \times 10^6\text{ m})^2} = \boxed{475\text{ N}}$
$m_S = 5.68 \times 10^{26}$ kg $r_S = 6.03 \times 10^7$ m $m = 65.0$ kg	**c.** $F_g = \dfrac{G\,mm_S}{r_S^2}$ $F = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)\dfrac{(65.0\text{ kg})(5.68 \times 10^{26}\text{ kg})}{(6.03 \times 10^7\text{ m})^2} = \boxed{678\text{ N}}$
$m_S = 5.68 \times 10^{26}$ kg $r = 6.13 \times 10^7$ m $m = 65.0$ kg	**d.** $F_g = G\dfrac{mm_S}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)\dfrac{(65.0\text{ kg})(5.68 \times 10^{26}\text{ kg})}{(6.13 \times 10^7\text{ m})^2} = \boxed{656\text{ N}}$
5. $r_E = 6.38 \times 10^6$ m $g = 9.81$ m/s^2 $G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$	$g = G\dfrac{m_E}{r_E^2}$, so $m_E = \dfrac{gr_E^2}{G}$ $m_E = \dfrac{(9.81\text{ m/s}^2)(6.38 \times 10^6\text{ m})^2}{6.673 \times 10^{-11}\text{ N•m}^2/\text{kg}^2} = \boxed{5.98 \times 10^{24}\text{ kg}}$

Circular Motion and Gravitation, Practice D

Givens

1. $r = 3.61 \times 10^5$ m

$m_E = 5.97 \times 10^{24}$ kg

$r_E = 6.38 \times 10^6$ m

$m_J = 1.90 \times 10^{27}$ kg

$r_J = 7.15 \times 10^7$ m

$m_m = 7.35 \times 10^{22}$ kg

$r_m = 1.74 \times 10^6$ m

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

Solutions

Above Earth:

$r_1 = r + r_E = 3.61 \times 10^5 \text{ m} + 6.38 \times 10^6 \text{ m} = 6.74 \times 10^6 \text{ m}$

$$v_t = \sqrt{G\frac{m_E}{r_1}}$$

$$v = \sqrt{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{5.97 \times 10^{24} \text{ kg}}{6.74 \times 10^6 \text{ m}}\right)} = \boxed{7.69 \times 10^3 \text{ m/s}}$$

$$T = 2\pi\sqrt{\frac{r_1^3}{Gm_E}}$$

$$T = 2\pi\sqrt{\frac{(6.74 \times 10^6 \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24} \text{ kg})}} = \boxed{5.51 \times 10^3 \text{ s}}$$

Above Jupiter:

$r_2 = r + r_J = 3.61 \times 10^5 \text{ m} + 7.15 \times 10^7 \text{ m} = 7.19 \times 10^7 \text{ m}$

$$v_t = \sqrt{G\frac{m_J}{r_2}}$$

$$v_t = \sqrt{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{1.90 \times 10^{27} \text{ kg}}{7.19 \times 10^7 \text{ m}}\right)} = \boxed{4.20 \times 10^4 \text{ m/s}}$$

$$T = 2\pi\sqrt{\frac{r_2^3}{Gm_J}}$$

$$T = 2\pi\sqrt{\frac{(7.19 \times 10^7 \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.90 \times 10^{27} \text{ kg})}} = \boxed{1.08 \times 10^4 \text{ s}}$$

Above Earth's moon:

$r_3 = r + r_m = 3.61 \times 10^5 \text{ m} + 1.74 \times 10^6 \text{ m} = 2.10 \times 10^6 \text{ m}$

$$v_t = \sqrt{G\frac{m_m}{r_3}}$$

$$v_t = \sqrt{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{7.35 \times 10^{22} \text{ kg}}{2.10 \times 10^6 \text{ m}}\right)} = \boxed{1.53 \times 10^3 \text{ m/s}}$$

$$T = 2\pi\sqrt{\frac{r_3^3}{Gm_m}}$$

$$T = 2\pi\sqrt{\frac{(2.10 \times 10^6 \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(7.35 \times 10^{22} \text{ kg})}} = \boxed{8.63 \times 10^3 \text{ s}}$$

Givens	*Solutions*
2. $T = 125$ min $r_E = 6.38 \times 10^6$ m $m_E = 5.97 \times 10^{24}$ kg $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$T^2 = \frac{4\pi^2 r^3}{Gm_E}$ $r^3 = \frac{T^2 Gm_E}{4\pi^2}$ $r = \sqrt[3]{\frac{[(125\text{ min})(60\text{ s/min})]^2(6.673 \times 10^{-11}\text{ N•m}^2/\text{kg}^2)(5.97 \times 10^{24}\text{ kg})}{4\pi^2}}$ $r = 8.28 \times 10^6$ m height above Earth $= r - r_E = 8.28 \times 10^6\text{ m} - 6.38 \times 10^6\text{ m} = \boxed{1.90 \times 10^6\text{ m}}$

Circular Motion and Gravitation, Section 3 Review

5. $r = 3.84 \times 10^8$ m $m_E = 5.97 \times 10^{24}$ kg $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$v_t = \sqrt{G\frac{m_E}{r}}$ $v_t = \sqrt{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{5.97 \times 10^{24}\text{ kg}}{3.84 \times 10^8\text{ m}}\right)} = \boxed{1.02 \times 10^3\text{ m/s}}$ $T = 2\pi\sqrt{\frac{r^3}{Gm_E}}$ $T = 2\pi\sqrt{\frac{(3.84 \times 10^8\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24}\text{ kg})}} = \boxed{2.37 \times 10^6\text{ s}}$

Circular Motion and Gravitation, Practice E

1. $F = 3.0$ N $d = 0.25$ m $\theta = 90.0°$	$\tau = Fd(\sin\theta) = (3.0\text{ N})(0.25\text{ m})(\sin 90.0°) = \boxed{0.75\text{ N•m}}$
2. $m = 3.0$ kg $d = 2.0$ m $\theta_1 = 5.0°$ $g = 9.81\text{ m/s}^2$	**a.** $\tau = Fd(\sin\theta_1) = mgd(\sin\theta_1)$ $\tau = (3.0\text{ kg})(9.81\text{ m/s}^2)(2.0\text{ m})(\sin 5.0°) = \boxed{5.1\text{ N•m}}$
$\theta_2 = 15.0°$	**b.** $\tau = mgd(\sin\theta_2) = (3.0\text{ kg})(9.81\text{ m/s}^2)(2.0\text{ m})(\sin 15.0°) = \boxed{15\text{ N•m}}$
3. $\tau = 40.0$ N•m $d = 30.0$ cm	For a given torque, the minimum force must be applied perpendicular to the lever arm, or $\sin\theta = 1$. Therefore, $F = \frac{\tau}{d} = \frac{40.0\text{ N•m}}{0.300\text{ m}} = \boxed{133\text{ N}}$

Circular Motion and Gravitation, Section 4 Review

Givens	*Solutions*
5. $eff = 0.73$ $d_{in} = 18.0$ m $d_{out} = 3.0$ m $m = 58$ kg $g = 9.81$ m/s^2	$eff = \dfrac{W_{out}}{W_{in}}$ $eff = \dfrac{F_{out}d_{out}}{F_{in}d_{in}}$ where $F_{out} = mg$ $F_{in} = \dfrac{mgd_{out}}{eff\,d_{in}} = \dfrac{(58\text{ kg})(9.81\text{ m/s}^2)(3.0\text{ m})}{(0.73)(18.0\text{ m})} = \boxed{1.3 \times 10^2\text{ N}}$
6. $F_g = 950$ N $F_{applied} = 350$ N	$MA = \dfrac{F_{out}}{F_{in}} = \dfrac{F_g}{F_{applied}} = \dfrac{950\text{ N}}{350\text{ N}} = \boxed{2.7}$
8. $F_{30} = 30.0$ N $\theta_{30} = 45°$ $d_{30} = 0$ m $F_{25} = 25.0$ N $\theta_{25} = 59°$ $d_{25} = 2.0$ m $F_{10} = 10.0$ N $\theta_{10} = 23°$ $d_{10} = 4.0$ m	$\tau_{30} = F_{30}d_{30}(\sin\theta_{30}) = (30.0\text{ N})(0\text{ m})(\sin 45°) = \boxed{0\text{ N•m}}$ $\tau_{25} = F_{25}d_{25}(\sin\theta_{25}) = (25.0\text{ N})(2.0\text{ m})(\sin 59°) = \boxed{43\text{ N•m}}$ $\tau_{10} = F_{10}d_{10}(\sin\theta_{10}) = (-10.0\text{ N})(4.0\text{ m})(\sin 23°) = \boxed{-16\text{ N•m}}$ The bar will rotate counterclockwise because τ_{net} is positive (43 N•m – 16 N•m = +27 N•m).

Circular Motion and Gravitation, Chapter Review

8. $a_c = 145$ m/s^2 $r = 0.34$ m	$v_t = \sqrt{ra_c} = \sqrt{(0.34\text{ m})(145\text{ m/s}^2)} = \boxed{7.0\text{ m/s}}$
9. $a_c = 28$ m/s^2 $r = 27$ cm	$v_t = \sqrt{ra_c} = \sqrt{(27 \times 10^{-2}\text{ m})(28\text{ m/s}^2)} = \boxed{2.7\text{ m/s}}$
10. $v_t = 20.0$ m/s $F_n = 2.06 \times 10^4$ N $r_1 = 10.0$ m $g = 9.81$ m/s^2	**a.** $F_{net} = F_n - F_g = F_n - mg$ $F_{net} = F_c = \dfrac{mv_t^2}{r_1}$ $F_n - mg = \dfrac{mv_t^2}{r_1}$ $mv_t^2 = r_1(F_n - mg)$ $m(v_t^2 + r_1g) = r_1F_n$ $m = \dfrac{r_1F_n}{v_t^2 + r_1g} = \dfrac{(10.0\text{ m})(2.06 \times 10^4\text{ N})}{(20.0\text{ m/s})^2 + (10.0\text{ m})(9.81\text{ m/s}^2)}$ $m = \dfrac{2.06 \times 10^5\text{ N•m}}{4.00 \times 10^2\text{ m}^2/\text{s}^2 + 98.1\text{ m}^2/\text{s}^2} = \dfrac{2.06 \times 10^5\text{ N•m}}{498\text{ m}^2/\text{s}^2}$ $m = \boxed{414\text{ kg}}$

Givens	*Solutions*
$r_2 = 15.0$ m	**b.** $F_c = mg$ $\frac{mv_t^2}{r_2} = mg$ $v_t = \sqrt{gr_2} = \sqrt{(9.81\ \text{m/s}^2)(15.0\ \text{m})} = \boxed{12.1\ \text{m/s}}$

I

11. $r = 10.0$ m

$v_t = 8.0$ m/s

$F_{rope,\ max} = 1.0 \times 10^3$ N

$g = 9.81\ \text{m/s}^2$

$$F_{total} = F_c + F_g = \frac{mv_t^2}{r} + mg$$

$$F_{total} \leq F_{rope,\ max}$$

$$F_{rope,\ max} = m_{max}\left(\frac{v_t^2}{r} + g\right)$$

$$m_{max} = \frac{F_{rope,\ max}}{\frac{v_t^2}{r} + g} = \frac{1.0 \times 10^3\ \text{N}}{\left[\frac{(8.0\ \text{m/s})^2}{10.0\ \text{m}}\right] + 9.81\ \text{m/s}^2}$$

$$m_{max} = \frac{1.0 \times 10^3\ \text{N}}{6.4\ \text{m/s}^2 + 9.81\ \text{m/s}^2} = \frac{1.0 \times 10^3\ \text{N}}{16.2\ \text{m/s}^2}$$

$$m_{max} = \boxed{62\ \text{kg}}$$

18. $F_g = 3.20 \times 10^{-8}$ N

$m_1 = 50.0$ kg

$m_2 = 60.0$ kg

$G = 6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \sqrt{\frac{(6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2)(50.0\ \text{kg})(60.\ \text{kg})}{3.20 \times 10^{-8}\ \text{N}}}$$

$$r = \boxed{2.50\ \text{m}}$$

19. $m_1 = 9.11 \times 10^{-31}$ kg

$m_2 = 1.67 \times 10^{-27}$ kg

$F_g = 1.0 \times 10^{-47}$ N

$G = 6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \frac{(6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^3)(9.11 \times 10^{-31}\ \text{kg})(1.67 \times 10^{-27}\ \text{kg})}{1.0 \times 10^{-47}\ \text{N}}$$

$$r = \boxed{1.0 \times 10^{-10}\ \text{m} = 0.10\ \text{nm}}$$

27. $r = 1.44 \times 10^8$ m

$r_E = 6.38 \times 10^6$ m

$m_E = 5.97 \times 10^{24}$ kg

$G = 6.673 \times 10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$

$$r_1 = r + r_E = 1.44 \times 10^8\ \text{m} + 6.38 \times 10^6\ \text{m} = 1.50 \times 10^8\ \text{m}$$

$$v_t = \sqrt{G\frac{m_E}{r_1}}$$

$$v_t = \sqrt{\left(6.673 \times 10^{-11}\frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\left(\frac{5.97 \times 10^{24}\ \text{kg}}{1.50 \times 10^8\ \text{m}}\right)} = \boxed{1630\ \text{m/s}}$$

$$T = 2\pi\sqrt{\frac{r_1^3}{Gm_E}}$$

$$T = 2\pi\sqrt{\frac{(1.50 \times 10^8\ \text{m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24}\ \text{kg})}} = \boxed{5.78 \times 10^5\ \text{s}}$$

Givens | *Solutions*

28. $T = 24.0$ h

$r_E = 6.38 \times 10^6$ m

$m_E = 5.97 \times 10^{24}$ kg

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$T = 2\pi\sqrt{\frac{r_1^3}{Gm_E}}$$

$$T^2 = 4\pi^2 \frac{r_1^3}{Gm_E}$$

$$r_1 = \sqrt[3]{\frac{T^2 Gm_E}{4\pi^2}}$$

$$r_1 = \sqrt[3]{\frac{\left[(24.0\text{ h})\left(3600\frac{\text{s}}{\text{h}}\right)\right]^2\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24}\text{ kg})}{4\pi^2}}$$

$r_1 = 4.22 \times 10^7$ m (from Earth's center)

$r = r_1 - r_E = 4.22 \times 10^7 \text{ m} - 6.38 \times 10^6 \text{ m} = \boxed{3.58 \times 10^7 \text{ m}}$

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29. $r = 2.0 \times 10^8$ m

$T = 5.0 \times 10^4$ s

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$T = 2\pi\sqrt{\frac{r^3}{Gm}}$$

$$T^2 = 4\pi^2 \frac{r^3}{Gm}$$

$$m = \frac{4\pi^2 r^3}{T^2 G} = \frac{4\pi^2(2.0 \times 10^8\text{ m})^3}{(5.0 \times 10^4\text{ s})^2\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)}$$

$m = \boxed{1.9 \times 10^{27} \text{ kg}}$

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37. $m = 54$ kg

$r = 0.050$ m

$g = 9.81 \text{ m/s}^2$

$\theta = 90°$

$\tau = Fd(\sin\theta) = mgr(\sin\theta)$

$\tau = (54\text{ kg})(9.81\text{ m/s}^2)(0.050\text{ m})(\sin 90°) = \boxed{26 \text{ N•m}}$

---

38. $\theta = 90.0° - 8.0° = 82.0°$

$m = 1130$ kg

$d = 3.05 \text{ m} - 1.12 \text{ m} - 0.40 \text{ m} = 1.53 \text{ m}$

$g = 9.81 \text{ m/s}^2$

$\tau_{net} = \tau_g + \tau_{jack} = 0$

$mgd(\sin\theta) + \tau_{jack} = 0$

$\tau_{jack} = -mgd(\sin\theta) = -(1130\text{ kg})(9.81\text{ m/s}^2)(1.53\text{ m})(\sin 82.0°)$

magnitude of $\tau_{jack} = \boxed{1.68 \times 10^4 \text{ N•m}}$

---

39. $m = 2.00 \times 10^3$ kg

$r = 20.0$ m

$\mu_k = 0.70$

$g = 9.81 \text{ m/s}^2$

$F_k = \mu_k F_n = \mu_k mg$

$$F_c = m\frac{v_t^2}{r}$$

$F_k = F_c$

$$\mu_k mg = m\frac{v_t^2}{r}$$

$v_t = \sqrt{r\mu_k g} = \sqrt{(20.0\text{ m})(0.70)(9.81\text{ m/s}^2)}$

$v_t = \boxed{12 \text{ m/s}}$

Givens	Solutions
40. $m_m = 7.35 \times 10^{22}$ kg $m_s = 1.99 \times 10^{30}$ kg $G = 6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$	$r = 1.50 \times 10^{11}$ m $- 0.00384 \times 10^{11}$ m $= 1.50 \times 10^{11}$ m **a.** $F_g = G\frac{m_m m_s}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\frac{(7.35 \times 10^{22}\text{ kg})(1.99 \times 10^{30}\text{ kg})}{(1.50 \times 10^{11}\text{ m})^2} = \boxed{4.34 \times 10^{20}\text{ N}}$
$r = 3.84 \times 10^8$ m $m_E = 5.97 \times 10^{24}$ kg $m_m = 7.35 \times 10^{22}$ kg	**b.** $F_g = G\frac{m_E m_m}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\frac{(5.97 \times 10^{24}\text{ kg})(7.35 \times 10^{22}\text{ kg})}{(3.84 \times 10^{8}\text{ m})^2} = \boxed{1.99 \times 10^{20}\text{ N}}$
$m_E = 5.97 \times 10^{24}$ kg $m_s = 1.99 \times 10^{30}$ kg $r = 1.50 \times 10^{11}$ m	**c.** $F_g = G\frac{m_E m_s}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\frac{(5.97 \times 10^{24}\text{ kg})(1.99 \times 10^{30}\text{ kg})}{(1.50 \times 10^{11}\text{ m})^2} = \boxed{3.52 \times 10^{22}\text{ N}}$
41. $m = 75$ kg $r = 0.075$ m $d = 0.25$ m $g = 9.81$ m/s^2	For a force perpendicular to d, $\tau = Fd$. $F = \frac{\tau}{d} = \frac{mgr}{d} = \frac{(75\text{ kg})(9.81\text{ m/s}^2)(0.075\text{ m})}{0.25\text{ m}} = \boxed{2.2 \times 10^2\text{ N}}$
42. $\tau = 58$ N•m $d = 0.35$ m $\theta = 56°$	$\tau = Fd(\sin\theta)$ $F = \frac{\tau}{d(\sin\theta)} = \frac{58\text{ N}\bullet\text{m}}{(0.35\text{ m})(\sin 56°)} = \boxed{2.0 \times 10^2\text{ N}}$
43. $d = 1.4$ m $F = 1600$ N $\theta = 53.5°$	$\tau = Fd(\sin\theta) = (1600\text{ N})(1.4\text{ m})(\sin 53.5°) = \boxed{1800\text{ N}\bullet\text{m}}$
44. $L_h = 2.7$ m $L_m = 4.5$ m $m_h = 60.0$ kg $m_m = 100.0$ kg $\theta_h = 20.0°$ from 6:00 $\theta_m = 60.0°$ from 6:00 $g = 9.81$ m/s^2	Consider the total mass of each hand to be at the midpoint of that hand. $\tau_{net} = -m_h g\left(\frac{L_h}{2}\right)(\sin\theta_h) - m_m g\left(\frac{L_m}{2}\right)(\sin\theta_m)$ $\tau_{net} = -(60.0\text{ kg})(9.81\text{ m/s}^2)\left(\frac{2.7\text{ m}}{2}\right)(\sin 20.0°) - (100.0\text{ kg})(9.81\text{ m/s}^2)\left(\frac{4.5\text{ m}}{2}\right)(\sin 60.0°)$ $\tau_{net} = -2.7 \times 10^2\text{ N}\bullet\text{m} - 1.9 \times 10^3\text{ N}\bullet\text{m} = \boxed{-2.2 \times 10^3\text{ N}\bullet\text{m}}$
45. $eff = 0.64$ $m = 78$ kg $d_{out} = 4.0$ m $d_{in} = 24$ m $g = 9.81$ m/s^2	$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}}$ $F_{in} = \frac{F_{out}d_{out}}{d_{in}(eff)} = \frac{mgd_{out}}{d_{in}(eff)} = \frac{(78\text{ kg})(9.81\text{ m/s}^2)(4.0\text{ m})}{(24\text{ m})(0.64)}$ $F_{in} = \boxed{2.0 \times 10^2\text{ N}}$

Givens	Solutions
46. $d = 2.0$ m $\theta = 15°$ $\mu_k = 0.160$	$W_{out} = F_g d(\sin\theta)$ $W_{in} = (F_f + F_{g,x})d = [\mu_k F_g(\cos\theta) + F_g(\sin\theta)]d$ $W_{in} = F_g d[\mu_k(\cos\theta) + (\sin\theta)]$ $eff = \frac{W_{out}}{W_{in}} = \frac{F_g d(\sin\theta)}{F_g d[\mu_k(\cos\theta) + (\sin\theta)]} = \frac{\sin\theta}{\mu_k(\cos\theta) + (\sin\theta)}$ $eff = \frac{\sin 15°}{(0.160)(\cos 15°) + (\sin 15°)} = \frac{0.26}{0.15 + 0.26}$ $eff = \frac{0.26}{0.41} = 0.63 = \boxed{63\%}$
47. $d_{out} = 3.0$ m $F_{in} = 2200$ N $d_{in} = 14$ m $m = 750$ kg $g = 9.81$ m/s^2	$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}} = \frac{mgd_{out}}{F_{in}d_{in}}$ $eff = \frac{(750 \text{ kg})(9.81 \text{ m/s}^2)(3.0 \text{ m})}{(2200 \text{ N})(14 \text{ m})} = 0.72 = \boxed{72\%}$
48. $eff = 0.875$ $F_{in} = 648$ N $m = 150$ kg $d_{out} = 2.46$ m $g = 9.81$ m/s^2	$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}} = \frac{mgd_{out}}{F_{in}d_{in}}$ $d_{in} = \frac{mgd_{out}}{F_{in}(eff)} = \frac{(150 \text{ kg})(9.81 \text{ m/s}^2)(2.46 \text{ m})}{(648 \text{ N})(0.875)} = \boxed{6.4 \text{ m}}$
49. $r_{Io} = 1.82 \times 10^6$ m $d = 4.22 \times 10^8$ m $r_J = 7.15 \times 10^7$ m $m_J = 1.90 \times 10^{27}$ kg $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	**a.** $r = r_{Io} + d + r_J$ $r = 1.82 \times 10^6 \text{ m} + 4.22 \times 10^8 \text{ m} + 7.15 \times 10^7 \text{ m}$ $r = 4.95 \times 10^8$ m $T = 2\pi\sqrt{\frac{r^3}{Gm_J}} = 2\pi\sqrt{\frac{(4.95 \times 10^8 \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.90 \times 10^{27} \text{ kg})}}$ $T = (1.94 \times 10^5 \text{ s})(1 \text{ h}/3600 \text{ s})(1 \text{ day}/24 \text{ h}) = \boxed{2.25 \text{ days}}$ **b.** $r = 4.95 \times 10^8$ m (see part **a.**) $v_t = \sqrt{G\frac{m_J}{r}}$ $v_t = \sqrt{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{1.90 \times 10^{27} \text{ kg}}{4.95 \times 10^8 \text{ m}}\right)} = \boxed{1.60 \times 10^4 \text{ m/s}}$

Givens	*Solutions*
50. $F_g = 13\,500$ N $r = 2.00 \times 10^2$ m $v_t = 50.0$ km/h $g = 9.81$ m/s^2	**a.** $a_c = \dfrac{v_t^2}{r} = \dfrac{(50.0 \times 10^3 \text{ m/h})^2(1 \text{ h/3600 s})^2}{2.00 \times 10^2 \text{ m}} = \boxed{0.965 \text{ m/s}^2}$ **b.** $F_c = ma_c = \left(\dfrac{F_g}{g}\right)a_c = \left(\dfrac{13\,500 \text{ N}}{9.81 \text{ m/s}^2}\right)(0.965 \text{ m/s}^2) = \boxed{1.33 \times 10^3 \text{ N}}$ **c.** $F_c = F_k = \mu_k F_n = \mu_k F_g$ $\mu_k = \dfrac{F_c}{F_g} = \dfrac{1330 \text{ N}}{13\,500 \text{ N}} = \boxed{0.0985}$
51. $d = 15.0$ m $\theta_1 = 90.0° - 20.0° = 70.0°$ $F_{g,max} = 450$ N $\theta_2 = 90.0° - 40.0° = 50.0°$	**a.** $\tau_{max} = F_{g,max}d(\sin\theta_1) = (450 \text{ N})(15.0 \text{ m})(\sin 70.0°) = \boxed{6.3 \times 10^3 \text{ N}\bullet\text{m}}$ **b.** $F_g = \dfrac{\tau_{max}}{d(\sin\theta_2)} = \dfrac{6.3 \times 10^3 \text{ N}\bullet\text{m}}{(15.0 \text{ m})(\sin 50.0°)} = \boxed{5.5 \times 10^2 \text{ N}}$
52. $m_1 = 5.00$ kg $m_2 = 1.99 \times 10^{30}$ kg $F_g = 1370$ N $G = 6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$	$F_g = G\dfrac{m_1 m_2}{r^2}$ $r = \sqrt{\dfrac{Gm_1m_2}{F_g}}$ $r = \sqrt{\dfrac{\left(6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)(5.00 \text{ kg})(1.99 \times 10^{30} \text{ kg})}{1370 \text{ N}}} = \boxed{6.96 \times 10^8 \text{ m}}$
53. $v_t = 55.0$ km/h $r = 40.0$ m $m = 1350$ kg $\mu_k = 0.500$ $g = 9.81$ m/s^2	$F_f = \mu_k F_n = \mu_k mg = (0.500)(1350 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{6620 \text{ N}}$ $F_c = \dfrac{mv_t^2}{r} = \dfrac{(1350 \text{ kg})[(55.0 \times 10^3 \text{ m/h})(1 \text{ h/3600 s})]^2}{40.0 \text{ m}} = \boxed{7880 \text{ N}}$ Because $F_c > F_f$, the frictional force is not large enough to maintain the circular motion.
54. $\theta = 60.0°$ $d = 0.35$ m $\tau = 2.0$ N•m	$F = \dfrac{\tau}{d \sin\theta} = \dfrac{2.0 \text{ N}\bullet\text{m}}{(0.35 \text{ m})(\sin 60.0°)} = \boxed{6.6 \text{ N}}$ τ_{max} is produced when $\theta = 90.0°$ $\tau_{max} = Fd\sin\theta = (6.6 \text{ N})(0.35 \text{ m})(\sin 90.0°) = \boxed{2.3 \text{ N}\bullet\text{m}}$

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Givens	Solutions
2. $v_t = 15$ m/s $r = 25$ m	$a_c = \frac{v_t^2}{r} = \frac{(15 \text{ m/s})^2}{25 \text{ m}} = \boxed{9.0 \text{ m/s}^2}$
4. $m_E = 5.97 \times 10^{24}$ kg $m_s = 1.99 \times 10^{30}$ kg $r = 1.50 \times 10^{11}$ m $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$F_g = G\frac{m_E m_s}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left(\frac{(5.97 \times 10^{24} \text{ kg})(1.99 \times 10^{30} \text{ kg})}{(1.50 \times 10^{11} \text{ m})^2}\right)$ $F_g = \boxed{3.52 \times 10^{22} \text{ N}}$
9. $F_1 = 6.0$ N $F_2 = 6.0$ N $F_3 = 6.0$ N $\theta_1 = 90.0°$ $\theta_2 = 90.0° - 60.0° = 30.0°$ $\theta_3 = 0.0°$ $d = 1.0$ m	$\tau_{net} = \tau_1 + \tau_2 + \tau_3$ $\tau_{net} = F_1 d \sin\theta_1 + F_2 d \sin\theta_2 + F_3 d \sin\theta_3$ $\tau_{net} = (6.0 \text{ N})(1.0 \text{ m})(\sin 90.0°) + (6.0 \text{ N})(1.0 \text{ m})(\sin 30.0°) + (6.0 \text{ N})(1.0 \text{ m})(\sin 0.0°)$ $\tau_{net} = 6.0 \text{ N•m} + 3.0 \text{ N•m} + 0.0 \text{ N•m} = \boxed{9.0 \text{ N•m}}$
10. $F_{in} = 75$ N $F_{out} = 225$ N	$MA = \frac{F_{out}}{F_{in}} = \frac{225 \text{ N}}{75 \text{ N}} = \boxed{3}$
11. $eff = 87.5\% = 0.875$ $F_{out} = 1320$ N $d_{out} = 1.50$ m	$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{W_{in}}$ $W_{in} = \frac{F_{out}d_{out}}{eff} = \frac{(1320 \text{ N})(1.50 \text{ m})}{0.875} = \boxed{2260 \text{ J}}$
17. $m_s = 1.99 \times 10^{30}$ kg $r = 2.28 \times 10^{11}$ m $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$T = 2\pi\sqrt{\frac{r^3}{Gm_s}}$ $T = \left[2\pi\sqrt{\frac{(2.28 \times 10^{11} \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.99 \times 10^{30} \text{ kg})}}\right]\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1 \text{ day}}{24 \text{ h}}\right)$ $T = \boxed{687 \text{ days}}$

Student Edition Solutions

Fluid Mechanics

I

Fluid Mechanics, Practice A

Givens	*Solutions*
1. $F_g = 50.0$ N apparent weight in water $= 36.0$ N $\rho_{water} = 1.00 \times 10^3$ kg/m^3	**a.** $F_B = F_g -$ apparent weight $= 50.0\text{ N} - 36.0\text{ N} = 14.0\text{ N}$ $\rho_{metal} = \dfrac{F_g}{F_B}\rho_{water} = \dfrac{(50.0\text{ N})(1.00 \times 10^3\text{ kg/m}^3)}{14.0\text{ N}}$ $\rho_{\mathrm{metal}} = \boxed{3.57 \times 10^3\text{ kg/m}^3}$
apparent weight in liquid $= 41.0$ N $\rho_{metal} = 3.57 \times 10^3$ kg/m^3	**b.** $F_B = F_g -$ apparent weight $= 50.0\text{ N} - 41.0\text{ N} = 9.0\text{ N}$ $\rho_{liquid} = \dfrac{F_B}{F_g}\rho_{metal} = \dfrac{(9.0\text{ N})(3.57 \times 10^3\text{ kg/m}^3)}{50.0\text{ N}}$ $\rho_{liquid} = \boxed{6.4 \times 10^2\text{ kg/m}^3}$
2. $m = 2.8$ kg $\ell = 2.00$ m $w = 0.500$ m $h = 0.100$ m $\rho_{\mathrm{water}} = 1.00 \times 10^3$ kg/m^3 $g = 9.81$ m/s^2	$F_B = F_g$ $\rho_{\mathrm{water}}\, Vg = (m + M)g$ $M = \rho_{water}\, V - m = \rho_{water}\,(\ell wh) - \mathrm{m}$ $M = (1.00 \times 10^3\text{ kg/m}^3)(2.00\text{ m})(0.500\text{ m})(0.100\text{ m}) - 2.8\text{ kg} = 1.00 \times 10^2\text{ kg} - 2.8\text{ kg}$ $M = \boxed{97\text{ kg}}$
3. $w = 4.0$ m $\ell = 6.0$ m $h = 4.00$ cm $\rho_{water} = 1.00 \times 10^3$ kg/m^3 $g = 9.81$ m/s^2	$F_g = F_B$ $mg = \rho_{water}Vg = \rho_{water}(w\ell h)g$ $F_g = (1.00 \times 10^3\text{ kg/m}^3)(4.0\text{ m})(6.0\text{ m})(0.0400\text{ m})(9.81\text{ m/s}^2) = \boxed{9.4 \times 10^3\text{ N}}$
4. $m_{balloon} = 0.0120$ kg $\rho_{helium} = 0.179$ kg/m^3 $r = 0.500$ m $\rho_{air} = 1.29$ kg/m^3 $g = 9.81$ m/s^2	**a.** $F_B = \rho_{air}Vg = \rho_{air}\left(\frac{4}{3}\pi r^3\right)g$ $F_B = \dfrac{(1.29\text{ kg/m}^3)(4\pi)(0.500\text{ m})^3(9.81\text{ m/s}^2)}{3} = \boxed{6.63\text{ N}}$ **b.** $m_{helium} = \rho_{helium}V = \rho_{helium}\left(\frac{4}{3}\pi r^3\right)$ $m_{helium} = \dfrac{(0.179\text{ kg/m}^3)(4\pi)(0.500\text{ m})^3}{3} = 0.0937\text{ kg}$ $F_g = (m_{balloon} + m_{helium})g = (0.0120\text{ kg} + 0.0937\text{ kg})(9.81\text{ m/s}^2)$ $F_g = (0.1057\text{ kg})(9.81\text{ m/s}^2) = 1.04\text{ N}$ $F_{net} = F_B - F_g = 6.63\text{ N} - 1.04\text{ N} = \boxed{5.59\text{ N}}$

Fluid Mechanics, Section 1 Review

Givens | *Solutions*

I

3. $m_{balloon} = 650$ kg

$m_{pack} = 4600$ kg

$\rho_{air} = 1.29$ kg/m^3

$\rho_{helium} = 0.179$ kg/m^3

$F_B = \rho_{air}Vg$

$F_g = (m_{balloon} + m_{pack} + m_{helium})g$

$m_{helium} = \rho_{helium}V$

$F_B = F_g$

$\rho_{air}Vg = (m_{balloon} + m_{pack} + \rho_{helium}V)g$

$$V = \frac{m_{balloon} + m_{pack}}{\rho_{air} - \rho_{helium}} = \frac{650 \text{ kg} + 4600 \text{ kg}}{1.29 \text{ kg/m}^3 - 0.179 \text{ kg/m}^3}$$

$$V = \frac{5200 \text{ kg}}{1.11 \text{ kg/m}^3} = \boxed{4.7 \times 10^3 \text{ m}^3}$$

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4. $a = 0.325$ m/s^2

$\rho_{sw} = 1.025 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

Use Newton's second law.

$m_s a = F_B - F_g = m_{sw}g - m_s g$

$\rho_s Va = \rho_{sw}Vg - \rho_s Vg$

$\rho_s(a + g) = \rho_{sw}g$

$$\rho_s = \rho_{sw}\left(\frac{g}{a+g}\right) = (1.025 \times 10^3 \text{ kg/m}^3)\left(\frac{9.81 \text{ m/s}^2}{0.325 \text{ m/s}^2 + 9.81 \text{ m/s}^2}\right)$$

$$\rho_s = (1.025 \times 10^3 \text{ kg/m}^3)\left(\frac{9.81 \text{ m/s}^2}{10.14 \text{ m/s}^2}\right) = \boxed{9.92 \times 10^2 \text{ kg/m}^3}$$

Fluid Mechanics, Practice B

1. $r_1 = 5.00$ cm

$r_2 = 15.0$ cm

$F_2 = 1.33 \times 10^4$ N

a. $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = \frac{F_2 A_1}{A_2} = \frac{F_2 \pi r_1^2}{\pi r_2^2} = \frac{F_2 r_1^2}{r_2^2}$$

$$F_1 = \frac{(1.33 \times 10^4 \text{ N})(0.0500 \text{ m})^2}{(0.150 \text{ m})^2} = \boxed{1.48 \times 10^3 \text{ N}}$$

b. $$P = \frac{F_2}{A_2} = \frac{F_2}{\pi r_2^2} = \frac{1.33 \times 10^4 \text{ N}}{(\pi)(0.150 \text{ m})^2} = \boxed{1.88 \times 10^5 \text{ Pa}}$$

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2. $F_g = 1025$ N

$w = 1.5$ m

$\ell = 2.5$ m

$$P = \frac{F}{A} = \frac{F_g}{w\ell} = \frac{1025 \text{ N}}{(1.5 \text{ m})(2.5 \text{ m})} = \boxed{2.7 \times 10^2 \text{ Pa}}$$

---

3. $r = 0.40$ cm

$P_b = 1.010 \times 10^5$ Pa

$P_t = 0.998 \times 10^5$ Pa

a. $P_{net} = P_b - P_t = 1.010 \times 10^5 \text{ Pa} - 0.998 \times 10^5 \text{ Pa} = \boxed{1.2 \times 10^3 \text{ Pa}}$

b. $F_{net} = P_{net}A = P_{net}\pi r^2$

$F_{net} = (1.2 \times 10^3 \text{ Pa})(\pi)(4.0 \times 10^{-3} \text{ m})^2 = \boxed{6.0 \times 10^{-2} \text{ N}}$

Fluid Mechanics, Section 2 Review

Givens	*Solutions*
1. $F_g = 25$ N $w = 1.5$ m	**a.** $P = \frac{F}{A} = \frac{F_g}{w^2}$ $P = \frac{25\text{ N}}{(1.5\text{ m})^2} = 11\text{ Pa}$
$F_g = 15$ N $r = 1.0$ m	**b.** $P = \frac{F}{A} = \frac{F_g}{\pi r^2}$ $P = \frac{15\text{ N}}{(\pi)(1.0\text{ m})^2} = 4.8\text{ Pa}$
$F_g = 25$ N $w = 2.0$ m	**c.** $P = \frac{F}{A} = \frac{F_g}{w^2}$ $P = \frac{25\text{ N}}{(2.0\text{ m})^2} = 6.2\text{ Pa}$
$F_g = 25$ N $r = 1.0$ m	**d.** $P = \frac{F}{A} = \frac{F_g}{\pi r^2}$ $P = \frac{25\text{ N}}{(\pi)(1.0\text{ m})^2} = 8.0\text{ Pa}$ $\boxed{\text{a is the largest pressure}}$
2. $h = 366$ m $\rho = 1.00 \times 10^3$ kg/m^3 $g = 9.81$ m/s^2	$P = \rho g h$ $P = (1.00 \times 10^3\text{ kg/m}^3)(9.81\text{ m/s}^2)(366\text{ m}) = \boxed{3.59 \times 10^6\text{ Pa}}$
3. $h = 5.0 \times 10^2$ m $P_o = 1.01 \times 10^5$ Pa $\rho = 1.025 \times 10^3$ kg/m^3 $g = 9.81$ m/s^2	$P = P_o + \rho g h = 1.01 \times 10^5\text{ Pa} + (1.025 \times 10^3\text{ kg/m}^3)(9.81\text{ m/s}^2)(5.0 \times 10^2\text{ m})$ $P = 1.01 \times 10^5\text{ Pa} + 5.0 \times 10^6\text{ Pa} = \boxed{5.1 \times 10^6\text{ Pa}}$ $N = \frac{P}{P_o} = \frac{5.1 \times 10^6\text{ Pa}}{1.01 \times 10^5\text{ Pa}} = \boxed{5.0 \times 10^1}$
4. $P = 3\ P_o$ $P_o = 1.01 \times 10^5$ Pa $\rho = 1.025 \times 10^3$ kg/m^3 $g = 9.81$ m/s^2	$P = P_0 + \rho g h$ $h = \frac{P - P_o}{\rho g} = \frac{3P_o - P_o}{\rho g} = \frac{2P_o}{\rho g}$ $h = \frac{(2)(1.01 \times 10^5\text{ Pa})}{(1.025 \times 10^3\text{ kg/m}^3)(9.81\text{ m/s}^2)} = \boxed{20.1\text{ m}}$

Fluid Mechanics, Section 3 Review

1. $P_1 = 3.00 \times 10^5$ Pa $v_1 = 1.00$ m/s $r_2 = \frac{1}{4}r_1$	$A_1 v_1 = A_2 v_2$ $v_2 = \frac{A_1 v_1}{A_2} = \frac{\pi r_1^2 v_1}{\pi r_2^2} = \frac{r_1^2 v_1}{\left(\frac{1}{4}r_1\right)^2} = 16 v_1$ $v_2 = (16)(1.00\text{ m/s}) = \boxed{16.0\text{ m/s}}$

I

Givens	*Solutions*
2. $r = \frac{2.0\ \text{cm}}{2} = 1.0\ \text{cm}$ $\rho = 1.00 \times 10^3\ \text{kg/m}^3$ $V = 2.5 \times 10^{-2}\ \text{m}^3$ $\Delta t = 30.0\ \text{s}$	flow rate $= Av$ $v = \frac{\text{flow rate}}{A} = \frac{\frac{V}{\Delta t}}{A} = \frac{V}{\pi r^2 \Delta t}$ $v = \frac{2.5 \times 10^{-2}\ \text{m}^3}{(\pi)(0.010\ \text{m})^2(30.0\ \text{s})} = \boxed{2.7\ \text{m/s}}$

I

Fluid Mechanics, Chapter Review

8. $F_g = 315\ \text{N}$ apparent weight in water $= 265\ \text{N}$ $\rho_{\text{water}} = 1.00 \times 10^3\ \text{kg/m}^3$	**a.** $F_B = F_g -$ apparent weight $= 315\ \text{N} - 265\ \text{N} = 5.0 \times 10^1\ \text{N}$ $\rho_o = \frac{F_g}{F_B}\rho_{water} = \frac{(315\ \text{N})(1.00 \times 10^3\ \text{kg/m}^3)}{5.0 \times 10^1\ \text{N}}$ $\rho_o = \boxed{6.3 \times 10^3\ \text{kg/m}^3}$
apparent weight in oil $= 269\ \text{N}$ $\rho_o = 6.3 \times 10^3 \text{kg/m}^3$	**b.** $F_B = F_g -$ apparent weight $= 315\ \text{N} - 269\ \text{N} = 46\ \text{N}$ $\rho_{oil} = \frac{F_B}{F_g}\rho_o = \frac{(46\ \text{N})(6.3 \times 10^3\ \text{kg/m}^3)}{315\ \text{N}}$ $\rho_{oil} = \boxed{9.2 \times 10^2\ \text{kg/m}^3}$
9. $F_g = 300.0\ \text{N}$ apparent weight $= 200.0\ \text{N}$ $\rho_{alcohol} = 0.70 \times 10^3\ \text{kg/m}^3$	$F_B = F_g -$ apparent weight $= 300.0\ \text{N} - 200.0\ \text{N} = 100.0\ \text{N}$ $\rho_o = \frac{F_g}{F_B}\rho_{alcohol} = \frac{(300.0\ \text{N})(0.70 \times 10^3\ \text{kg/m}^3)}{100.0\ \text{N}}$ $\rho_o = \boxed{2.1 \times 10^3\ \text{kg/m}^3}$
14. $P = 2.0 \times 10^5\ \text{Pa}$ $A = 0.024\ \text{m}^2$	$F_g = 4PA = (4)(2.0 \times 10^5\ \text{Pa})(0.024\ \text{m}^2) = \boxed{1.9 \times 10^4\ \text{N}}$
15. $P = 5.00 \times 10^5\ \text{Pa}$ $r = \frac{4.00\ \text{mm}}{2} = 2.00\ \text{mm}$	$F = PA = P(\pi r^2)$ $F = (5.00 \times 10^5\ \text{Pa})(\pi)(2.00 \times 10^{-3}\ \text{m})^2 = \boxed{6.28\ \text{N}}$
16. $r_A = \frac{0.64\ \text{cm}}{2} = 0.32\ \text{cm}$ $r_B = \frac{3.8\ \text{cm}}{2} = 1.9\ \text{cm}$ $F_{g,B} = 500.0\ \text{N}$	$\frac{F_A}{A_A} = \frac{F_{g,B}}{A_B}$ $F_A = \frac{F_{g,B}A_A}{A_B} = \frac{F_{g,B}(\pi r_A^2)}{\pi r_B^2} = \frac{F_{g,B}r_A^2}{r_B^2}$ $F_A = \frac{(500.0\ \text{N})(0.0032\ \text{m})^2}{(0.019\ \text{m})^2} = 14\ \text{N}$ $\mathbf{F} = \boxed{14\ \text{N downward}}$

Givens	*Solutions*

20. $F_g = 4.5$ N

$\rho = 13.6 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$V = \frac{m}{\rho} = \frac{\left(\frac{F_g}{g}\right)}{\rho} = \frac{F_g}{g\rho}$$

$$V = \frac{4.5\text{ N}}{(9.81\text{ m/s}^2)(13.6 \times 10^3\text{ kg/m}^3)} = \boxed{3.4 \times 10^{-5}\text{ m}^3}$$

21. $A = 1.00$ km^2

$P = 1.01 \times 10^5$ Pa

$$F = PA = (1.01 \times 10^5\text{ Pa})(1.00\text{ km}^2)(10^6\text{ m}^2/\text{km}^2) = \boxed{1.01 \times 10^{11}\text{ Pa}}$$

22. $m_m = 70.0$ kg

$m_c = 5.0$ kg

$r = 1.0$ cm

$g = 9.81$ m/s^2

$$F_g = PA = P(4\pi r^2)$$

$$P = \frac{F_g}{4\pi v^2} = \frac{(m_m + m_c)g}{4\pi r^2} = \frac{(70.0\text{ kg} + 5.0\text{ kg})(9.81\text{ m/s}^2)}{(4\pi)(0.010\text{ m})^2}$$

$$P = \frac{(75.0\text{ kg})(9.81\text{ m/s}^2)}{(4\pi)(0.010\text{ m})^2} = \boxed{5.9 \times 10^5\text{ Pa}}$$

23. $\rho = 1.35 \times 10^3$ kg/m^3

$r = 6.00$ cm

$$m = \rho V = \rho\left[\frac{1}{2}\left(\frac{4}{3}\pi r^3\right)\right] = \frac{2}{3}\rho\pi r^3$$

$$m = \frac{(2)(1.35 \times 10^3\text{ kg/m}^3)(\pi)(6.00 \times 10^{-2}\text{ m})^3}{3} = \boxed{6.11 \times 10^{-1}\text{kg}}$$

24. $F_g = 1.0 \times 10^6$ N

$h = 2.5$ cm

$\rho = 1.025 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$F_g = mg = \rho Vg = \rho Ahg$$

$$A = \frac{F_g}{\rho hg} = \frac{1.0 \times 10^6\text{ N}}{(1.025 \times 10^3\text{ kg/m}^3)(2.5 \times 10^{-2}\text{m})(9.81\text{ m/s}^2)}$$

$$A = \boxed{4.0 \times 10^3\text{ m}^2}$$

25. $m = 1.0$ kg $+ 2.0$ kg $= 3.0$ kg

$\rho_f = 916$ kg/m^3

$m_b = 2.0$ kg

$\rho_b = 7.86 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

For the spring scale, apparent weight of block $= F_{g,b} - F_B = F_{g,b} - F_{g,b}\dfrac{\rho_f}{\rho_b} = m_b g\left(1 - \dfrac{\rho_f}{\rho_b}\right)$

$$\text{apparent weight of block} = (2.0\text{ kg})(9.81\text{ m/s}^2)\left(1 - \frac{916\text{ kg/m}^3}{7.86 \times 10^3\text{ kg/m}^3}\right)$$

$$= (2.0\text{ kg})(9.81\text{ m/s}^2)(1 - 0.117)$$

$$\text{apparent weight of block} = (2.0\text{ kg})(9.81\text{ m/s}^2)(0.883) = \boxed{17\text{ N}}$$

For the lower scale, the measured weight equals the weight of the beaker and oil, plus a force equal to and opposite in direction to the buoyant force on the block. Therefore,

$$\text{apparent weight} = mg + F_B = mg + F_{g,b}\frac{\rho_f}{\rho_b} = \left(m + \frac{m_b\rho_f}{\rho_b}\right)g$$

$$\text{apparent weight} = \left[3.0\text{ kg} + \frac{(2.0\text{ kg})(916\text{ kg/m}^3)}{7.86 \times 10^3\text{ kg/m}^3}\right](9.81\text{ m/s}^2)$$

$$= (3.0\text{ kg} + 0.23\text{ kg})(9.81\text{ m/s}^2)$$

$$\text{apparent weight} = (3.2\text{ kg})(9.81\text{ m/s}^2) = \boxed{31\text{ N}}$$

Givens | *Solutions*

I

26. $\rho v = 600.0 \text{ kg/m}^3$

$A = 5.7 \text{ m}^2$

$V_r = 0.60 \text{ m}^3$

$\rho_{water} = 1.0 \times 10^3 \text{ kg/m}^3$

$g = 9.81 \text{ m/s}^2$

$F_B = F_{g,r}$

$F_B = \rho_{water} V_{water} g = \rho_{water}(Ah)g$

$F_{g,r} = m_r g = \rho r V_r g$

$\rho_{water} Ahg = \rho_r V_r g$

$$h = \frac{\rho_r V_r}{\rho_{water} A} = \frac{(600.0 \text{ kg/m}^3)(0.60 \text{ m}^3)}{(1.0 \times 10^3 \text{ kg/m}^3)(5.7 \text{ m}^2)} = \boxed{6.3 \times 10^{-2} \text{ m} = 6.3 \text{ cm}}$$

---

27. $h = 26 \text{ cm}$

$w = 21 \text{ cm}$

$y = 3.5 \text{ cm}$

$F_g = 19 \text{ N}$

$g = 9.81 \text{ m/s}^2$

a. $$\rho = \frac{m}{V} = \frac{\left(\frac{F_g}{g}\right)}{hwy} = \frac{F_g}{hwyg}$$

$$\rho = \frac{19 \text{ N}}{(0.26 \text{ m})(0.21 \text{ m})(0.035 \text{ m})(9.81 \text{ m/s}^2)} = \boxed{1.0 \times 10^3 \text{ kg/m}^3}$$

b. $$P = \frac{F_g}{A} = \frac{F_g}{hw} = \frac{19 \text{ N}}{(0.26 \text{ m})(0.21 \text{ m})} = \boxed{3.5 \times 10^2 \text{ Pa}}$$

c. $$P = \frac{F_g}{A} = \frac{F_g}{hy} = \frac{19 \text{ N}}{(0.26 \text{ m})(0.035 \text{ m})} = \boxed{2.1 \times 10^3 \text{ Pa}}$$

---

28. $r = \dfrac{0.250 \text{ m}}{2} = 0.125 \text{ m}$

flow rate $= 1.55 \text{ m}^3\text{/s}$

flow rate $= Av = \pi r^2 v$

$$v = \frac{\text{flow rate}}{\pi r^2} = \frac{1.55 \text{ m}^3\text{/s}}{(\pi)(0.125 \text{ m})^2} = \boxed{31.6 \text{ m/s}}$$

---

29. $h = 2.0 \text{ cm} = 0.020 \text{ m}$

$y_{water} = 1.5 \text{ cm} = 0.015 \text{ m}$

$\rho_{oil} = 900.0 \text{ kg/m}^3$

$\rho_{water} = 1.00 \times 10^3 \text{ kg/m}^3$

In water:

$F_{g,b} = F_{B,water} = \rho_{water} Vg = \rho_{water} A y_{water} g$

In oil:

$F_{g,b} = F_{B,oil} = \rho_{oil} Vg = \rho_{oil} A y_{oil} g$

$\rho_{water} A y_{water} g = \rho_{oil} A y_{oil} g$

$\rho_{water} y_{water} = \rho_{oil} y_{oil}$

$$y_{oil} = \frac{\rho_{water} \times y_{water}}{\rho_{oil}}$$

$$y_{oil} = \frac{1.00 \times 10^3 \text{ kg/m}^3 \times 0.015 \text{ m}}{900.0 \text{ kg/m}^3}$$

$y_{oil} = 0.017 \text{ m} = \boxed{1.7 \times 10^{-2} \text{ m}}$

Givens	Solutions

31. $k = 90.0$ N/m

$m_b = 2.00$ g

$V = 5.00\ m^3$

$g = 9.81\ m/s^2$

$\rho_{air} = 1.29\ kg/m^3$

$\rho_{hel} = 0.179\ kg/m^3$

$$F_{net} = F_B - F_{g,b} - F_{g,hel} - F_{spring} = 0$$

$$\rho_{air}Vg - m_b g - \rho_{hel}Vg - k\Delta x = 0$$

$$\Delta x = \frac{g(\rho_{air}V - m_b - \rho_{hel}V)}{k}$$

$$\Delta x = \frac{(9.81\ m/s^2)[(1.29\ kg/m^3)(5.00\ m^3) - 2.00 \times 10^{-3}\ kg - (0.179\ kg/m^3)(5.00\ m^3)]}{90.0\ N/m}$$

$$\Delta x = \frac{(9.81\ m/s^2)(6.45\ kg - 2.00 \times 10^{-3}\ kg - 0.895\ kg)}{90.0\ N/m}$$

$$\Delta x = \frac{(9.81\ m/s^2)(5.55\ kg)}{90.0\ N/m} = \boxed{0.605\ m}$$

---

32. $A = 2.0\ cm^2$

$\rho = 1.0\ g/cm^3$

$v = 42$ cm/s

$A_2 = 3.0 \times 10^3\ cm^2$

a. flow rate $= Av = (2.0\ cm^2)(42\ cm/s) = 84\ cm^3/s$

In g/s:

flow rate $= (84\ cm^3/s)(1.0\ g/cm^3) = \boxed{84\ g/s}$

b. Use the continuity equation.

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{(2.0\ cm^2)(42\ cm/s)}{3.0 \times 10^3\ cm^2} = \boxed{0.028\ cm/s = 2.8 \times 10^{-4}\ m/s}$$

---

33. $m = 1.0$ kg

$r = 0.10$ m

$h = 2.0$ m

$\rho_{water} = 1.00 \times 10^3\ kg/m^3$

$g = 9.81\ m/s^2$

$\rho_{air} = 1.29\ kg/m^3$

$$F_{net} = (m + m_{air})a = F_B - F_{g,b} - F_{g,a}$$

$$(m + m_{air})a = \rho_{water}Vg - g(m + m_{air})$$

$$a = \frac{\rho_{water}Vg}{m + m_{air}} - g = \frac{\rho_{water}\left(\frac{4}{3}\pi r^3\right)g}{m + \rho_{air}\left(\frac{4}{3}\pi r^3\right)} - g = \frac{\rho_{water}(4\pi r^3)g}{3m + \rho_{air}(4\pi r^3)} - g$$

$$a = \frac{(1.00 \times 10^3\ kg/m^3)(4\pi)(0.10\ m)^3(9.81\ m/s^2)}{(3)(1.0\ kg) + (1.29\ kg/m^3)(4\pi)(0.10\ m)^3} - 9.81\ m/s^2$$

$$a = \frac{(1.00 \times 10^3\ kg/m^3)(4\pi)(0.10\ m)^3(9.81\ m/s^2)}{3.0\ kg + 0.016\ kg} - 9.81\ m/s^2$$

$$a = \frac{(1.00 \times 10^3\ kg/m^3)(4\pi)(0.10\ m^3)(9.81\ m/s^2)}{3.0\ kg} - 9.81\ m/s^2$$

$$a = 41\ m/s^2 - 9.81\ m/s^2 = 31\ m/s^2$$

Use the following equation to find the speed of the ball as it exits the water.

Note that $v_i = 0$.

$$v_f^2 = v_i^2 + 2ah = 2ah$$

Use the following equation to find the maximum height of the ball above the water. Note that $v_i = v_f$ for the ball leaving the water.

$$v_f^2 = v_i^2 - 2g\Delta y = 0$$

$$\Delta y = \frac{v_i^2}{2g} = \frac{2ah}{2g} = \frac{ah}{g}$$

$$\Delta y = \frac{(31\ m/s^2)(2.0\ m)}{9.81\ m/s^2} = \boxed{6.3\ m}$$

Givens	Solutions

34. $\Delta t = 1.00$ min

$N = 150$

$m = 8.0$ g

$v = 400.0$ m/s

$A = 0.75\ \text{m}^2$

For one bullet:

$$P = \frac{F}{A} = \frac{\Delta p}{A\Delta t} = \frac{mv_f - mv_i}{A\Delta t}$$

In a perfect elastic collision with the wall, $v_i = -v_f$.

$$P = \frac{2mv}{A\Delta t}$$

For all the bullets:

$$P = N\left(\frac{2mv}{A\Delta t}\right) = \frac{(150)(2)(8.0 \times 10^{-3}\ \text{kg})(400.0\ \text{m/s})}{(0.75\ \text{m}^2)(1.00\ \text{min})(60\ \text{s/min})} = \boxed{21\ \text{Pa}}$$

---

35. $m = 4.00$ kg

$r = \frac{0.200\ \text{m}}{2} = 0.100$ m

$h = 4.00$ m

$\rho_{water} = 1.00 \times 10^3\ \text{kg/m}^3$

$g = 9.81\ \text{m/s}^2$

a. Assume that the mass of the helium in the sphere is not significant compared with the 4.00 kg mass of the sphere.

$$F_{net} = ma = F_B - F_g$$

$$ma = \rho_{water}Vg - mg$$

$$a = \frac{\rho_{water}\left(\frac{4}{3}\pi r^3\right)g - mg}{m}$$

$$a = \frac{(1.00 \times 10^3\ \text{kg/m}^3)\left(\frac{4}{3}\right)(\pi)(0.100\ \text{m})^3(9.81\ \text{m/s}^2) - (4.00\ \text{kg})(9.81\ \text{m/s}^2)}{4.00\ \text{kg}}$$

$$a = \frac{41.1\ \text{N} - 39.2\ \text{N}}{4.00\ \text{kg}} = \frac{1.9\ \text{N}}{4.00\ \text{kg}} = \boxed{0.48\ \text{m/s}^2}$$

b. Noting that $v_i = 0$,

$$\Delta y = v_i\Delta t + \tfrac{1}{2}a\Delta t^2 = \tfrac{1}{2}a\Delta t^2$$

$$\Delta t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{2(h - 2r)}{a}}$$

$$\Delta t = \sqrt{\frac{(2)(4.00\ \text{m} - 0.200\ \text{m})}{0.48\ \text{m/s}^2}} = \sqrt{\frac{(2)(3.80\ \text{m})}{0.48\ \text{m/s}^2}} = \boxed{4.0\ \text{s}}$$

Givens	Solutions

37. $k = 16.0$ N/m

$m_b = 5.00 \times 10^{-3}$ kg

$\rho_b = 650.0$ kg/m^3

$\rho_{water} = 1.00 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$F_{net} = F_B - F_g - F_{spring} = 0$$

$$\rho_{water} V g - m_b g - k\Delta x = 0$$

$$\rho_{water}\left(\frac{m_b}{\rho_b}\right)g - m_b g - k\Delta x = 0$$

$$\Delta x = \frac{\rho_{water}\left(\frac{m_b}{\rho_b}\right)g - m_b g}{k}$$

$$\Delta x = \frac{\left(\frac{\rho_{water}}{\rho_b} - 1\right)m_b g}{k}$$

$$\Delta x = \frac{\left(\frac{1.00 \times 10^3 \text{ kg/m}^3}{650.0 \text{ kg/m}^3} - 1\right)(5.00 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)}{16.0 \text{ N/m}}$$

$$\Delta x = \frac{(1.54 - 1)(5.00 \times 10^{-3} \text{kg})(9.81 \text{ m/s}^2)}{16.0 \text{ N/m}}$$

$$\Delta x = \frac{(0.54)(5.00 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)}{16.0 \text{ N/m}} = \boxed{1.7 \times 10^{-3} \text{ m}}$$

Fluid Mechanics, Standardized Test Prep

2. $\dfrac{A_{applied}}{A_{lifted}} = \dfrac{1}{7}$

$$\frac{F_{applied}}{A_{applied}} = \frac{F_{lifted}}{A_{lifted}}$$

$$F_{applied} = \frac{F_{lifted} \times A_{applied}}{A_{lifted}}$$

$$F_{applied} = \boxed{\frac{1}{7}F_{lifted}}$$

---

7. $v_{top} = v_i = 0$ m/s

$$v_f^2 = v_i^2 + 2g(h_{top} - h_{bottom})$$

$$v_{bottom}^2 = 2g(h_{top} - h_{bottom})$$

$$v_{bottom} = \boxed{\sqrt{2g(h_{top} - h_{bottom})}}$$

---

8. $A_2 = 0.5\ A_1$

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2}$$

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{A_1 v_1}{0.5\ A_1}$$

$$v_2 = \frac{v_1}{0.5}$$

$$v_2 = \boxed{2v_1}$$

I

Givens	*Solutions*

10. $r_a = \dfrac{1.6 \text{ cm}}{2} = 0.80 \text{ cm}$

$r_c = \dfrac{1.0 \times 10^{-6} \text{ m}}{2} = 0.50 \times 10^{-6} \text{ m}$

$v_a = 1.0 \text{ m/s}$

$v_c = 1.0 \text{ cm/s}$

Use the continuity equation.

$A_c = \dfrac{A_a v_a}{v_c}$, where A_c is the total capillary cross section needed.

$$A_c = \frac{\pi r_a^2 v_a}{v_c} = \frac{(\pi)(8.0 \times 10^{-3} \text{ m})^2(1.0 \text{ m/s})}{0.010 \text{ m/s}} = 2.0 \times 10^{-2} \text{ m}^2$$

$A_c = NA$

$$N = \frac{A_c}{A} = \frac{A_c}{\pi r_c^2} = \frac{2.0 \times 10^{-2} \text{ m}^2}{(\pi)(0.50 \times 10^{-6} \text{ m})^2} = \boxed{2.5 \times 10^{10} \text{ capillaries}}$$

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11. $A_m = 6.40 \text{ cm}^2$

$A_b = 1.75 \text{ cm}^2$

$\mu_k = 0.50$

$F_p = 44 \text{ N}$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_b = \frac{A_b}{A_m} F_p = \left(\frac{1.75 \text{ cm}^2}{6.40 \text{ cm}^2}\right)(44 \text{ N}) = 12 \text{ N}$$

F_b is the normal force exerted on the brake shoe. F_k is given as follows:

$$F_k = \mu_k F_n = (0.50)(12 \text{ N}) = \boxed{6.0 \text{ N}}$$

12.

$F_B = F_g$

$$\boxed{F_{B,oil} + F_{B,water} = F_{g,block}}$$

13.

$F_{B,oil} + F_{B,water} = F_{g,block}$

$m_{oil}g + m_{water}g = m_{block}g$

$\rho_{oil}V_{oil} + \rho_{water}V_{water} = \rho_{block}V_{block}$

$\rho_{oil}A(h - y) + \rho_{water}Ay = \rho_{block}Ah$

$\rho_{oil}(h - y) + \rho_{water}y = \rho_{block}h$

$\rho_{oil}h - \rho_{oil}y + \rho_{water}y = \rho_{block}h$

$y(\rho_{water} - \rho_{oil}) = h(\rho_{block} - \rho_{oil})$

$$\boxed{y = \frac{(\rho_{block} - \rho_{oil})h}{(\rho_{water} - \rho_{oil})}}$$

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14. $\rho_{oil} = 930 \text{ kg/m}^3$

$h = 4.00 \text{ cm}$

$\rho_{block} = 960 \text{ kg/m}^3$

$\rho_{water} = 1.00 \times 10^3 \text{ kg/m}^3$

$g = 9.81 \text{ m/s}^2$

$$y = \frac{(\rho_{block} - \rho_{oil})h}{(\rho_{water} - \rho_{oil})} = \frac{(0.0400 \text{ m})(960 \text{ kg/m}^3 - 930 \text{ kg/m}^3)}{1.00 \times 10^3 \text{ kg/m}^3 - 930 \text{ kg/m}^3}$$

$$y = \frac{(0.0400 \text{ m})(30 \text{ kg/m}^3)}{70 \text{ kg/m}^3} = \boxed{1.71 \times 10^{-2} \text{ m} = 1.71 \text{ cm}}$$

Heat

Heat, Practice A

Givens | *Solutions*

1. $T_F = -128.6°F$

$T_C = \frac{5}{9}(T_F - 32.0) = \frac{5}{9}(-128.6 - 32.0)°C = \frac{5}{9}(-160.6)°C$

$T_C = \boxed{-89.22°C}$

$T = T_C + 273.15 = (-89.22 + 273.15)\text{ K} = \boxed{183.93\text{ K}}$

---

2. $T_{F,1} = 105°F$

$T_{F,2} = -25°F$

$T_{C,1} = \frac{5}{9}(T_{F,1} - 32.0) = \frac{5}{9}(105 - 32.0)°C = \frac{5}{9}(73)°C$

$T_{C,1} = \boxed{41°C}$

$T = (T_C + 273.15)\text{K}$

$T_1 = (41 + 273.15)\text{K} = \boxed{314\text{ K}}$

$T_{C,2} = \frac{5}{9}(T_{F,2} - 32.0) = \frac{5}{9}(-25 - 32.0)°C = \frac{5}{9}(-57)°C$

$T_{C,2} = \boxed{-32°C}$

$T_2 = (-32 + 273.15)\text{K} = \boxed{241\text{ K}}$

---

3. $T_{F,1} = 98.6°F$

$T_{F,2} = 102°F$

$T_{C,1} = \frac{5}{9}(T_{F,1} - 32.0) = \frac{5}{9}(98.6 - 32.0)°C = \frac{5}{9}(66.6)°C$

$T_{C,1} = \boxed{37.0°C}$

$T_{C,2} = \frac{5}{9}(T_{F,2} - 32.0) = \frac{5}{9}(102° - 32.0)°C = \frac{5}{9}(7.0 \times 10^1)°C$

$T_{C,2} = \boxed{39°C}$

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4. $T_{C,i} = 23°C$

$T_{C,f} = 78°C$

$T = T_C + 273.15$

$T_i = T_{C,i} + 273.15 = (23 + 273.15)\text{ K} = 296\text{ K}$

$T_f = T_{C,f} + 273.15 = (78 + 273.15)\text{ K} = 351\text{ K}$

$\Delta T = T_f - T_i = 351\text{ K} - 296\text{ K} = \boxed{55\text{ K}}$

Alternatively, because a degree Celsius equals a kelvin,

$\Delta T = \Delta T_C = T_{C,f} - T_{C,i} = 78°C - 23°C$

$\Delta T = 55°C = \boxed{55\text{ K}}$

$\Delta T_F = \frac{9}{5}(78 - 23)°F = \frac{9}{5}(55)°F = \boxed{99°F}$

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5. $T = 77.34\text{ K}$

$T_C = T - 273.15 = (77.34 - 273.15)°C = \boxed{-195.81°C}$

$T_F = \frac{9}{5}T_C + 32.0 = \frac{9}{5}(-195.81)°F + 32.0°F = (-352.46 + 32.0)°F$

$T_F = \boxed{-320.5°F}$

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Heat, Section 1 Review

Givens | *Solutions*

2. $T = 90.2$ K

$T_C = T - 273.15 = (90.2 - 273.15)°C = \boxed{-183.0°C}$

$T_F = \frac{9}{5}(T_C) + 32.0 = \frac{9}{5}(-183.0)°F + 32.0°F = (-329.4 + 32.0)°F$

$T_F = \boxed{-297.4°F}$

3. boiling point = 444.6°C

melting point = 586.1°F below boiling point

a. $\Delta T_C = \frac{5}{9}(\Delta T_F) = \frac{5}{9}(586.1)°C = 325.6°C$

melting point = 444.6°C − 325.6°C = $\boxed{119.0°C}$

b. $T_{F,1} = \frac{9}{5}(T_{C,1}) + 32.0 = \frac{9}{5}(119.0)°F + 32.0°F = (214.2 + 32.0)°F$

$T_{F,1} = \boxed{246.2°F}$

$T_{F,2} = \frac{9}{5}(T_{C,2}) + 32.0 = \frac{9}{5}(444.6)°F + 32.0°F = (800.3 + 32.0)°F$

$T_{F,2} = \boxed{832.3°F}$

c. $T_1 = T_{C,1} + 273.15 = (119.0 + 273.15)\text{ K} = \boxed{392.2\text{ K}}$

$T_2 = T_{C,2} + 273.15 = (444.6 + 273.15)\text{ K} = \boxed{717.8\text{ K}}$

Heat, Practice B

1. $m = 11.5$ kg

$g = 9.81$ m/s^2

$h = 6.69$ m

$\Delta U = mgh = (11.5\text{ kg})(9.81\text{ m/s}^2)(6.69\text{ m}) = \boxed{755\text{ J}}$

2. $m_s = 0.500$ kg

$m_h = 2.50$ kg

$v_h = 65.0$ m/s

$\Delta U = \frac{1}{3}(KE_h) = \frac{1}{3}\left(\frac{1}{2}m_h v_h^2\right) = \frac{1}{6}(2.50\text{ kg})(65.0\text{ m/s})^2$

$\Delta U = \boxed{1.76 \times 10^3\text{ J}}$

3. $m = 3.0 \times 10^{-3}$ kg

$h = 50.0$ m

$\Delta U = (0.65)(PE_i) = (0.65)(mgh) = (0.65)(3.0 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2)(50.0\text{ m})$

$\Delta U = \boxed{0.96\text{ J}}$

4. $\Delta U = 209.3$ J

$m = 0.25$ kg

$\Delta U = KE = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2\Delta U}{m}} = \sqrt{\frac{(2)(209.3\text{ J})}{0.25\text{ kg}}} = \boxed{41\text{ m/s}}$

Heat, Section 2 Review

3. $m = 505$ kg

$h = 50.0$ m

$g = 9.81$ m/s^2

$\Delta U = PE_i = mgh = (505\text{ kg})(9.81\text{ m/s}^2)(50.0\text{ m}) = \boxed{2.48 \times 10^5\text{ J}}$

Heat, Practice C

Givens	*Solutions*
1. $m_g = 3.0$ kg $T_g = 99°C$ $c_{p,g} = 129$ J/kg•°C $m_w = 0.22$ kg $T_w = 25°C$ $c_{p,w} = 4186$ J/kg•°C	$c_{p,w}m_w\Delta T_w = -c_{p,g}m_g\Delta T_g$ $c_{p,w}m_w(T_f - T_w) = -c_{p,g}m_g(T_f - T_g)$ $T_f = \dfrac{T_w c_{p,w}m_w + T_g c_{p,g}m_g}{c_{p,w}m_w + c_{p,g}m_g}$ $c_{p,w}m_w = (4186 \text{ J/kg•°C})(0.22 \text{ kg}) = 920 \text{ J/°C}$ $T_w c_{p,w}m_w = (25°C)(4186 \text{ J/kg•°C})(0.22 \text{ kg}) = 2.3 \times 10^4 \text{ J}$ $c_{p,g}m_g = (129 \text{ J/kg•°C})(3.0 \text{ kg}) = 390 \text{ J/°C}$ $T_g c_{p,g}m_g = (99°C)(129 \text{ J/kg•°C})(3.0 \text{ kg}) = 3.8 \times 10^4 \text{ J}$ $T_f = \dfrac{2.3 \times 10^4 \text{ J} + 3.8 \times 10^4 \text{ J}}{920 \text{ J/°C} + 390 \text{ J/°C}} = \dfrac{6.1 \times 10^4 \text{ J}}{1310 \text{ J/°C}}$ $T_f = \boxed{47°C}$
2. $m_t = 0.225$ kg $T_t = 97.5°C$ $m_w = 0.115$ kg $T_w = 10.0°C$ $c_{p,t} = 230$ J/kg•°C $c_{p,w} = 4186$ J/kg•°C	$c_{p,w}m_w\Delta T_w = -c_{p,t}m_t\Delta T_t$ $c_{p,w}m_w(T_f - T_w) = -c_{p,t}m_t(T_f - T_t)$ $T_f = \dfrac{T_w c_{p,w}m_w + T_t c_{p,t}m_t}{c_{p,w}m_w + c_{p,t}m_t}$ $c_{p,w}m_w = (4186 \text{ J/kg•°C})(0.115 \text{ kg}) = 481 \text{ J/°C}$ $T_w c_{p,w}m_w = (10.0°)(4186 \text{ J/kg•°C})(0.115 \text{ kg}) = 4.81 \times 10^3 \text{ J}$ $c_{p,t}m_t = (230 \text{ J/kg•°C})(0.225 \text{ kg}) = 52 \text{ J/°C}$ $T_t c_{p,t}m_t = (97.5°C)(230 \text{ J/kg•°C})(0.225 \text{ kg}) = 5.0 \times 10^3 \text{ J}$ $T_f = \dfrac{4.81 \times 10^3 \text{ J} + 5.0 \times 10^3 \text{ J}}{481 \text{ J/°C} + 52 \text{ J/°C}} = \dfrac{9.8 \times 10^3 \text{ J}}{533 \text{ J/°C}}$ $T_f = \boxed{18°C}$
3. $m_b = 0.59$ kg $T_b = 98.0°C$ $m_w = 2.80$ kg $T_w = 5.0°C$ $T_f = 6.8°C$ $c_{p,w} = 4186$ J/kg•°C	$-c_{p,b}\, m_b\, \Delta T_b = c_{p,w}\, m_w\, \Delta T_w$ $\Delta T_w = T_f - T_w = 6.8°C - 5.0°C = 1.8°C$ $\Delta T_b = T_f - T_b = 6.8°C - 98.0°C = -91.2°C$ $c_{p,b} = -\dfrac{c_{p,w}m_w\Delta T_w}{m_b\Delta T_b} = -\dfrac{(4186 \text{ J/kg•°C})(2.80 \text{ kg})(1.8°C)}{(0.59 \text{ kg})(-91.2°C)}$ $c_{p,b} = \boxed{390 \text{ J/kg•°C}}$
4. $\Delta T_w = 8.39°C$ $m_w = 101$ g $c_{p,w} = 4186$ J/kg•°C $\Delta T_c = -68.0°C$ $c_{p,c} = 387$ J/kg•°C	$-c_{p,c}\, m_c\, \Delta T_c = c_{p,w}\, m_w\, \Delta T_w$ $m_c = -\dfrac{c_{p,w}\ m_w\ \Delta T_w}{c_{p,c}\Delta T_c}$ $m_c = -\dfrac{(4186 \text{ J/kg•°C})(0.101 \text{ kg})(8.39°C)}{(387 \text{ J/kg•°C})(-68.0°C)}$ $m_c = 0.135 \text{ kg} = \boxed{135 \text{ g}}$

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Heat, Section 3 Review

Givens | *Solutions*

1. $m_g = 47$ g
$T_g = 99°C$
$T_w = 25°C$
$T_f = 38°C$
$c_{p,g} = 1.29 \times 10^2$ J/kg•°C
$c_{p,w} = 4186$ J/kg•°C

$c_{p,w}\, m_w\, \Delta T_w = -c_{p,g}\, m_g\, \Delta T_g$

$\Delta T_g = T_f - T_g = 38°C - 99°C = -61°C$

$\Delta T_w = T_f - T_w = 38°C - 25°C = 13°C$

$$m_w = -\frac{c_{p,g} m_g \Delta T_g}{c_{p,w} \Delta T_w} = -\frac{(1.29 \times 10^2 \text{ J/kg•°C})(47 \times 10^{-3} \text{ kg})(-61°C)}{(4186 \text{ J/kg•°C})(13°C)}$$

$m_w = 6.8 \times 10^{-3}$ kg $= \boxed{6.8 \text{ g}}$

2. $T_f = 175°C$
$T_p = 21°C$
$c_{p,p} = 1650$ J/kg•°C
$m_p = (0.105$ g/kernel$)$ $(125$ kernels$)$

$\Delta T = T_f - T_p = 175°C - 21°C = 154°C$

$Q = m_p c_{p,p} \Delta T = (0.105 \times 10^{-3}$ kg/kernel$)(125$ kernels$)(1650$ J/kg•°C$)(154°C)$

$Q = \boxed{3340 \text{ J}}$

3. $m_w = (0.14)(95.0$ g$)$
$L_v = (0.90)(2.26 \times 10^6$ J/kg$)$

$Q = m_w L_v = (0.14)(95.0 \times 10^{-3}$ kg$)(0.90)(2.26 \times 10^6$ J/kg$)$

$Q = \boxed{2.7 \times 10^4 \text{ J}}$

6. $m = 15$ g $= 0.015$ kg

a. $$c_{p,l} = \frac{Q}{m\Delta T} = \frac{15.8 \text{ kJ} - 8.37 \text{ kJ}}{(0.015 \text{ kg})(300°C - 80°C)} = \frac{7.4 \times 10^3 \text{ J}}{(0.015 \text{ kg})(200°C)} = \boxed{2 \times 10^3 \text{ J/kg•°C}}$$

b. $$L_f = \frac{Q}{m} = \frac{8.37 \text{ kJ} - 1.27 \text{ kJ}}{0.015 \text{ kg}} = \frac{7.10 \times 10^3 \text{ J}}{0.015 \text{ kg}} = \boxed{4.7 \times 10^5 \text{ J/kg}}$$

c. $$c_{p,s} = \frac{Q}{m\Delta T} = \frac{1.27 \text{ kJ} - 0 \text{ kJ}}{(0.015 \text{ kg})(80°C - 0°C)} = \frac{1.27 \times 10^3 \text{ J}}{(0.015 \text{ kg})(80°C)} = \boxed{1 \times 10^3 \text{ J/kg•°C}}$$

d. $$c_{p,v} = \frac{Q}{m\Delta T} = \frac{796 \text{ kJ} - 795 \text{ kJ}}{(0.015 \text{ kg})(400°C - 300°C)} = \frac{1 \times 10^3 \text{ J}}{(0.015 \text{ kg})(100°C)} = \boxed{7 \times 10^2 \text{ J/kg•°C}}$$

e. $$L_v = \frac{Q}{m} = \frac{795 \text{ kJ} - 15.8 \text{ kJ}}{0.015 \text{ kg}} = \frac{779 \times 10^3 \text{ J}}{0.015 \text{ kg}} = \boxed{5.2 \times 10^7 \text{ J/kg}}$$

Heat, Chapter Review

9. $T_F = 136°F$

$T_C = \frac{5}{9}(T_F - 32.0) = \frac{5}{9}(136 - 32.0)°C = \frac{5}{9}(104)°C = \boxed{57.8°C}$

$T = (T_C + 273.15)$K $= (57.8 + 273.15)$K

$T = \boxed{331.0 \text{ K}}$

10. $T_F = 1947°F$

$T_C = \frac{5}{9}(T_F - 32.0) = \frac{5}{9}(1947 - 32.0) = \frac{5}{9}(1915)°C = \boxed{1064°C}$

$T = T_C + 273.15 = (1064 + 273.15)$ K $= \boxed{1337 \text{ K}}$

24. $F = 315$ N
$d = 35.0$ m
$W = (0.14)(U_i)$

$W = (0.14)(U_i)$

$$U_i = \frac{W}{0.14} = \frac{Fd}{0.14} = \frac{(315 \text{ N})(35.0 \text{ m})}{0.14} = \boxed{7.9 \times 10^4 \text{ J}}$$

Givens	*Solutions*
25. $m = 0.75$ kg $v_i = 3.0$ m/s	**a.** $\Delta U = (0.85)(KE) = (0.85)\left(\frac{1}{2}mv^2\right)$ $\Delta U = \frac{1}{2}(0.85)(0.75 \text{ kg})(3.0 \text{ m/s})^2 = \boxed{2.9 \text{ J}}$

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31. $m_r = 25.5$ g $T_r = 84.0°C$ $m_w = 5.00 \times 10^{-2}$ kg $T_w = 24.0°C$ $Q_w = -Q_r - 0.14$ kJ $c_{p,r} = 234$ J/kg•°C $c_{p,w} = 4186$ J/kg•°C	$Q_w = -Q_r - 0.14$ kJ $c_{p,w}m_w(T_f - T_w) = -c_{p,r}m_r(T_f - T_r) - 0.14$ kJ $T_f = \dfrac{c_{p,r}m_rT_r + c_{p,w}m_wT_w - 0.14 \text{ kJ}}{c_{p,w}m_w + c_{p,r}m_r}$ $c_{p,r}m_r = (234 \text{ J/kg•°C})(2.55 \times 10^{-2} \text{ kg}) = 5.97 \text{ J/°C}$ $c_{p,r}m_rT_r = (234 \text{ J/kg•°C})(2.55 \times 10^{-2} \text{ kg})(84.0°C) = 501 \text{ J}$ $c_{p,w}m_w = 4186 \text{ J/kg•°C})(5.00 \times 10^{-2} \text{ kg}) = 209 \text{ J/°C}$ $c_{p,w}m_wT_w = (4186 \text{ J/kg•°C})(5.00 \times 10^{-2} \text{ kg})(24.0°C) = 5.02 \times 10^3 \text{ J}$ $T_f = \dfrac{501 \text{ J} + (5.02 \times 10^3 \text{ J}) - 140 \text{ J}}{209 \text{ J/°C} + 5.97 \text{ J/°C}} = \dfrac{5.38 \times 10^3 \text{ J}}{215 \text{ J/°C}}$ $T_f = \boxed{25.0°C}$
32. $m_1 = 1500$ kg $v_i = 32$ m/s $v_f = 0$ m/s $c_{p,iron} = 448$ J/kg•°C $m_2 = (4)(3.5$ kg$)$	$\Delta U = \Delta KE = \frac{1}{2}m_1(v_f - v_i)^2 = (0.5)(1500 \text{ kg})(0 \text{ m/s} - 32 \text{ m/s})^2 = 7.7 \times 10^5 \text{ J}$ $Q = \Delta U = 7.7 \times 10^5$ J $Q = m_2c_{p,iron}\Delta T$ $\Delta T = \dfrac{Q}{m_2c_{p,iron}} = \dfrac{7.7 \times 10^5 \text{ J}}{(4)(3.5 \text{ kg})(448 \text{ J/kg•°C})} = \boxed{120°C}$
33. $T_R = 0°R$ = absolute zero one Rankine degree = one Fahrenheit degree	**a.** $T_R = T_F -$ (absolute zero in T_F) $T_F = \frac{9}{5}T_C + 32.0$ absolute zero in $T_c = -273.15°C$ absolute zero in $T_F = \frac{9}{5}(-273.15)°F + 32.0°F$ absolute zero in $T_F = (-491.67 + 32.0)°F = -459.7°F$ $T_R = T_F - (-459.7)°F = T_F + 459.7°F$ $\boxed{T_R = T_F + 459.7, \text{ or } T_F = T_R - 459.7}$ **b.** $T = T_C + 273.15$ $T_C = \frac{5}{9}(T_F - 32.0)$ $T = \frac{5}{9}(T_F - 32.0) + 273.15$ $T_F = T_R - 459.7$ $T = \frac{5}{9}(T_R - 459.7 - 32.0) + 273.15$ $T = \frac{5}{9}(T_R - 491.7) + 273.15$ $T = \frac{5}{9}T_R - \frac{5}{9}(491.7) + 273.15$ $T = \frac{5}{9}T_R - 273.2 + 273.15$ $\boxed{T = \frac{5}{9}T_R, \text{ or } T_R = \frac{9}{5}T}$

Givens / Solutions

34. $m_r = 3.0$ kg

$m_w = 1.0$ kg

$\Delta T = 0.10°C$

$c_{p,w} = 4186$ J/kg•°C

$g = 9.81$ m/s^2

$PE_i = \Delta U$

$m_r gh = c_{p,w} m_w \Delta T$

$$h = \frac{c_{p,w} m_w \Delta T}{m_r g} = \frac{(4186 \text{ J/kg•°C})(1.0 \text{ kg})(0.10°\text{C})}{(3.0 \text{ kg})(9.81 \text{ m/s}^2)}$$

$h = \boxed{14 \text{ m}}$

35. freezing point = 50°TH (0°C)

boiling point = 200°TH (100°C)

a. Set up a graph with Celsius on the x-axis and "Too Hot" on the y-axis. The equation relating the two scales can be found by graphing one scale versus the other scale and then finding the equation of the resulting line. In this case, the two known coordinates of the line are (0, 50) and (100, 200).

$$\text{slope} = a = \frac{\Delta y}{\Delta x} = \frac{(200 - 50)}{(100 - 0)} = \frac{150}{100} = \frac{3}{2}$$

$y = ax + b$

$b = y - ax = 50 - \left(\frac{3}{2}\right)0 = 50$

The values $y = T_{TH}$, $a = \frac{3}{2}$, $x = T_C$, and $b = 50$ can be substituted into the equation for a line to find the conversion equation.

$y = ax + b$

$$\boxed{T_{TH} = \tfrac{3}{2}T_C + 50}$$

$$\text{or } x = \frac{y - b}{a}$$

$$T_C = \frac{T_{TH} - 50}{\frac{3}{2}}$$

$$\boxed{T_C = \tfrac{2}{3}(T_{TH} - 50)}$$

T_C = absolute zero = −273.15°C

b. $T_{TH} = \frac{3}{2}(T_C) + 50 = \frac{3}{2}(-273.15)°\text{TH} + 50°\text{TH} = (-409.72 + 50)°\text{TH} = \boxed{-360°\text{TH}}$

36. $A = 6.0$ m^2

$P/A = 550$ W/m^2

$V_w = 1.0$ m^3

$T_i = 21°C$

$T_f = 61°C$

$\rho_w = 1.00 \times 10^3$ kg/m^3

$c_{p,w} = 4186$ J/kg•°C

$\Delta T = T_f - T_i = 61°\text{C} - 21°\text{C} = (4.0 \times 10^1)°\text{C}$

$m_w = V_w \rho_w = (1.0 \text{ m}^3)(1.00 \times 10^3 \text{ kg/m}^3) = 1.0 \times 10^3$ kg

$$\Delta t = \frac{Q}{P} = \frac{m_w c_{p,w} \Delta T}{(P/A)(A)} = \frac{(1.0 \times 10^3 \text{ kg})(4186 \text{ J/kg•°C})(4.0 \times 10^1 °\text{C})}{(550 \text{ W/m}^2)(6.0 \text{ m}^2)}$$

$\Delta t = \boxed{5.1 \times 10^4 \text{ s}}$

or $(5.1 \times 10^4 \text{ s})(1 \text{ h}/3600 \text{ s}) = \boxed{14 \text{ h}}$

Givens	*Solutions*

37. $m_c = 253$ g

$T_c = 85°C$

$T_a = 5°C$

$T_f = 25°C$

$c_{p,a} = 8.99 \times 10^2$ J/kg•°C

$c_{p,c} = 3.87 \times 10^2$ J/kg•°C

$c_{p,a}\, m_a\, \Delta T_a = -c_{p,c}\, m_c\, \Delta T_c$

$\Delta T_c = T_f - T_c = 25°C - 85°C = (-6.0 \times 10^1)°C$

$\Delta T_a = T_f - T_a = 25°C - 5°C = (2.0 \times 10^1)°C$

$$m_a = -\frac{m_c \Delta T_c c_{p,c}}{\Delta T_a c_{p,a}} = -\frac{(0.253 \text{ kg})(-6.0 \times 10^1 °C)(3.87 \times 10^2 \text{ J/kg•°C})}{(2.0 \times 10^1 °C)(8.99 \times 10^2 \text{ J/kg•°C})}$$

$m_a = 0.33 \text{ kg} = \boxed{330 \text{ g}}$

38.

$T_F = \frac{9}{5} T_C + 32.0 \qquad T_C = T - 273.15$

$T_F - 32.0 = \frac{9}{5} T_C$

$\frac{5}{9} T_F - \frac{5}{9}(32.0) = T_C$

$\frac{5}{9} T_F - \frac{5}{9}(32.0) + 273.15 = T$

$T = T_F$

$\frac{5}{9} T_F - \frac{5}{9}(32.0) + 273.15 = T_F$

$\frac{5}{9} T_F - 17.8 + 273.15 = T_F$

$\frac{5}{9} T_F + 255.4 = T_F$

$255.4 = \frac{4}{9} T_F$

$T_F = \frac{9}{4}(255.4)°F = 574.6°F$

$T_F = T$

$\boxed{574.6°F = 574.6 \text{ K}}$

39. $m_a = 250$ g

$m_w = 850$ g

$\frac{\Delta T}{\Delta t} = 1.5°C/\text{min}$

$c_{p,a} = 899$ J/kg•°C

$c_{p,w} = 4186$ J/kg•°C

$$\frac{Q}{\Delta t} = \frac{Q_a + Q_w}{\Delta t} = \frac{m_a c_{p,a} \Delta T + m_w c_{p,w} \Delta T}{\Delta t} = (m_a c_{p,a} + m_w c_{p,w})\left(\frac{\Delta T}{\Delta t}\right)$$

$$\frac{Q}{\Delta t} = [(0.250 \text{ kg})(899 \text{ J/kg•°C}) + (0.850 \text{ kg})(4186 \text{ J/kg•°})](1.5°C/\text{min})$$

$$\frac{Q}{\Delta t} = (225 \text{ J/°C} + 3.56 \times 10^3 \text{ J/°C})(1.5°C/\text{min}) = (3.78 \times 10^3 \text{ J/°C})(1.5°C/\text{min})$$

$$\frac{Q}{\Delta t} = \boxed{5.7 \times 10^3 \text{ J/min}}$$

or $(5700 \text{ J/min})(1 \text{ min}/60 \text{ s}) = \boxed{95 \text{ J/s}}$

Givens | *Solutions*

40. $T_{tea} = 32°C$

$T_{ice} = 0°C$

$T_f = 15°C$

$m_{tea} = 180$ g

$m_{ice,tot} = 112$ g

$c_{p,tea} = c_{p,w} = 4186$ J/kg•°C

$L_f = 3.33 \times 10^5$ J/kg

$$-\Delta Q_{tea} = \Delta Q_{melted\ ice}$$

$$-m_{tea}\, c_{p,tea}\, \Delta T_{tea} = m_{ice}\, L_f + m_{ice}\, c_{p,w}\, \Delta T_{ice}$$

$$m_{ice} = \frac{-m_{tea}\, c_{p,tea}\, \Delta T_{tea}}{L_f + c_{p,w}\, \Delta T_{ice}}$$

$$\Delta T_{tea} = T_f - T_{tea} = 15°C - 32°C = -17°C$$

$$\Delta T_{ice} = T_f - T_{ice} = 15°C - 0°C = 15°C$$

$$m_{ice} = \frac{-(180 \times 10^{-3}\text{ kg})(4186\text{ J/kg•°C})(-17°C)}{3.33 \times 10^5\text{ J/kg} + (4186\text{ J/kg•°C})(15°C)}$$

$$m_{ice} = \frac{(180 \times 10^{-3}\text{ kg})(4186\text{ J/kg•°C})(17°C)}{3.33 \times 10^5\text{ J/kg} + 6.3 \times 10^4\text{ J/kg}}$$

$$m_{ice} = \frac{(180 \times 10^{-3}\text{ kg})(4186\text{ J/kg•°C})(17°C)}{3.96 \times 10^5\text{ kg}} = 3.2 \times 10^{-2}\text{ kg} = 32\text{ g}$$

mass of unmelted ice $= m_{ice,tot} - m_{ice} = 112\text{ g} - 32\text{ g} = \boxed{8.0 \times 10^1\text{ g}}$

Heat, Standardized Test Prep

3. $T_C = -252.87°C$

$$T_F = \tfrac{9}{5}T_C + 32.0 = \tfrac{9}{5}(-252.87)°F + 32.0°F$$

$$T_F = (-455.17 + 32.0)°F = \boxed{-423.2°F}$$

4. $T_C = -252.87°C$

$$T = T_C + 273.15 = (-252.87 + 273.15)\text{ K} = \boxed{20.28\text{ K}}$$

8. $m = 23$ g

$$c_{p,l} = \frac{Q}{m\Delta T} = \frac{16.6\text{ kJ} - 12.0\text{ kJ}}{(23 \times 10^{-3}\text{ kg})(340°C - 160°C)} = \frac{4.6 \times 10^3\text{ J}}{(23 \times 10^{-3}\text{ kg})(180°C)}$$

$$c_{p,l} = \boxed{1.1 \times 10^3\text{ J/kg•°C}}$$

9. $m = 23$ g

$$L_f = \frac{Q}{m} = \frac{12.0\text{ kJ} - 1.85\text{ kJ}}{23 \times 10^{-3}\text{ kg}} = \frac{10.2 \times 10^3\text{ J}}{23 \times 10^{-3}\text{ kg}} = \boxed{4.4 \times 10^5\text{ J/kg}}$$

10. $m = 23$ g

$$c_{p,s} = \frac{Q}{m\Delta T} = \frac{1.85\text{ kJ} - 0\text{ kJ}}{(23 \times 10^{-3}\text{ kg})(160°C - 0°C)} = \frac{1.85 \times 10^3\text{ J}}{(23 \times 10^{-3}\text{ kg})(160°C)}$$

$$c_{p,s} = \boxed{5.0 \times 10^2\text{ J/kg•°C}}$$

11. $m_w = 1.20 \times 10^{16}$ kg

$c_{p,w} = 4186$ J/kg•°C

$\Delta T = 1.0°C$

$$Q = m_w c_{p,w} \Delta T = (1.20 \times 10^{16}\text{ kg})(4186\text{ J/kg•°C})(1.0°C) = \boxed{5.0 \times 10^{19}\text{ J}}$$

Givens	*Solutions*
12. $m_w = 1.20 \times 10^{16}$ kg $L_f = 3.33 \times 10^5$ J/kg	$Q = m_w L_f = (1.20 \times 10^{16}\text{ kg})(3.33 \times 10^5\text{ J/kg}) = \boxed{4.00 \times 10^{21}\text{ J}}$
14. $m_g = 0.200$ kg $m_w = 0.300$ kg $\Delta T = 2.0°C$ $c_{p,g} = 837$ J/kg•°C $c_{p,w} = 4186$ J/kg•°C	$Q = Q_g + Q_w = m_g c_{p,g}\Delta T + m_w c_{p,w}\Delta T = (m_g c_{p,g} + m_w c_{p,w})(\Delta T)$ $Q = [(0.200\text{ kg})(837\text{ J/kg•°C}) + (0.300\text{ kg})(4186\text{ J/kg•°C})](2.0°C)$ $Q = (167\text{ J/°C} + 1260\text{ J/°C})(2.0°C) = (1430\text{ J/°C})(2.0°C) = \boxed{2900\text{ J}}$
16. $T_C = -40.0°C$	$T_F = \frac{9}{5}T_C + 32.0 = \frac{9}{5}(-40.0)°F + 32.0°F = (-72.0 + 32.0)°F$ $T_F = \boxed{-40.0°F}$

I

Thermodynamics

Thermodynamics, Practice A

Givens	Solutions
1. $P = 1.6 \times 10^5$ Pa $V_i = 4.0$ m^3	**a.** $V_f = 2V_i = (2)(4.0 \text{ m}^3) = 8.0 \text{ m}^3$ $W = P\Delta V = P(V_f - V_i) = (1.6 \times 10^5 \text{ Pa})(8.0 \text{ m}^3 - 4.0 \text{ m}^3)$ $W = (1.6 \times 10^5 \text{ Pa})(4.0 \text{ m}^3) = \boxed{6.4 \times 10^5 \text{ J}}$ **b.** $V_f = \frac{1}{4}V_i = \frac{1}{4}(4.0 \text{ m}^3) = 1.0 \text{ m}^3$ $W = P\Delta V = P(V_f - V_i) = (1.6 \times 10^5 \text{ Pa})(1.0 \text{ m}^3 - 4.0 \text{ m}^3)$ $W = (1.6 \times 10^5 \text{ Pa})(-3.0 \text{ m}^3) = \boxed{-4.8 \times 10^5 \text{ J}}$
2. $P = 599.5$ kPa $V_i = 5.317 \times 10^{-4}$ m^3 $V_f = 2.523 \times 10^{-4}$ m^3	$W = P\Delta V = P(V_f - V_i) = (599.5 \times 10^3 \text{ Pa})[(2.523 \times 10^{-4} \text{ m}^3) - (5.317 \times 10^{-4} \text{ m}^3)]$ $W = (599.5 \times 10^3 \text{ Pa})(-2.794 \times 10^{-4} \text{ m}^3) = \boxed{-167.5 \text{ J}}$
3. $P = 4.3 \times 10^5$ Pa $V_i = 1.8 \times 10^{-4}$ m^3 $V_f = 9.5 \times 10^{-4}$ m^3	$W = P\Delta V = P(V_f - V_i) = (4.3 \times 10^5 \text{ Pa})[(9.5 \times 10^{-4} \text{ m}^3) - (1.8 \times 10^{-4} \text{ m}^3)]$ $W = (4.3 \times 10^5 \text{ Pa})(7.7 \times 10^{-4} \text{ m}^3) = \boxed{3.3 \times 10^2 \text{ J}}$
4. $r = \frac{1.6 \text{ cm}}{2} = 0.80$ cm $d = 2.1$ cm $W = 0.84$ J	$W = P\Delta V = PAd = P\pi r^2 d$ $P = \frac{W}{\pi r^2 d} = \frac{0.84 \text{ J}}{\pi(0.80 \times 10^{-2} \text{ m})^2 (2.1 \times 10^{-2} \text{ m})} = \boxed{2.0 \times 10^5 \text{ Pa}}$

Thermodynamics, Section 1 Review

Givens	Solutions
2. $A = 7.4 \times 10^{-3}$ m^2 $d = -7.2 \times 10^{-2}$ m $P = 9.5 \times 10^5$ Pa	$W = P\Delta V = PAd = (9.5 \times 10^5 \text{ Pa})(7.4 \times 10^{-3} \text{ m}^2)(-7.2 \times 10^{-2} \text{ m}) = \boxed{-5.1 \times 10^2 \text{ J}}$
3. $P = 1.5 \times 10^3$ Pa $\Delta V = 5.4 \times 10^{-5}$ m^3	$W = P\Delta V = (1.5 \times 10^3 \text{ Pa})(5.4 \times 10^{-5} \text{ m}^3) = \boxed{8.1 \times 10^{-2} \text{ J}}$

Thermodynamics, Practice B

Givens	Solutions
1. $W = 26$ J $\Delta U = 7$ J	$\Delta U = Q - W$ $Q = W + \Delta U = 26 \text{ J} + 7 \text{ J} = \boxed{33 \text{ J}}$

Givens	*Solutions*
2. $\Delta U = -195$ J $W = 52.0$ J	$Q = \Delta U + W = -195 \text{ J} + 52.0 \text{ J} = \boxed{-143 \text{ J}}$
3. $U_{lost} = 2.0 \times 10^3$ J $W = 0$ J $\Delta U = 8.0 \times 10^3$ J	$Q = \Delta U + W + U_{lost} = 8.0 \times 10^3 \text{ J} + 0 \text{ J} + 2.0 \times 10^3 \text{ J} = \boxed{1.00 \times 10^4 \text{ J}}$
4. $\Delta U = -344$ J	$Q = \boxed{0 \text{ J}}$ for adiabatic processes. $W = Q - \Delta U = 0 \text{ J} - (-344 \text{ J}) = \boxed{344 \text{ J}}$
5. $Q = 3.50 \times 10^8$ J $W = 1.76 \times 10^8$ J	$\Delta U = Q - W = 3.50 \times 10^8 \text{ J} - 1.76 \times 10^8 \text{ J} = \boxed{1.74 \times 10^8 \text{ J}}$

Thermodynamics, Section 2 Review

4. $P = 8.6 \times 10^5$ Pa $\Delta V = 4.05 \times 10^{-4}$ m^3 $Q = -9.5$ J	**a.** $W = P\Delta V = (8.6 \times 10^5 \text{ Pa})(4.05 \times 10^{-4} \text{ m}^3) = \boxed{3.5 \times 10^2 \text{ J}}$ **b.** $\Delta U = Q - W = -9.5 \text{ J} - 350 \text{ J} = \boxed{-3.6 \times 10^2 \text{ J}}$
5. $P = 7.07 \times 10^5$ Pa $\Delta V = -1.1 \times 10^{-4}$ m^3 $\Delta U = 62$ J	$Q = W + \Delta U = P\Delta V + \Delta U = (7.07 \times 10^5 \text{ Pa})(-1.1 \times 10^{-4} \text{ m}^3) + 62 \text{ J}$ $Q = -78 \text{ J} + 62 \text{ J} = \boxed{-16 \text{ J}}$
6. $W = -1.51 \times 10^4$ J $Q_c = 7.55 \times 10^4$ J	**a.** For removal of energy from inside refrigerator, $\Delta U_c = Q_c - W = (7.55 \times 10^4 \text{ J}) - (-1.51 \times 10^4 \text{ J}) = 9.06 \times 10^4 \text{ J}$ No work is done on or by outside air, so all internal energy is given up as heat. $Q_h = \Delta U_h = \Delta U_c = \boxed{9.06 \times 10^4 \text{ J transferred to outside air}}$ **b.** For cyclic processes, $\Delta U_{ref} = \boxed{0 \text{ J}}$ **c.** Because there is no change in the air's volume, $W_{air} = \boxed{0 \text{ J}}$ **d.** For air inside refrigerator, $Q_{air} = -Q_c$ and $W_{air} = 0$ J. $Q_{air} - W_{air} = \Delta U_{air} = -Q_c = \boxed{-7.55 \times 10^4 \text{ J}}$
7. $Q = -15$ J $W = 13$ J	$\Delta U = Q - W = -15 \text{ J} - 13 \text{ J} = \boxed{-28 \text{ J}}$

Thermodynamics, Practice C

1. $Q_h = 2.254 \times 10^4$ kJ $Q_c = 1.915 \times 10^4$ kJ	$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{1.915 \times 10^4 \text{ kJ}}{2.254 \times 10^4 \text{ kJ}} = 1 - 0.8496 = \boxed{0.1504}$
2. $W = 45$ J $Q_c = 31$ J	$Q_h = W + Q_c = 45 \text{ J} + 31 \text{ J} = 76 \text{ J}$ $eff = \frac{W}{Q_h} = \frac{45 \text{ J}}{76 \text{ J}} = \boxed{0.59}$

Givens	*Solutions*
3. $Q_h = 1.98 \times 10^5$ J $Q_c = 1.49 \times 10^5$ J	**a.** $eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{1.49 \times 10^5 \text{ J}}{1.98 \times 10^5 \text{ J}} = 1 - 0.753 = \boxed{0.247}$ **b.** $W = Q_h - Q_c = (1.98 \times 10^5 \text{ J}) - (1.49 \times 10^5 \text{ J}) = \boxed{4.9 \times 10^4 \text{ J}}$
4. $eff = 0.21$ $Q_c = 780$ J	$eff = 1 - \frac{Q_c}{Q_h}$ $eff - 1 = -\frac{Q_c}{Q_h}$ $1 - eff = \frac{Q_c}{Q_h}$ $Q_h = \frac{Q_c}{1 - eff} = \frac{780 \text{ J}}{1 - 0.21} = \frac{780 \text{ J}}{0.79} = 990 \text{ J}$ $W = Q_h - Q_c = 990 \text{ J} - 780 \text{ J} = \boxed{210 \text{ J}}$
5. $W = 372$ J $eff = 0.330$	$Q_h = W + Q_c$ $eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{Q_c}{W + Q_c} = \frac{W + Q_c - Q_c}{W + Q_c} = \frac{W}{W + Q_c}$ $W + Q_c = \frac{W}{eff}$ $Q_c = \frac{W}{eff} - W = \left(\frac{1}{eff} - 1\right)W = \left(\frac{1}{0.330} - 1\right)(372 \text{ J})$ $Q_c = (3.03 - 1)(372 \text{ J}) = (2.03)(372 \text{ J}) = \boxed{755 \text{ J}}$
6. $Q_c = 6.0 \times 10^2$ J $eff = 0.31$	$Q_h = \frac{Q_c}{1 - eff} = \frac{6.0 \times 10^2 \text{ J}}{1 - 0.31} = \frac{6.0 \times 10^2 \text{ J}}{0.69} = \boxed{8.7 \times 10^2 \text{ J}}$

Thermodynamics, Section 3 Review

2. $Q_h = 75\,000$ J $Q_c = 35\,000$ J	**a.** $W = Q_h - Q_c = 75\,000 \text{ J} - 35\,000 \text{ J} = \boxed{4.0 \times 10^4 \text{ J}}$ **b.** $eff = \frac{W}{Q_h} = \frac{4.0 \times 10^4 \text{ J}}{75\,000 \text{ J}} = \boxed{0.53}$

Thermodynamics, Chapter Review

9. $V_i = 35.25 \times 10^{-3}$ m^3 $V_f = 39.47 \times 10^{-3}$ m^3 $P = 2.55 \times 10^5$ Pa	$W = P\Delta V = P(V_f - V_i) = (2.55 \times 10^5 \text{ Pa})[(39.47 \times 10^{-3} \text{ m}^3) - (35.25 \times 10^{-3} \text{ m}^3)]$ $W = (2.55 \times 10^5 \text{ Pa})(4.22 \times 10^{-3} \text{ m}^3) = \boxed{1.08 \times 10^3 \text{ J}}$
10. $P = 2.52 \times 10^5$ Pa $V_i = 1.1 \times 10^{-4}$ m^3 $V_f = 1.50 \times 10^{-3}$ m^3	$W = P\Delta V = P(V_f - V_i)$ $W = (2.52 \times 10^5 \text{ Pa})(1.50 \times 10^{-3} \text{ m}^3 - 1.1 \times 10^{-4} \text{ m}^3)$ $W = (2.52 \times 10^5 \text{ Pa})(1.4 \times 10^{-3} \text{ m}^3)$ $W = \boxed{3.5 \times 10^2 \text{ J}}$

Givens | *Solutions*

16. $\Delta U = 604 \times 10^3$ J
$W = 43.0 \times 10^3$ J

$Q = \Delta U + W = (604 \times 10^3 \text{ J}) + (43.0 \times 10^3 \text{ J}) = \boxed{647 \times 10^3 \text{ J}}$

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17. $m_1 = 150$ kg
$m_2 = 6050$ kg
$T_i = 22°C$
$T_f = 47°C$
$d = 5.5$ mm
$c_p = 448$ J/kg•°C
$g = 9.81$ m/s^2

a. $Q = m_1c_p\Delta T = m_1c_p(T_f - T_i) = (150 \text{ kg})(448 \text{ J/kg•°C})(47°C - 22°C)$

$Q = (150 \text{ kg})(448 \text{ J/kg•°C})(25°C) = \boxed{1.7 \times 10^6 \text{ J}}$

b. $W = Fd = m_2gd = (6050 \text{ kg})(9.81 \text{ m/s}^2)(5.5 \times 10^{-3} \text{ m})$

$W = \boxed{3.3 \times 10^2 \text{ J}}$

c. $\Delta U = Q - W = (1.7 \times 10^6 \text{ J}) - (3.3 \times 10^2 \text{ J}) = \boxed{1.7 \times 10^6 \text{ J}}$

---

26. $Q_h = 525$ J
$Q_c = 415$ J

$$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{415 \text{ J}}{525 \text{ J}} = 1 - 0.790 = \boxed{0.210}$$

---

27. $Q_h = 9.5 \times 10^{12}$ J
$Q_c = 6.5 \times 10^{12}$ J

$$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{6.5 \times 10^{12} \text{ J}}{9.5 \times 10^{12} \text{ J}} = 1 - 0.68 = \boxed{0.32}$$

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28. $Q_h = 850$ J
$Q_c = 5.0 \times 10^2$ J
$W = 3.5 \times 10^2$ J

$$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{5.0 \times 10^2 \text{ J}}{850 \text{ J}} = 1 - 0.59 = \boxed{0.41}$$

Alternatively,

$$eff = \frac{W}{Q_h} = \frac{3.5 \times 10^2 \text{ J}}{850 \text{ J}} = \boxed{0.41}$$

---

29. $Q_1 = 606$ J
$W_1 = 418$ J
$W_2 = 1212$ J

a. $\Delta U_1 = Q_1 - W_1 = 606 \text{ J} - 418 \text{ J} = \boxed{188 \text{ J}}$

b. Because $\Delta U_2 = \Delta U_1$, $Q_2 = \Delta U_1 + W_2$

$Q_2 = 188 \text{ J} + 1212 \text{ J} = \boxed{1.400 \times 10^3 \text{ J}}$

---

30. $Q = 5175$ J

d. Because $\Delta V = 0$, $W = 0$ J and $\Delta U = Q = \boxed{5175 \text{ J}}$.

Thermodynamics, Standardized Test Prep

9. $P = 1055$ MW
$eff = 0.330$

$$Q_h = \frac{W}{eff}$$

$$\frac{Q_h}{\Delta t} = \frac{W}{eff\,\Delta t} = \frac{P}{eff} = \frac{1055 \text{ MW}}{0.330} = 3.20 \times 10^3 \text{ MW}$$

$$Q_c = Q_h - W$$

$$\frac{Q_c}{\Delta t} = \frac{Q_h}{\Delta t} - \frac{W}{\Delta t} = \frac{Q_h}{\Delta t} - P = 3.20 \times 10^3 \text{ MW} - 1055 \text{ MW}$$

$$\frac{Q_c}{\Delta t} = 2140 \text{ MW} = 2140 \text{ MJ/s} = \boxed{2.14 \times 10^9 \text{ J/s}}$$

Givens | *Solutions*

10. $\Delta V = 0.041\ m^3 - 0.031\ m^3 = 0.010\ m^3$

$P = 300.0$ kPa

$W = P\Delta V = (300.0 \times 10^3\ Pa)(0.010\ m^3) = \boxed{3.0 \times 10^3\ J}$

---

13. $Q_h = 1600$ J

$Q_c = 1200$ J

$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{1200\ J}{1600\ J} = 1 - 0.75$

$eff = \boxed{0.25}$

---

15. $m = 450.0$ kg

$h = 8.6$ m

$W = mgh = (450.0\ kg)(9.81\ m/s^2)(8.6\ m) = \boxed{3.8 \times 10^4\ J}$

---

16. $Q_h = 2.00 \times 10^5$ J

$W = 3.8 \times 10^4$ J (see **15.**)

$eff = \frac{W}{Q_h} = \frac{3.8 \times 10^4\ J}{2.00 \times 10^5\ J} = \boxed{0.19}$

---

17. $Q_h = 2.00 \times 10^5$ J

$eff = 0.19$ (see **16.**)

$eff = \frac{Q_h - Q_c}{Q_h}$

$eff(Q_h) = Q_h - Q_c$

$Q_c = Q_h - eff(Q_h) = 2.00 \times 10^5\ J - (0.19)(2.00 \times 10^5\ J)$

$Q_c = 2.00 \times 10^5\ J - 3.8 \times 10^4\ J = \boxed{1.62 \times 10^5\ J}$

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18. $Q_h = 2.00 \times 10^5$ J

$W = 3.8 \times 10^4$ J (see **15.**)

$\Delta U = 5.0 \times 10^3$ J

$\Delta U = Q - W = Q_h - Q_c - W$

$Q_c = Q_h - W - \Delta U$

$Q_c = 2.00 \times 10^5\ J - 3.8 \times 10^4\ J - 5.0 \times 10^3\ J = \boxed{1.57 \times 10^5\ J}$

Vibrations and Waves

I

Vibrations and Waves, Practice A

Givens | *Solutions*

1. $x = -36$ cm

$m = 0.55$ kg

$g = 9.81$ m/s^2

a. $F_g + F_{elastic} = 0$

$F_g = -mg$

$F_{elastic} = -kx$

$-mg - kx = 0$

$$k = \frac{-mg}{x} = \frac{-(0.55 \text{ kg})(9.81 \text{ m/s}^2)}{-0.36 \text{ m}} = \boxed{15 \text{ N/m}}$$

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2. $F_g = -45$ N

$x = -0.14$ m

$F_g + F_{elastic} = 0$

$F_g + (-kx) = 0$

$$k = \frac{F_g}{x} = \frac{-45 \text{ N}}{-0.14 \text{ m}} = \boxed{3.2 \times 10^2 \text{ N/m}}$$

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3. $F_1 = 32$ N

$x_1 = -1.2$ cm

$$k = \frac{-F_1}{x_1} = \frac{-32 \text{ N}}{-0.012 \text{ m}} = \boxed{2.7 \times 10^3 \text{ N/m}}$$

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4. $x_2 = -3.0$ cm

$F_2 = -kx_2$

$F_2 = -(2.7 \times 10^3 \text{ N/m})(-0.030 \text{ m}) = \boxed{81 \text{ N}}$

Vibrations and Waves, Section 1 Review

2. $x = -4.0$ cm

$k = 13$ N/m

$F = -kx = -(13 \text{ N/m})(-0.040 \text{ m})$

$F = \boxed{0.52 \text{ N}}$

Vibrations and Waves, Practice B

1. $T = 24$ s

$a_g = g = 9.81$ m/s^2

$$T = 2\pi\sqrt{\frac{L}{a_g}}$$

$$L = a_g\left(\frac{T}{2\pi}\right)^2 = (9.81 \text{ m/s}^2)\left(\frac{24 \text{ s}}{2\pi}\right)^2 = \boxed{1.4 \times 10^2 \text{ m}}$$

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2. $T = 1.0$ s

$a_g = g = 9.81$ m/s^2

$$T = 2\pi\sqrt{\frac{L}{a_g}}$$

$$L = a_g\left(\frac{T}{2\pi}\right)^2 = (9.81 \text{ m/s}^2)\left(\frac{1.0 \text{ s}}{2\pi}\right)^2 = 0.25 \text{ m} = \boxed{25 \text{ cm}}$$

Givens	*Solutions*
3. $T = 3.8$ s $a_g = g = 9.81$ m/s^2	$T = 2\pi\sqrt{\dfrac{L}{a_g}}$ $L = a_g\left(\dfrac{T}{2\pi}\right)^2 = (9.81 \text{ m/s}^2)\left(\dfrac{3.8 \text{ s}}{2\pi}\right)^2 = \boxed{3.6 \text{ m}}$
4. $L = 3.500$ m $a_g = 9.832$ m/s^2	**a.** $T_1 = 2\pi\sqrt{\dfrac{L}{a_g}} = 2\pi\sqrt{\dfrac{3.500 \text{ m}}{9.832 \text{ m/s}^2}} = \boxed{3.749 \text{ s}}$ $f_1 = \dfrac{1}{T_1} = \dfrac{1}{3.749 \text{ s}} = \boxed{0.2667 \text{ Hz}}$
$a_g = 9.803$ m/s^2	**b.** $T_2 = 2\pi\sqrt{\dfrac{L}{a_g}} = 2\pi\sqrt{\dfrac{3.500 \text{ m}}{9.803 \text{ m/s}^2}} = \boxed{3.754 \text{ s}}$ $f_2 = \dfrac{1}{T_2} = \dfrac{1}{3.754 \text{ s}} = \boxed{0.2664 \text{ Hz}}$
$a_g = 9.782$ m/s^2	**c.** $T_3 = 2\pi\sqrt{\dfrac{L}{a_g}} = 2\pi\sqrt{\dfrac{3.500 \text{ m}}{9.782 \text{ m/s}^2}} = \boxed{3.758 \text{ s}}$ $f_3 = \dfrac{1}{T_3} = \dfrac{1}{3.758 \text{ s}} = \boxed{0.2661 \text{ Hz}}$

Vibrations and Waves, Practice C

1. $T = 0.24$ s $m = 0.30$ kg	$T = 2\pi\sqrt{\dfrac{m}{k}}$ $k = \dfrac{4\pi^2 m}{T^2} = \dfrac{4\pi^2 (0.30 \text{ kg})}{(0.24 \text{ s})} = \boxed{2.1 \times 10^2 \text{ N/m}}$
2. $m = 25$ g $= 0.025$ kg $f = \dfrac{20 \text{ vibrations}}{4.0 \text{ s}} = 5.0$ Hz	$T = \dfrac{1}{f} = 2\pi\sqrt{\dfrac{m}{k}}$ $k = 4\pi^2 mf^2 = 4\pi^2(0.025 \text{ kg})(5.0 \text{ Hz})^2 = \boxed{25 \text{ N/m}}$
3. $F = 125$ N $g = 9.81$ m/s^2 $T = 3.56$ s	$T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{F}{g\,k}}$ $k = \dfrac{4\pi^2 F}{g\,T^2} = \dfrac{(4\pi^2)(125 \text{ N})}{(9.81 \text{ m/s}^2)(3.56 \text{ s})^2}$ $k = \boxed{39.7 \text{ N/m}}$
4. $m_p = 255$ kg $m_c = 1275$ kg $k = 2.00 \times 10^4$ N/m	$m = \dfrac{m_p + m_c}{4} = \dfrac{255 \text{ kg} + 1275 \text{ kg}}{4} = \dfrac{1.530 \times 10^3 \text{ kg}}{4} = 382.5 \text{ kg}$ $T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{382.5 \text{ kg}}{2.00 \times 10^4 \text{ N/m}}} = \boxed{0.869 \text{ s}}$

Givens	Solutions
5. $k = 30.0$ N/m	**a.** $T_1 = 2\pi\sqrt{\frac{m_1}{k}} = 2\pi\sqrt{\frac{2.3 \text{ kg}}{30.0 \text{ N/m}}}$
$m_1 = 2.3$ kg	$T_1 = \boxed{1.7 \text{ s}}$
	$f_1 = \frac{1}{T_1} = \frac{1}{1.7 \text{ s}} = \boxed{0.59 \text{ Hz}}$
$m_2 = 15$ g	**b.** $T_2 = 2\pi\sqrt{\frac{m_2}{k}} = 2\pi\sqrt{\frac{0.015 \text{ kg}}{30.0 \text{ N/m}}}$
	$T_2 = \boxed{0.14 \text{ s}}$
	$f_2 = \frac{1}{T_2} = \frac{1}{0.14 \text{ s}} = \boxed{7.1 \text{ Hz}}$
$m_3 = 1.9$ kg	**c.** $T_3 = 2\pi\sqrt{\frac{m_3}{k}} = 2\pi\sqrt{\frac{1.9 \text{ kg}}{30.0 \text{ N/m}}}$
	$T_3 = \boxed{1.6 \text{ s}}$
	$f_3 = \frac{1}{T_3} = \frac{1}{1.6 \text{ s}} = \boxed{0.62 \text{ Hz}}$

Vibrations and Waves, Section 2 Review

1. $f = 180$ oscillations/min	$f = (180 \text{ oscillations/min})(1 \text{ min}/60 \text{ s})$
	$f = \boxed{3.0 \text{ Hz}}$
	$T = \frac{1}{f} = \frac{1}{3.0 \text{ Hz}} = \boxed{0.33 \text{ s}}$
2. $L = 2.5$ m	**a.** $T = 2\pi\sqrt{\frac{L}{a_g}} = 2\pi\sqrt{\frac{2.5 \text{ m}}{9.81 \text{ m/s}^2}}$
$a_g = g = 9.81 \text{ m/s}^2$	$T = \boxed{3.2 \text{ s}}$
	b. $f = \frac{1}{T} = \frac{1}{3.2 \text{ s}} = \boxed{0.31 \text{ Hz}}$
3. $m = 0.75$ kg	**a.** $-kx - mg = 0$
$x = -0.30$ m	$k = \frac{-mg}{x} = \frac{-(0.75 \text{ kg})(9.81 \text{ m/s}^2)}{-0.30 \text{ m}}$
$g = 9.81 \text{ m/s}^2$	$k = \boxed{25 \text{ N/m}}$
	b. $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.75 \text{ kg}}{25 \text{ N/m}}}$
	$T = \boxed{1.1 \text{ s}}$

Vibrations and Waves, Practice D

1. $f_1 = 28$ Hz	$\lambda_1 = \frac{v}{f_1} = \frac{340 \text{ m/s}}{28 \text{ Hz}} = \boxed{12 \text{ m}}$
$f_2 = 4200$ Hz	
$v = 340$ m/s	$\lambda_2 = \frac{v}{f_2} = \frac{340 \text{ m/s}}{4200 \text{ Hz}} = \boxed{0.081 \text{ m}}$

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Givens	*Solutions*
2. $v = 3.00 \times 10^8$ m/s $f_1 = 88.0$ MHz	**a.** $\lambda_1 = \frac{v}{f_1} = \frac{3.00 \times 10^8 \text{ m/s}}{8.80 \times 10^7 \text{ Hz}}$ $\lambda_1 = \boxed{3.41 \text{ m}}$
$f_2 = 6.0 \times 10^8$ MHz	**b.** $\lambda_2 = \frac{v}{f_2} = \frac{3.00 \times 10^8 \text{ m/s}}{6.0 \times 10^{14} \text{ Hz}}$ $\lambda_2 = \boxed{5.0 \times 10^{-7} \text{ m}}$
$f_3 = 3.0 \times 10^{12}$ MHz	**c.** $\lambda_3 = \frac{v}{f_3} = \frac{3.00 \times 10^8 \text{ m/s}}{3.0 \times 10^{18} \text{ Hz}}$ $\lambda_3 = \boxed{1.0 \times 10^{-10} \text{ m}}$
3. $\lambda = 633$ nm $= 6.33 \times 10^{-7}$ m $v = 3.00 \times 10^8$ m/s	$f = \frac{v}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{6.33 \times 10^{-7} \text{ m}}$ $f = \boxed{4.74 \times 10^{14} \text{ Hz}}$
4. $f = 256$ Hz $\lambda_{air} = 1.35$ m $v_{water} = 1500$ m/s	**a.** $v_{air} = \lambda_{air} f = (1.35 \text{ m})(256 \text{ Hz})$ $v_{air} = \boxed{346 \text{ m/s}}$ **b.** $\lambda_{water} = \frac{v_{water}}{f} = \frac{1500 \text{ m/s}}{256 \text{ Hz}}$ $\lambda_{water} = \boxed{5.86 \text{ m}}$

Vibrations and Waves, Section 3 Review

5. $\lambda = 0.57 \text{ cm} = 5.7 \times 10^{-3}$ m $v = 340$ m/s	$f = \frac{v}{\lambda} = \frac{340 \text{ m/s}}{5.7 \times 10^{-3} \text{ m}}$ $f = \boxed{6.0 \times 10^4 \text{ Hz}}$

Vibrations and Waves, Chapter Review

8. $m = 0.40$ kg $x = -3.0$ cm $g = 9.81$ m/s^2	$-kx - mg = 0$ $k = \frac{-mg}{x} = \frac{-(0.40 \text{ kg})(9.81 \text{ m/s}^2)}{-0.030 \text{ m}}$ $k = \boxed{130 \text{ N/m}}$
9. $x = -0.40$ m $F = 230$ N	$k = \frac{-F}{x} = \frac{-230 \text{ N}}{-0.40 \text{ m}} = \boxed{580 \text{ N/m}}$
19. $f = 0.16$ Hz $a_g = g = 9.81$ m/s^2	$T = \frac{1}{f} = 2\pi\sqrt{\frac{L}{a_g}}$ $L = \frac{a_g}{(2\pi f)^2} = \frac{(9.81 \text{ m/s}^2)}{(4\pi^2)(0.16 \text{ Hz})^2}$ $L = \boxed{9.7 \text{ m}}$

Givens	Solutions
20.	**a.** Because a pendulum passes through its equilibrium position twice each cycle, $T = (2)(1.000\text{ s}) = \boxed{2.000\text{ s}}$.
$L_1 = 0.9942$ m	**b.** $a_g = \dfrac{4\pi^2 L_1}{T^2} = \dfrac{(4\pi^2)(0.9942\text{ m})}{(2.000\text{ s})^2}$ $a_g = \boxed{9.812\text{ m/s}^2}$
$L_2 = 0.9927$ m	**c.** $a_g = \dfrac{4\pi^2 L_2}{T^2} = \dfrac{(4\pi^2)(0.9927\text{ m})}{(2.000\text{ s})^2}$ $a_g = \boxed{9.798\text{ m/s}^2}$
21. $k = 1.8 \times 10^2$ N/m $m = 1.5$ kg	**a.** $T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{1.5\text{ kg}}{1.8 \times 10^2\text{ N/m}}}$ $T = \boxed{0.57\text{ s}}$ **b.** $f = \dfrac{1}{T} = \dfrac{1}{0.57\text{ s}} = \boxed{1.8\text{ Hz}}$
34. $f = 25.0$ Hz $\frac{1}{2}\lambda = 10.0$ cm 2(amplitude) = 18 cm	**a.** amplitude $= \dfrac{18\text{ cm}}{2} = \boxed{9.0\text{ cm}}$ **b.** $\lambda = (2)(10.0\text{ cm}) = \boxed{20.0\text{ cm}}$ **c.** $T = \dfrac{1}{f} = \dfrac{1}{25.0\text{ Hz}} = \boxed{0.0400\text{ s}}$ **d.** $v = \lambda f = (0.200\text{ m})(25.0\text{ Hz}) = \boxed{5.00\text{ m/s}}$
35. $v = 3.00 \times 10^8$ m/s $f = 9.00 \times 10^9$ Hz	$\lambda = \dfrac{v}{f} = \dfrac{3.00 \times 10^8\text{ m/s}}{9.00 \times 10^9\text{ Hz}} = \boxed{0.0333\text{ m}}$
44. $k = 230$ N/m $x = -6.0$ cm	$F = -kx$ $F = -(230\text{ N/m})(-0.060\text{ m})$ $F = \boxed{14\text{ N}}$
45. $x = -2.0$ cm $k = 85$ N/m	$F = -kx = -(85\text{ N/m})(-0.020\text{ m})$ $F = \boxed{1.7\text{ N}}$
46. $\lambda = 0.15$ m	Because a wave is generated twice each second, $f = \boxed{2.0\text{ Hz}}$. $T = \dfrac{1}{f} = \dfrac{1}{2.0\text{ Hz}} = \boxed{0.50\text{ s}}$ $v = \lambda f = (0.15\text{ m})(2.0\text{ Hz}) = \boxed{0.30\text{ m/s}}$

Givens	Solutions
47. $v = 343$ m/s $\Delta t = 2.60$ s	$\Delta x = \frac{v\Delta t}{2} = \frac{(343 \text{ m/s})(2.60 \text{ s})}{2} = \boxed{446 \text{ m}}$
48. $f_1 = 196$ Hz $f_2 = 2637$ Hz $v = 340$ m/s	$\lambda_1 = \frac{v}{f_1} = \frac{340 \text{ m/s}}{196 \text{ Hz}} = \boxed{1.73 \text{ m}}$ $\lambda_2 = \frac{v}{f_2} = \frac{340 \text{ m/s}}{2637 \text{ Hz}} = \boxed{0.129 \text{ m}}$
49. $L = 0.850$ m $T = 1.86$ s	$T = 2\pi\sqrt{\frac{L}{a_g}}$ $a_g = \frac{4\pi^2 L}{T^2} = \frac{(4\pi^2)(0.850 \text{ m})}{(1.86 \text{ s})^2} = \boxed{9.70 \text{ m/s}^2}$
50. $v = 1.97 \times 10^8$ m/s $\lambda = 3.81 \times 10^{-7}$ m	$f = \frac{v}{\lambda} = \frac{1.97 \times 10^8 \text{ m/s}}{3.81 \times 10^{-7} \text{ m}} = \boxed{5.17 \times 10^{14} \text{ Hz}}$
51. $a_{g,moon} = 1.63$ m/s^2 $\Delta t = 24$ h $a_{g,Earth} = 9.81$ m/s^2	$T_{Earth} = 2\pi\sqrt{\frac{L}{a_{g,Earth}}}$ $T_{moon} = 2\pi\sqrt{\frac{L}{a_{g,moon}}}$ $\frac{T_{moon}}{T_{Earth}} = \sqrt{\frac{a_{g,Earth}}{a_{g,moon}}} = \sqrt{\frac{9.81 \text{ m/s}^2}{1.63 \text{ m/s}^2}} = 2.45$ The clock on the moon runs slower than the same clock on Earth by a factor of 2.45. Thus, after 24.0 h Earth time, the clock on the moon will have advanced by $\frac{24.0 \text{ h}}{2.45} = 9.80 \text{ h} = 9 \text{ h} + (0.80 \text{ h})(60 \text{ min/h}) = 9 \text{ h, } 48 \text{ min}$ Thus, the clock will read $\boxed{\text{9:48 A.M.}}$

Vibrations and Waves, Standardized Test Prep

Givens	Solutions
2. $F = 7.0$ N $x = -0.35$ m	$F = -kx$ $k = -\frac{F}{x} = -\frac{(7.0 \text{ N})}{(-0.35 \text{ m})} = \boxed{2.0 \times 10^1 \text{ N/m}}$
6. $m = 48$ kg $k = 12$ N/m	$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{48 \text{ kg}}{12 \text{ N/m}}} = 2\pi \times 2 \text{ s} = \boxed{4\pi \text{ s}}$
9. $t = 2.0$ min	$f = 12 \text{ cycles}/120 \text{ s} = \boxed{0.10 \text{ Hz}}$

Givens	Solutions
10. $L = 2.00$ m $a_g = 9.80$ m/s^2 $\Delta t = 5.00$ min	$\text{oscillations} = \dfrac{\Delta t}{T} = \dfrac{\Delta t}{2\pi\sqrt{\dfrac{L}{a_g}}}$ $\text{oscillations} = \dfrac{(5.00 \text{ min})(60 \text{ s/min})}{(2\pi)\left(\sqrt{\dfrac{2.00 \text{ m}}{9.80 \text{ m/s}^2}}\right)}$ $\text{oscillations} = \boxed{106}$
16. $\lambda = 1.20$ m $f = \dfrac{8}{12.0 \text{ s}}$	$v = \lambda f = (1.20 \text{ m})\left(\dfrac{8}{12.0 \text{ s}}\right) = \boxed{0.800 \text{ m/s}}$
17. $\lambda = 5.20 \times 10^{-7}$ m $v = 3.00 \times 10^8$ m/s	$f = \dfrac{v}{\lambda} = \dfrac{3.00 \times 10^8 \text{ m/s}}{5.20 \times 10^{-7} \text{ m}} = \boxed{5.77 \times 10^{14} \text{ Hz}}$ $T = \dfrac{1}{f} = \dfrac{1}{5.77 \times 10^{14} \text{ Hz}} = \boxed{1.73 \times 10^{-15} \text{ s}}$
20. $T = 9.49$ s $a_g = g = 9.81$ m/s^2	$T = 2\pi\sqrt{\dfrac{L}{a_g}}$ $L = \dfrac{T^2 a_g}{4\pi^2} = \dfrac{(9.49 \text{ s})^2(9.81 \text{ m/s}^2)}{4\pi^2}$ $L = \boxed{22.4 \text{ m}}$
21. $f = \left(\dfrac{40.0}{30.0}\right)$ Hz $v = \left(\dfrac{425 \text{ cm}}{10.0 \text{ s}}\right) = \left(\dfrac{4.25}{10.0}\right)$ m/s	$\lambda = \dfrac{v}{f} = \dfrac{\left(\dfrac{4.25}{10.0}\right) \text{ m/s}}{\left(\dfrac{40.0}{30.0}\right) \text{Hz}} = \boxed{0.319 \text{ m}}$

Student Edition Solutions

Sound

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Sound, Practice A

Givens	Solutions
1. $r = 5.0$ m $P_1 = 0.25$ W	**a.** $\text{intensity} = \frac{P_1}{4\pi r^2} = \frac{0.25 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{8.0 \times 10^{-4} \text{ W/m}^2}$
$P_2 = 0.50$ W	**b.** $\text{intensity} = \frac{P_2}{4\pi r^2} = \frac{0.50 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{1.6 \times 10^{-3} \text{ W/m}^2}$
$P_3 = 2.0$ W	**c.** $\text{intensity} = \frac{P_3}{4\pi r^2} = \frac{2.0 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{6.4 \times 10^{-3} \text{ W/m}^2}$
2. $P = 70.0$ W $r = 25.0$ m	$\text{intensity} = \frac{P}{4\pi r^2} = \frac{70.0 \text{ W}}{(4\pi)(25.0 \text{ m})^2} = \boxed{8.91 \times 10^{-3} \text{ W/m}^2}$
3. intensity $= 4.6 \times 10^{-7}$ W/m^2 $r = 2.0$ m	$P = (\text{intensity})(4\pi r^2) = (4.6 \times 10^{-7} \text{ W/m}^2)(4\pi)(2.0 \text{ m})^2 = \boxed{2.3 \times 10^{-5} \text{ W}}$
4. intensity $= 1.6 \times 10^{-3}$ W/m^2 $r = 15$ m	$P = (\text{intensity})(4\pi r^2) = (1.6 \times 10^{-3} \text{ W/m}^2)(4\pi)(15 \text{ m})^2 = \boxed{4.5 \text{ W}}$
5. $P = 0.35$ W intensity $= 1.2 \times 10^{-3}$ W/m^2	$r = \sqrt{\frac{P}{(\text{intensity})(4\pi)}} = \sqrt{\frac{0.35 \text{ W}}{(1.2 \times 10^{-3} \text{ W/m}^2)(4\pi)}} = \boxed{4.8 \text{ m}}$

Sound, Section 2 Review

4. decibel level = 10 dB $P = 0.050$ W	intensity at 10 dB $= 1.0 \times 10^{-11}$ W/m^2 (See **Table 2** of this chapter in the textbook.) $r = \sqrt{\frac{P}{(\text{intensity})(4\pi)}} = \sqrt{\frac{0.050 \text{ W}}{(1.0 \times 10^{-11} \text{ W/m}^2)(4\pi)}} = \boxed{2.0 \times 10^4 \text{ m}}$

Sound, Practice B

1. $L = 0.20$ m $v = 352$ m/s	$f_1 = \frac{nv}{4L} = \frac{(1)(352 \text{ m/s})}{(4)(0.20 \text{ m})} = \boxed{440 \text{ Hz}}$
2. $L = 66.0$ cm $v = 340$ m/s	$f_1 = \frac{nv}{2L} = \frac{(1)(340 \text{ m/s})}{(2)(0.660 \text{ m})} = \boxed{260 \text{ Hz}}$ $f_2 = 2f_1 = (2)(260 \text{ Hz}) = \boxed{520 \text{ Hz}}$ $f_3 = 3f_1 = (3)(260 \text{ Hz}) = \boxed{780 \text{ Hz}}$

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Givens	*Solutions*
3. $v = 115$ m/s $L_1 = 70.0$ cm	**a.** $f_1 = \frac{nv}{2L_1} = \frac{(1)(115 \text{ m/s})}{(2)(0.700 \text{ m})} = \boxed{82.1 \text{ Hz}}$
$L_2 = 50.0$ cm	**b.** $f_1 = \frac{nv}{2L_2} = \frac{(1)(115 \text{ m/s})}{(2)(0.500 \text{ m})} = \boxed{115 \text{ Hz}}$
$L_3 = 40.0$ cm	**c.** $f_1 = \frac{nv}{2L_3} = \frac{(1)(115 \text{ m/s})}{(2)(0.400 \text{ m})} = \boxed{144 \text{ Hz}}$
4. $L = 50.0$ cm $f_1 = 440$ Hz	$v = \frac{f_1 2L}{n} = \frac{(440 \text{ Hz})(2)(0.500 \text{ m})}{1} = \boxed{440 \text{ m/s}}$

Sound, Section 3 Review

1. $f_1 = 262$ Hz	$f_2 = 2f_1 = (2)(262 \text{ Hz}) = \boxed{524 \text{ Hz}}$
2. $f_1 = 264$ Hz $L = 66.0$ cm	$v = \frac{f_1 2L}{n} = \frac{(264 \text{ Hz})(2)(0.660 \text{ m})}{1} = \boxed{348 \text{ m/s}}$

Sound, Chapter Review

22. $P = 3.1 \times 10^{-3}$ W $r = 5.0$ m	intensity $= \frac{P}{4\pi r^2} = \frac{3.1 \times 10^{-3} \text{ W}}{4\pi(5.0 \text{ m})^2} = 1.0 \times 10^{-5} \text{ W/m}^2 = \boxed{70 \text{ dB}}$
23. $P = 100.0$ W $r = 10.0$ m	intensity $= \frac{P}{4\pi r^2} = \frac{100.0 \text{ W}}{(4\pi)(10.0 \text{ m})^2} = \boxed{7.96 \times 10^{-2} \text{ W/m}^2}$
34. $L = 31.0$ cm $v = 274.4$ m/s	$f_1 = \frac{nv}{2L} = \frac{(1)(274.4 \text{ m/s})}{(2)(0.310 \text{ m})} = \boxed{443 \text{ Hz}}$ $f_2 = 2f_1 = (2)(443 \text{ Hz}) = \boxed{886 \text{ Hz}}$ $f_3 = 3f_1 = (3)(443 \text{ Hz}) = \boxed{1330 \text{ Hz}}$
35. $L = 2.8$ cm $v = 340$ m/s	$f_1 = \frac{nv}{4L} = \frac{(1)(340 \text{ m/s})}{(4)(0.028 \text{ m})} = \boxed{3.0 \times 10^3 \text{ Hz}}$
36. $f_1 = 320$ Hz $v = 331$ m/s	**a.** $L = \frac{nv}{2f_1} = \frac{(1)(331 \text{ m/s})}{(2)(320 \text{ Hz})} = 0.52 \text{ m} = \boxed{52.0 \text{ cm}}$ **b.** $f_2 = 2f_1 = (2)(320 \text{ Hz}) = \boxed{640 \text{ Hz}}$ $f_3 = 3f_1 = (3)(320 \text{ Hz}) = \boxed{960 \text{ Hz}}$

Givens	*Solutions*
37. $f_1 = 132$ Hz $f_2 = 137$ Hz	number of beats each second $= f_2 - f_1 = 137\text{ Hz} - 132\text{ Hz} = \boxed{5\text{ Hz}}$
38. $v = 343$ m/s $f_1 = 20$ Hz $f_2 = 20\,000$ Hz	$\lambda_1 = \dfrac{v}{f_1} = \dfrac{343\text{ m/s}}{20\text{ Hz}} = \boxed{20\text{ m}}$ $\lambda_2 = \dfrac{v}{f_2} = \dfrac{343\text{ m/s}}{20\,000\text{ Hz}} = \boxed{2 \times 10^{-2}\text{ m}}$
39. $\Delta x = (150\text{ m})(2)$ $v = 1530$ m/s	$\Delta t = \dfrac{\Delta x}{v} = \dfrac{(150\text{ m})(2)}{1530\text{ m/s}} = \boxed{0.20\text{ s}}$
40. $L = 2.46$ m $v = 345$ m/s	**a.** $f_1 = \dfrac{nv}{2L} = \dfrac{(1)(345\text{ m/s})}{(2)(2.46\text{ m})} = \boxed{70.1\text{ Hz}}$ **b.** $\dfrac{nv}{2L} \leq 20\,000$ Hz $n \leq \dfrac{(20\,000\text{ Hz})(2)(L)}{v} = \dfrac{(20\,000\text{ Hz})(2)(2.46\text{ m})}{345\text{ m/s}} = \boxed{285}$
41. $f_{1,open} = 261.6$ Hz $f_{3,closed} = 261.6$ Hz	$L_{open} = \dfrac{v}{(f_{1,open})(2)}$ $L_{closed} = \dfrac{3v}{(f_{3,closed})(4)}$ $\dfrac{L_{closed}}{L_{open}} = \dfrac{\dfrac{3v}{(f_{3,closed})(4)}}{\dfrac{v}{(f_{1,open})(2)}} = \dfrac{(3)(f_{1,open})(2)}{(f_{3,closed})(4)}$ Because $f_{1,open} = f_{3,closed}$, $\dfrac{L_{closed}}{L_{open}} = \dfrac{6}{4} = \dfrac{1.5}{1}$ $\boxed{(L_{closed}) = 1.5(L_{open})}$
42. $f = 2.0 \times 10^4$ Hz $v = 378$ m/s	$\lambda = \dfrac{v}{f} = \dfrac{378\text{ m/s}}{2.0 \times 10^4\text{ Hz}} = \boxed{1.9 \times 10^{-2}\text{ m}}$
43. decibel level = 130 dB $r = 20.0$ m diameter = 1.9×10^{-2} m	**a.** intensity at 30 dB = 1.0×10^1 W/m^2 (See **Table 2** of this chapter in the textbook.) $P = (\text{intensity})(4\pi r^2) = (1.0 \times 10^1\text{ W/m}^2)(4\pi)(20.0\text{ m})^2 = \boxed{5.0 \times 10^4\text{ W}}$ **b.** area $= \pi\left(\dfrac{\text{diameter}}{2}\right)^2 = \pi\left(\dfrac{1.9 \times 10^{-2}\text{ m}}{2}\right)^2$ $P = (\text{intensity})(\text{area}) = (1.0 \times 10^1\text{ W/m}^2)(\pi)\left(\dfrac{1.9 \times 10^{-2}\text{ m}}{2}\right)^2$ $P = \boxed{2.8 \times 10^{-3}\text{ W}}$

I

Givens	*Solutions*
8. $v = 1.0 \times 10^4$ m/s $f = 2.0 \times 10^{10}$ Hz	$\lambda = \dfrac{v}{f} = \dfrac{1.0 \times 10^4 \text{ m/s}}{2.0 \times 10^{10} \text{ Hz}} = \boxed{5.0 \times 10^{-7} \text{ m}}$
10. $f_2 = 165$ Hz $v = 120$ m/s	$f_2 = \dfrac{v}{L}$ $L = \dfrac{v}{f_2} = \dfrac{120 \text{ m/s}}{165 \text{ Hz}} = \boxed{0.73 \text{ m}}$
12. $f_1 = 250$ Hz	$f_3 = 3f_1 = (3)(250 \text{ Hz}) = \boxed{750 \text{ Hz}}$
13. $L = 1.0$ m	$\lambda_6 = \dfrac{2}{6}L = \dfrac{1}{3}L = \dfrac{1}{3}(1.0 \text{ m}) = \boxed{0.33 \text{ m}}$
14. $P = 250.0$ W $r = 6.5$ m	$I = \dfrac{P}{4\pi r^2} = \dfrac{250.0 \text{ W}}{4\pi(6.5 \text{ m})^2} = \boxed{0.47 \text{ W/m}^2}$
15. $A = 5.0 \times 10^{-5}$ m^2 intensity = 1.0×10^0 W/m^2	$P = (\text{intensity})(A) = (1.0 \times 10^0 \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = \boxed{5.0 \times 10^{-5} \text{ W}}$
16. $A = 5.0 \times 10^{-5}$ m^2 intensity = 1.0×10^{-12} W/m^2	$P = (\text{intensity})(A) = (1.0 \times 10^{-12} \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = \boxed{5.0 \times 10^{-17} \text{ W}}$
17. $f_1 = 456$ Hz $v = 331$ m/s	$f_1 = \dfrac{v}{2L}$ $L = \dfrac{v}{2f_1} = \dfrac{331 \text{ m/s}}{(2)(456 \text{ Hz})} = \boxed{0.363 \text{ m}}$
18. $f_1 = 456$ Hz	$f_2 = 2f_1 = 2(456 \text{ Hz}) = \boxed{912 \text{ Hz}}$
19. $v = 367$ m/s $L = 0.363$ m (see **17.**)	$f_1 = \dfrac{v}{2L} = \dfrac{367 \text{ m/s}}{(2)(0.363 \text{ m})} = \boxed{506 \text{ Hz}}$

Student Edition Solutions

Sound

I

Sound, Practice A

Givens / *Solutions*

1. $r = 5.0$ m
$P_1 = 0.25$ W

a. $\text{intensity} = \dfrac{P_1}{4\pi r^2} = \dfrac{0.25 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{8.0 \times 10^{-4} \text{ W/m}^2}$

$P_2 = 0.50$ W

b. $\text{intensity} = \dfrac{P_2}{4\pi r^2} = \dfrac{0.50 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{1.6 \times 10^{-3} \text{ W/m}^2}$

$P_3 = 2.0$ W

c. $\text{intensity} = \dfrac{P_3}{4\pi r^2} = \dfrac{2.0 \text{ W}}{(4\pi)(5.0 \text{ m})^2} = \boxed{6.4 \times 10^{-3} \text{ W/m}^2}$

---

2. $P = 70.0$ W
$r = 25.0$ m

$\text{intensity} = \dfrac{P}{4\pi r^2} = \dfrac{70.0 \text{ W}}{(4\pi)(25.0 \text{ m})^2} = \boxed{8.91 \times 10^{-3} \text{ W/m}^2}$

---

3. $\text{intensity} = 4.6 \times 10^{-7}$ W/m^2
$r = 2.0$ m

$P = (\text{intensity})(4\pi r^2) = (4.6 \times 10^{-7} \text{ W/m}^2)(4\pi)(2.0 \text{ m})^2 = \boxed{2.3 \times 10^{-5} \text{ W}}$

---

4. $\text{intensity} = 1.6 \times 10^{-3}$ W/m^2
$r = 15$ m

$P = (\text{intensity})(4\pi r^2) = (1.6 \times 10^{-3} \text{ W/m}^2)(4\pi)(15 \text{ m})^2 = \boxed{4.5 \text{ W}}$

---

5. $P = 0.35$ W
$\text{intensity} = 1.2 \times 10^{-3}$ W/m^2

$r = \sqrt{\dfrac{P}{(\text{intensity})(4\pi)}} = \sqrt{\dfrac{0.35 \text{ W}}{(1.2 \times 10^{-3} \text{ W/m}^2)(4\pi)}} = \boxed{4.8 \text{ m}}$

Sound, Section 2 Review

4. decibel level = 10 dB
$P = 0.050$ W

intensity at 10 dB = 1.0×10^{-11} W/m^2 (See **Table 2** of this chapter in the textbook.)

$r = \sqrt{\dfrac{P}{(\text{intensity})(4\pi)}} = \sqrt{\dfrac{0.050 \text{ W}}{(1.0 \times 10^{-11} \text{ W/m}^2)(4\pi)}} = \boxed{2.0 \times 10^{4} \text{ m}}$

Sound, Practice B

1. $L = 0.20$ m
$v = 352$ m/s

$f_1 = \dfrac{nv}{4L} = \dfrac{(1)(352 \text{ m/s})}{(4)(0.20 \text{ m})} = \boxed{440 \text{ Hz}}$

---

2. $L = 66.0$ cm
$v = 340$ m/s

$f_1 = \dfrac{nv}{2L} = \dfrac{(1)(340 \text{ m/s})}{(2)(0.660 \text{ m})} = \boxed{260 \text{ Hz}}$

$f_2 = 2f_1 = (2)(260 \text{ Hz}) = \boxed{520 \text{ Hz}}$

$f_3 = 3f_1 = (3)(260 \text{ Hz}) = \boxed{780 \text{ Hz}}$

Givens	*Solutions*
37. $f_1 = 132$ Hz $f_2 = 137$ Hz	number of beats each second $= f_2 - f_1 = 137\text{ Hz} - 132\text{ Hz} = \boxed{5\text{ Hz}}$
38. $v = 343$ m/s $f_1 = 20$ Hz $f_2 = 20\,000$ Hz	$\lambda_1 = \frac{v}{f_1} = \frac{343\text{ m/s}}{20\text{ Hz}} = \boxed{20\text{ m}}$ $\lambda_2 = \frac{v}{f_2} = \frac{343\text{ m/s}}{20\,000\text{ Hz}} = \boxed{2\times10^{-2}\text{ m}}$
39. $\Delta x = (150\text{ m})(2)$ $v = 1530$ m/s	$\Delta t = \frac{\Delta x}{v} = \frac{(150\text{ m})(2)}{1530\text{ m/s}} = \boxed{0.20\text{ s}}$
40. $L = 2.46$ m $v = 345$ m/s	**a.** $f_1 = \frac{nv}{2L} = \frac{(1)(345\text{ m/s})}{(2)(2.46\text{ m})} = \boxed{70.1\text{ Hz}}$ **b.** $\frac{nv}{2L} \le 20\,000$ Hz $n \le \frac{(20\,000\text{ Hz})(2)(L)}{v} = \frac{(20\,000\text{ Hz})(2)(2.46\text{ m})}{345\text{ m/s}} = \boxed{285}$
41. $f_{1,open} = 261.6$ Hz $f_{3,closed} = 261.6$ Hz	$L_{open} = \frac{v}{(f_{1,open})(2)}$ $L_{closed} = \frac{3v}{(f_{3,closed})(4)}$ $\frac{L_{closed}}{L_{open}} = \frac{\frac{3v}{(f_{3,closed})(4)}}{\frac{v}{(f_{1,open})(2)}} = \frac{(3)(f_{1,open})(2)}{(f_{3,closed})(4)}$ Because $f_{1,open} = f_{3,closed}$, $\frac{L_{closed}}{L_{open}} = \frac{6}{4} = \frac{1.5}{1}$ $\boxed{(L_{closed}) = 1.5(L_{open})}$
42. $f = 2.0 \times 10^4$ Hz $v = 378$ m/s	$\lambda = \frac{v}{f} = \frac{378\text{ m/s}}{2.0\times10^4\text{ Hz}} = \boxed{1.9\times10^{-2}\text{ m}}$
43. decibel level = 130 dB $r = 20.0$ m diameter = 1.9×10^{-2} m	**a.** intensity at 30 dB $= 1.0 \times 10^1\text{ W/m}^2$ (See **Table 2** of this chapter in the textbook.) $P = (\text{intensity})(4\pi r^2) = (1.0\times10^1\text{ W/m}^2)(4\pi)(20.0\text{ m})^2 = \boxed{5.0\times10^4\text{ W}}$ **b.** area $= \pi\left(\frac{\text{diameter}}{2}\right)^2 = \pi\left(\frac{1.9\times10^{-2}\text{ m}}{2}\right)^2$ $P = (\text{intensity})(\text{area}) = (1.0\times10^1\text{ W/m}^2)(\pi)\left(\frac{1.9\times10^{-2}\text{ m}}{2}\right)^2$ $P = \boxed{2.8\times10^{-3}\text{ W}}$

I

Givens	*Solutions*
8. $v = 1.0 \times 10^4$ m/s $f = 2.0 \times 10^{10}$ Hz	$\lambda = \frac{v}{f} = \frac{1.0 \times 10^4 \text{ m/s}}{2.0 \times 10^{10} \text{ Hz}} = \boxed{5.0 \times 10^{-7} \text{ m}}$
10. $f_2 = 165$ Hz $v = 120$ m/s	$f_2 = \frac{v}{L}$ $L = \frac{v}{f_2} = \frac{120 \text{ m/s}}{165 \text{ Hz}} = \boxed{0.73 \text{ m}}$
12. $f_1 = 250$ Hz	$f_3 = 3f_1 = (3)(250 \text{ Hz}) = \boxed{750 \text{ Hz}}$
13. $L = 1.0$ m	$\lambda_6 = \frac{2}{6}L = \frac{1}{3}L = \frac{1}{3}(1.0 \text{ m}) = \boxed{0.33 \text{ m}}$
14. $P = 250.0$ W $r = 6.5$ m	$I = \frac{P}{4\pi r^2} = \frac{250.0 \text{ W}}{4\pi(6.5 \text{ m})^2} = \boxed{0.47 \text{ W/m}^2}$
15. $A = 5.0 \times 10^{-5}$ m^2 intensity = 1.0×10^0 W/m^2	$P = (\text{intensity})(A) = (1.0 \times 10^0 \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = \boxed{5.0 \times 10^{-5} \text{ W}}$
16. $A = 5.0 \times 10^{-5}$ m^2 intensity = 1.0×10^{-12} W/m^2	$P = (\text{intensity})(A) = (1.0 \times 10^{-12} \text{ W/m}^2)(5.0 \times 10^{-5} \text{ m}^2) = \boxed{5.0 \times 10^{-17} \text{ W}}$
17. $f_1 = 456$ Hz $v = 331$ m/s	$f_1 = \frac{v}{2L}$ $L = \frac{v}{2f_1} = \frac{331 \text{ m/s}}{(2)(456 \text{ Hz})} = \boxed{0.363 \text{ m}}$
18. $f_1 = 456$ Hz	$f_2 = 2f_1 = 2(456 \text{ Hz}) = \boxed{912 \text{ Hz}}$
19. $v = 367$ m/s $L = 0.363$ m (see **17.**)	$f_1 = \frac{v}{2L} = \frac{367 \text{ m/s}}{(2)(0.363 \text{ m})} = \boxed{506 \text{ Hz}}$

Light and Reflection

Light and Reflection, Practice A

Givens	*Solutions*
1. $f = 3.0 \times 10^{21}$ Hz $c = 3.00 \times 10^{8}$ m/s	$\lambda = \dfrac{c}{f} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{3.0 \times 10^{21} \text{ Hz}} = \boxed{1.0 \times 10^{-13} \text{ m}}$
2. $f_1 = 88$ MHz $f_2 = 108$ MHz $c = 3.00 \times 10^{8}$ m/s	$\lambda_1 = \dfrac{c}{f_1} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{8.8 \times 10^{7} \text{ Hz}} = \boxed{3.4 \text{ m}}$ $\lambda_2 = \dfrac{c}{f_2} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{1.08 \times 10^{8} \text{ Hz}} = \boxed{2.78 \text{ m}}$
3. $f_1 = 3.50$ MHz $f_2 = 29.7$ MHz $c = 3.00 \times 10^{8}$ m/s	$\lambda_1 = \dfrac{c}{f_1} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{3.50 \times 10^{6} \text{ Hz}} = \boxed{85.7 \text{ m}}$ $\lambda_2 = \dfrac{c}{f_2} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{2.97 \times 10^{7} \text{ m/s}} = \boxed{10.1 \text{ m}}$
4. $\lambda = 1.0$ km $c = 3.00 \times 10^{8}$ m/s	$f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{1.0 \times 10^{3} \text{ m}} = \boxed{3.0 \times 10^{5} \text{ Hz}}$
5. $\lambda = 560$ nm $c = 3.00 \times 10^{8}$ m/s	$f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{5.6 \times 10^{-7} \text{ m}} = \boxed{5.4 \times 10^{14} \text{ Hz}}$
6. $\lambda = 125$ nm $c = 3.00 \times 10^{8}$ m/s	$f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{1.25 \times 10^{-7} \text{ m}} = \boxed{2.40 \times 10^{15} \text{ Hz}}$

Light and Reflection, Section 1 Review

2. $f = 7.57 \times 10^{14}$ Hz $c = 3.00 \times 10^{8}$ m/s	$\lambda = \dfrac{c}{f} = \dfrac{3.00 \times 10^{8} \text{ m/s}}{7.57 \times 10^{14} \text{ Hz}} = \boxed{3.96 \times 10^{-7} \text{ m}}$

Light and Reflection, Section 2 Review

2.

The normal to the surface of the mirror is halfway between 12 o'clock and 5 o'clock.

$$\theta = \tfrac{1}{2}(5.0 \text{ h})\left(\frac{360°}{12.0 \text{ h}}\right) = \boxed{75°}$$

$$\theta' = \theta = \boxed{75°}$$

Light and Reflection, Practice B

Givens — *Solutions*

I

1. $p_1 = 10.0$ cm

$p_2 = 5.00$ cm

$f = 10.0$ cm

$$\frac{1}{q_1} = \frac{1}{f} - \frac{1}{p_1} = \frac{1}{10.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}} = 0 \quad \boxed{\text{no image (infinite } q)}$$

$$\frac{1}{q_2} = \frac{1}{f} - \frac{1}{p_2} = \frac{1}{10.0 \text{ cm}} - \frac{1}{5.00 \text{ cm}}$$

$$\frac{1}{q_2} = \frac{0.100}{1 \text{ cm}} - \frac{0.200}{1 \text{ cm}} = \frac{-0.100}{1 \text{ cm}}$$

$$q_2 = \boxed{-10.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-10.0 \text{ cm}}{5.00 \text{ cm}} = \boxed{2.00} \quad \boxed{\text{virtual, upright image}}$$

---

2. $f = 33$ cm

$p = 93$ cm

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{33 \text{ cm}} - \frac{1}{93 \text{ cm}}$$

$$\frac{1}{q} = \frac{0.030}{1 \text{ cm}} - \frac{0.011}{1 \text{ cm}} = \frac{0.019}{1 \text{ cm}}$$

$$q = \boxed{53 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{53 \text{ cm}}{93 \text{ cm}} = \boxed{-0.57} \quad \boxed{\text{real, inverted image}}$$

---

3. $p = 25.0$ cm

$q = -50.0$ cm

$$\frac{2}{R} = \frac{1}{p} + \frac{1}{q}$$

$$\frac{1}{R} = \frac{1}{2p} + \frac{1}{2q} = \frac{1}{(2)(25.0 \text{ cm})} + \frac{1}{(2)(-50.0 \text{ cm})} = \frac{1}{50.0 \text{ cm}} - \frac{1}{1.00 \times 10^2 \text{ cm}}$$

$$\frac{1}{R} = \frac{0.0200}{1 \text{ cm}} - \frac{0.0100}{1 \text{ cm}} = \frac{0.0100}{1 \text{ cm}}$$

$$R = \boxed{1.00 \times 10^2 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-50.0 \text{ cm}}{25.0 \text{ cm}} = \boxed{2.00} \quad \boxed{\text{virtual image}}$$

---

4. concave spherical mirror

$p_1 = 11.0$ cm

$p_2 = 27.0$ cm

$q_1 = 13.2$ cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{11.0 \text{ cm}} + \frac{1}{13.2 \text{ cm}}$$

$$\frac{1}{f} = \frac{0.0909}{\text{cm}} + \frac{0.0758}{\text{cm}} = \frac{0.1667}{\text{cm}}$$

$$f = \boxed{6.00 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{13.2 \text{ cm}}{11.0 \text{ cm}} = \boxed{-1.20}$$

Givens | *Solutions*

$p = 27.0$ cm

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{5.999 \text{ cm}} - \frac{1}{27.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{0.1667}{1 \text{ cm}} - \frac{0.0370}{1 \text{ cm}} = \frac{0.1297}{1 \text{ cm}}$$

$$q = \boxed{7.71 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{7.710 \text{ cm}}{27.0 \text{ cm}} = \boxed{-0.286} \quad \boxed{\text{real image}}$$

I

Light and Reflection, Practice C

1. $q = 23.0$ cm

$h' = 1.70$ cm

$f = 46.0$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{46.0 \text{ cm}} - \frac{1}{23.0 \text{ cm}}$$

$$\frac{1}{p} = \frac{1}{46.0 \text{ cm}} - \frac{2}{46.0 \text{ cm}} = \frac{-1}{46.0 \text{ cm}}$$

$$p = \boxed{-46.0 \text{ cm}}$$

$$M = \frac{h'}{h} = \frac{-q}{p} = -\frac{23.0 \text{ cm}}{-46.0 \text{ cm}} = \boxed{0.500} \quad \boxed{\text{virtual, upright image}}$$

$$h = \frac{h'}{M} = \frac{1.70 \text{ cm}}{0.500} = \boxed{3.40 \text{ cm}}$$

2. $f = -0.25$ m

$q = -0.24$ m

$h' = 0.080$ m

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-0.25 \text{ m}} - \frac{1}{-0.24 \text{ m}}$$

$$\frac{1}{p} = \frac{-0.24}{0.060 \text{ m}} + \frac{0.25}{0.060 \text{ m}} = \frac{0.01}{0.060 \text{ m}}$$

$$p = \boxed{6 \text{ m}}$$

$$M = -\frac{q}{p} = -\frac{-0.24 \text{ m}}{6 \text{ m}}$$

$$M = \boxed{0.04} \quad \boxed{\text{virtual, upright image}}$$

$$h = \frac{ph'}{q} = -\frac{(6 \text{ m})(0.080 \text{ m})}{(-0.24 \text{ m})} = \boxed{2 \text{ m}}$$

3. $f = -33$ cm

$q = -19$ cm

$h' = 7.0$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-33 \text{ cm}} - \frac{1}{-19 \text{ cm}}$$

$$\frac{1}{p} = \frac{-19}{630 \text{ cm}} + \frac{33}{630 \text{ cm}} = \frac{14}{630 \text{ cm}}$$

$$p = \boxed{45 \text{ cm}}$$

$$h = -\frac{ph'}{q} = -\frac{(45 \text{ cm})(7.0 \text{ cm})}{(-19 \text{ cm})} = \boxed{17 \text{ cm}}$$

$$M = \frac{h'}{h} = \frac{7.0 \text{ cm}}{17 \text{ cm}} = \boxed{0.41} \quad \boxed{\text{virtual, upright image}}$$

Givens | *Solutions*

I

4. $R = -0.550$ m

$p = 3.1$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{-0.550 \text{ m}} - \frac{1}{3.1 \text{ m}}$$

$$\frac{1}{q} = \frac{-3.64}{1 \text{ m}} - \frac{0.32}{1 \text{ m}} = \frac{4.0}{1 \text{ m}}$$

$$q = \boxed{-0.25 \text{ m}}$$

$$M = -\frac{q}{p} = -\frac{-0.25 \text{ m}}{3.1 \text{ m}} = \boxed{0.081} \quad \boxed{\text{virtual, upright image}}$$

---

5. $R = \dfrac{-6.00 \text{ cm}}{2} = -3.00$ cm

$p = 10.5$ cm

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{-3.00 \text{ cm}} - \frac{1}{10.5 \text{ cm}}$$

$$\frac{1}{q} = \frac{-0.667}{1 \text{ cm}} - \frac{0.0952}{1 \text{ cm}} = \frac{-0.762}{1 \text{ cm}}$$

$$q = \boxed{-1.31 \text{ cm}}$$

$$M = -\frac{q}{p} = \frac{-1.31 \text{ cm}}{-10.5 \text{ cm}} = \boxed{0.125} \quad \boxed{\text{virtual, upright image}}$$

---

6. $p = 49$ cm

$f = -35$ cm

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-35 \text{ cm}} - \frac{1}{49 \text{ cm}}$$

$$\frac{1}{q} = \frac{-0.029}{1 \text{ cm}} - \frac{0.020}{1 \text{ cm}} = \frac{-0.049}{1 \text{ cm}}$$

$$q = \boxed{-2.0 \times 10^1 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-2.0 \times 10^1 \text{ cm}}{49 \text{ cm}} = \boxed{0.41} \quad \boxed{\text{virtual, upright image}}$$

Light and Reflection, Section 3 Review

1. $R = -1.5$ cm

$p = 1.1$ cm

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{-1.5 \text{ cm}} - \frac{1}{1.1 \text{ cm}}$$

$$\frac{1}{q} = \frac{-1.3}{1 \text{ cm}} - \frac{0.91}{1 \text{ cm}} = \frac{-2.2}{1 \text{ cm}}$$

$$q = \boxed{-0.45 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-0.45 \text{ cm}}{1.1 \text{ cm}} = \boxed{0.41} \quad \boxed{\text{virtual, upright image}}$$

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2. $M = -95$

$q = 13$ m

$$p = -\frac{q}{M} = -\frac{13 \text{ m}}{-95} = \boxed{0.14 \text{ m}}$$

Givens | *Solutions*

5. $R = 265.0$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

Because objects in space are so far away,

$$\frac{1}{p} = 0\text{; therefore,}$$

$$\frac{1}{q} = \frac{2}{R} = \frac{2}{265.0\text{ m}} = \frac{7.547 \times 10^{-3}}{1\text{ m}}$$

$$q = \boxed{132.5\text{ m}}$$

I

Light and Reflection, Chapter Review

10. $f_1 = 7.5 \times 10^{14}$ Hz

$f_2 = 1.0 \times 10^{15}$ Hz

$c = 3.00 \times 10^8$ m/s

$$\lambda_1 = \frac{c}{f_1} = \frac{3.00 \times 10^8\text{ m/s}}{7.5 \times 10^{14}\text{ m}} = \boxed{4.0 \times 10^{-7}\text{ m}}$$

$$\lambda_2 = \frac{c}{f_2} = \frac{3.00 \times 10^8\text{ m/s}}{1.0 \times 10^{15}\text{ m}} = \boxed{3.0 \times 10^{-7}\text{ m}}$$

11. $c = 3.00 \times 10^8$ m/s

$f = 3 \times 10^{14}$ Hz

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8\text{ m/s}}{3 \times 10^{14}\text{ Hz}} = \boxed{1 \times 10^{-6}\text{ m}}$$

12. $f = 99.5$ MHz

$c = 3.00 \times 10^8$ m/s

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8\text{ m/s}}{9.95 \times 10^7\text{ Hz}} = \boxed{3.02\text{ m}}$$

13. $f = 33$ GHz

$c = 3.00 \times 10^8$ m/s

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8\text{ m/s}}{3.3 \times 10^{10}\text{ Hz}} = \boxed{9.1 \times 10^{-3}\text{ m}}$$

34. $R = 25.0$ cm

$p = 45.0$ cm

a. $$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{25.0\text{ cm}} - \frac{1}{45.0\text{ cm}}$$

$$\frac{1}{q} = \frac{0.0800}{1\text{ cm}} - \frac{0.0222}{1\text{ cm}} = \frac{0.0578}{1\text{ cm}}$$

$$q = 17.3\text{ cm}$$

$$M = -\frac{q}{p} = -\frac{17.3\text{ cm}}{45.0\text{ cm}} = \boxed{-0.384} \quad \boxed{\text{real, inverted image}}$$

$p = 25.0$ cm

b. $$\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{25.0\text{ cm}} - \frac{1}{25.0\text{ cm}}$$

$$\frac{1}{q} = \frac{0.0800}{1\text{ cm}} - \frac{0.0400}{1\text{ cm}} = \frac{0.0400}{1\text{ cm}}$$

$$q = 25.0\text{ cm}$$

$$M = -\frac{q}{p} = -\frac{25.0\text{ cm}}{25.0\text{ cm}} = \boxed{-1.00} \quad \boxed{\text{real, inverted image}}$$

Givens	Solutions

$p = 5.00$ cm

c. $\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{25.0\text{ cm}} - \frac{1}{5.00\text{ cm}}$

$\frac{1}{q} = \frac{0.0800}{1\text{ cm}} - \frac{0.200}{1\text{ cm}} = \frac{-0.120}{1\text{ cm}}$

$q = -8.33$ cm

$M = -\frac{q}{p} = -\frac{-8.33\text{ cm}}{5.00\text{ cm}} = \boxed{1.67}$ $\boxed{\text{virtual, upright image}}$

I

35. $f = 8.5$ cm

$q = 2p$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} + \frac{1}{2p}$

$\frac{1}{f} = \frac{3}{2p}$

$p = \frac{3f}{2}$

$q = 2p = 3f = 3(8.5\text{ cm}) = \boxed{26\text{ cm}}$

$M = \frac{-q}{p} = \frac{-2p}{p} = \boxed{-2}$ $\boxed{\text{real, inverted image}}$

36. $R = -45.0$ cm

$h' = 1.70$ cm

$q = -15.8$ cm

$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$

$\frac{1}{p} = \frac{2}{R} - \frac{1}{q} = \frac{2}{-45.0\text{ cm}} - \frac{1}{-15.8\text{ cm}}$

$\frac{1}{p} = \frac{-0.0444}{\text{cm}} + \frac{0.0633}{\text{cm}} = \frac{0.0189}{1\text{ cm}}$

$p = \boxed{52.9\text{ cm}}$

$M = \frac{-q}{p} = -\frac{(-15.8\text{ cm})}{(52.9\text{ cm})} = \boxed{0.299}$

$h = \frac{-ph'}{q} = -\frac{(52.9\text{ cm})(1.70\text{ cm})}{(-15.8\text{ cm})} = \boxed{5.69\text{ cm}}$ $\boxed{\text{virtual, upright image}}$

46. $M = -0.085$

$q = 35$ cm

$p = -\frac{q}{M} = -\frac{35\text{ cm}}{-0.085} = \boxed{4.1 \times 10^2\text{ cm}}$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{410\text{ cm}} + \frac{1}{35\text{ cm}}$

$\frac{1}{f} = \frac{0.0024}{1\text{ cm}} + \frac{0.029}{1\text{ cm}} = \frac{0.031}{1\text{ cm}}$

$f = \boxed{32\text{ cm}}$

$R = 2f = (2)(32\text{ cm}) = \boxed{64\text{ cm}}$ $\boxed{\text{real, inverted image}}$

Givens | *Solutions*

47. $M = -0.75$

$q = 4.6$ cm

$$p = -\frac{q}{M} = -\frac{4.6 \text{ cm}}{-0.75} = \boxed{6.1 \text{ cm}}$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{6.1 \text{ cm}} + \frac{1}{4.6 \text{ cm}}$$

$$\frac{1}{f} = \frac{0.16}{1 \text{ cm}} + \frac{0.22}{1 \text{ cm}} = \frac{0.38}{1 \text{ cm}}$$

$$f = \boxed{2.6 \text{ cm}} \quad \boxed{\text{real, inverted image}}$$

---

48. $p = 15.5$ cm

$M = \frac{1}{2}$

$$M = -\frac{q}{p} = \frac{1}{2}$$

$$q = -\frac{p}{2}$$

$$\frac{2}{R} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} - \frac{2}{p} = -\frac{1}{p}$$

$$R = -2p = (-2)(15.5 \text{ cm}) = \boxed{-31.0 \text{ cm}}$$

---

49. $p_1 = 15$ cm

$q_1 = 8.5$ cm

$p_2 = 25$ cm

$$\frac{1}{f} = \frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{15 \text{ cm}} + \frac{1}{8.5 \text{ cm}}$$

$$\frac{1}{f} = \frac{0.067}{1 \text{ cm}} + \frac{0.12}{1 \text{ cm}} = \frac{0.19}{1 \text{ cm}}$$

$$\frac{1}{q_2} = \frac{1}{f} - \frac{1}{p_2} = \frac{0.19}{1 \text{ cm}} - \frac{1}{25 \text{ cm}}$$

$$\frac{1}{q_2} = \frac{0.19}{1 \text{ cm}} - \frac{0.040}{1 \text{ cm}} = \frac{0.15}{1 \text{ cm}}$$

$$q_2 = \boxed{6.7 \text{ cm}} \quad \boxed{\text{real image}}$$

$$M_1 = -\frac{q_1}{p_1} = -\frac{8.5 \text{ cm}}{15 \text{ cm}} = \boxed{-0.57}$$

$$M_2 = -\frac{q_2}{p_2} = -\frac{6.7 \text{ cm}}{25 \text{ cm}} = \boxed{-0.27} \quad \boxed{\text{both images are inverted}}$$

---

50. $p = 195$ cm

$q = -12.8$ cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{195 \text{ cm}} + \frac{1}{-12.8 \text{ cm}}$$

$$\frac{1}{f} = \left(\frac{5.13 \times 10^{-3}}{1 \text{ cm}}\right) + \left(\frac{-7.81 \times 10^{-2}}{1 \text{ cm}}\right) = \frac{-7.30 \times 10^{-2}}{1 \text{ cm}}$$

$$f = \boxed{-13.7 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-12.8 \text{ cm}}{195 \text{ cm}} = \boxed{0.0656} \quad \boxed{\text{virtual, upright image}}$$

---

51. $R = -11.3$ cm

$M = \frac{1}{3}$

$$M = -\frac{q}{p} = \frac{1}{3}$$

$$q = -\frac{p}{3}$$

$$\frac{2}{R} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} - \frac{3}{p} = -\frac{2}{p}$$

$$p = -R = \boxed{11.3 \text{ cm}}$$

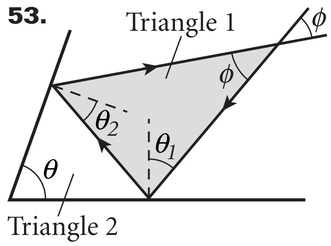
Givens / Solutions

52. $p = 10.0$ cm

$q = 2.00$ m

$$M = -\frac{q}{p} = -\frac{2.00 \times 10^2 \text{ cm}}{10.0 \text{ cm}} = \boxed{-20.0} \quad \boxed{\text{real, inverted image}}$$

53.



Let θ_1 and θ_2 be the angles of incidence at the first and second surfaces, respectively.

Triangle 1:

$$2\theta_1 + 2\theta_2 + \phi = 180°$$

$$\phi = 180° - 2(\theta_1 + \theta_2)$$

Triangle 2:

$$(90° - \theta_1) + (90° - \theta_2) + \theta = 180°$$

$$\theta = \theta_1 + \theta_2$$

Substitute this θ value into the equation for ϕ.

$$\phi = 180° - 2\theta$$

---

54. $R = \infty$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{\infty}$$

$$\frac{1}{p} + \frac{1}{q} = 0$$

$$\frac{1}{q} = -\frac{1}{p}$$

$$q = -p$$

---

55. $p = 70.0 \text{ cm} - 20.0 \text{ cm}$

$= 50.0$ cm

$q = 10.0 \text{ cm} - 20.0 \text{ cm}$

$= -10.0$ cm

$$\frac{2}{R} = \frac{1}{p} + \frac{1}{q}$$

$$\frac{1}{R} = \frac{1}{2p} + \frac{1}{2q} = \frac{1}{(2)(50.0 \text{ cm})} + \frac{1}{(2)(10.0 \text{ cm})}$$

$$\frac{1}{R} = \frac{0.0100}{1 \text{ cm}} - \frac{0.0500}{1 \text{ cm}} = \frac{-0.0400}{1 \text{ cm}}$$

$$R = \boxed{-25.0 \text{ cm}}$$

---

56. $q_1 = -30.0$ cm

$q_2 = -10.0$ cm

$R_1 = -R_2$

a. $R_1 = -R_2$

$$\frac{2}{R_1} = -\frac{2}{R_2}$$

$$\frac{1}{p_1} + \frac{1}{q_1} = -\left(\frac{1}{p_2} + \frac{1}{q_2}\right) \quad \text{where } p_1 = p_2 = p$$

$$\frac{2}{p} = -\frac{1}{q_1} - \frac{1}{q_2} = -\frac{1}{-30.0 \text{ cm}} + \frac{1}{10.0 \text{ cm}}$$

$$\frac{2}{p} = \frac{0.0333}{1 \text{ cm}} + \frac{0.100}{1 \text{ cm}} = \frac{0.133}{1 \text{ cm}}$$

$$p = \frac{2}{0.133} \text{cm} = \boxed{15.0 \text{ cm}}$$

b. $\frac{2}{R} = \frac{1}{p} + \frac{1}{q_1} = \frac{1}{15.0\text{ cm}} + \frac{1}{-30.0\text{ cm}}$

$\frac{2}{R} = \frac{0.0667}{1\text{ cm}} - \frac{0.0333}{1\text{ cm}} = \frac{0.0334}{1\text{ cm}}$

$R = \frac{2}{0.0334}\text{ cm} = \boxed{59.9\text{ cm}}$

c. $M_{concave} = -\frac{q_1}{p_1} = -\frac{-30.0\text{ cm}}{15.0\text{ cm}} = \boxed{2.00}$

$M_{convex} = -\frac{q_2}{p_2} = -\frac{-10.0\text{ cm}}{15.0\text{ cm}} = \boxed{0.667}$

---

57. $h = 2.70$ cm

$p = 12.0$ cm

$h' = 5.40$ cm

$M = -\frac{q}{p} = \frac{h'}{h} = \frac{5.40\text{ cm}}{2.70\text{ cm}} = \boxed{2.00}$ $\boxed{\text{virtual image}}$

$q = -Mp = -(2.00)(12.0\text{ cm}) = -24.0\text{ cm}$

$\frac{2}{R} = \frac{1}{p} + \frac{1}{q} = \frac{1}{12.0\text{ cm}} + \frac{1}{-24.0\text{ cm}}$

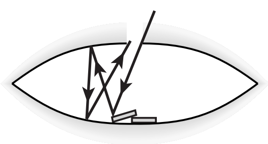
$\frac{2}{R} = \frac{0.0833}{1\text{ cm}} - \frac{0.0417}{1\text{ cm}} = \frac{0.0416}{1\text{ cm}}$

$R = \frac{2}{0.0416}\text{ cm} = \boxed{48.1\text{ cm}}$

---

58. $f = 7.5$ cm

$p_1 = 7.5$ cm



Locate the image of the coins formed by the upper mirror:

$\frac{1}{q_1} = \frac{1}{f} - \frac{1}{p_1} = \frac{1}{7.5\text{ cm}} - \frac{1}{7.5\text{ cm}} = 0$

Thus, $q_1 = \infty$.

Now, locate the final image, realizing that parallel rays are reflected toward the lower mirror by the upper mirror; thus, $p_2 = \infty$.

$\frac{1}{q_2} = \frac{1}{f} - \frac{1}{p_2} = \frac{1}{7.5\text{ cm}} - \frac{1}{\infty} = \frac{1}{7.5\text{ cm}}$

$q_2 = 7.5$ cm

$M = M_1M_2 = \left(-\frac{q_1}{p_1}\right)\left(-\frac{q_2}{p_2}\right)$ where $q_1 = p_2$

$M = \frac{q_2}{p_1} = \frac{7.5\text{ cm}}{7.5\text{ cm}} = 1.0$

Givens *Solutions*

59. For a convex mirror:

$f < 0$, or $f = -|f|$

$$\frac{1}{q} = \frac{1}{-|f|} - \frac{1}{p} = -\frac{p+|f|}{p|f|}$$

$$q = -\frac{p|f|}{p+|f|}$$

$$M = -\frac{q}{p} = -\frac{1}{p}\left(-\frac{p|f|}{p+|f|}\right) = \frac{p|f|}{p+|f|}$$

For a real object ($p > 0$), $1 > M > 0$; this means that the image is an upright, virtual image.

For a spherical mirror, the image is virtual and upright if $p < |f|$ and $f < 0$. For $f > 0$:

$f > 0$, or $f = +|f|$

$$\frac{1}{q} = \frac{1}{|f|} - \frac{1}{p} = \frac{p-|f|}{p|f|}$$

$$q = \frac{p|f|}{p-|f|}$$

$$M = -\frac{q}{p} = -\frac{1}{p}\left(\frac{p|f|}{p-|f|}\right) = \frac{|f|}{|f|-p}$$

When $p < |f|$, $M > 1$; thus the image is enlarged, upright, and virtual.

60.

$$\tan\theta = \frac{h}{p}$$

$$\tan\theta' = \frac{-h'}{q}$$

$\theta = \theta'$; thus, $\tan\theta = \tan\theta'$.

$$\frac{h}{p} = -\frac{h'}{q}$$

Cross multiply to find the magnification equation.

$$M = \frac{h'}{h} = -\frac{q}{p}$$

From two other triangles in the figure, we note that:

$$\tan\alpha = \frac{h}{p-R} \text{ and } \tan\alpha = -\frac{h'}{R-q}$$

so that

$$\frac{h'}{h} = -\frac{R-q}{p-R} = -\frac{q}{p}$$

Cross multiply to find the following:

$p(R - q) = q(p - R)$

$pR - pq = qp - qR$

$R(p + q) = 2pq$

$$\frac{2}{R} = \frac{p+q}{pq} = \frac{1}{q} + \frac{1}{p}$$

Givens	*Solutions*
7. $p = 15.0$ cm $q = -6.00$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{15.0 \text{ cm}} + \frac{1}{-6.00 \text{ cm}}$ $\frac{1}{f} = \frac{0.0667}{\text{cm}} - \frac{0.167}{\text{cm}} = \frac{-0.100}{\text{cm}}$ $f = \boxed{-10.0 \text{ cm}}$
9. $\lambda = 5.5\ \mu\text{m} = 5.5 \times 10^{-6}$ m $c = 3.00 \times 10^8$ m/s	$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{5.5 \times 10^{-6} \text{ m}} = \boxed{5.5 \times 10^{13} \text{ Hz}}$
13. $f = 5.0 \times 10^{19}$ Hz $c = 3.00 \times 10^8$ m/s	$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m/s}}{5.0 \times 10^{19} \text{ /s}} = \boxed{6.0 \times 10^{-12} \text{ m} = 6.0 \text{ pm}}$
15. $p = 30.0$ cm $R = 20.0$ cm	$\frac{2}{R} = \frac{1}{p} + \frac{1}{q}$ $\frac{1}{q} = \frac{2}{R} - \frac{1}{p} = \frac{2}{20.0 \text{ cm}} - \frac{1}{30.0 \text{ cm}}$ $\frac{1}{q} = \frac{60.0}{600 \text{ cm}} - \frac{20.0}{600 \text{ cm}} = \frac{40.0}{600 \text{ cm}}$ $q = \boxed{15.0 \text{ cm}}$
16. $p = 30.0$ cm $q = 15.0$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{30.0 \text{ cm}} + \frac{1}{15.0 \text{ cm}}$ $\frac{1}{f} = \frac{15.0}{450 \text{ cm}} + \frac{30.0}{450 \text{ cm}} = \frac{45.0}{450 \text{ cm}}$ $f = \boxed{10.0 \text{ cm}}$
17. $p = 30.0$ cm $q = 15.0$ cm	$M = \frac{-q}{p} = \frac{-15.0 \text{ cm}}{30.0 \text{ cm}} = \boxed{-0.500}$
18. $h = 12$ cm $M = -0.500$	$M = \frac{h'}{h}$ $h' = Mh = (-0.500)(12 \text{ cm}) = \boxed{-6.0 \text{ cm}}$

Refraction

Refraction, Practice A

Givens | *Solutions*

1. $n_i = 1.00$

$n_r = 1.333$

$\theta_i = 25.0°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.333}(\sin 25.0°)\right] = \boxed{18.5°}$$

---

2. $n_i = 1.66$

$n_r = 1.52$

$\theta_i = 25.0°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

a. $$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.66}{1.52}(\sin 25.0°)\right] = \boxed{27.5°}$$

$n_i = 1.00$

$\theta_i = 14.5°$

$\theta_r = 9.80°$

b. $$n_r = \frac{n_i(\sin\theta_i)}{\sin\theta_r} = \frac{1.00(\sin 14.5°)}{\sin 9.80°} = 1.47\ \boxed{\text{glycerine}}$$

$n_i = 1.00$

$n_r = 2.419$

$\theta_i = 31.6°$

c. $$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{2.419}(\sin 31.6°)\right] = \boxed{12.5°}$$

---

3. $\theta_i = 40.0°$

$\theta_r = 26.0°$

$n_i = 1.00$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$$n_r = \frac{n_i(\sin\theta_i)}{\sin\theta_r} = \frac{(1.00)(\sin 40.0°)}{\sin 26.0°} = \boxed{1.47}$$

Refraction, Section 1 Review

1. $n_i = 1.00$

$n_r = 1.333$

$\theta_i = 22.5°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.333}(\sin 22.5°)\right] = \boxed{16.7°}$$

---

3. $n_i = 1.00$

$n_r = 2.419$

$\theta_i = 15.0°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{2.419}(\sin 15.0°)\right] = \boxed{6.14°}$$

Refraction, Practice B

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Givens	*Solutions*
1. $p = 20.0$ cm $f = 10.0$ cm	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{10.0\text{ cm}} - \frac{1}{20.0\text{ cm}}$ $\frac{1}{q} = \frac{0.100}{1\text{ cm}} - \frac{0.0500}{1\text{ cm}} = \frac{0.0500}{1\text{ cm}}$ $q = \boxed{20.0\text{ cm}}$ $M = -\frac{q}{p} = -\frac{20.0\text{ cm}}{20.0\text{ cm}} = \boxed{-1.00}$ $\boxed{\text{real, inverted image}}$
2. $f = 15.0$ cm $p = 10.0$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{15.0\text{ cm}} - \frac{1}{10.0\text{ cm}} = \frac{2}{30.0\text{ cm}} - \frac{3}{30.0\text{ cm}}$ $\frac{1}{q} = \frac{-1}{30.0\text{ cm}}$ $q = \boxed{-30.0\text{ cm}}$
3. $p = 20.0$ cm $f = -10.0$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-10.0\text{ cm}} - \frac{1}{20.0\text{ cm}}$ $\frac{1}{q} = \frac{-0.100}{1\text{ cm}} - \frac{0.0500}{1\text{ cm}} = \frac{-0.150}{1\text{ cm}}$ $q = \boxed{-6.67\text{ cm}}$ $M = -\frac{q}{p} = -\frac{-6.67\text{ cm}}{20.0\text{ cm}} = \boxed{0.333}$ $\boxed{\text{virtual, upright image}}$
4. $f = 6.0$ cm $q = -3.0$ cm	**a.** $\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{6.0\text{ cm}} - \frac{1}{-3.0\text{ cm}}$ $\frac{1}{p} = \frac{0.17}{1\text{ cm}} - \frac{-0.33}{1\text{ cm}} = \frac{0.50}{1\text{ cm}}$ $p = \boxed{2.0\text{ cm}}$ $M = -\frac{q}{p} = -\frac{-3.0\text{ cm}}{2.0\text{ cm}} = \boxed{1.5}$
$f = 2.9$ cm $q = 7.0$ cm	**b.** $\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{2.9\text{ cm}} - \frac{1}{7.0\text{ cm}}$ $\frac{1}{p} = \frac{0.34}{1\text{ cm}} - \frac{0.14}{1\text{ cm}} = \frac{0.20}{1\text{ cm}}$ $p = \boxed{5.0\text{ cm}}$ $M = -\frac{q}{p} = -\frac{7.0\text{ cm}}{5.0\text{ cm}} = \boxed{-1.4}$

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Givens | *Solutions*

$f = -6.0$ cm

$p = 4.0$ cm

c. $\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-6.0 \text{ cm}} - \frac{1}{4.0 \text{ cm}}$

$\frac{1}{q} = \frac{-0.17}{1 \text{ cm}} - \frac{0.25}{1 \text{ cm}} = \frac{-0.42}{1 \text{ cm}}$

$q = \boxed{-2.4 \text{ cm}}$

$M = -\frac{q}{p} = -\frac{-2.4 \text{ cm}}{4.0 \text{ cm}} = \boxed{0.60}$

$p = 5.0$ cm

$M = 0.50$

d. $q = -Mp = -(0.50)(5.0 \text{ cm}) = \boxed{-2.5 \text{ cm}}$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{5.0 \text{ cm}} + \frac{1}{-2.5 \text{ cm}}$

$\frac{1}{f} = \frac{0.20}{1 \text{ cm}} + \frac{-0.40}{1 \text{ cm}} = \frac{-0.20}{1 \text{ cm}}$

$f = \boxed{-5.0 \text{ cm}}$

Refraction, Section 2 Review

3. $f = 4.0$ cm

$p = 3.0 \text{ cm} + 4.0 \text{ cm} = 7.0 \text{ cm}$

$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$

$\frac{1}{q} = \frac{1}{(4.0 \text{ cm})} - \frac{1}{(7.0 \text{ cm})} = \frac{7}{28 \text{ cm}} - \frac{4}{28 \text{ cm}} = \frac{3}{28 \text{ cm}}$

$q = \frac{28 \text{ cm}}{3} = \boxed{9.3 \text{ cm}}$

4. $p = 7.0$ cm

$q = 9.1$ cm

$M = -\frac{q}{p} = -\frac{9.1 \text{ cm}}{7.0 \text{ cm}} = \boxed{-1.3}$

Refraction, Practice C

1. $n_i = 1.473$

$n_r = 1.00$

$\sin \theta_c = \frac{n_r}{n_i}$

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.473}\right) = \boxed{42.8°}$

2. $n_i = 1.473$

$n_r = 1.333$

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.333}{1.473}\right) = \boxed{64.82°}$

3. $n_i = 1.309$

$n_r = 1.00$

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.309}\right) = \boxed{49.8°}$

Givens | *Solutions*

4. $n_i = 2.419$
$n_r = 1.00$

diamond: $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{2.419}\right) = \boxed{24.4°}$

$n_i = 2.20$
$n_r = 1.00$

cubic zirconia: $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{2.20}\right) = \boxed{27.0°}$

Refraction, Section 3 Review

1. $n_i = 1.333$
$n_r = 1.309$

$\sin \theta_c = \frac{n_r}{n_i}$

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.309}{1.333}\right) = \boxed{79.11°}$

Refraction, Chapter Review

10. $n_i = 1.00$
$n_r = 1.333$
$\theta_i = 42.3°$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.333}(\sin 42.3°)\right] = \boxed{30.3°}$

11. $n_i = 1.00$
$n_r = 1.333$
$\theta_i = 36°$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.333}(\sin 36°)\right] = \boxed{26°}$

12. $n_i = 1.00$
$n_r = 1.333$
$\theta_i = 35.0°$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.333}(\sin 35.0°)\right] = \boxed{25.5°}$

13. $\theta_{i,1} = 30.0°$
$n_{i,1} = 1.00$
$n_{r,1} = 1.50$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

air to glass:

$\theta_{r,1} = \sin^{-1}\left[\frac{n_{i,1}}{n_{r,1}}(\sin \theta_{i,1})\right] = \sin^{-1}\left[\frac{1.00}{1.50}(\sin 30.0°)\right] = 19.5°$

$\boxed{\theta_{i,1} = 30.0° \text{ and } \theta_{r,1} = 19.5°}$

glass to air:

$\theta_{i,2} = \theta_{r,1}$ because they are alternate interior angles. $\theta_{r,2} = \theta_{i,1}$ because of the reversibility of refraction; thus, $\boxed{\theta_{i,2} = 19.5° \text{ and } \theta_{r,2} = 30.0°}$

14. $\theta_r = 20.0°$
$n_i = 1.00$
$n_r = 1.48$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

air to oil: $\theta_1 = \theta_i = \sin^{-1}\left[\frac{n_r}{n_i}(\sin \theta_r)\right] = \sin^{-1}\left[\frac{1.48}{1.00}(\sin 20.0°)\right] = \boxed{30.4°}$

$\theta_i = 20.0°$
$n_i = 1.48$
$n_r = 1.333$

oil to water: $\theta_2 = \theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.48}{1.333}(\sin 20.0°)\right] = \boxed{22.3°}$

Givens | *Solutions*

24. $f = -20.0$ cm

$p = 40.0$ cm

a. $$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-20.0 \text{ cm}} - \frac{1}{40.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{-0.0500}{1 \text{ cm}} - \frac{0.0250}{1 \text{ cm}} = \frac{-0.0750}{1 \text{ cm}}$$

$$q = \boxed{-13.3 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-13.3 \text{ cm}}{40.0 \text{ cm}} = \boxed{0.332} \quad \boxed{\text{virtual, upright image}}$$

$p = 20.0$ cm

b. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-20.0 \text{ cm}} - \frac{1}{20.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{-0.0500}{1 \text{ cm}} - \frac{0.0500}{1 \text{ cm}} = \frac{-0.100}{1 \text{ cm}}$$

$$q = \boxed{-10.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-10.0 \text{ cm}}{20.0 \text{ cm}} = \boxed{0.500} \quad \boxed{\text{virtual, upright image}}$$

$p = 10.0$ cm

c. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-20.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{-0.0500}{1 \text{ cm}} - \frac{0.100}{1 \text{ cm}} = \frac{-0.150}{1 \text{ cm}}$$

$$q = \boxed{-6.67 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-6.67 \text{ cm}}{10.0 \text{ cm}} = \boxed{0.667} \quad \boxed{\text{virtual, upright image}}$$

---

25. $f = 12.5$ cm

$q = -30.0$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{12.5 \text{ cm}} - \frac{1}{-30.0 \text{ cm}}$$

$$\frac{1}{p} = \frac{0.0800}{1 \text{ cm}} - \frac{-0.0333}{1 \text{ cm}} = \frac{0.1133}{1 \text{ cm}}$$

$$p = 8.826 \text{ cm}$$

$$M = -\frac{q}{p} = -\frac{-30.0 \text{ cm}}{8.826 \text{ cm}} = \boxed{3.40} \quad \boxed{\text{upright image}}$$

---

26. $f = 20.0$ cm

$p = 40.0$ cm

a. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{40.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{0.0500}{1 \text{ cm}} - \frac{0.0250}{1 \text{ cm}} = \frac{0.0250}{1 \text{ cm}}$$

$$q = \boxed{40.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{40.0 \text{ cm}}{40.0 \text{ cm}} = \boxed{-1.00} \quad \boxed{\text{real, inverted image}}$$

$p = 10.0$ cm

b. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{20.0 \text{ cm}} - \frac{1}{10.0 \text{ cm}}$$

$$\frac{1}{q} = \frac{0.0500}{1 \text{ cm}} - \frac{0.100}{1 \text{ cm}} = \frac{-0.0500}{1 \text{ cm}}$$

$$q = \boxed{-20.0 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-20.0 \text{ cm}}{10.0 \text{ cm}} = \boxed{2.00} \quad \boxed{\text{virtual, upright image}}$$

Givens | *Solutions*

36. $n_i = 1.473$

$n_r = 1.00$

$$\sin\theta_c = \frac{n_r}{n_i}$$

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.473}\right) = \boxed{42.8°}$$

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37. $n_r = 1.00$

$n_i = 1.923$

a. $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.923}\right) = \boxed{31.3°}$

$n_i = 1.434$

b. $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.434}\right) = \boxed{44.2°}$

$n_i = 1.309$

c. $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.309}\right) = \boxed{49.8°}$

---

38. $n_i = 1.52$

$n_r = 1.00$

$\theta_r = 45°$

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.52}\right) = 41.1°$$

$\boxed{\theta_r > \theta_c\text{, therefore the ray will be totally internally reflected.}}$

---

39. $n_i = 1.00$

$\theta_i = 63.5°$

$\theta_r = 42.9°$

$$n_i(\sin\theta_i) = n_r(\sin\theta_r)$$

$$n_r = \frac{n_i(\sin\theta_i)}{\sin\theta_r} = \frac{(1.00)(\sin 63.5°)}{\sin 42.9°} = \boxed{1.31}$$

---

40. $n_i = 1.00$

$n_r = 1.333$

$\theta_r = 36.2°$

$$n_i(\sin\theta_i) = n_r(\sin\theta_r)$$

$$\theta_i = \sin^{-1}\left[\frac{n_r}{n_i}(\sin\theta_r)\right] = \sin^{-1}\left[\frac{1.333}{1.00}(\sin 36.2°)\right] = \boxed{51.9°}$$

---

41. $v = 1.85 \times 10^8$ m/s

$c = 3.00 \times 10^8$ m/s

$$n = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ m/s}}{1.85 \times 10^8 \text{ m/s}} = \boxed{1.62} \quad \boxed{\text{carbon disulfide}}$$

---

42. $n_i = 1.66$

$n_r = 1.333$

$\theta_i = 28.7°$

$$n_i(\sin\theta_i) = n_r(\sin\theta_r)$$

a. $\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.66}{1.333}(\sin 28.7°)\right] = \boxed{36.7°}$

$\theta_r = 90.0°$

b. $\theta_i = \sin^{-1}\left[\frac{n_r}{n_i}(\sin\theta_r)\right] = \sin^{-1}\left[\frac{1.333}{1.66}(\sin 90.0°)\right] = \boxed{53.4°}$

---

43. $f = 15.0$ cm

$M = +2.00$

$$M = -\frac{p}{q}$$

$$q = -Mp = -2.00p$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} - \frac{1}{2.00p} = \frac{1}{2.00p}$$

$$\frac{1}{15.0 \text{ cm}} = \frac{1}{2.00\,p}$$

$$p = \frac{15.0 \text{ cm}}{2.00} = \boxed{7.50 \text{ cm}}$$

Givens / *Solutions*

44. $M = 1.50$

$p = 2.84$ cm

$$M = -\frac{q}{p} = 1.50$$

$$q = -1.50p = -(1.50)(2.84 \text{ cm}) = -4.26 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{2.84 \text{ cm}} + \frac{1}{-4.26 \text{ cm}}$$

$$\frac{1}{f} = \frac{0.352}{1 \text{ cm}} + \frac{-0.235}{1 \text{ cm}} = \frac{0.117}{1 \text{ cm}}$$

$$f = \boxed{8.55 \text{ cm}}$$

---

45. $M = 2.00$

$f = 12.0$ cm

a. $$M = -\frac{q}{p} = 2.00$$

$$q = -2.00p$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} - \frac{1}{2.00p} = \frac{1}{2.00p}$$

$$p = \frac{f}{M} = \frac{12.0 \text{ cm}}{2.00} = \boxed{6.00 \text{ cm}}$$

---

46. $p = 80.0$ cm

$q = -40.0$ cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{80.0 \text{ cm}} + \frac{1}{-40.0 \text{ cm}}$$

$$\frac{1}{f} = \frac{0.0125}{1 \text{ cm}} + \frac{-0.0250}{1 \text{ cm}} = \frac{-0.0125}{1 \text{ cm}}$$

$$f = \boxed{-80.0 \text{ cm}}$$

---

47. $f = 2.44$ cm

$q = 12.9$ cm

a. $$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{2.44 \text{ cm}} + \frac{1}{12.9 \text{ cm}}$$

$$\frac{1}{p} = \frac{0.410}{1 \text{ cm}} + \frac{0.0775}{1 \text{ cm}} = \frac{0.332}{1 \text{ cm}}$$

$$p = \boxed{3.01 \text{ cm}}$$

$q = -12.9$ cm

b. $$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{2.44 \text{ cm}} - \frac{1}{-12.9 \text{ cm}}$$

$$\frac{1}{p} = \frac{0.410}{1 \text{ cm}} - \frac{-0.0775}{1 \text{ cm}} = \frac{0.488}{1 \text{ cm}}$$

$$p = \boxed{2.05 \text{ cm}}$$

---

48. $q = -30.0$ cm

$f = -40.0$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-40.0 \text{ cm}} - \frac{1}{-30.0 \text{ cm}}$$

$$\frac{1}{p} = \frac{-0.0250}{1 \text{ cm}} - \frac{-0.0333}{1 \text{ cm}} = \frac{0.0083}{1 \text{ cm}}$$

$$p = \boxed{1.20 \times 10^2 \text{ cm}}$$

$$M = -\frac{q}{p} = -\frac{-30.0 \text{ cm}}{120 \text{ cm}} = \boxed{0.250}$$

Givens	Solutions

Givens — *Solutions*

49. $n_r = 1.331$, $n_b = 1.340$, $\theta_i = 83.0°$, $n_i = 1.00$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

blue: $\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.340}(\sin 83.0°)\right] = \boxed{47.8°}$

red: $\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_r)\right] = \sin^{-1}\left[\frac{1.00}{1.331}(\sin 83.0°)\right] = \boxed{48.2°}$

---

50. $\theta_i = 23.1°$, $v = 2.17 \times 10^8$ m/s, $n_i = 1.00$, $c = 3.00 \times 10^8$ m/s

$n_r = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ m/s}}{2.17 \times 10^8 \text{ m/s}} = 1.38$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.38}(\sin 23.1°)\right] = \boxed{16.5°}$

---

51. $\theta_i = 30.0°$, $\theta_r = 22.0°$, $n_i = 1.00$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$n_r = n_i\left(\frac{\sin\theta_i}{\sin\theta_r}\right) = (1.00)\left(\frac{\sin 30.0°}{\sin 22.0°}\right) = 1.33$

$\sin\theta_c = \frac{n_r}{n_i}$

n_i is now n_r, and n_r is now n_i, so

$\theta_c = \sin^{-1}\left(\frac{n_i}{n_r}\right) = \sin^{-1}\left(\frac{1.00}{1.33}\right) = \boxed{48.8°}$

---

52. $v_a = 340$ m/s, $v_w = 1510$ m/s, $\theta_i = 12.0°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{(c/v_a)}{(c/v_w)}(\sin\theta_i)\right]$

$\theta_r = \sin^{-1}\left[\frac{v_w}{v_a}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1510 \text{ m/s}}{340 \text{ m/s}}(\sin 12.0°)\right] = \boxed{67°}$

---

53. $n_i = 1.333$, $n_r = 1.00$, $\Delta y = 2.00$ m

$\sin\theta_c = \frac{n_r}{n_i}$

$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.333}\right) = 48.6°$

$\tan\theta_c = \frac{(d/2)}{\Delta y} = \frac{d}{2\Delta y}$ where d is the diameter of the piece of wood

$d = 2\Delta y(\tan\theta_c) = (2)(2.00 \text{ m})(\tan 48.6°) = \boxed{4.54 \text{ m}}$

---

54. $n_i = 1.00$, $n_r = 1.309$, $\theta_i = 40.0°$

$n_i(\sin\theta_i) = n_r(\sin\theta_r)$

$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.309}(\sin 40.0°)\right] = 29.4°$

$\theta = 180.0° - 29.4° = \boxed{110.6°}$

Givens	*Solutions*

55. $p = 10f$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{f} - \frac{1}{10f} = \frac{9}{10f}$$

$$q = \boxed{\frac{10}{9}f}$$

---

56. $n_i = 1.53$

$n_r = 1.00$

$n_r = 1.333$

$$\sin \theta_c = \frac{n_r}{n_i}$$

a. $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.53}\right) = \boxed{40.8°}$

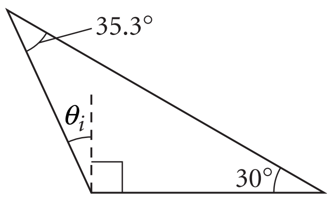
b. $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.333}{1.53}\right) = \boxed{60.6°}$

---

57. $n_r = 1.50$

$n_i = 1.00$

$\theta_i = 90° - 30° = 60°$



a. $n_i(\sin \theta_i) = n_r(\sin \theta_r)$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.00}{1.50}(\sin 60°)\right] = 35.3°$$

Using the figure at left, the angle of incidence of the ray at the bottom of the prism can be found as follows.

$\theta_i = 180° - 35.3° - 30° - 90° = \boxed{24.7°}$

$n_i = 1.50$

$n_r = 1.00$

$\theta_i = 24.7°$

b. $\sin \theta_c = \left(\frac{n_r}{n_i}\right)$

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.50}\right) = 41.8°$$

$\boxed{\text{The ray will pass through the bottom surface because } \theta_i < \theta_c.}$

---

58. $n_i = 1.8$

$\theta_c = 45°$

$n_r = n_i(\sin \theta_c) = (1.8)(\sin 45°) = \boxed{1.3}$

---

59. $n_i = 1.60$

$\theta_c = 59.5°$

$n_r = n_i(\sin \theta_c) = (1.60)(\sin 59.5°) = \boxed{1.38}$

---

60. $n_i = 1.333$

$n_r = 1.00$

$\Delta y = 4.00$ m

$\Delta x = 2.00$ m

$$\theta_i = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) = \tan^{-1}\left(\frac{2.00 \text{ m}}{4.00 \text{ m}}\right) = 26.6°$$

$n_i(\sin \theta_i) = n_r(\sin \theta_r)$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin \theta_i)\right] = \sin^{-1}\left[\frac{1.333}{1.00}(\sin 26.6°)\right] = 36.6°$$

The angle, θ, with respect to the water surface is $90° - \theta_r$.

$\theta = 90° - 36.6° = \boxed{53.4°}$

Givens	Solutions

61. $n_i = 1.333$

$n_r = 1.00$

$\Delta x = 325\text{ m} - 205\text{ m} = 120\text{ m}$

$\Delta y = 115\text{ m}$

$$\theta_i = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) = \tan^{-1}\left(\frac{120\text{ m}}{115\text{ m}}\right) = 46.2°$$

$$n_i(\sin\theta_i) = n_r(\sin\theta_r)$$

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\frac{1.333}{1.00}(\sin 46.2°)\right] = 74.2°$$

$$h = \frac{205\text{ m}}{(\tan 74.2°)} = \boxed{58.0\text{ m}}$$

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62. $n_i = 1.00$

$\theta_i = 50.0°$

$n_r = 1.48$

$h = 3.1\text{ mm} = 0.31\text{ cm}$

$\ell = 42.0\text{ cm}$

$$n_i \sin\theta_i = n_r \sin\theta_r$$

$$\theta_r = \sin^{-1}\left[\frac{n_i \sin\theta_i}{n_r}\right] = \sin^{-1}\left[\frac{(1.00)(\sin 50.0°)}{(1.48)}\right]$$

$$\theta_r = \sin^{-1}(0.518) = 31.2°$$

The distance, d, that the beam travels before being reflected is given by:

$$\tan\theta_r = \frac{h}{d}$$

$$d = \frac{h}{\tan\theta_r} = \frac{(0.31\text{ cm})}{\tan(31.2°)} = 0.51\text{ cm}$$

The incident beam hits at the midpoint, so the initially refracted beam travels a distance of $d/2 = 0.26$ cm. The remaining reflections travel $d = 0.51$ cm.

The length (after the first beam) is $\ell = d/2 = 42.5\text{ cm} - 0.26\text{ cm} = 41.7\text{ cm}$.

Thereafter, the number of reflections is:

$$\text{\# of reflections} = \frac{\ell}{d} = 1 + \frac{41.7\text{ cm}}{0.51\text{ cm}}$$

$$\boxed{\text{\# of reflections} = 1 + 81.7 = 82}$$

(Note: the last, fractional reflection is not internal, but goes out the end of the fiber optic)

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63. $f = 4.80\text{ cm}$

$= 4.80 \times 10^{-2}\text{ m}$

$p = 10.0\text{ m}$

a. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{4.80 \times 10^{-2}\text{ m}} - \frac{1}{10.0\text{ m}}$$

$$\frac{1}{q} = \frac{20.8}{1\text{ m}} - \frac{0.100}{1\text{ m}} = \frac{20.7}{1\text{ m}}$$

$$q = 4.83 \times 10^{-2}\text{ m} = \boxed{4.83\text{ cm}}$$

$p = 1.75\text{ m}$

b. $$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{4.80 \times 10^{-2}\text{ m}} - \frac{1}{1.75\text{ m}}$$

$$\frac{1}{q} = \frac{20.8}{1\text{ m}} - \frac{0.571}{1\text{ m}} = \frac{20.2}{1\text{ m}}$$

$$q = 4.95 \times 10^{-2}\text{ m} = 4.95\text{ cm}$$

$$\Delta q = 4.95\text{ cm} - 4.83\text{ cm} = \boxed{0.12\text{ cm}}$$

Givens	Solutions
64. $q = 1.90$ cm $p = 35.0$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{35.0\text{ cm}} + \frac{1}{1.90\text{ cm}}$ $\frac{1}{f} = \frac{0.0286}{1\text{ cm}} + \frac{0.526}{1\text{ cm}} = \frac{0.555}{1\text{ cm}}$ $f = \boxed{1.80\text{ cm}}$
65. $q = 1.90$ cm $= 1.90 \times 10^{-2}$ m $p = 15.0$ m	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{15.0\text{ m}} + \frac{1}{1.90 \times 10^{-2}\text{ m}}$ $\frac{1}{f} = \frac{0.0667}{1\text{ m}} + \frac{52.6}{1\text{ m}} = \frac{52.7}{1\text{ m}}$ $f = 1.90 \times 10^{-2}\text{ m} = \boxed{1.90\text{ cm}}$

Refraction, Standardized Test Prep

3. $p = 50.0$ cm $q = -10.0$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{50.0\text{ cm}} + \frac{1}{-10.0\text{ cm}} = \frac{1}{50.0\text{ cm}} - \frac{5}{50.0\text{ cm}} = -\frac{4}{50.0\text{ cm}}$ $f = \boxed{-12.5\text{ cm}}$
5. $n_{flint\ glass} = 1.66$ $n_{air} = 1.00$ $n_{oil} = 1.33$	$\sin\theta_c = \frac{n_r}{n_i}$ $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.00}{1.66}\right) = \boxed{37.0°}$ (glass to air) $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.33}{1.66}\right) = \boxed{53.2°}$ (glass to oil)
9. $\lambda = 500.0$ nm $n = 1.5$	$n = \frac{c_{vacuum}}{v_{benzene}} = \frac{f_{vac}\lambda_{vac}}{f_{ben}\lambda_{ben}} = \frac{\lambda_{vac}}{\lambda_{ben}}$ $\lambda_{ben} = \frac{\lambda_{vac}}{n} = \frac{500.0\text{ nm}}{1.5} = \boxed{330\text{ nm}}$
12. $n_i = 1.46$ $n_r = 1.36$ $q_i = 25.0°$	$n_i \sin\theta_i = n_r \sin\theta_r$ $\theta_r = \sin^{-1}\left(\frac{n_i \sin\theta_i}{n_r}\right) = \sin^{-1}\left(\frac{(1.46)(\sin 25.0°)}{(1.36)}\right) = \boxed{27.0°}$
13. $n_i = 1.92$ $n_r = 1.47$	$\sin\theta_c = \frac{n_r}{n_i}$ $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.47}{1.92}\right) = \boxed{50.0°}$
15. Converging Lens $p = -5.00$ cm (object behind lens) $q = +7.50$ cm (image in back of lens)	$\frac{1}{f} - \frac{1}{p} + \frac{1}{q} = \frac{1}{-5.00\text{ cm}} + \frac{1}{7.50\text{ cm}}$ $\frac{1}{f} = \frac{-7.50}{37.5\text{ cm}} + \frac{5.00}{37.5\text{ cm}} = \frac{-2.50}{37.5\text{ cm}}$ $f = \boxed{-15.0\text{ cm or } 15.0\text{ cm (since focal point on both sides of lens)}}$

Givens | *Solutions*

16. $p = -5.00$ cm

$q = +7.50$ cm

$$M = \frac{-q}{p} = \frac{-(+7.50 \text{ cm})}{(-5.00 \text{ cm})} = \boxed{1.5}$$

17. $d_{coin} = 2.8$ cm

$$M = \frac{h'}{h} = \frac{d_{image}}{d_{coin}}$$

$$d_{image} = M\, d_{coin} = (1.5)(2.8 \text{ cm}) = \boxed{4.2 \text{ cm}}$$

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Student Edition Solutions

Inference and Diffraction

I

Inference and Diffraction, Practice A

Givens | *Solutions*

1. $d = 0.50$ mm

$\theta = 0.059°$

$m = 1$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(5.0 \times 10^{-4}\ \text{m})(\sin 0.059°)}{1} = 5.1 \times 10^{-7}\ \text{m} = \boxed{5.1 \times 10^{2}\ \text{nm}}$$

2. $d = 2.02 \times 10^{-6}$ m

$\theta = 16.5°$

$m = 1$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(2.02 \times 10^{-6}\ \text{m})(\sin 16.5°)}{1}$$

$$\lambda = \boxed{574\ \text{nm}}$$

3. $d = 0.250$ mm

$\lambda = 546.1$ nm

$m = 1$

$$\theta = \sin^{-1}\left(\frac{\lambda m}{d}\right) = \sin^{-1}\left[\frac{(5.461 \times 10^{-7}\ \text{m})(1)}{2.50 \times 10^{-4}\ \text{m}}\right] = \boxed{0.125°}$$

4. $m = 1$

$d = 2.02 \times 10^{-6}$ m

$\lambda = 574\ \text{nm} = 5.74 \times 10^{-7}$ m

$$\theta = \sin^{-1}\left[\frac{\left(m + \frac{1}{2}\right)\lambda}{d}\right] = \sin^{-1}\left[\frac{\left(1 + \frac{1}{2}\right)(5.74 \times 10^{-7}\ \text{m})}{(2.02 \times 10^{-6}\ \text{m})}\right]$$

$$\theta = \boxed{25.2°}$$

Inference and Diffraction, Section 1 Review

3. $d = 0.0550$ mm

$m = 1$ and $m = 2$

$\lambda = 605$ nm

$$m = 1\text{: } \theta_1 = \sin^{-1}\left(\frac{\lambda m}{d}\right) = \sin^{-1}\left[\frac{(6.05 \times 10^{-7}\ \text{m})(1)}{5.50 \times 10^{-5}\ \text{m}}\right] = 0.630°$$

$$m = 2\text{: } \theta_2 = \sin^{-1}\left(\frac{\lambda m}{d}\right) = \sin^{-1}\left[\frac{(6.05 \times 10^{-7}\ \text{m})(2)}{5.50 \times 10^{-5}\ \text{m}}\right] = 1.26°$$

$$\Delta\theta = \theta_2 - \theta_1 = 1.26° - 0.630° = \boxed{0.63°}$$

4. $m = 2$

$\theta = 1.28°$

$\lambda = 3.35$ m

$$d = \frac{\lambda m}{\sin\theta} = \frac{(3.35\ \text{m})(2)}{\sin 1.28°} = \boxed{3.00 \times 10^{2}\ \text{m}}$$

I

Givens	*Solutions*
1. 5000×10^3 lines/cm $= \frac{1}{d}$ $d = 2.000 \times 10^{-6}$ m $\lambda_1 = 588.995$ nm $= 5.88995 \times 10^{-7}$ m $\lambda_2 = 589.592$ nm $= 5.89592 \times 10^{-7}$ m $m = 1,2,3$	

For $m = 1$:

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda_1}{d}\right) = \sin^{-1}\left[\frac{(1)(5.88995 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 17.13°$$

$$\theta_2 = \sin^{-1}\left(\frac{m\lambda_2}{d}\right) = \sin^{-1}\left[\frac{(1)(5.89592 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 17.15°$$

$$\Delta\theta = \theta_2 - \theta_1 = 17.15° - 17.13° = \boxed{0.02°}$$

For $m = 2$:

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda_1}{d}\right) = \sin^{-1}\left[\frac{(2)(5.88995 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 36.09°$$

$$\theta_2 = \sin^{-1}\left(\frac{m\lambda_2}{d}\right) = \sin^{-1}\left[\frac{(2)(5.89592 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 36.13°$$

$$\Delta\theta = \theta_2 - \theta_1 = 36.13° - 36.09° = \boxed{0.04°}$$

For $m = 3$:

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda_1}{d}\right) = \sin^{-1}\left[\frac{(3)(5.88995 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 62.07°$$

$$\theta_2 = \sin^{-1}\left(\frac{m\lambda_2}{d}\right) = \sin^{-1}\left[\frac{(3)(5.89592 \times 10^{-7}\ \text{m})}{(2.000 \times 10^{-6}\ \text{m})}\right] = 62.18°$$

$$\Delta\theta = \theta_2 - \theta_1 = 62.18° - 62.07° = \boxed{0.11°}$$

---

2. 4525 lines/cm

$m = 1$

$\lambda_b = 422$ nm

$\lambda_r = 655$ nm

blue: $$\theta = \sin^{-1}\left(\frac{m\lambda_b}{d}\right) = \sin^{-1}\left[\frac{(1)(4.22 \times 10^{-7}\ \text{m})}{\left(\frac{1}{452\ 500}\right)\text{m}}\right] = \boxed{11.0°}$$

red: $$\theta = \sin^{-1}\left(\frac{m\lambda_r}{d}\right) = \sin^{-1}\left[\frac{(1)(6.55 \times 10^{-7}\ \text{m})}{\left(\frac{1}{452\ 500}\right)\text{m}}\right] = \boxed{17.2°}$$

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3. 1555 lines/cm

$\lambda = 565$ nm

$\theta < 90°$

$m = 11$: $$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(11)(5.65 \times 10^{-7}\ \text{m})}{\left(\frac{1}{155\ 500}\right)\text{m}}\right] = 75.1°$$

$m = 12$: $$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(12)(5.65 \times 10^{-7}\ \text{m})}{\left(\frac{1}{155\ 500}\right)\text{m}}\right] = \infty$$

Therefore, 11 is the highest-order number that can be observed.

Givens	*Solutions*
4. 15 550 lines/cm $\lambda = 565$ nm $\theta < 90°$	$m = 1$: $\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(1)(5.65 \times 10^{-7}\text{ m})}{\left(\frac{1}{1\,555\,000}\right)\text{ m}}\right] = 61.5°$ $m = 2$: $\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(2)(5.65 \times 10^{-7}\text{ m})}{\left(\frac{1}{1\,555\,000}\right)\text{ m}}\right] = \infty$ Therefore, 1 is the highest-order number that can be observed.
5. $\theta = 21.2°$ $\lambda = 546.1$ nm $m = 1$	$d = \frac{m\lambda}{\sin\theta} = \frac{(1)(5.461 \times 10^{-7}\text{ m})}{\sin 21.2°} = 1.51 \times 10^{-6}\text{ m} = 1.51 \times 10^{-4}\text{ cm}$ $\text{Lines/cm} = \frac{1}{1.51 \times 10^{-4}\text{ cm}} = \boxed{6.62 \times 10^{3}\text{ lines/cm}}$

Inference and Diffraction, Section 2 Review

1. 3550 lines/cm $= \frac{1}{d}$ $m = 1$ $\theta = 12.07°$	**a.** $\lambda = \frac{d\sin\theta}{m} = \frac{\left(\frac{\text{m}}{355\,000}\right)(\sin 12.07°)}{(1)}$ $\lambda = 5.89 \times 10^{-7}\text{ m} = \boxed{589\text{ nm}}$ **b.** $m = 2$, $\theta_2 = ?$ $\theta_2 = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(2)(5.89 \times 10^{-7}\text{ m})}{\frac{1}{355\,000\text{ m}}}\right]$ $\theta_2 = \boxed{24.7°}$

Inference and Diffraction, Chapter Review

9. $d = 0.33\text{ mm} = 3.3 \times 10^{-4}\text{ m}$ $\theta = 0.055°$ $m = 0$	$\lambda = \frac{d\sin\theta}{m + \frac{1}{2}} = \frac{(3.3 \times 10^{-4}\text{ m})(\sin 0.055°)}{\left(0 + \frac{1}{2}\right)}$ $\lambda = 6.3 \times 10^{-7}\ m = \boxed{630\text{ nm}}$
10. $d = 0.3096$ mm $\theta = 0.218°$ $m = 2$	**a.** $\lambda = \frac{d(\sin\theta)}{m} = \frac{(3.096 \times 10^{-4}\text{ m})(\sin 0.218°)}{2} = 5.89 \times 10^{-7}\text{ m} = \boxed{589\text{ nm}}$
$m = 3$	**b.** $\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(3)(5.89 \times 10^{-7}\text{ m})}{3.096 \times 10^{-4}\text{ m}}\right] = \boxed{0.327°}$
$m = 4$	**c.** $\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(4)(5.89 \times 10^{-7}\text{ m})}{3.096 \times 10^{-4}\text{ m}}\right] = \boxed{0.436°}$

I

Givens	Solutions
11. $d = 3.2\ \text{cm} = 3.2 \times 10^{-2}\ \text{m}$ $m = 2$ $\theta = 0.56°$	$\lambda = \dfrac{d(\sin\theta)}{m} = \dfrac{(3.2 \times 10^{-2}\ \text{m})(\sin 0.56°)}{2}$ $\lambda = 1.6 \times 10^{-4}\ \text{m} = \boxed{1.6 \times 10^{2}\ \mu\text{m}}$
19. 795 slits/cm $\lambda = 707\ \text{nm} = 7.07 \times 10^{-5}\ \text{cm}$	$m = 1{:}\ \theta_1 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left(\dfrac{7.07 \times 10^{-5}\ \text{cm}}{\frac{1}{795}\ \text{cm}}\right)$ $\theta_1 = \boxed{3.22°}$
20. 795 slits/cm $\lambda = 353\ \text{nm} = 3.53 \times 10^{-5}\ \text{cm}$	$m = 2{:}\ \theta_2 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left(\dfrac{(2)(3.53 \times 10^{-5}\ \text{cm})}{\frac{1}{795}\ \text{cm}}\right)$ $\theta_2 = \boxed{3.22°}$
21. 3661 slits/cm $\lambda_1 = 478.5\ \text{nm}$ $\lambda_2 = 647.4\ \text{nm}$ $\lambda_3 = 696.4\ \text{nm}$	**a.** $m = 1$: $\theta_1 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{4.785 \times 10^{-5}\ \text{cm}}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{10.09°}$ $\theta_2 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{6.474 \times 10^{-5}\ \text{cm}}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{13.71°}$ $\theta_3 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{6.964 \times 10^{-5}\ \text{cm}}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{14.77°}$ **b.** $m = 2$: $\theta_1 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{(2)(4.785 \times 10^{-5}\ \text{cm})}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{20.51°}$ $\theta_2 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{(2)(6.474 \times 10^{-5}\ \text{cm})}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{28.30°}$ $\theta_3 = \sin^{-1}\left(\dfrac{m\lambda}{d}\right) = \sin^{-1}\left[\dfrac{(2)(6.964 \times 10^{-5}\ \text{cm})}{\frac{1}{3661\ \text{cm}}}\right] = \boxed{30.66°}$
26. $\lambda = 546.1\ \text{nm}$ $\theta = 81.0°$ $m = 3$	$\text{lines/mm} = \dfrac{\sin\theta}{m\lambda} = \dfrac{\sin 81.0°}{(3)(5.461 \times 10^{-3}\ \text{cm})} = \boxed{6030\ \text{lines/cm}}$

Givens	*Solutions*
28. $\lambda = 486$ nm $m = 5$ $\theta = 0.578°$	$d = \frac{m\lambda}{\sin\theta} = \frac{(5)(4.86\times10^{-7}\text{ m})}{(\sin 0.578°)} = \boxed{2.41\times10^{-4}\text{ m}}$
29. $\lambda_1 = 540.0$ nm	$4\lambda_1 = 5\lambda_2$ $\lambda_2 = \frac{4\lambda_1}{5} = \frac{4(540.0\text{ nm})}{5} = \boxed{432.0\text{ nm}}$
30. $m = 2$ $\lambda = 4.000\times10^{-7}$ m $\theta = 90.00°$	d is at a maximum when $\lambda = 400.0$ nm (red light). $d = \frac{m\lambda}{\sin\theta} = \frac{(2)(4.000\times10^{-7}\text{ m})}{(\sin 90.00°)} = \boxed{8.000\times10^{-7}\text{ m}}$
31. $\lambda = 643$ nm $\theta = 0.737°$ $d = 0.150$ mm	path difference $= d(\sin\theta) = (0.150\text{ mm})(\sin 0.737°) = \boxed{1.93\times10^{-3}\text{ mm} = 3\lambda}$ $\boxed{\text{a maximum}}$

Inference and Diffraction, Standardized Test Prep

5. $\lambda = 720\text{ nm} = 7.5\times10^{-7}$ m $d = 25\ \mu\text{m} = 2.5\times10^{-5}$ m $m = 4$	$\theta = \sin^{-1}\left(\frac{\lambda m}{d}\right) = \sin^{-1}\left[\frac{(4)(7.5\times10^{-7}\text{ m})}{(2.5\times10^{-5}\text{ m})}\right]$ $\theta = \boxed{6.9°}$
6. $\lambda = 640\text{ nm} = 6.4\times10^{-7}$ m $5.0\times10^4\text{ lines/m} = \frac{1}{d}$ $\theta = 11.1°$	$d\sin\theta = \pm m\lambda$ $\pm m = \frac{d\sin\theta}{\lambda} = \left[\frac{\left(\frac{1}{5.0\times10^4\text{ /m}}\right)(\sin 11.1°)}{(6.4\times10^{-7}\text{ m})}\right]$ $m = \boxed{\pm 6}$
7. $A_1 = 80\text{ m}^2$ $A_2 = 20\text{ m}^2$	$A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$ $d = 2\sqrt{\frac{A}{\pi}}$ $d_1 = 2\sqrt{\frac{A_1}{\pi}} = 2\sqrt{\frac{80\text{ m}^2}{\pi}} = 10$ m $d_2 = 2\sqrt{\frac{A_2}{\pi}} = 2\sqrt{\frac{20\text{ m}^2}{\pi}} = 5$ m Since resolving power is proportional to the diameter, *d:* $\boxed{\frac{d_1}{d_2} = \frac{10\text{ m}}{5\text{ m}} = 2}$

Givens	*Solutions*
12. $m = 3$ $\lambda = 490\ \text{nm} = 4.90 \times 10^{-7}\ \text{m}$ $\theta = 6.33°$	$d = \frac{m\lambda}{\sin\theta} = \frac{(3)(4.90 \times 10^{-7}\ \text{m})}{(\sin 6.33°)}$ $d = 1.33 \times 10^{-5}\ \text{m}$ $\frac{1}{d} = 7.5 \times 10^{4}\ \text{lines/m} = \boxed{750\ \text{lines/cm}}$
15. $d = 15.0\ \mu\text{m} = 1.50 \times 10^{-5}\ \text{m}$ $m = 1$ $\lambda = 2.25°$	$\lambda = \frac{d\sin\theta}{m} = \frac{(1.50 \times 10^{-5}\ \text{m})(\sin 2.25°)}{(1)}$ $\lambda = 5.89 \times 10^{-7}\ \text{m} = \boxed{589\ \text{nm}}$
16. $d = 1.50 \times 10^{-5}\ \text{m}$ $m = 3$ (bright) $\lambda = 5.89 \times 10^{-7}\ \text{m}$	$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left[\frac{(3)(5.89 \times 10^{-7}\ \text{m})}{(1.50 \times 10^{-5}\ \text{m})}\right]$ $\theta = \boxed{6.77°}$
17. $d = 1.50 \times 10^{-5}\ \text{m}$ $m = 3$ (dark) $\lambda = 5.89 \times 10^{-7}\ \text{m}$	$\theta = \sin^{-1}\left[\frac{\left(m + \frac{1}{2}\right)\lambda}{d}\right] = \sin^{-1}\left[\frac{\left(3 + \frac{1}{2}\right)(5.89 \times 10^{-7}\ \text{m})}{(1.50 \times 10^{-5}\ \text{m})}\right]$ $\theta = \boxed{7.90°}$

Student Edition Solutions

Electric Forces and Fields

Electric Forces and Fields, Section 1 Review

Givens	*Solutions*
3. $q = 10.0$ C	$N = \dfrac{q}{1.60 \times 10^{-19}\ \text{C/electron}} = \dfrac{10.0\ \text{C}}{1.60 \times 10^{-19}\ \text{C/electron}} = \boxed{6.25 \times 10^{19}\ \text{electrons}}$

Electric Forces and Fields, Practice A

1. $q_1 = -8.0\ \mu\text{C}$

$q_2 = 8.0\ \mu\text{C}$

$r = 5.0$ cm

$$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(8.0 \times 10^{-6}\ \text{C})^2}{(0.050\ \text{m})^2}$$

$$F = \boxed{230\ \text{N}}$$

2. $r = 0.30$ m

$q_1 = 12 \times 10^{-9}$ C

$q_2 = -18 \times 10^{-9}$ C

a. $$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(12 \times 10^{-9}\ \text{C})(18 \times 10^{-9}\ \text{C})}{(0.30\ \text{m})^2}$$

$$F = \boxed{2.2 \times 10^{-5}\ \text{N}}$$

$q_1 = -3.0 \times 10^{-9}$ C

$q_2 = -3.0 \times 10^{-9}$ C

b. $$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(3.0 \times 10^{-9}\ \text{C})^2}{(0.30\ \text{m})^2} = \boxed{9.0 \times 10^{-7}\ \text{N}}$$

3. $q_1 = 60.0\ \mu\text{C}$

$q_2 = 50.0\ \mu\text{C}$

$F = 175$ N

$$r = \sqrt{\frac{k_C q_1 q_2}{F}} = \sqrt{\frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(60.0 \times 10^{-6}\ \text{C})(50.0 \times 10^{-6}\ \text{C})}{175\ \text{N}}}$$

$$r = 0.393\ \text{m} = \boxed{39.3\ \text{cm}}$$

1. $q_1 = 6.0\ \mu\text{C}$ at $x = 0$ cm

$q_2 = 1.5\ \mu\text{C}$ at $x = 3.0$ cm

$q_3 = -2.0\ \mu\text{C}$ at $x = 5.0$ cm

$$F_{1,2} = \frac{k_C q_1 q_2}{(r_{1,2})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(6.0 \times 10^{-6}\ \text{C})(1.5 \times 10^{-6}\ \text{C})}{(0.030\ \text{m})^2} = 9.0 \times 10^1\ \text{N}$$

$$F_{2,3} = \frac{k_C q_2 q_3}{(r_{2,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(1.5 \times 10^{-6}\ \text{C})(2.0 \times 10^{-6}\ \text{C})}{(0.020\ \text{m})^2} = 67\ \text{N}$$

$$F_{1,3} = \frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(6.0 \times 10^{-6}\ \text{C})(2.0 \times 10^{-6}\ \text{C})}{(0.050\ \text{m})^2} = 43\ \text{N}$$

Givens | *Solutions*

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$F_{1,tot} = F_{1,2} + F_{1,3} = -(9.0 \times 10^1 \text{ N}) + (43 \text{ N}) = -47 \text{ N}$

$\mathbf{F_{1,tot}} = \boxed{\text{47 N, along the negative } x\text{-axis}}$

$F_{2,tot} = F_{1,2} + F_{2,3} = (9.0 \times 10^1 \text{ N}) + (67 \text{ N}) = 157 \text{ N}$

$\mathbf{F_{2,tot}} = \boxed{\text{157 N, along the positive } x\text{-axis}}$

$F_{3,tot} = F_{2,3} + F_{1,3} = -(67 \text{ N}) - (43 \text{ N}) = -11.0 \times 10^1 \text{ N}$

$\mathbf{F_{3,tot}} = \boxed{11.0 \times 10^1 \text{ N, along the negative } x\text{-axis}}$

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2. $q_1 = 3.0\ \mu\text{C}$

$q_2 = -6.0\ \mu\text{C}$

$q_3 = -2.4\ \mu\text{C}$

$q_4 = -9.0\ \mu\text{C}$

$r_{1,2} = r_{2,4} = r_{3,4} = r_{1,3} =$ 15 cm

a. $r_{1,4} = r_{2,3} = \sqrt{(15 \text{ cm})^2 + (15 \text{ cm})^2} = \sqrt{220 \text{ cm}^2 + 220 \text{ cm}^2} = \sqrt{440 \text{ cm}^2}$

$r_{1,4} = r_{2,3} = 21$ cm

$$F_{1,2} = \frac{k_C q_1 q_2}{(r_{1,2})^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(3.0 \times 10^{-6} \text{ C})(6.0 \times 10^{-6} \text{ C})}{(0.15 \text{ m})^2} = 7.2 \text{ N}$$

$$F_{1,3} = \frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(3.0 \times 10^{-6} \text{ C})(2.4 \times 10^{-6} \text{ C})}{(0.15 \text{ m})^2} = 2.9 \text{ N}$$

$$F_{1,4} = \frac{k_C q_1 q_4}{(r_{1,4})^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(3.0 \times 10^{-6} \text{ C})(9.0 \times 10^{-6} \text{ C})}{(0.21 \text{ m})^2} = 5.5 \text{ N}$$

$F_{1,x} = (7.2 \text{ N}) + (5.5 \text{ N})(\cos 45°) = 7.2 \text{ N} + 3.9 \text{ N} = 11.1 \text{ N}$

$F_{1,y} = -(2.9 \text{ N}) - (5.5 \text{ N})(\sin 45°) = -2.9 \text{ N} - 3.9 \text{ N} = -6.8 \text{ N}$

$F_{1,tot} = \sqrt{(F_{1,x})^2 + (F_{1,y})^2} = \sqrt{(11.1 \text{ N})^2 + (6.8 \text{ N})^2} = \sqrt{123 \text{ N}^2 + 46 \text{ N}^2}$

$F_{1,tot} = \sqrt{169 \text{ N}^2} = 13.0 \text{ N}$

$$\theta = \tan^{-1}\left(\frac{6.8}{11.1}\right) = 31°$$

$\mathbf{F_{1,tot}} = \boxed{\text{13.0 N, 31° below the positive } x\text{-axis}}$

b. $F_{2,1} = 7.2$ N (See **a.**)

$$F_{2,3} = \frac{k_C q_2 q_3}{(r_{2,3})^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(6.0 \times 10^{-6} \text{ C})(2.4 \times 10^{-6} \text{ C})}{(0.21 \text{ m})^2} = 2.9 \text{ N}$$

$$F_{2,4} = \frac{k_C q_2 q_4}{(r_{2,4})^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(6.0 \times 10^{-6} \text{ C})(9.0 \times 10^{-6} \text{ C})}{(0.15 \text{ m})^2} = 22 \text{ N}$$

$F_{2,x} = -(7.2 \text{ N}) + (2.9 \text{ N})(\cos 45°) = -7.2 \text{ N} + 2.1 \text{ N} = -5.1 \text{ N}$

$F_{2,y} = (22 \text{ N}) + (2.9 \text{ N})(\sin 45°) = 22 \text{ N} + 2.1 \text{ N} = 24 \text{ N}$

$F_{2,tot} = \sqrt{(F_{2,x})^2 + (F_{2,y})^2} = \sqrt{(5.1 \text{ N})^2 + (24 \text{ N})^2} = \sqrt{26 \text{ N}^2 + 580 \text{ N}^2}$

$F_{2,tot} = \sqrt{610 \text{ N}^2} = 25 \text{ N}$

$$\theta = \tan^{-1}\left(\frac{24}{5.1}\right) = 78°$$

$\mathbf{F_{2,tot}} = \boxed{\text{25 N, 78° above the negative } x\text{-axis}}$

Givens *Solutions*

c. $F_{4,1} = 5.5$ N (See **a.**)

$F_{4,2} = 22$ N (See **b.**)

$$F_{4,3} = \frac{k_C q_4 q_3}{(r_{4,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(9.0 \times 10^{-6}\ \text{C})(2.4 \times 10^{-6}\ \text{C})}{(0.15\ \text{m})^2} = 8.6\ \text{N}$$

$$F_{4,x} = -(5.5\ \text{N})(\cos 45°) + (8.6\ \text{N}) = -3.9\ \text{N} + 8.6\ \text{N} = 4.7\ \text{N}$$

$$F_{4,y} = (5.5\ \text{N})(\sin 45°) - (22\ \text{N}) = 3.9\ \text{N} - 22\ \text{N} = -18\ \text{N}$$

$$F_{4,tot} = \sqrt{(F_{4,x})^2 + (F_{4,y})^2} = \sqrt{(4.7\ \text{N})^2 + (18\ \text{N})^2} = \sqrt{22\ \text{N}^2 + 320\ \text{N}^2}$$

$$F_{4,tot} = \sqrt{340\ \text{N}^2} = 18\ \text{N}$$

$$\theta = \tan^{-1}\left(\frac{18}{4.7}\right) = 75°$$

$\mathbf{F_{4,tot}} = \boxed{18\ \text{N, 75° below the positive } x\text{-axis}}$

Electric Forces and Fields, Practice C

1. $q_1 = +2.00 \times 10^{-9}$ C at $x_1 = 0$, $y_1 = 0$

$q_2 = +4.00 \times 10^{-9}$ C at $x_2 = 1.5$ m, $y_2 = 0$

$q_3 = +3.00 \times 10^{-9}$ C

$$F_{3,1} = F_{3,2}$$

$$\frac{k_C q_3 q_1}{(r_{3,1})^2} = \frac{k_C q_3 q_2}{(r_{3,2})^2}$$

$$\frac{q_1}{(r_{3,1})^2} = \frac{q_2}{(r_{3,2})^2}$$

Lets define $r_{3,1} = P$ so that $r_{3,2} = 1.5\ \text{m} - P$.

$$\frac{q_1}{P^2} = \frac{q_2}{(1.5\ \text{m} - P)^2}$$

$$P^2 q_2 = (1.5\ \text{m} - P)^2 q_1$$

$$P\sqrt{q_2} = (1.5\ \text{m} - P)\sqrt{q_1}$$

$$P\sqrt{q_2} + P\sqrt{q_1} = (1.5\ \text{m})\sqrt{q_1}$$

$$P(\sqrt{q_1} + \sqrt{q_2}) = (1.5\ \text{m})\sqrt{q_1}$$

$$P = \frac{(1.5\ \text{m})\sqrt{q_1}}{\sqrt{q_1} + \sqrt{q_2}}$$

$$P = \frac{(1.5\ \text{m})\sqrt{2.00 \times 10^{-9}\ \text{C}}}{\sqrt{2.00 \times 10^{-9}\ \text{C}} + \sqrt{4.00 \times 10^{-9}\ \text{C}}}$$

$$P = \frac{(1.5\ \text{m})(4.47 \times 10^{-5}\sqrt{\text{C}}}{(4.47 \times 10^{-5}\sqrt{\text{C}}) + (6.32 \times 10^{-5}\sqrt{\text{C}})}$$

$P = \boxed{0.62\ \text{m}}$

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Givens | *Solutions*

2. $q_1 = -5.00 \times 10^{-9}$ C

$q_2 = -2.00 \times 10^{-9}$ C

$r_{1,2} = 40.0$ cm

$q_3 = 15.0 \times 10^{-9}$ C

$$\frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{k_C q_2 q_3}{(r_{2,3})^2}$$

$$\frac{q_1}{(r_{1,3})^2} = \frac{q_2}{(r_{2,3})^2}$$

$$\frac{5.00 \times 10^{-9}\ \text{C}}{P^2} = \frac{2.00 \times 10^{-9}\ \text{C}}{(0.400\ \text{m} - P)^2}$$

$$(2.00 \times 10^{-9}\ \text{C})(P^2) = (5.00 \times 10^{-9}\ \text{C})(0.400\ \text{m} - P)^2$$

$$P = \left(\sqrt{\frac{5.00 \times 10^{-9}\ \text{C}}{2.00 \times 10^{-9}\ \text{C}}}\right)(0.400\ \text{m} - P)$$

$$P = 0.632\ \text{m} - (1.58)(P)$$

$$(2.58)(P) = 0.632\ \text{m}$$

$$P = 0.245\ \text{m} = \boxed{24.5\ \text{cm from } q_1}$$

$$\text{or } (40.0\ \text{cm} - 24.5\ \text{cm}) = \boxed{15.5\ \text{cm from } q_2}$$

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3. $q_1 = q_2 = 1.60 \times 10^{-19}$ C

$m_e = 9.109 \times 10^{-31}$ kg

$$F_{electric} = F_g$$

$$\frac{k_C q_1 q_2}{r^2} = m_e g$$

$$r = \sqrt{\frac{k_C q_1 q_2}{m_e g}} = \sqrt{\frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(1.60 \times 10^{-19}\ \text{C})^2}{(9.109 \times 10^{-31}\ \text{kg})(9.81\ \text{m/s}^2)}} = \boxed{5.07\ \text{m}}$$

Electric Forces and Fields, Section 2 Review

1. $q_1 = 2.0\ \mu$C

$r = 12$ cm

$q_2 = -3.5\ \mu$C

a. $$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-6}\ \text{C})(3.5 \times 10^{-6}\ \text{C})}{(0.12\ \text{m})^2}$$

$$F = \boxed{4.4\ \text{N}}$$

c. $$N = \frac{q_1}{1.60 \times 10^{-19}\ \text{C/electron}} = \frac{2.0 \times 10^{-6}\ \text{C}}{1.60 \times 10^{-19}\ \text{C/electron}} = \boxed{1.2 \times 10^{13}\ \text{electrons}}$$

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3. $q_1 = 2.2 \times 10^{-9}$ C at $x = 1.5$ m

$q_2 = 5.4 \times 10^{-9}$ C at $x = 2.0$ m

$q_3 = 3.5 \times 10^{-9}$ C at the origin

$$F_{1,3} = \frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.2 \times 10^{-9}\ \text{C})(3.5 \times 10^{-9}\ \text{C})}{(1.5\ \text{m})^2}$$

$$F_{1,3} = 3.1 \times 10^{-8}\ \text{N}$$

$$F_{2,3} = \frac{k_C q_2 q_3}{(r_{2,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(5.4 \times 10^{-9}\ \text{C})(3.5 \times 10^{-9}\ \text{C})}{(2.0\ \text{m})^2}$$

$$F_{2,3} = 4.2 \times 10^{-8}\ \text{N}$$

$$\mathbf{F_{3,tot}} = -(3.1 \times 10^{-8}\ \text{N}) - (4.2 \times 10^{-8}\ \text{N}) = -7.3 \times 10^{-8}\ \text{N}$$

$$\mathbf{F_{3,tot}} = \boxed{7.3 \times 10^{-8}\ \text{N, along the negative } x\text{-axis}}$$

Givens	*Solutions*

4. $q_1 = -6.00 \times 10^{-9}$ C

$q_2 = -3.00 \times 10^{-9}$ C

$r_{1,2} = 60.0$ cm

$$\frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{k_C q_2 q_3}{(r_{2,3})^2}$$

$$\frac{q_1}{(r_{1,3})^2} = \frac{q_2}{(r_{2,3})^2}$$

$$\frac{6.00 \times 10^{-9}\ \text{C}}{P^2} = \frac{3.00 \times 10^{-9}\ \text{C}}{(0.600\ \text{m} - P)^2}$$

$$(3.00 \times 10^{-9}\ \text{C})(P^2) = (6.00 \times 10^{-9}\ \text{C})(0.600\ \text{m} - P)^2$$

$$P = \left(\sqrt{\frac{6.00 \times 10^{-9}\ \text{C}}{3.00 \times 10^{-9}\ \text{C}}}\right)(0.600\ \text{m} - P)$$

$$P = 0.849\ \text{m} - (1.41)(P)$$

$$(2.41)(P) = 0.849\ \text{m}$$

$$P = 0.352\ \text{m from } q_1 = \boxed{35.2\ \text{cm from } q_1}$$

$$\text{or } (60.0\ \text{cm} - 35.2\ \text{cm}) = \boxed{24.8\ \text{cm from } q_2}$$

Electric Forces and Fields, Practice D

1. $q_1 = 5.00\ \mu$C at the origin

$q_2 = -3.00\ \mu$C at $x = 0.800$ m

For the point $y = 0.500$ m on the y-axis,

$$E_1 = \frac{k_C q_1}{r_1^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(5.00 \times 10^{-6}\ \text{C})}{(0.500\ \text{m})^2} = 1.80 \times 10^5\ \text{N/C}$$

$$E_2 = \frac{k_C q_2}{r_2^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(3.00 \times 10^{-6}\ \text{C})}{\left(\sqrt{(0.800\ \text{m})^2 + (0.500\ \text{m})^2}\right)^2}$$

$$E_2 = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(3.00 \times 10^{-6}\ \text{C})}{\left(\sqrt{0.640\ \text{m}^2 + 0.250\ \text{m}^2}\right)^2}$$

$$E_2 = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(3.00 \times 10^{-6}\ \text{C})}{\left(\sqrt{0.890\ \text{m}^2}\right)^2} = 3.03 \times 10^4\ \text{N/C}$$

$$\theta = \tan^{-1}\left(\frac{0.800}{0.500}\right) = 58.0°$$

$$E_y = (1.80 \times 10^5\ \text{N/C}) - (3.03 \times 10^4\ \text{N/C})(\cos 58.0°)$$

$$E_y = (1.80 \times 10^5\ \text{N/C}) - (1.61 \times 10^4\ \text{N/C}) = 1.64 \times 10^5\ \text{N/C}$$

$$E_x = (3.03 \times 10^4\ \text{N/C})(\sin 58.0°) = 2.57 \times 10^4\ \text{N/C}$$

$$E_{tot} = \sqrt{(E_y)^2 + (E_x)^2} = \sqrt{(1.64 \times 10^5\ \text{N/C})^2 + (2.57 \times 10^4\ \text{N/C})^2}$$

$$E_{tot} = \sqrt{(2.69 \times 10^{10}\ \text{N}^2/\text{C}^2) + (6.60 \times 10^8\ \text{N}^2/\text{C}^2)}$$

$$E_{tot} = \sqrt{2.76 \times 10^{10}\ \text{N}^2/\text{C}^2} = 1.66 \times 10^5\ \text{N/C}$$

$$\varphi = \tan^{-1}\left(\frac{1.64 \times 10^5}{2.57 \times 10^4}\right) = 81.1°$$

$$\mathbf{E_{tot}} = \boxed{1.66 \times 10^5\ \text{N/C, } 81.1° \text{ above the positive } x\text{-axis}}$$

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Givens	*Solutions*
2. $r = 5.3 \times 10^{-11}$ m $q = 1.60 \times 10^{-19}$ C	$E = \frac{k_C q}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(1.60 \times 10^{-19}\ \text{C})}{(5.3 \times 10^{-11}\ \text{m})^2} = 5.1 \times 10^{11}$ N/C $\mathbf{E} = \boxed{5.1 \times 10^{11}\ \text{N/C, away from the proton}}$
3. $\mathbf{E} = 2.0 \times 10^4$ N/C, along the positive *x*-axis $q_e = q_p = 1.60 \times 10^{-19}$ C	**a.** $F = Eq_e = (2.0 \times 10^4\ \text{N/C})(1.60 \times 10^{-19}\ \text{C})$ $\mathbf{F} = \boxed{3.2 \times 10^{-15}\ \text{N, along the negative } x\text{-axis}}$ **b.** $F = Eq_p = (2.0 \times 10^4\ \text{N/C})(1.60 \times 10^{-19}\ \text{C})$ $\mathbf{F} = \boxed{3.2 \times 10^{-15}\ \text{N, along the positive } x\text{-axis}}$

Electric Forces and Fields, Section 3 Review

1. $q_1 = 40.0 \times 10^{-9}$ C $q_2 = 60.0 \times 10^{-9}$ C $r = \frac{30.0\ \text{cm}}{2} = 15.0$ cm	$E_1 = \frac{k_C q_1}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(40.0 \times 10^{-9}\ \text{C})}{(0.150\ \text{m})^2} = 1.60 \times 10^4$ N/C $E_2 = \frac{k_C q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(60.0 \times 10^{-9}\ \text{C})}{(0.150\ \text{m})^2} = 2.40 \times 10^4$ N/C $E_{tot} = E_1 + E_2 = (1.60 \times 10^4\ \text{N/C}) - (2.40 \times 10^4\ \text{N/C}) = -0.80 \times 10^4$ N/C $\mathbf{E_{tot}} = \boxed{8.0 \times 10^3\ \text{N/C toward the } 40.0 \times 10^{-9}\ \text{C charge}}$

Electric Forces and Fields, Chapter Review

3. $q = 3.5\ \mu$C	$N = \frac{q}{1.60 \times 10^{-19}\ \text{C/electron}} = \frac{3.5 \times 10^{-6}\ \text{C}}{1.60 \times 10^{-19}\ \text{C/electron}} = \boxed{2.2 \times 10^{13}\ \text{electrons}}$
15. $q_1 = q_2 = (46)(1.60 \times 10^{-19}\ \text{C})$ $r = (2)(5.90 \times 10^{-15}\ \text{m})$	$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)[(46)(1.60 \times 10^{-19}\ \text{C})]^2}{[(2)(5.90 \times 10^{-15}\ \text{m})]^2}$ $F = \boxed{3.50 \times 10^3\ \text{N}}$
16. $q_1 = 2.5\ \mu$C $q_2 = -5.0\ \mu$C $r = 5.0$ cm	$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.5 \times 10^{-6}\ \text{C})(5.0 \times 10^{-6}\ \text{C})}{(0.050\ \text{m})^2}$ $F = \boxed{45\ \text{N}}$
17. $q_1 = 2.0e$ $q_2 = 79e$ $r = 2.0 \times 10^{-14}$ m $e = 1.60 \times 10^{-19}$ C	$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.0)(79)(1.60 \times 10^{-19}\ \text{C})^2}{(2.0 \times 10^{-14}\ \text{m})^2}$ $F = \boxed{91\ \text{N}}$

Givens | *Solutions*

18. $q_1 = 3.0$ nC

$q_2 = 6.0$ nC

$q_3 = 2.0$ nC

$r_{1,2} = r_{2,3} = \sqrt{(1.0\text{ m})^2 + (1.0\text{ m})^2}$

$r_{1,2} = r_{2,3} = \sqrt{(1.0\text{ m})^2 + (1.0\text{ m})^2} = \sqrt{2.0\text{ m}^2} = 1.4\text{ m}$

$$F_{1,2} = \frac{k_C q_1 q_2}{(r_{1,2})^2} = \frac{(8.99\times10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(3.0\times10^{-9}\text{ C})(6.0\times10^{-9}\text{ C})}{(1.4\text{ m})^2}$$

$F_{1,2} = 8.3\times10^{-8}$ N

$$F_{2,3} = \frac{k_C q_2 q_3}{(r_{2,3})^2} = \frac{(8.99\times10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(6.0\times10^{-9}\text{ C})(2.0\times10^{-9}\text{ C})}{(1.4\text{ m})^2}$$

$F_{2,3} = 5.5\times10^{-8}$ N

$F_x = (8.3\times10^{-8}\text{ N})(\cos 45°) + (5.5\times10^{-8}\text{ N})(\cos 45°)$

$F_x = (5.9\times10^{-8}\text{ N}) + (3.9\times10^{-8}\text{ N}) = 9.8\times10^{-8}\text{ N}$

$F_y = -(8.3\times10^{-8}\text{ N})(\sin 45°) + (5.5\times10^{-8}\text{ N})(\sin 45°)$

$F_y = -(5.9\times10^{-8}\text{ N}) + (3.9\times10^{-8}\text{ N}) = -2.0\times10^{-8}\text{ N}$

$F_{tot} = \sqrt{(F_x)^2 + (F_y)^2} = \sqrt{(9.8\times10^{-8}\text{ N})^2 + (2.0\times10^{-8}\text{ N})^2}$

$F_{tot} = \sqrt{(9.6\times10^{-15}\text{ N}^2) + (4.0\times10^{-16}\text{ N}^2)} = \sqrt{1.00\times10^{-14}\text{ N}^2}$

$F_{tot} = 1.00\times10^{-7}$ N

$$\theta = \tan^{-1}\left(\frac{2.0}{9.8}\right) = 12°$$

$\mathbf{F_{tot}} = \boxed{1.00\times10^{-7}\text{ N, }12°\text{ below the positive }x\text{-axis}}$

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19. $q_1 = q_2 = 2.5\times10^{-9}$ C

$q_3 = 3.0\times10^{-9}$ C

$r_{2,1} = 1.0$ m

$r_{3,1} = r_{3,2}$

$r_{3,1} = r_{3,2} = \sqrt{(0.50\text{ m})^2 + (0.70\text{ m})^2} = 0.86\text{ m}$

$$F_{3,1} = F_{3,2} = \frac{k_C q_3 q_1}{(r_{3,1})^2} = \frac{(8.99\times10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(3.0\times10^{-9}\text{ C})(2.5\times10^{-9}\text{ C})}{(0.86\text{ m})^2}$$

$F_{3,1} = F_{3,2} = 9.1\times10^{-8}$ N

$F_x = F_{3,1}\cos\theta + F_{3,2}\cos\theta$

$$F_x = (9.1\times10^{-8}\text{ N})\left(\frac{0.70\text{ m}}{0.86\text{ m}}\right) + (9.1\times10^{-8}\text{ N})\left(\frac{0.70\text{ m}}{0.86\text{ m}}\right)$$

$F_x = 7.4\times10^{-8}\text{ N} + 7.4\times10^{-8}\text{ N} = 14.8\times10^{-8}\text{ N}$

$F_y = F_{3,1}\sin\theta + F_{3,2}\sin\theta$

$$F_x = (9.1\times10^{-8}\text{ N})\left(\frac{0.50\text{ m}}{0.86\text{ m}}\right) + (9.1\times10^{-8}\text{ N})\left(\frac{-0.50\text{ m}}{0.86\text{ m}}\right) = 0\text{ N}$$

$F_{tot} = \sqrt{(F_1)^2 + (F_4)^2} = \sqrt{(14.8\times10^{-8}\text{ N})^2} = 14.8\times10^{-8}\text{ N}$

$$\theta = \tan^{-1}\left(\frac{0\text{ N}}{14.8\times10^{-8}\text{ N}}\right) = 0$$

$\mathbf{F_{tot}} = \boxed{1.48\times10^{-7}\text{ N along the }+x\text{-axis}}$

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Givens	Solutions

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20. $q_1 = -9.0\ \mu C$ at $y = 6.0$ m

$q_2 = -8.0\ \mu C$ at $y = -4.0$ m

$$\frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{k_C q_2 q_3}{(r_{2,3})^2}$$

$$\frac{9.0 \times 10^{-6}\ C}{P^2} = \frac{8.0 \times 10^{-6}\ C}{(10.0\ m - P)^2}$$

$$(8.0 \times 10^{-6}\ C)(P^2) = (9.0 \times 10^{-6}\ C)(10.0\ m - P)^2$$

$$P = \left(\sqrt{\frac{9.0 \times 10^{-6}\ C}{8.0 \times 10^{-6}\ C}}\right)(10.0\ m - P)$$

$$P = 11\ m - (1.1)(P)$$

$$(2.1)(P) = 11\ m$$

$P = 5.2$ m below q_1, or $y = 6.0\ m - 5.2\ m = 0.8$ m

q_3 is located at $\boxed{y = 0.8\ m}$

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21. $q_1 = 3.5$ nC

$q_2 = 5.0$ nC

$r = 40.0$ cm

$q_3 = -6.0$ nC

$$\frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{k_C q_2 q_3}{(r_{2,3})^2}$$

$$\frac{3.5 \times 10^{-9}\ C}{P^2} = \frac{5.0 \times 10^{-9}\ C}{(0.400\ m - P)^2}$$

$$(5.0 \times 10^{-9}\ C)(P^2) = (3.5 \times 10^{-9}\ C)(0.400\ m - P)^2$$

$$P = \left(\sqrt{\frac{3.5 \times 10^{-9}\ C}{5.0 \times 10^{-9}\ C}}\right)(0.400\ m - P)$$

$$P = 0.33\ m - (0.84)(P)$$

$$(1.84)(P) = 0.33\ m$$

$P = 0.18\ m = \boxed{18 \text{ cm from } q_1}$

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32. $q_1 = 30.0 \times 10^{-9}$ C

$q_2 = 60.0 \times 10^{-9}$ C

$r = \frac{30.0\ cm}{2} = 15.0$ cm

$$E_1 = \frac{k_C q_1}{r^2} = \frac{(8.99 \times 10^9\ N\bullet m^2/C^2)(30.0 \times 10^{-9}\ C)}{(0.150\ m)^2} = 1.20 \times 10^4\ N/C$$

$$E_2 = \frac{k_C q_2}{r^2} = \frac{(8.99 \times 10^9\ N\bullet m^2/C^2)(60.0 \times 10^{-9}\ C)}{(0.150\ m)^2} = 2.40 \times 10^4\ N/C$$

$$E_{tot} = (1.20 \times 10^4\ N/C) - (2.40 \times 10^4\ N/C) = -12.0 \times 10^3\ N/C$$

$\mathbf{E_{tot}} = \boxed{12.0 \times 10^3 \text{ N/C toward the } 30.0 \times 10^{-9} \text{ C charge}}$

Givens	*Solutions*
33. $q_1 = 5.7\ \mu C$ at $x = -3.0$ m $q_2 = 2.0\ \mu C$ at $x = 1.0$ m	For E at $y = 2.0$ m on the y-axis,

$$r_1 = \sqrt{(2.0\text{ m})^2 + (3.0\text{ m})^2} = \sqrt{4.0\text{ m}^2 + 9.0\text{ m}^2} = \sqrt{13.0\text{ m}^2} = 3.61\text{ m}$$

$$r_2 = \sqrt{(2.0\text{ m})^2 + (1.0\text{ m})^2} = \sqrt{4.0\text{ m}^2 + 1.0\text{ m}^2} = \sqrt{5.0\text{ m}^2} = 2.2\text{ m}$$

$$E_1 = \frac{k_C q_1}{r_1^2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(5.7 \times 10^{-6}\text{ C})}{(3.61\text{ m})^2} = 3.9 \times 10^3\text{ N/C}$$

$$E_2 = \frac{k_C q_2}{r_2^2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-6}\text{ C})}{(2.2\text{ m})^2} = 3.7 \times 10^3\text{ N/C}$$

$$\theta_1 = \tan^{-1}\left(\frac{2.0}{3.0}\right) = 34°$$

$$\theta_2 = \tan^{-1}\left(\frac{2.0}{1.0}\right) = 63°$$

$$E_x = (3.9 \times 10^3\text{ N/C})(\cos 34°) - (3.7 \times 10^3\text{ N/C})(\cos 63°)$$

$$E_x = (3.2 \times 10^3\text{ N/C}) - (1.7 \times 10^3\text{ N/C}) = 1.5 \times 10^3\text{ N/C}$$

$$E_y = (3.9 \times 10^3\text{ N/C})(\sin 34°) + (3.7 \times 10^3\text{ N/C})(\sin 63°)$$

$$E_y = (2.2 \times 10^3\text{ N/C}) + (3.3 \times 10^3\text{ N/C}) = 5.5 \times 10^3\text{ N/C}$$

$$E_{tot} = \sqrt{(E_x)^2 + (E_y)^2} = \sqrt{(1.5 \times 10^3\text{ N/C})^2 + (5.5 \times 10^3\text{ N/C})^2}$$

$$E_{tot} = \sqrt{(2.2 \times 10^6\text{ N}^2/\text{C}^2) + (3.0 \times 10^7\text{ N}^2/\text{C}^2)} = \sqrt{(3.2 \times 10^7\text{ N}^2/\text{C}^2)} = 5.7 \times 10^3\text{ N/C}$$

$$\theta = \tan^{-1}\left(\frac{5.5}{1.5}\right) = 75°$$

$$\mathbf{E_{tot}} = \boxed{5.7 \times 10^3\text{ N/C, 75° above the positive } x\text{-axis}}$$

Givens	*Solutions*
34. $q_1 = (7.0 \times 10^{13}\text{ protons})(e)$ $q_2 = (4.0 \times 10^{13}\text{ electrons})(e)$ $e = 1.60 \times 10^{-19}$ C	$Q_{net} = q_1 + q_2 = [(7.0 \times 10^{13}) - (4.0 \times 10^{13})](e) = (3.0 \times 10^{13})(e)$ $Q_{net} = (3.0 \times 10^{13})(1.60 \times 10^{-19}\text{ C})$ $Q_{net} = \boxed{4.8 \times 10^{-6}\text{ C}}$
35. $a = 6.3 \times 10^3\text{ m/s}^2$ $m_e = 9.109 \times 10^{-31}$ kg $q = 1.60 \times 10^{-19}$ C	**a.** $F = m_e a = (9.109 \times 10^{-31}\text{ kg})(6.3 \times 10^3\text{ m/s}^2) = 5.7 \times 10^{-27}$ N $\mathbf{F} = \boxed{5.7 \times 10^{-27}\text{ N, in a direction opposite } \mathbf{E}}$ **b.** $E = \frac{F}{q} = \frac{5.7 \times 10^{-27}\text{ N}}{1.60 \times 10^{-19}\text{ C}} = \boxed{3.6 \times 10^{-8}\text{ N/C}}$
36. 1.00 g of Cu has 9.48×10^{21} atoms. 1 Cu atom has 29 electrons.	**a.** 1.00 g of Cu has $(9.48 \times 10^{21}\text{ atoms})(29\text{ electrons/atom}) = \boxed{2.75 \times 10^{23}\text{ electrons}}$ **b.** $q_{tot} = (2.75 \times 10^{23}\text{ electrons})(1.60 \times 10^{-19}\text{ C/electron}) = \boxed{4.40 \times 10^4\text{ C}}$

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37. $q_1 = 6.0\ \mu C$
$q_2 = 1.5\ \mu C$
$q_3 = -2.0\ \mu C$
$r_{1,2} = 3.0$ cm
$r_{2,3} = 2.0$ cm

a. **E** at 1.0 cm left of $q_2 = \mathbf{E_1} + \mathbf{E_2} + \mathbf{E_3}$

$r_1 = r_{1,2} - 1.0 \text{ cm} = 3.0 \text{ cm} - 1.0 \text{ cm} = 2.0 \text{ cm}$

$r_2 = 1.0$ cm

$r_3 = r_{2,3} + 1.0 \text{ cm} = 2.0 \text{ cm} + 1.0 \text{ cm} = 3.0 \text{ cm}$

$$E_1 = \frac{k_C q_1}{r_1^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(6.0 \times 10^{-6}\ \text{C})}{(0.020\ \text{m})^2} = 1.3 \times 10^8\ \text{N/C}$$

$$E_2 = \frac{k_C q_2}{r_2^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(1.5 \times 10^{-6}\ \text{C})}{(0.010\ \text{m})^2} = 1.3 \times 10^8\ \text{N/C}$$

$$E_3 = \frac{k_C q_3}{r_3^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-6}\ \text{C})}{(0.030\ \text{m})^2} = 2.0 \times 10^7\ \text{N/C}$$

$$E_{tot} = (1.3 \times 10^8\ \text{N/C}) - (1.3 \times 10^8\ \text{N/C}) + (2.0 \times 10^7\ \text{N/C})$$

$$\mathbf{E_{tot}} = \boxed{2.0 \times 10^7\ \text{N/C along the positive } x\text{-axis}}$$

$q_4 = -2.0\ \mu C$

b. $F = q_4 E = (2.0 \times 10^{-6}\ \text{C})(2.0 \times 10^7\ \text{N/C}) = \boxed{4.0 \times 10^1\ \text{N}}$

---

38. $q_1 = 5.0$ nC
$q_2 = 6.0$ nC
$q_3 = -3.0$ nC
$r_{1,2} = 0.30$ m
$r_{1,3} = 0.10$ m

a. $$F_{1,2} = \frac{k_C q_1 q_2}{(r_{1,2})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(5.0 \times 10^{-9}\ \text{C})(6.0 \times 10^{-9}\ \text{C})}{(0.30\ \text{m})^2}$$

$F_{1,2} = 3.0 \times 10^{-6}$ N

$$F_{1,3} = \frac{k_C q_1 q_3}{(r_{1,3})^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(5.0 \times 10^{-9}\ \text{C})(3.0 \times 10^{-9}\ \text{C})}{(0.10\ \text{m})^2}$$

$F_{1,3} = 1.3 \times 10^{-5}$ N

$$F_{1,tot} = \sqrt{(F_{1,2})^2 + (F_{1,3})^2} = \sqrt{(3.0 \times 10^{-6}\ \text{N})^2 + (1.3 \times 10^{-5}\ \text{N})^2}$$

$$F_{1,tot} = \sqrt{(9.0 \times 10^{-12}\ \text{N}^2) + (1.7 \times 10^{-10}\ \text{N}^2)} = \sqrt{1.8 \times 10^{-10}\ \text{N}^2} = 1.3 \times 10^{-5}\ \text{N}$$

$$\theta = \tan^{-1}\left(\frac{13}{3.0}\right) = 77°$$

$$\mathbf{F_{1,tot}} = \boxed{1.3 \times 10^{-5}\ \text{N, } 77° \text{ below the negative } x\text{-axis}}$$

b. $$\mathbf{E} = \frac{\mathbf{F}}{q_1} = \frac{1.3 \times 10^{-5}\ \text{N}}{5.0 \times 10^{-9}\ \text{C}} = \boxed{2.6 \times 10^3\ \text{N/C, } 77° \text{ below the negative } x\text{-axis}}$$

---

40. $m_1 = 7.36 \times 10^{22}$ kg
$m_2 = 5.98 \times 10^{24}$ kg

$F_g = F_{electric}$

$$\frac{Gm_1m_2}{r^2} = \frac{k_C q^2}{r^2}$$

$$q = \sqrt{\frac{Gm_1m_2}{k_C}} = \sqrt{\frac{(6.673 \times 10^{-11}\text{N}\bullet\text{m}^2/\text{kg}^2)(7.36 \times 10^{22}\ \text{kg})(5.98 \times 10^{24}\ \text{kg})}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$$

$$q = \boxed{5.72 \times 10^{13}\ \text{C}}$$

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41. $m_1 = m_2 = 0.20$ g

$\theta = 5.0°$

$L = 30.0$ cm

$\Sigma \mathbf{F_y} = 0$ N, so $\mathbf{F_g} = \mathbf{F_{T,y}} = \mathbf{F_T}(\cos 5.0°)$

$\Sigma \mathbf{F_x} = 0$ N, so $\mathbf{F_{electric}} = \mathbf{F_{T,x}} = \mathbf{F_T}(\sin 5.0°)$

$$\frac{F_{electric}}{F_g} = \frac{F_T(\sin 5.0°)}{F_T(\cos 5.0°)} = \tan 5.0°$$

$$\frac{k_C q^2}{r^2 mg} = \tan 5.0°$$

$r = (2)(0.300 \text{ m})(\sin 5.0°)$

$$q = \sqrt{\frac{r^2 mg(\tan 5.0°)}{k_C}}$$

$$q = \sqrt{\frac{[(2)(0.300 \text{ m})(\sin 5.0°)]^2(0.20 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)(\tan 5.0°)}{8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2}}$$

$$q = \boxed{7.2 \times 10^{-9} \text{ C}}$$

---

42. $m_e = 9.109 \times 10^{-31}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$q = 1.60 \times 10^{-19}$ C

a. $F = Eq = mg$

$$E_e = \frac{m_e g}{q} = \frac{(9.109 \times 10^{-31} \text{ kg})(9.81 \text{ m/s}^2)}{1.60 \times 10^{-19} \text{ C}} = 5.58 \times 10^{-11} \text{ N/C}$$

$$\mathbf{E_e} = \boxed{5.58 \times 10^{-11} \text{ N/C, downward}}$$

b. $$E_p = \frac{m_p g}{q} = \frac{(1.673 \times 10^{-27} \text{ kg})(9.81 \text{ m/s}^2)}{1.60 \times 10^{-19} \text{ C}} = 1.03 \times 10^{-7} \text{ N/C}$$

$$\mathbf{E_p} = \boxed{1.03 \times 10^{-7} \text{ N/C upward}}$$

---

43. $E = 520$ N/C

$\Delta t = 48$ ns

$v_i = 0$ m/s

$m_e = 9.109 \times 10^{-31}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$q = 1.60 \times 10^{-19}$ C

$$a = \frac{F}{m} = \frac{qE}{m}$$

$$v_f = a\Delta t = \left(\frac{qE}{m}\right)\Delta t$$

For the electron,

$$v_{f,e} = \frac{qE\Delta t}{m_e} = \frac{(1.60 \times 10^{-19} \text{ C})(520 \text{ N/C})(48 \times 10^{-9} \text{ s})}{9.109 \times 10^{-31} \text{ kg}} = \boxed{4.4 \times 10^6 \text{ m/s}}$$

For the proton,

$$v_{f,p} = \frac{qE\Delta t}{m_p} = \frac{(1.60 \times 10^{-19} \text{ C})(520 \text{ N/C})(48 \times 10^{-9} \text{ s})}{1.673 \times 10^{-27} \text{ kg}} = \boxed{2.4 \times 10^3 \text{ m/s}}$$

---

44. $E = 3.0 \times 10^4$ N/C

$q = 1.60 \times 10^{-19}$ C

$m_p = 1.673 \times 10^{-27}$ kg

a. $F = qE = (1.60 \times 10^{-19} \text{ C})(3.0 \times 10^4 \text{ N/C}) = \boxed{4.8 \times 10^{-15} \text{ N}}$

b. $$a = \frac{F}{m_p} = \frac{4.8 \times 10^{-15} \text{ N}}{1.673 \times 10^{-27} \text{ kg}} = \boxed{2.9 \times 10^{12} \text{ m/s}^2}$$

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45. $E = 3.4 \times 10^5$ N/C

$q = 1.60 \times 10^{-19}$ C

$F = qE = (1.60 \times 10^{-19}\ \text{C})(3.4 \times 10^5\ \text{N/C}) = \boxed{5.4 \times 10^{-14}\ \text{N}}$

---

46. $q = 24\ \mu\text{C}$

$E = 610$ N/C

$F_{electric} = F_g$

$qE = mg$

$m = \dfrac{qE}{g} = \dfrac{(24 \times 10^{-6}\ \text{C})(610\ \text{N/C})}{9.81\ \text{m/s}^2} = \boxed{1.5 \times 10^{-3}\ \text{kg}}$

---

47. $m = 0.10$ kg

$L = 30.0$ cm

$\theta = 45°$

$\Sigma \mathbf{F_x} = 0\ \text{N} = \mathbf{F_{electric}} - \mathbf{F_{T,x}}$

$\mathbf{F_{T,x}} = \mathbf{F_{electric}} = \mathbf{F_T}(\sin 45°)$

$\Sigma \mathbf{F_y} = 0\ \text{N} = \mathbf{F_{T,y}} - \mathbf{F_g}$

$\mathbf{F_{T,y}} = \mathbf{F_g} = \mathbf{F_T}(\cos 45°)$

$$\frac{F_{electric}}{F_g} = \frac{F_T(\sin 45°)}{F_T(\cos 45°)} = \tan 45°$$

$$F_{electric} = \frac{k_C q^2}{(L \sin \theta)^2} + \frac{k_C q^2}{(2L \sin \theta)^2} = \frac{4k_C q^2 + k_C q^2}{4L^2(\sin^2\theta)} = \frac{5k_C q^2}{4L^2(\sin^2\theta)}$$

$F_g = mg$

$$\frac{F_{electric}}{F_g} = \frac{5k_C q^2}{4L^2(\sin^2\theta)mg} = \tan 45°$$

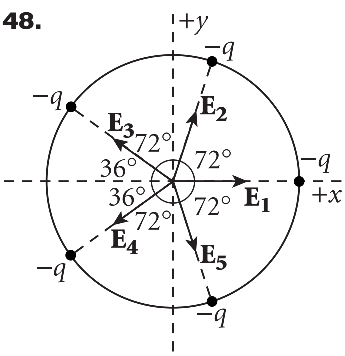
$5k_C q^2 = 4L^2(\sin^2\theta)mg(\tan 45°)$

$$q = \sqrt{\frac{4L^2(\sin^2\theta)mg(\tan 45°)}{5k_C}} = 2L(\sin \theta)\sqrt{\frac{mg(\tan 45°)}{5k_C}}$$

$$q = (2)(0.300\ \text{m})(\sin 45°)\sqrt{\frac{(0.10\ \text{kg})(9.81\ \text{m/s}^2)(\tan 45°)}{(5)(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)}}$$

$q = \boxed{2.0 \times 10^{-6}\ \text{C}}$

48.



Because each charge is the same size and all are the same distance from the center,

$E_1 = E_2 = E_3 = E_4 = E_5 = \dfrac{k_C q}{r^2}$

$E_{1,y} = 0$ N/C

$E_{5,y} = -E_{2,y} = -E(\sin 72°)$

$E_{4,y} = -E_{3,y} = -E(\sin 36°)$

$E_y = E_{1,y} + E_{2,y} + E_{3,y} + E_{4,y} + E_{5,y}$

$E_y = 0\ \text{N/C} + E(\sin 72°) + E(\sin 36°) - E(\sin 36°) - E(\sin 72°) = 0\ \text{N/C}$

$E_{1,x} = E$

$E_{2,x} = E_{5,x} = E(\cos 72°)$

$E_{3,x} = E_{4,x} = -E(\cos 36°)$

$E_x = E_{1,x} + E_{2,x} + E_{3,x} + E_{4,x} + E_{5,x}$

$E_x = E + E(\cos 72°) - E(\cos 36°) - E(\cos 36°) + E(\cos 72°)$

$E_x = E + 2E(\cos 72°) - 2E(\cos 36°) = E(1 + 0.62 - 1.62)$

$E_x = 0$ N/C

$E = \sqrt{(E_x)^2 + (E_y)^2} = \sqrt{(0\ \text{N/C})^2 + (0\ \text{N/C})^2} = \boxed{0\ \text{N/C}}$

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49. $E = 370.0$ N/C

$\Delta t = 1.00\ \mu s$

$m_e = 9.109 \times 10^{-31}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$q = 1.60 \times 10^{-19}$ C

$$a_e = \frac{F}{m_e} = \frac{qE}{m_e} = \frac{(1.60 \times 10^{-19}\ \text{C})(370.0\ \text{N/C})}{9.109 \times 10^{-31}\ \text{kg}} = 6.50 \times 10^{13}\ \text{m/s}^2$$

$$\Delta x_e = \tfrac{1}{2}a_e\Delta t^2 = (0.5)(6.50 \times 10^{13}\ \text{m/s}^2)(1.00 \times 10^{-6}\ \text{s})^2 = 32.5\ \text{m}$$

$$a_p = \frac{F}{m_p} = \frac{qE}{m_p} = \frac{(1.60 \times 10^{-19}\ \text{C})(370.0\ \text{N/C})}{1.673 \times 10^{-27}\ \text{kg}} = 3.54 \times 10^{10}\ \text{m/s}^2$$

$$\Delta x_p = \tfrac{1}{2}a_p\Delta t^2 = (0.5)(3.54 \times 10^{10}\ \text{m/s}^2)(1.00 \times 10^{-6}\ \text{s})^2$$

$$\Delta x_p = 1.77 \times 10^{-2}\ \text{m}$$

$$\Delta x_{tot} = \Delta x_e + \Delta x_p = 32.5\ \text{m} + (1.77 \times 10^{-2}\ \text{m}) = \boxed{32.5\ \text{m}}$$

---

50. $E = 300.0$ N/C

$m_e = 9.109 \times 10^{-31}$ kg

$q = 1.60 \times 10^{-19}$ C

a. $$a = \frac{F}{m_e} = \frac{qE}{m_e} = \frac{(1.60 \times 10^{-19}\ \text{C})(300.0\ \text{N/C})}{9.109 \times 10^{-31}\ \text{kg}} = \boxed{5.27 \times 10^{13}\ \text{m/s}^2}$$

$\Delta t = 1.00 \times 10^{-8}$ s

b. $$v_f = a\Delta t = (5.27 \times 10^{13}\ \text{m/s}^2)(1.00 \times 10^{-8}\ \text{s}) = \boxed{5.27 \times 10^{5}\ \text{m/s}}$$

---

51. $E = 3.0 \times 10^6$ N/C

$q = 1.60 \times 10^{-19}$ C

$m_e = 9.109 \times 10^{-31}$ kg

a. $$a = \frac{F}{m_e} = \frac{qE}{m_e} = \frac{(1.60 \times 10^{-19}\ \text{C})(3.0 \times 10^{6}\ \text{N/C})}{9.109 \times 10^{-31}\ \text{kg}} = \boxed{5.3 \times 10^{17}\ \text{m/s}^2}$$

$v_i = 0$ m/s

$v_f = (0.100)(3.00 \times 10^8\ \text{m/s})$

b. $v_f^2 = 2a\Delta x$

$$\Delta x = \frac{v_f^2}{2a} = \frac{[(0.100)(3.00 \times 10^8\ \text{m/s})]^2}{(2)(5.3 \times 10^{17}\ \text{m/s}^2)} = \boxed{8.5 \times 10^{-4}\ \text{m}}$$

$m_p = 1.673 \times 10^{-27}$ kg

c. $$a = \frac{F}{m_p} = \frac{qE}{m_p} = \frac{(1.60 \times 10^{-19}\ \text{C})(3.0 \times 10^{6}\ \text{N/C})}{1.673 \times 10^{-27}\ \text{kg}} = \boxed{2.9 \times 10^{14}\ \text{m/s}^2}$$

---

52. $KE = 3.25 \times 10^{-15}$ J

$\Delta x = 1.25$ m

$v_f = 0$ m/s

$q = 1.60 \times 10^{-19}$ C

$m_p = 1.673 \times 10^{-27}$ kg

$$KE = \tfrac{1}{2}m_p v_i^2$$

$$v_i = \sqrt{\frac{2KE}{m_p}}$$

$$a = \frac{v_f^2 - v_i^2}{2\Delta x}$$

$$F = qE = m_p a$$

$$E = \frac{m_p a}{q} = \frac{(m_p)(v_f^2 - v_i^2)}{(q)(2\Delta x)} = \frac{m_p v_f^2 - m_p\left(\sqrt{\frac{2KE}{m_p}}\right)^2}{(q)(2\Delta x)} = \frac{m_p v_f^2 - 2KE}{(q)(2\Delta x)}$$

$$E = \frac{(1.673 \times 10^{-27}\ \text{kg})(0\ \text{m/s})^2 - (2)(3.25 \times 10^{-15}\ \text{J})}{(1.60 \times 10^{-19}\ \text{C})(2)(1.25\ \text{m})} = -1.62 \times 10^4\ \text{N/C}$$

$$E = \boxed{1.62 \times 10^4\ \text{N/C opposite the proton's velocity}}$$

Givens | *Solutions*

I

53. $m = 2.0$ g

$L = 20.0$ cm

$E = 1.0 \times 10^4$ N/C

$\theta = 15°$

b. $F_{T,y} = F_g = mg$

$$F_T = \frac{F_{T,y}}{\cos 15°} = \frac{mg}{\cos 15°}$$

$$qE = F_{T,x} = F_T(\sin 15°) = \frac{mg(\sin 15°)}{\cos 15°} = mg(\tan 15°)$$

$$q = \frac{mg(\tan 15°)}{E} = \frac{(2.0 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2)(\tan 15°)}{1.0 \times 10^4\text{ N/C}} = \boxed{5.3 \times 10^{-7}\text{ C}}$$

---

54. $E = 2.0 \times 10^3$ N/C along the positive x-axis

$q = 1.60 \times 10^{-19}$ C

a. $F = qE = (1.60 \times 10^{-19}\text{ C})(2.0 \times 10^3\text{ N/C}) = 3.2 \times 10^{-16}\text{ N}$

$\mathbf{F} = \boxed{3.2 \times 10^{-16}\text{ N, along the positive } x\text{-axis}}$

$m_p = 1.673 \times 10^{-27}$ kg

b. $$a = \frac{F}{m_p} = \frac{3.2 \times 10^{-16}\text{ N}}{1.673 \times 10^{-27}\text{ kg}} = \boxed{1.9 \times 10^{11}\text{ m/s}^2}$$

$v_f = 1.00 \times 10^6$ m/s

c. $$\Delta t = \frac{v_f}{a} = \frac{1.00 \times 10^6\text{ m/s}}{1.9 \times 10^{11}\text{ m/s}^2} = \boxed{5.3 \times 10^{-6}\text{ s}}$$

---

55. $v_{f,1} = (0.010)(3.00 \times 10^8\text{ m/s})$

$\Delta x_1 = 2.0$ mm

$q = 1.60 \times 10^{-19}$ C

$m_e = 9.109 \times 10^{-31}$ kg

a. $$a = \frac{{v_{f,1}}^2}{2\Delta x_1}$$

$$E = \frac{m_e a}{q} = \frac{m_e {v_{f,1}}^2}{2\Delta x_1 q}$$

$$E = \frac{(9.109 \times 10^{-31}\text{ kg})[(0.010)(3.00 \times 10^8\text{ m/s})]^2}{(2)(2.0 \times 10^{-3}\text{ m})(1.60 \times 10^{-19}\text{ C})}$$

$E = \boxed{1.3 \times 10^4\text{ N/C}}$

$\Delta x_2 = 4.0$ mm

b. $$a = \frac{{v_{f,1}}^2}{2\Delta x_1} = \frac{[(0.010)(3.00 \times 10^8\text{ m/s})]^2}{(2)(2.0 \times 10^{-3}\text{ m})} = 2.2 \times 10^{15}\text{ m/s}^2$$

$${v_{f,2}}^2 = 2a\Delta x_2$$

$$v_{f,2} = \sqrt{2a\Delta x_2} = \sqrt{(2)(2.2 \times 10^{15}\text{ m/s}^2)(4.0 \times 10^{-3}\text{ m})} = \boxed{4.2 \times 10^6\text{ m/s}}$$

---

56. $r_1 = 2.17\ \mu$m

$q_1 = 1.60 \times 10^{-19}$ C

$q_2 = -1.60 \times 10^{-19}$ C

$r_2 = (0.0100)(2.17\ \mu\text{m})$

$F_{electric} = F_{elastic}$ $$\frac{k_C q_1 q_2}{{r_1}^2} = kr_2$$

$$k = \frac{k_C q_1 q_2}{{r_1}^2 r_2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(2.17 \times 10^{-6}\text{ m})^3(0.0100)}$$

$k = \boxed{2.25 \times 10^{-9}\text{ N/m}}$

Givens | *Solutions*

11. $q = 5.0\ \mu C$

$r = 2.0$ m

$$E_1 = E_2 = E_3 = \frac{k_C q}{r^2} = \frac{(8.99 \times 10^9\ N{\bullet}m^2/C^2)(5.0 \times 10^{-6}\ C)}{(2.0\ m)^2} = 1.1 \times 10^4\ N/C$$

$\mathbf{E_x} = (1.1 \times 10^4\ N/C)(\sin 60°) - (1.1 \times 10^4\ N)(\sin 60°) = 0.0\ N/C$

$\mathbf{E_y} = (1.1 \times 10^4\ N/C) - (1.1 \times 10^4\ N/C)(\cos 60°) - (1.1 \times 10^4\ N/C)(\cos 60°)$

$\mathbf{E_y} = (1.1 \times 10^4\ N/C) - (5.5 \times 10^3\ N/C) - (5.5 \times 10^3\ N/C) = 0.0\ N/C$

$\mathbf{E_{tot}} = \sqrt{(0.0\ N/C)^2 + (0.0\ N/C)^2} = \boxed{0.0\ N/C}$

---

13. $q_1 = (6.02 \times 10^{23})(e)$

$q_2 = (6.02 \times 10^{23})(e)$

$r = (2)(6.38 \times 10^6\ m)$

$e = 1.60 \times 10^{-19}\ C$

$$F = \frac{k_C q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ N{\bullet}m^2/C^2)[(6.02 \times 10^{23})(1.60 \times 10^{-19}\ C)]^2}{[(2)(6.38 \times 10^6\ m)]^2}$$

$F = \boxed{5.12 \times 10^5\ N}$

---

14. $E = 3.0 \times 10^6$ N/C

$r = 2.0$ m

$$q = \frac{Er^2}{k_C} = \frac{(3.0 \times 10^6\ N/C)(2.0\ m)^2}{(8.99 \times 10^9\ N{\bullet}m^2/C^2)} = \boxed{1.3 \times 10^{-3}\ C}$$

---

15. $E = 640$ N/C

$m_p = 1.673 \times 10^{-27}$ kg

$q = 1.60 \times 10^{-19}$ C

$$a = \frac{F}{m_p} = \frac{qE}{m_p} = \frac{(1.60 \times 10^{-19}\ C)(640\ N/C)}{1.673 \times 10^{-27}\ kg} = \boxed{6.1 \times 10^{10}\ m/s^2}$$

---

16. $v_f = 1.20 \times 10^6$ m/s

$a = 6.1 \times 10^{10}\ m/s^2$

$$\Delta t = \frac{v_f}{a} = \frac{1.20 \times 10^6\ m/s}{6.1 \times 10^{10}\ m/s^2} = \boxed{2.0 \times 10^{-5}\ s}$$

---

17. $a = 6.1 \times 10^{10}\ m/s^2$

$\Delta t = 2.0 \times 10^{-5}$ s

$\Delta x = \frac{1}{2}a\Delta t^2 = (0.5)(6.1 \times 10^{10}\ m/s^2)(2.0 \times 10^{-5}\ s)^2$

$\Delta x = \boxed{12\ m}$

---

18. $m_p = 1.673 \times 10^{-27}$ kg

$v_f = 1.20 \times 10^6$ m/s

$KE_f = \frac{1}{2}m_p v_f^2 = (0.5)(1.673 \times 10^{-27}\ kg)(1.20 \times 10^6\ m/s)^2$

$KE_f = \boxed{1.20 \times 10^{-15}\ J}$

Student Edition Solutions

Electrical Energy and Current

I

Electrical Energy and Current, Practice A

Givens	*Solutions*
1. $\Delta PE_{electric} = -4.8 \times 10^{-16}$ J $d = 10.0$ m $E = 75$ N/C	$\Delta PE_{electric} = -qEd$ $q = \dfrac{\Delta PE_{electric}}{Ed} = \dfrac{(-4.8 \times 10^{-16}\ \text{J})}{(75\ \text{N/C})(10.0\ \text{m})}$ $q = \boxed{6.4 \times 10^{-19}\ \text{C}}$
2. $E = 75$ N/C $d = 10.0$ m	$\Delta V = -Ed = -(75\ N/C)(10.0\ m)$ $\Delta V = \boxed{-750\ \text{V}}$
3. $q = -1.6 \times 10^{-19}$ C $d = 4.5$ m $E = 325$ N/C	$\Delta PE_{electric} = -qEd$ $\Delta PE_{electric} = -(-1.6 \times 10^{-19}\ \text{C})(325\ \text{N/C})(4.5\ \text{m})$ $\Delta PE_{electric} = \boxed{2.3 \times 10^{-16}\ \text{J}}$

Electrical Energy and Current, Section 1 Review

5. $\mathbf{E} = 250$ N/C, in the positive x direction $q_1 = 12\ \mu$C q_1 moves from the origin to (20.0 cm, 50.0 cm).	The displacement in the direction of the field (d) is 20.0 cm. $\Delta PE = -qEd = -(12 \times 10^{-6}\ \text{C})(250\ \text{N/C})(20.0 \times 10^{-2}\ \text{m})$ $\Delta PE = \boxed{-6.0 \times 10^{-4}\ \text{J}}$
6. $q = 35$ C $d = 2.0$ km $E = 1.0 \times 10^6$ N/C	$\Delta PE = -qEd = -(35\ \text{C})(1.0 \times 10^6\ \text{N/C})(2.0 \times 10^3\ \text{m}) = \boxed{-7.0 \times 10^{10}\ \text{J}}$
7. $\Delta d = 0.060$ cm $E = 3.0 \times 10^6$ V/m	$\Delta V = -E\Delta d = -(3.0 \times 10^6\ \text{V/m})(0.060 \times 10^{-2}\ \text{m}) = -1.8 \times 10^3\ \text{V}$ $\Delta V = \boxed{1.8 \times 10^3\ \text{V}}$
8. $E = 8.0 \times 10^4$ V/m $\Delta d = 0.50$ m $q = 1.60 \times 10^{-19}$ C	**a.** $\Delta V = -E\Delta d = -(8.0 \times 10^4\ \text{V/m})(0.50\ \text{m}) = \boxed{-4.0 \times 10^4\ \text{V}}$ **b.** $\Delta PE = -qEd = -(1.60 \times 10^{-19}\ \text{C})(8.0 \times 10^4\ \text{V/m})(0.50\ \text{m})$ $\Delta PE = \boxed{-6.4 \times 10^{-15}\ \text{J}}$

Givens	*Solutions*
9. $E = 1.0 \times 10^6$ V/m	$\Delta V = -E\Delta d = -(1.0 \times 10^6 \text{ V/m})(1.60 \times 10^3 \text{ m}) = -1.6 \times 10^9$ V
$\Delta d = 1.60$ km	$\Delta V = \boxed{1.6 \times 10^9 \text{ V}}$

I

Electrical Energy and Current, Practice B

1. $C = 4.00\ \mu$F	**a.** $Q = C\Delta V_1 = (4.00 \times 10^{-6} \text{ F})(12.0 \text{ V}) = \boxed{4.80 \times 10^{-5} \text{ C}}$
$\Delta V_1 = 12.0$ V	
$\Delta V_2 = 1.50$ V	**b.** $PE = \frac{1}{2}C(\Delta V_2)^2 = (0.5)(4.00 \times 10^{-6} \text{ F})(1.50 \text{ V})^2 = \boxed{4.50 \times 10^{-6} \text{ J}}$
2. $Q = 6.0\ \mu$C	**a.** $C = \dfrac{Q}{\Delta V_1} = \dfrac{6.0 \times 10^{-6} \text{ C}}{1.25 \text{ V}} = \boxed{4.8 \times 10^{-6} \text{ F}}$
$\Delta V_1 = 1.25$ V	
$\Delta V_2 = 1.50$ V	**b.** $PE = \frac{1}{2}C(\Delta V_2)^2 = (0.5)(4.8 \times 10^{-6} \text{ F})(1.50 \text{ V})^2 = \boxed{5.4 \times 10^{-6} \text{ J}}$
3. $C = 2.00$ pF	**a.** $\Delta V_1 = \dfrac{Q}{C} = \dfrac{18.0 \times 10^{-12} \text{ C}}{2.00 \times 10^{-12} \text{ F}} = \boxed{9.00 \text{ V}}$
$Q = 18.0$ pC	
$\Delta V_2 = 2.5$ V	**b.** $Q = C\Delta V_2 = (2.00 \times 10^{-12} \text{ F})(2.5 \text{ V}) = \boxed{5.0 \times 10^{-12} \text{ C}}$
4. C = 1.00 F	$A = \dfrac{Cd}{\varepsilon_0} = \dfrac{(1.00 \text{ F})(1.00 \times 10^{-3} \text{ m})}{8.85 \times 10^{-12} \text{ C}^2/\text{N}\bullet\text{m}^2} = \boxed{1.13 \times 10^8 \text{ m}^2}$
$d = 1.00$ mm	

Electrical Energy and Current, Section 2 Review

1. $d = 800.0$ m	**a.** $C = \dfrac{\varepsilon_0 A}{d} = \dfrac{(8.85 \times 10^{-12} \text{ C}^2/\text{N}\bullet\text{m}^2)(1.00 \times 10^6 \text{ m}^2)}{800.0 \text{ m}} = \boxed{1.11 \times 10^{-8} \text{ F}}$
$A = 1.00 \times 10^6$ m^2	
$E = 2.0 \times 10^6$ N/C	**b.** $\Delta V = -E\Delta d$
	$Q = C\Delta V = C(-E\Delta d) = (1.11 \times 10^{-8} \text{ F})(-2.0 \times 10^6 \text{ N/C})(800.0 \text{ m}) = -18$ C
	$\boxed{Q = \pm 18 \text{ C}}$
2. $A = 2.0$ cm^2	**a.** $C = \dfrac{\varepsilon_0 A}{d} = \dfrac{(8.85 \times 10^{-12} \text{ C}^2/\text{N}\bullet\text{m}^2)(2.0 \times 10^{-4} \text{ m}^2)}{2.0 \times 10^{-3} \text{ m}} = \boxed{8.8 \times 10^{-13} \text{ F}}$
$d = 2.0$ mm	
$\Delta V = 6.0$ V	**b.** $Q = C\Delta V = (8.8 \times 10^{-13} \text{ F})(6.0 \text{ V}) = \boxed{5.3 \times 10^{-12} \text{ C}}$
3. $C = 1.35$ pF	$PE = \frac{1}{2}C(\Delta V)^2 = (0.5)(1.35 \times 10^{-12} \text{ F})(12.0 \text{ V})^2$
$\Delta V = 12.0$ V	$PE = \boxed{9.72 \times 10^{-11} \text{ J}}$

Electrical Energy and Current, Practice C

Givens	*Solutions*
1. $I = 5.00 \times 10^{-3}$ A $\Delta Q = 2.00$ C	$I = \dfrac{\Delta Q}{\Delta t}$ $\Delta t = \dfrac{\Delta Q}{I} = \dfrac{2.00 \text{ C}}{5.00 \times 10^{-3} \text{ A}} = \boxed{4.00 \times 10^{2} \text{ s}}$
2. $I = 60.0 \times 10^{-6}$ A $N = 3.75 \times 10^{14}$ electrons $q_e = 1.60 \times 10^{-19}$ C	$\Delta t = \dfrac{N(1.60 \times 10^{-19} \text{ C/electron})}{I}$ $\Delta t = \dfrac{(3.75 \times 10^{14} \text{ electrons})(1.60 \times 10^{-19} \text{ C/electron})}{6.00 \times 10^{-5} \text{ A}}$ $\Delta t = \boxed{1.00 \text{ s}}$
3. $I = 8.00 \times 10^{-2}$ A $N = 3.00 \times 10^{20}$ electrons $q_e = 1.60 \times 10^{-19}$ C	$\Delta t = \dfrac{N(1.60 \times 10^{-19} \text{ C/electron})}{I}$ $\Delta t = \dfrac{(3.00 \times 10^{20} \text{ electrons})(1.60 \times 10^{-19} \text{ C/electron})}{8.00 \times 10^{-2} \text{ A}}$ $\Delta t = \boxed{6.00 \times 10^{2} \text{ s}}$
4. $I = 40.0$ A $\Delta t = 0.50$ s	$\Delta Q = I\Delta t = (40.0 \text{ A})(0.50 \text{ s}) = \boxed{2.0 \times 10^{1} \text{ C}}$
5. $\Delta Q_1 = 9.0$ mC $\Delta t_1 = 3.5$ s $\Delta t_2 = 10.0$ s $\Delta Q_2 = 2\Delta Q_1$ $q_e = 1.60 \times 10^{-19}$ C	**a.** $I = \dfrac{\Delta Q_1}{\Delta t_1} = \dfrac{9.0 \times 10^{-3} \text{ C}}{3.5 \text{ s}} = \boxed{2.6 \times 10^{-3} \text{ A}}$ **b.** $N = \dfrac{I\Delta t_2}{1.60 \times 10^{-19} \text{ C/electron}} = \dfrac{(2.6 \times 10^{-3} \text{ A})(10.0 \text{ s})}{1.60 \times 10^{-19} \text{ C/electron}} = \boxed{1.6 \times 10^{17} \text{ electrons}}$ **c.** $I = \dfrac{\Delta Q_2}{\Delta t_1} = \dfrac{2\Delta Q_1}{\Delta t_1} = \dfrac{2(9.0 \times 10^{-3} \text{ C})}{3.5 \text{ s}} = \boxed{5.1 \times 10^{-3} \text{ A}}$

Electrical Energy and Current, Practice D

Givens	*Solutions*
1. $\Delta V = 1.5$ V $R = 3.5\ \Omega$	$I = \dfrac{\Delta V}{R} = \dfrac{1.5 \text{ V}}{3.5\ \Omega} = \boxed{0.43 \text{ A}}$
2. $\Delta V = 120$ V $R = 65\ \Omega$	$I = \dfrac{\Delta V}{R} = \dfrac{120 \text{ V}}{65\ \Omega} = \boxed{1.8 \text{ A}}$
3. $\Delta V = 120$ V $R_1 = 48\ \Omega$ $R_2 = 20.0\ \Omega$	**a.** $I_1 = \dfrac{\Delta V}{R_1} = \dfrac{120 \text{ V}}{48\ \Omega} = \boxed{2.5 \text{ A}}$ **b.** $I_2 = \dfrac{\Delta V}{R_2} = \dfrac{120 \text{ V}}{20.0\ \Omega} = \boxed{6.0 \text{ A}}$

Givens	*Solutions*

4. $I = 6.25$ A

$R = 17.6\ \Omega$

$\Delta V = IR = (6.25\text{ A})(17.6\ \Omega) = \boxed{1.10 \times 10^2\text{ V}}$

---

5. $I = 2.5$ A

$\Delta V = 115$ V

$$R = \frac{\Delta V}{I} = \frac{115\text{ V}}{2.5\text{ A}} = \boxed{46\ \Omega}$$

---

6. $I_1 = 0.50$ A

$\Delta V_1 = 110$ V

$\Delta V_2 = 90.0$ V

$\Delta V_3 = 130$ V

a. $$R = \frac{\Delta V_1}{I_1} = \frac{110\text{ V}}{0.50\text{A}} = 220\ \Omega$$

$$I_2 = \frac{\Delta V_2}{R} = \frac{90.0\text{ V}}{220\ \Omega} = \boxed{0.41\text{ A}}$$

b. $$I_3 = \frac{\Delta V_3}{R} = \frac{130\text{ V}}{220\ \Omega} = \boxed{0.59\text{ A}}$$

Electrical Energy and Current, Section 3 Review

2. $\Delta t_1 = 5.00$ s

$\Delta Q = 3.0$ C

$\Delta t_2 = 1.0$ min

a. $$I = \frac{\Delta Q}{\Delta t_1} = \frac{3.0\text{ C}}{5.00\text{ s}} = \boxed{0.60\text{ A}}$$

b. $$N = \frac{I\Delta t_2}{1.60 \times 10^{-19}\text{ C/electron}} = \frac{(0.60\text{ A})(1.0\text{ min})(60\text{ s/min})}{1.60 \times 10^{-19}\text{ C/electrons}}$$

$$N = \boxed{2.2 \times 10^{20}\text{ electrons}}$$

---

3. $R = 10.2\ \Omega$

$\Delta V = 120$ V

$$I = \frac{\Delta V}{R} = \frac{120\text{ V}}{10.2\ \Omega} = \boxed{12\text{ A}}$$

---

4. $I = 2.5$ A

$\Delta V = 9.0$ V

$$R = \frac{\Delta V}{I} = \frac{9.0\text{ V}}{2.5\text{A}} = \boxed{3.6\ \Omega}$$

---

7. $R_1 = 75\ \Omega$

$\Delta V = 115$ V

$R_2 = 47\ \Omega$

$$I_1 = \frac{\Delta V}{R_1} = \frac{115\text{ V}}{75\ \Omega} = \boxed{1.5\text{ A}}$$

$$I_2 = \frac{\Delta V}{R_2} = \frac{115\text{ V}}{47\ \Omega} = \boxed{2.4\text{ A}}$$

Electrical Energy and Current, Practice E

1. $P = 1050$ W

$\Delta V = 120$ V

$$P = \frac{(\Delta V)^2}{R}$$

$$R = \frac{(\Delta V)^2}{P} = \frac{(120\text{ V})^2}{1050\text{ W}} = \boxed{14\ \Omega}$$

---

2. $P = 0.25$ W

$\Delta V = 120$ V

$$R = \frac{(\Delta V)^2}{P} = \frac{(120\text{ V})^2}{0.25\text{ W}} = \boxed{5.8 \times 10^4\ \Omega}$$

Givens	*Solutions*
3. $P = 0.10$ W $R = 22\ \Omega$	$P = \frac{(\Delta V)^2}{R}$ $\Delta V = \sqrt{PR} = \sqrt{(0.10\text{ W})(22\ \Omega)} = \boxed{1.5\text{ V}}$
4. $\Delta V = 50.0$ V $R = 8.00\ \Omega$	$I = \frac{\Delta V}{R} = \frac{50.0\text{ V}}{8.00\ \Omega} = \boxed{6.25\text{ A}}$ $P = \frac{(\Delta V)^2}{R} = \frac{(50.0\text{ V})^2}{8.00\ \Omega} = \boxed{312\text{ W}}$
5. $\Delta V = 50.0$ V $R = 0.100\ \Omega$	$I = \frac{\Delta V}{R} = \frac{50.0\text{ V}}{0.100\ \Omega}$ $I = \boxed{5.00 \times 10^2\text{ A}}$

Electrical Energy and Current, Section 4 Review

3. $\Delta V = 70$ mV $I = 200\ \mu$A	$P = I\Delta V = (200 \times 10^{-6}\text{ A})(70 \times 10^{-3}\text{ V}) = \boxed{1 \times 10^{-5}\text{ W}}$
4. $\Delta t = 21$ h $P = 90.0$ W cost of energy = \$0.070/kW•h	cost = $(P\Delta t)$(cost/kW•h) cost = $(90.0 \times 10^{-3}\text{ kW})(21\text{ h})(\$0.070/\text{kW}\bullet\text{h}) = \boxed{\$0.13}$

Electrical Energy and Current, Chapter Review

8. $E = 1.7 \times 10^6$ N/C $\Delta d = 1.5$ cm	$\Delta V = -E\Delta d = -(1.7 \times 10^6\text{ N/C})(1.5 \times 10^{-2}\text{ m}) = -2.6 \times 10^4\text{ V}$ $\Delta V = \boxed{2.6 \times 10^4\text{ V}}$

Givens | *Solutions*

I

9. $q_1 = +8.0\ \mu C$

$q_2 = -8.0\ \mu C$

$q_3 = -12\ \mu C$

$r_{1,P} = 0.35$ m

$r_{2,P} = 0.20$ m

$$V_1 = \frac{k_C q_1}{r_{1,P}} = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(8.0 \times 10^{-6}\ \mathrm{C})}{0.35\ \mathrm{m}} = 2.1 \times 10^5\ \mathrm{V}$$

$$V_2 = \frac{k_C q_2}{r_{2,P}} = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(-8.0 \times 10^{-6}\ \mathrm{C})}{0.20\ \mathrm{m}} = -3.6 \times 10^5\ \mathrm{V}$$

$$(r_{1,P})^2 + (r_{2,P})^2 = (r_{3,P})^2$$

$$r_{3,P} = \sqrt{(r_{1,P})^2 + (r_{2,P})^2} = \sqrt{(0.35\ \mathrm{m})^2 + (0.20\ \mathrm{m})^2}$$

$$V_3 = \frac{k_C q_3}{r_{3,P}} = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(-12 \times 10^{-6}\ \mathrm{C})}{\sqrt{(0.35\ \mathrm{m})^2 + (0.20\ \mathrm{m})^2}}$$

$$V_3 = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(-12 \times 10^{-6}\ \mathrm{C})}{\sqrt{0.12\ \mathrm{m^2} + 0.040\ \mathrm{m^2}}}$$

$$V_3 = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(-12 \times 10^{-6}\ \mathrm{C})}{\sqrt{0.16\ \mathrm{m^2}}} = -2.7 \times 10^5\ \mathrm{V}$$

$$V_{tot} = V_1 + V_2 + V_3 = (2.1 \times 10^5\ \mathrm{V}) + (-3.6 \times 10^5\ \mathrm{V}) + (-2.7 \times 10^5\ \mathrm{V})$$

$$V_{tot} = \boxed{-4.2 \times 10^5\ \mathrm{V}}$$

---

18. $\Delta V = 12.0$ V

$C = 6.0$ pF

$$Q = C\Delta V = (6.0 \times 10^{-12}\ \mathrm{F})(12.0\ \mathrm{V}) = 7.2 \times 10^{-11}\ \mathrm{C}$$

$$Q = \boxed{\pm 7.2 \times 10^{-11}\ \mathrm{C}}$$

---

19. $C_1 = 25\ \mu F$

$C_2 = 5.0\ \mu F$

$\Delta V = 120$ V

$$PE_1 = \tfrac{1}{2}C_1(\Delta V)^2 = (0.5)(25 \times 10^{-6}\ \mathrm{F})(120\ \mathrm{V})^2 = 0.18\ \mathrm{J}$$

$$PE_2 = \tfrac{1}{2}C_2(\Delta V)^2 = (0.5)(5.0 \times 10^{-6}\ \mathrm{F})(120\ \mathrm{V})^2 = 3.6 \times 10^{-2}\ \mathrm{J}$$

$$PE_{tot} = PE_1 + PE_2 = 0.18\ \mathrm{J} + (3.6 \times 10^{-2}\ \mathrm{J}) = \boxed{0.22\ \mathrm{J}}$$

---

32. $\Delta Q = 10.0$ C

$I = 5.0$ A

$$\Delta t = \frac{\Delta Q}{I} = \frac{10.0\ \mathrm{C}}{5.0\ \mathrm{A}} = \boxed{2.0\ \mathrm{s}}$$

---

33. $I = 9.1$ A

$\Delta Q = 1.9 \times 10^3$ C

$q_e = 1.60 \times 10^{-19}$ C

a. $$\Delta t = \frac{\Delta Q}{I} = \frac{1.9 \times 10^3\ \mathrm{C}}{9.1\ \mathrm{A}} = 2.1 \times 10^2\ \mathrm{s} = \boxed{3.5\ \mathrm{min}}$$

b. $$N = \frac{\Delta Q}{1.60 \times 10^{-19}\ \mathrm{C/electron}} = \frac{1.9 \times 10^3\ \mathrm{C}}{1.60 \times 10^{-19}\ \mathrm{C/electron}} = \boxed{1.2 \times 10^{22}\ \mathrm{electrons}}$$

---

40. $R = 15\ \Omega$

$\Delta V = 3.0$ V

$$I = \frac{\Delta V}{R} = \frac{3.0\ \mathrm{V}}{15\ \Omega} = \boxed{0.20\ \mathrm{A}}$$

---

41. $R = 35\ \Omega$

$\Delta V = 120$ V

$$I = \frac{\Delta V}{R} = \frac{120\ \mathrm{V}}{35\ \Omega} = \boxed{3.4\ \mathrm{A}}$$

Givens | *Solutions*

42. $\Delta V = 9.0 \text{ V}$

$R_1 = 5.0\ \Omega$

a. $I_1 = \frac{\Delta V}{R_1} = \frac{9.0 \text{ V}}{5.0\ \Omega} = \boxed{1.8 \text{ A}}$

$R_2 = 2.0\ \Omega$

b. $I_2 = \frac{\Delta V}{R_2} = \frac{9.0 \text{ V}}{2.0\ \Omega} = \boxed{4.5 \text{ A}}$

$R_3 = 20.0\ \Omega$

c. $I_3 = \frac{\Delta V}{R_3} = \frac{9.0 \text{ V}}{20.0\ \Omega} = \boxed{0.45 \text{ A}}$

---

53. $P/\text{clock} = 2.5 \text{ W}$

$N = 2.5 \times 10^8 \text{ clocks}$

$\Delta t = 1.0 \text{ year}$

$E = P\Delta t = (P/\text{clock})N\Delta t$

$E = (2.5 \text{ W})(2.5 \times 10^8)(1.0 \text{ year})(365.25 \text{ d/year})(24 \text{ h/d})(3600 \text{ s/h})$

$E = \boxed{2.0 \times 10^{16} \text{ J}}$

---

55. $\Delta V = 110 \text{ V}$

$P = 130 \text{ W}$

$$R = \frac{(\Delta V)^2}{P} = \frac{(110 \text{ V})^2}{130 \text{ W}} = \boxed{93\ \Omega}$$

---

56. $\Delta V = 120 \text{ V}$

$P = 75 \text{ W}$

$$I = \frac{P}{\Delta V} = \frac{75 \text{ W}}{120 \text{ V}} = \boxed{0.62 \text{ A}}$$

$$R = \frac{P}{I^2} = \frac{75 \text{ W}}{(0.62 \text{ A})^2} = \boxed{190\ \Omega}$$

---

57. $\Delta V = 600.0 \text{ V}$

$E = 200.0 \text{ N/C}$

$$\frac{\Delta V}{E} = \frac{\frac{k_C q}{r}}{\frac{k_C q}{r^2}} = r$$

$$r = \frac{\Delta V}{E} = \frac{600.0 \text{ V}}{200.0 \text{ N/C}} = \boxed{3.000 \text{ m}}$$

$$q = \frac{\Delta V r}{k_C} = \frac{(600.0 \text{ V})(3.000 \text{ m})}{8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2} = \boxed{2.00 \times 10^{-7} \text{ C}}$$

---

58. $d = 3.0 \text{ mm}$

$E = 3.0 \times 10^6 \text{ N/C}$

$Q = -1.0\ \mu\text{C}$

$$C = \frac{\varepsilon_0 A}{d} = \frac{Q}{\Delta V} = \frac{Q}{-E\Delta d}$$

$$-\varepsilon_0 AE\Delta d = Qd$$

$$A = \frac{-Q}{\varepsilon_0 E}$$

$$A = \pi r^2$$

$$r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{-Q}{\varepsilon_0 E\pi}} = \sqrt{\frac{-(-1.0 \times 10^{-6} \text{ C})}{(8.85 \times 10^{-12} \text{ C}^2/\text{N}\bullet\text{m}^2)(3.0 \times 10^6 \text{ N/C})(\pi)}}$$

$$r = \boxed{0.11 \text{ m}}$$

---

59. $\Delta V = 12 \text{ V}$

$\Delta d = 0.30 \text{ cm}$

$$E = \frac{\Delta V}{\Delta d} = \frac{12 \text{ V}}{0.30 \times 10^{-2} \text{ m}} = \boxed{4.0 \times 10^3 \text{ V/m}}$$

I

Givens	*Solutions*

60. $A = 5.00\ \text{cm}^2$

$d = 1.00\ \text{mm}$

$Q = 400.0\ \text{pC}$

a. $\Delta V = \dfrac{Q}{C}$

$C = \dfrac{\varepsilon_0 A}{d}$

$$\Delta V = \frac{Q}{\dfrac{\varepsilon_0 A}{d}} = \frac{Qd}{\varepsilon_0 A} = \frac{(400.0 \times 10^{-12}\ \text{C})(1.00 \times 10^{-3}\ \text{m})}{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(5.00 \times 10^{-4}\ \text{m}^2)} = \boxed{90.4\ \text{V}}$$

b. $E = \dfrac{\Delta V}{\Delta d} = \dfrac{90.4\ \text{V}}{1.00 \times 10^{-3}\ \text{m}} = \boxed{9.04 \times 10^4\ \text{V/m}}$

---

61. $\Delta V = 25\ 700\ \text{V}$

$v_i = 0\ \text{m/s}$

$q = 1.60 \times 10^{-19}\ \text{C}$

$m_p = 1.673 \times 10^{-27}\ \text{kg}$

a. $KE_f = \Delta PE = q\Delta V = (1.60 \times 10^{-19}\ \text{C})(25\ 700\ \text{V}) = \boxed{4.11 \times 10^{-15}\ \text{J}}$

b. $v_f = \sqrt{\dfrac{2KE_f}{m_p}} = \sqrt{\dfrac{(2)(4.11 \times 10^{-15}\ \text{J})}{1.673 \times 10^{-27}\ \text{kg}}} = \boxed{2.22 \times 10^6\ \text{m/s}}$

---

62. $\Delta V = 120\ \text{V}$

$v_i = 0\ \text{m/s}$

$m_p = 1.673 \times 10^{-27}\ \text{kg}$

$q = 1.60 \times 10^{-19}\ \text{C}$

$KE_f = \Delta PE = q\Delta V$

$\frac{1}{2} m_p v_f^2 = q\Delta V$

$v_f = \sqrt{\dfrac{2q\Delta V}{m_p}} = \sqrt{\dfrac{(2)(1.60 \times 10^{-19}\ \text{C})(120\ \text{V})}{1.673 \times 10^{-27}\ \text{kg}}} = \boxed{1.5 \times 10^5\ \text{m/s}}$

---

63. $\Delta d = 5.33\ \text{mm}$

$\Delta V = 600.0\ \text{V}$

$q = -1.60 \times 10^{-19}\ \text{C}$

a. $E = \dfrac{\Delta V}{\Delta d} = \dfrac{600.0\ \text{V}}{5.33 \times 10^{-3}\ \text{m}} = \boxed{1.13 \times 10^5\ \text{V/m}}$

b. $F = qE = (-1.60 \times 10^{-19}\ \text{C})(1.13 \times 10^5\ \text{V/m}) = -1.81 \times 10^{-14}\ \text{N}$

$F = \boxed{1.81 \times 10^{-14}\ \text{N}}$

$\Delta d = (5.33\ \text{mm} - 2.90\ \text{mm})$
$= 2.43\ \text{mm}$

c. $\Delta PE = -qEd = -(-1.60 \times 10^{-19}\ \text{C})(1.13 \times 10^5\ \text{V/m})(2.43 \times 10^{-3}\ \text{m})$

$\Delta PE = \boxed{4.39 \times 10^{-17}\ \text{J}}$

Givens | *Solutions*

64. $q_1 = 5.0 \times 10^{-9}$ C

$q_2 = -5.0 \times 10^{-9}$ C

$q_3 = -5.0 \times 10^{-9}$ C

$r_{1,2} = r_{1,3} = 4.0$ cm

$r_{2,3} = 2.0$ cm

$$r_1^2 + (0.010\text{ m})^2 = (0.040\text{ m})^2$$

$$r_1 = \sqrt{(0.040\text{ m})^2 - (0.010\text{ m})^2}$$

$$V_1 = \frac{k_C q_1}{r_1} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(5.0 \times 10^{-9}\text{ C})}{\sqrt{(0.040\text{ m})^2 - (0.010\text{ m})^2}}$$

$$V_1 = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(5.0 \times 10^{-9}\text{ C})}{\sqrt{(1.6 \times 10^{-3}\text{ m}^2) - (1.0 \times 10^{-4}\text{ m}^2)}}$$

$$V_1 = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(5.0 \times 10^{-9}\text{ C})}{\sqrt{1.5 \times 10^{-3}\text{ m}^2}} = 1200\text{ V}$$

$$r_2 = r_3 = \frac{0.020\text{ m}}{2} = 0.010\text{ m}$$

$$V_2 = \frac{k_C q_2}{r_2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(-5.0 \times 10^{-9}\text{ C})}{0.010\text{ m}} = -4500\text{ V}$$

$$V_3 = \frac{k_C q_3}{r_3} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(-5.0 \times 10^{-9}\text{ C})}{0.010\text{ m}} = -4500\text{ V}$$

$$V_{tot} = V_1 + V_2 + V_3 = (1200\text{ V}) + (-4500\text{ V}) + (-4500\text{ V}) = \boxed{-7800\text{ V}}$$

---

65. $q_1 = -3.00 \times 10^{-9}$ C at the origin

$q_2 = 8.00 \times 10^{-9}$ C at $x = 2.00$ m, $y = 0.00$ m

For the location between the two charges,

$$V_{tot} = V_1 + V_2 = 0\text{ V}$$

$$V_1 = -V_2 \qquad V_1 = \frac{k_C q_1}{P}$$

$$V_2 = \frac{k_C q_2}{(2.00\text{ m} - P)}$$

$$\frac{k_C q_1}{P} = \frac{-k_C q_2}{(2.00\text{ m} - P)}$$

$$-Pq_2 = (2.00\text{ m} - P)(q_1)$$

$$-Pq_2 = (2.00\text{ m})(q_1) - Pq_1$$

$$P(q_1 - q_2) = (2.00\text{ m})(q_1)$$

$$P = \frac{(2.00\text{ m})(q_1)}{q_1 - q_2} = \frac{(2.00\text{ m})(-3.00 \times 10^{-9}\text{ C})}{(-3.00 \times 10^{-9}\text{ C}) - (8.00 \times 10^{-9}\text{ C})} = 0.545\text{ m}$$

P is 0.545 m to the right of the origin, at $x = \boxed{0.545\text{ m}}$.

For the location to the left of the y-axis,

$$V_1 = \frac{k_C q_1}{P}$$

$$V_2 = \frac{k_C q_2}{(2.00\text{ m} + P)}$$

$$\frac{k_C q_1}{P} = \frac{-k_C q_2}{(2.00\text{ m} + P)}$$

$$-Pq_2 = (2.00\text{ m} + P)(q_1)$$

$$-Pq_2 = (2.00\text{ m})(q_1) + Pq_1$$

$$P(q_1 + q_2) = -(2.00\text{ m})(q_1)$$

$$P = \frac{-(2.00\text{ m})(q_1)}{q_1 + q_2} = \frac{-(2.00\text{ m})(-3.00 \times 10^{-9}\text{ C})}{(-3.00 \times 10^{-9}\text{ C}) + (8.00 \times 10^{-9}\text{ C})} = 1.20\text{ m}$$

P is 1.20 m to the left of the origin, at $x = \boxed{-1.20\text{ m}}$.

Givens	*Solutions*
66. $\Delta V = 60.0\ \text{V}$ $\Delta PE = 1.92 \times 10^{-17}\ \text{J}$	$q = \dfrac{\Delta PE}{\Delta V} = \dfrac{1.92 \times 10^{-17}\ \text{J}}{60.0\ \text{V}} = \boxed{3.20 \times 10^{-19}\ \text{C}}$
67. $\Delta V = 4.5 \times 10^{6}\ \text{V}$ $v_i = 0\ \text{m/s}$ $q = 1.60 \times 10^{-19}\ \text{C}$ $m_p = 1.673 \times 10^{-27}\ \text{kg}$	**a.** $KE_f = \Delta PE = \Delta Vq = (4.5 \times 10^{6}\ \text{V})(1.60 \times 10^{-19}\ \text{C}) = \boxed{7.2 \times 10^{-13}\ \text{J}}$ **b.** $v_f = \sqrt{\dfrac{2KE_f}{m_p}} = \sqrt{\dfrac{(2)(7.2 \times 10^{-13}\ \text{J})}{1.673 \times 10^{-27}\ \text{kg}}} = \boxed{2.9 \times 10^{7}\ \text{m/s}}$
68. $C = 3750\ \text{pF}$ $Q = 1.75 \times 10^{-8}\ \text{C}$ $d = 6.50 \times 10^{-4}\ \text{m}$	**a.** $\Delta V = \dfrac{Q}{C} = \dfrac{1.75 \times 10^{-8}\ \text{C}}{3750 \times 10^{-12}\ \text{F}} = \boxed{4.67\ \text{V}}$ **b.** $E = \dfrac{\Delta V}{d} = \dfrac{4.67\ \text{V}}{6.50 \times 10^{-4}\ \text{m}} = \boxed{7180\ \text{V/m}}$
69. $\Delta Q = 45\ \text{mC}$ $\Delta t_1 = 15\ \text{s}$ $\Delta t_2 = 1.0\ \text{min}$	**a.** $I = \dfrac{\Delta Q}{\Delta t_1} = \dfrac{45 \times 10^{-3}\ \text{C}}{15\ \text{s}} = \boxed{3.0 \times 10^{-3}\ \text{A}}$ **b.** $N = \dfrac{I\Delta t_2}{1.60 \times 10^{-19}\ \text{C/electron}} = \dfrac{(3.0 \times 10^{-3}\ \text{A})(1.0\ \text{min})(60\ \text{s/min})}{1.60 \times 10^{-19}\ \text{C/electron}}$ $N = \boxed{1.1 \times 10^{18}\ \text{electrons}}$
70. $I = 2.0 \times 10^{5}\ \text{A}$ $\Delta t = 0.50\ \text{s}$	$\Delta Q = I\Delta t = (2.0 \times 10^{5}\ \text{A})(0.50\ \text{s}) = \boxed{1.0 \times 10^{5}\ \text{C}}$
71. $I = 80.0\ \mu\text{A}$ $R_1 = 4.0 \times 10^{5}\ \Omega$ $R_2 = 2.0 \times 10^{3}\ \Omega$	**a.** $\Delta V_1 = IR_1 = (80.0 \times 10^{-6}\ \text{A})(4.0 \times 10^{5}\ \Omega) = \boxed{32\ \text{V}}$ **b.** $\Delta V_2 = IR_2 = (80.0 \times 10^{-6}\ \text{A})(2.0 \times 10^{3}\ \Omega) = \boxed{0.16\ \text{V}}$
72. $P = 325\ \text{W}$ $\Delta V = 120\ \text{V}$	$I = \dfrac{P}{\Delta V} = \dfrac{325\ \text{W}}{120\ \text{V}} = \boxed{2.7\ \text{A}}$
73. $\Delta V = 4.0\ \text{MV}$ $I = 25\ \text{mA}$	$P = I\Delta V = (25 \times 10^{-3}\ \text{A})(4.0 \times 10^{6}\ \text{V}) = \boxed{1.0 \times 10^{5}\ \text{W}}$
74. $m_{atom} = 3.27 \times 10^{-25}\ \text{kg}$ $m_{tot} = 1.25\ \text{kg}$ $\Delta t = 2.78\ \text{h}$ $Q_{atom} = 1.60 \times 10^{-19}\ \text{C}$	$\Delta Q = (\text{number of atoms})(Q_{atom}) = \left(\dfrac{m_{tot}}{m_{atom}}\right)(Q_{atom})$ $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{\left(\dfrac{m_{tot}}{m_{atom}}\right)(Q_{atom})}{\Delta t}$ $I = \dfrac{\left(\dfrac{1.25\ \text{kg}}{3.27 \times 10^{-25}\ \text{kg}}\right)(1.60 \times 10^{-19}\ \text{C})}{(2.78\ \text{h})(3600\ \text{s/h})} = \boxed{61.1\ \text{A}}$

Givens	Solutions
75. $P = 90.0$ W $\Delta V = 120$ V $\Delta t = 1.0$ h	$E = P\Delta t = (90.0 \text{ W})(1.0 \text{ h})(3600 \text{ s/h}) = \boxed{3.2 \times 10^5 \text{ J}}$
76. $I = 2.5$ A $\Delta V = 120$ V $E = 3.2 \times 10^5$ J	$\Delta t = \dfrac{E}{P} = \dfrac{E}{I\Delta V} = \dfrac{3.2 \times 10^5 \text{ J}}{(2.5 \text{ A})(120 \text{ V})} = \boxed{1.1 \times 10^3 \text{ s}}$ or $(1.1 \times 10^3 \text{ s})(1 \text{ min}/60 \text{ s}) = \boxed{18 \text{ min}}$
77. $P = 80.0$ W $\Delta V = 12.0$ V $Q = 90.0$ A•h	$\Delta t = \dfrac{Q}{I} = \dfrac{Q\Delta V}{P} = \dfrac{(90.0 \text{ A•h})(12.0 \text{ V})}{80.0 \text{ W}} = \boxed{13.5 \text{ h}}$
78. $\Delta t = 5.0$ s	**a.** $\Delta Q = I\Delta t = (2 \text{ A})(2 \text{ s}) + (4 \text{ A})(1 \text{ s}) + (6 \text{ A})(1 \text{ s}) + (4 \text{ A})(1 \text{ s})$ $\Delta Q = 4 \text{ C} + 4 \text{ C} + 6 \text{ C} + 4 \text{ C} = \boxed{18 \text{ C}}$ **b.** $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{18 \text{ C}}{5.0 \text{ s}} = \boxed{3.6 \text{ A}}$
79. $I = 50.0$ A $R/d = 1.12 \times 10^{-5}$ Ω/m $d = 4.0$ cm	$\Delta V = IR = (50.0 \text{ A})(1.12 \times 10^{-5} \text{ }\Omega\text{/m})(4.0 \times 10^{-2} \text{ m}) = \boxed{2.2 \times 10^{-5} \text{ V}}$
80. $\Delta V = 12$ V $E = 2.0 \times 10^7$ J $P = 8.0$ kW $v = 20.0$ m/s	**a.** $I = \dfrac{P}{\Delta V} = \dfrac{8.0 \times 10^3 \text{ W}}{12 \text{ V}} = \boxed{670 \text{ A}}$ **b.** $\Delta t = \dfrac{E}{P}$ $\Delta x = v\Delta t = v\left(\dfrac{E}{P}\right) = \dfrac{(20.0 \text{ m/s})(2.0 \times 10^7 \text{ J})}{8.0 \times 10^3 \text{ W}} = \boxed{5.0 \times 10^4 \text{ m}}$

Electrical Energy and Current, Alternative Assessment

Givens	Solutions
1. $v_{f,1} = 10^7$ m/s $q = 1.60 \times 10^{-19}$ C $m_e = 9.109 \times 10^{-31}$ kg $v_{f,2} = 100$ m/s	$\Delta V_1 = \dfrac{\Delta PE}{q} = \dfrac{KE_{f1}}{q} = \dfrac{\frac{1}{2}m_e v_{f1}^2}{q}$ $\Delta V_1 = \dfrac{(9.109 \times 10^{-31} \text{ kg})(10^7 \text{ m/s})^2}{2(1.60 \times 10^{-19} \text{ C})}$ $\Delta V_1 = \boxed{300 \text{ V}}$ $\Delta V_2 = \dfrac{\Delta PE}{q} = \dfrac{KE_{f2}}{q} = \dfrac{\frac{1}{2}m_e v_{f2}^2}{q}$ $\Delta V_1 = \dfrac{(9.109 \times 10^{-31} \text{ kg})(100 \text{ m/s})^2}{2(1.60 \times 10^{-19} \text{ C})}$ $\Delta V_1 = \boxed{3 \times 10^{-8} \text{ V}}$

Givens | *Solutions*

I

3. $q = 1.6 \times 10^{-19}$ C
$d = 2.0 \times 10^{-6}$ m
$E = 2.0$ N/C

$\Delta PE_{electric} = -qEd = -(1.6 \times 10^{-19}\text{ C})(2.0\text{ N/C})(2.0 \times 10^{-6}\text{ m})$

$\Delta PE_{electric} = \boxed{-6.4 \times 10^{-25}\text{ N•m} = -6.4 \times 10^{-25}\text{ J}}$

4. $d = 2.0 \times 10^{-6}$ m
$E = 2.0$ N/C

$\Delta V = -Ed = -(2.0\text{ N/C})(2.0 \times 10^{-6}\text{ m})$

$\Delta V = \boxed{-4.0 \times 10^{-6}\text{ V}}$

7. $\Delta V = 10.0$ V
$Q = 40.0\ \mu\text{C} = 40.0 \times 10^{-6}$ C

$$C = \frac{Q}{\Delta V} = \frac{(40.0 \times 10^{-6}\text{ C})}{(10.0\text{ V})}$$

$C = \boxed{4.00 \times 10^{-6}\text{ F}}$

8. $\Delta V = 10.0$ V
$Q = 40.0\ \mu C = 40.0 \times 10^{-6}$ C

$PE_{electric} = \frac{1}{2}Q\Delta V = \frac{1}{2}(40.0 \times 10^{-6}\text{ C})(10.0\text{ V})$

$PE_{electric} = \boxed{2.00 \times 10^{-4}\text{ J}}$

9. $I = 5.0$ A
$\Delta Q = 5.0$ C

$$\Delta t = \frac{\Delta Q}{I} = \frac{5.0\text{ C}}{5.0\text{ A}} = \boxed{1.0\text{ s}}$$

10. $\Delta V = 12$ V
$I = 0.40$ A

$$R = \frac{\Delta V}{I} = \frac{12\text{ V}}{0.40\text{ A}} = \boxed{3.0 \times 10^{1}\ \Omega}$$

11. $P = 50.0$ W
$\Delta t = 2.00$ s

$E = P\Delta t = (50.0\text{ W})(2.00\text{ s})$

$E = \boxed{1.00 \times 10^{2}\text{ J}}$

12. $I = 7.0$ A
$\Delta V = 115$ V

$P = I\Delta V = (7.0\text{ A})(115\text{ V}) = \boxed{8.0 \times 10^{2}\text{ W}}$

Givens	*Solutions*
16. $r = \frac{2.50 \times 10^{-3}\ \text{m}}{2}$ $d = 1.40 \times 10^{-4}\ \text{m}$	**a.** $C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 \pi r^2}{d} = \frac{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(\pi)(2.50 \times 10^{-3}\ \text{m}/2)^2}{1.40 \times 10^{-4}\ \text{m}}$ $C = \boxed{3.10 \times 10^{-13}\ \text{F}}$
$\Delta V_1 = 0.12\ \text{V}$	**b.** $Q = C\Delta V_1 = (3.10 \times 10^{-13}\ \text{F})(0.12\ \text{V}) = \boxed{3.7 \times 10^{-14}\ \text{C}}$
	c. $PE_{electric} = \frac{1}{2}Q\Delta V_1 = (0.5)(3.7 \times 10^{-14}\ \text{C})(0.12\ \text{V}) = \boxed{2.2 \times 10^{-15}\ \text{J}}$
$\Delta d_1 = 1.40 \times 10^{-4}\ \text{m}$	**d.** $\Delta V_1 = E\Delta d_1$ $E = \frac{\Delta V_1}{\Delta d_1} = \frac{0.12\ \text{V}}{1.40 \times 10^{-4}\ \text{m}} = 860\ \text{V/m}$ $\Delta d_2 = 1.10 \times 10^{-4}\ \text{m} - \left(\frac{1.40 \times 10^{-4}\ \text{m}}{2}\right) = 4.00 \times 10^{-5}\ \text{m}$ $\Delta V_2 = E\Delta d_2 = (860\ \text{V/m})(4.00 \times 10^{-5}\ \text{m}) = \boxed{3.4 \times 10^{-2}\ \text{V}}$
$Q_2 = (0.707)Q$	**e.** $\Delta V_3 = \frac{Q_2}{C}$ Because the capacitance has not changed, $\Delta V_3 = (0.707)(\Delta V_1)$. $\Delta V_3 = (0.707)(\Delta V_1) = (0.707)(0.12\ \text{V}) = \boxed{8.5 \times 10^{-2}\ \text{V}}$

I

Circuits and Circuit Elements

Circuits and Circuit Elements, Practice A

Givens	*Solutions*
1. $R_1 = 6.75\ \Omega$ $R_2 = 15.3\ \Omega$ $R_3 = 21.6\ \Omega$ $\Delta V = 12.0\ \text{V}$	**a.** $R_{eq} = R_1 + R_2 + R_3$ $R_{eq} = 6.75\ \Omega + 15.3\ \Omega + 21.6\ \Omega = \boxed{43.6\ \Omega}$ **b.** $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{12.0\ \text{V}}{43.6\ \Omega} = \boxed{0.275\ \text{A}}$
2. $R_1 = 4.0\ \Omega$ $R_2 = 8.0\ \Omega$ $R_3 = 12.0\ \Omega$ $\Delta V = 24.0\ \text{V}$	**a.** $R_{eq} = R_1 + R_2 + R_3 = 4.0\ \Omega + 8.0\ \Omega + 12.0\ \Omega = \boxed{24.0\ \Omega}$ **b.** $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{24.0\ \text{V}}{24.0\ \Omega} = \boxed{1.00\ \text{A}}$ **c.** $I = \boxed{1.00\ \text{A}}$
3. $I = 0.50\ \text{A}$ $R_1 = 2.0\ \Omega$ $R_2 = 4.0\ \Omega$ $R_3 = 5.0\ \Omega$ $R_4 = 7.0\ \Omega$	$\Delta V_1 = IR_1 = (0.50\ \text{A})(2.0\ \Omega) = \boxed{1.0\ \text{V}}$ $\Delta V_2 = IR_2 = (0.50\ \text{A})(4.0\ \Omega) = \boxed{2.0\ \text{V}}$ $\Delta V_3 = IR_3 = (0.50\ \text{A})(5.0\ \Omega) = \boxed{2.5\ \text{V}}$ $\Delta V_4 = IR_4 = (0.50\ \text{A})(7.0\ \Omega) = \boxed{3.5\ \text{V}}$
4. $\Delta V = 9.00\ \text{V}$ $R_1 = 7.25\ \Omega$ $R_2 = 4.03\ \Omega$	**a.** $R_{eq} = R_1 + R_2 = 7.25\ \Omega + 4.03\ \Omega = \boxed{11.28\ \Omega}$ $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{9.00\ \text{V}}{11.28\ \Omega} = \boxed{0.798\ \text{A}}$ **b.** $\Delta V_1 = IR_1 = (0.798\ \text{A})(7.25\ \Omega) = \boxed{5.79\ \text{V}}$ $\Delta V_2 = IR_2 = (0.798\ \text{A})(4.03\ \Omega) = \boxed{3.22\ \text{V}}$
5. $R_1 = 7.0\ \Omega$ $\Delta V = 4.5\ \text{V}$ $I = 0.60\ \text{A}$	$R_{eq} = R_1 + R_2 = \dfrac{\Delta V}{I}$ $R_2 = \dfrac{\Delta V}{I} - R_1 = \dfrac{4.5\ \text{V}}{0.60\ \text{A}} - 7.0\ \Omega$ $R_2 = 7.5\ \Omega - 7.0\ \Omega = \boxed{0.5\ \Omega}$
6. $\Delta V = 115\ \text{V}$ $I = 1.70\ \text{A}$ $R = 1.50\ \Omega$	**a.** $R_{eq} = \dfrac{\Delta V}{I} = \dfrac{115\ \text{V}}{1.70\ \text{A}} = \boxed{67.6\ \Omega}$ **b.** $NR = R_{eq}$ $N = \dfrac{R_{eq}}{R} = \dfrac{67.6\ \Omega}{1.50\ \Omega} = \boxed{45\ \text{bulbs}}$

Circuits and Circuit Elements, Practice B

Givens | *Solutions*

1. $\Delta V = 9.0 \text{ V}$

$R_1 = 2.0\ \Omega$

$R_2 = 4.0\ \Omega$

$R_3 = 5.0\ \Omega$

$R_4 = 7.0\ \Omega$

$$I_1 = \frac{\Delta V}{R_1} = \frac{9.0 \text{ V}}{2.0\ \Omega} = \boxed{4.5 \text{ A}}$$

$$I_2 = \frac{\Delta V}{R_2} = \frac{9.0 \text{ V}}{4.0\ \Omega} = \boxed{2.2 \text{ A}}$$

$$I_3 = \frac{\Delta V}{R_3} = \frac{9.0 \text{ V}}{5.0\ \Omega} = \boxed{1.8 \text{ A}}$$

$$I_4 = \frac{\Delta V}{R_4} = \frac{9.0 \text{ V}}{7.0\ \Omega} = \boxed{1.3 \text{ A}}$$

2. $R_{eq} = 2.00\ \Omega$

Parallel: $R_{eq} = \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} = \left(\frac{5}{R}\right)^{-1}$

$R = 5R_{eq} = 5(2.00\ \Omega) = 10.0\ \Omega$

Series: $R_{eq} = 5R = 5(10.0\ \Omega) = \boxed{50.0\ \Omega}$

3. $R_1 = 4.0\ \Omega$

$R_2 = 8.0\ \Omega$

$R_3 = 12.0\ \Omega$

$\Delta V = 24.0 \text{ V}$

a. $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{4.0\ \Omega} + \frac{1}{8.0\ \Omega} + \frac{1}{12.0\ \Omega}\right)^{-1}$

$R_{eq} = \left(0.25\ \frac{1}{\Omega} + 0.12\ \frac{1}{\Omega} + 0.0833\ \frac{1}{\Omega}\right)^{-1} = \left(0.45\ \frac{1}{\Omega}\right)^{-1}$

$R_{eq} = \boxed{2.2\ \Omega}$

b. $I_1 = \frac{\Delta V}{R_1} = \frac{24.0 \text{ V}}{4.0\ \Omega} = \boxed{6.0 \text{ A}}$

$I_2 = \frac{\Delta V}{R_2} = \frac{24.0 \text{ V}}{8.0\ \Omega} = \boxed{3.0 \text{ A}}$

$I_3 = \frac{\Delta V}{R_3} = \frac{24.0 \text{ V}}{12.0\ \Omega} = \boxed{2.00 \text{ A}}$

4. $R_1 = 18.0\ \Omega$

$R_2 = 9.00\ \Omega$

$R_3 = 6.00\ \Omega$

$I_2 = 4.00 \text{ A}$

a. $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{18.0\ \Omega} + \frac{1}{9.00\ \Omega} + \frac{1}{6.00\ \Omega}\right)^{-1}$

$R_{eq} = \left(0.0555\ \frac{1}{\Omega} + 0.111\ \frac{1}{\Omega} + 0.167\ \frac{1}{\Omega}\right)^{-1} = \left(0.334\ \frac{1}{\Omega}\right)^{-1}$

$R_{eq} = \boxed{2.99\ \Omega}$

b. $\Delta V = I_2 R_2 = (4.00 \text{ A})(9.00\ \Omega) = \boxed{36.0 \text{ V}}$

c. $I_1 = \frac{\Delta V}{R_1} = \frac{36.0 \text{ V}}{18.0\ \Omega} = \boxed{2.00 \text{ A}}$

$I_3 = \frac{\Delta V}{R_3} = \frac{36.0 \text{ V}}{6.00\ \Omega} = \boxed{6.00 \text{ A}}$

Circuits and Circuit Elements, Section 2 Review

Givens	*Solutions*
4. $R_1 = 2.0\ \Omega$ $R_2 = 4.0\ \Omega$ $\Delta V = 12\ \text{V}$	**a.** $R_{eq} = R_1 + R_2 = 2.0\ \Omega + 4.0\ \Omega = 6.0\ \Omega$ $I_1 = I_2 = I = \dfrac{\Delta V}{R_{eq}} = \dfrac{12\ \text{V}}{6.0\ \Omega} = \boxed{2.0\ \text{A}}$ $\Delta V_1 = I_1 R_1 = (2.0\ \text{A})(2.0\ \Omega) = \boxed{4.0\ \text{V}}$ $\Delta V_2 = I_2 R_2 = (2.0\ \text{A})(4.0\ \Omega) = \boxed{8.0\ \text{V}}$
$R_1 = 2.0\ \Omega$ $R_2 = 4.0\ \Omega$ $\Delta V = 12\ \text{V}$	**b.** $R_{eq} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)^{-1} = \left(\dfrac{1}{2.0\ \Omega} + \dfrac{1}{4.0\ \Omega}\right)^{-1}$ $R_{eq} = \left(0.50\ \dfrac{1}{\Omega} + 0.25\ \dfrac{1}{\Omega}\right)^{-1} = \left(0.75\ \dfrac{1}{\Omega}\right)^{-1} = 1.3\ \Omega$ $\Delta V_1 = \Delta V_2 = \Delta V = \boxed{12\ \text{V}}$ $I_1 = \dfrac{\Delta V_1}{R_1} = \dfrac{12\ \text{V}}{2.0\ \Omega} = \boxed{6.0\ \text{A}}$ $I_2 = \dfrac{\Delta V_2}{R_2} = \dfrac{12\ \text{V}}{4.0\ \Omega} = \boxed{3.0\ \text{A}}$

Circuits and Circuit Elements, Practice C

1. $R_a = 25.0\ \Omega$ $R_b = 3.0\ \Omega$ $R_c = 40.0\ \Omega$	**a.** $R_{bc} = \left(\dfrac{1}{R_b} + \dfrac{1}{R_c}\right)^{-1} = \left(\dfrac{1}{3.0\ \Omega} + \dfrac{1}{40.0\ \Omega}\right)^{-1}$ $R_{bc} = \left(0.33\ \dfrac{1}{\Omega} + 0.0250\ \dfrac{1}{\Omega}\right)^{-1} = \left(0.36\ \dfrac{1}{\Omega}\right)^{-1}$ $R_{bc} = 2.8\ \Omega$ $R_{eq} = R_a + R_{bc} = 25.0\ \Omega + 2.8\ \Omega = \boxed{27.8\ \Omega}$
$R_a = 12.0\ \Omega$ $R_b = 35.0\ \Omega$ $R_c = 25.0\ \Omega$	**b.** $R_{bc} = \left(\dfrac{1}{R_b} + \dfrac{1}{R_c}\right)^{-1} = \left(\dfrac{1}{35.0\ \Omega} + \dfrac{1}{25.0\ \Omega}\right)^{-1}$ $R_{bc} = \left(0.0286\ \dfrac{1}{\Omega} + 0.0400\ \dfrac{1}{\Omega}\right)^{-1} = \left(0.0686\ \dfrac{1}{\Omega}\right)^{-1}$ $R_{bc} = 14.6\ \Omega$ $R_{eq} = R_a + R_{bc} = 12.0\ \Omega + 14.6\ \Omega = \boxed{26.6\ \Omega}$
$R_a = 15.0\ \Omega$ $R_b = 28.0\ \Omega$ $R_c = 12.0\ \Omega$	**c.** $R_{bc} = \left(\dfrac{1}{R_b} + \dfrac{1}{R_c}\right)^{-1} = \left(\dfrac{1}{28.0\ \Omega} + \dfrac{1}{12.0\ \Omega}\right)^{-1}$ $R_{bc} = \left(0.0357\ \dfrac{1}{\Omega} + 0.0833\ \dfrac{1}{\Omega}\right)^{-1} = \left(0.0119\ \dfrac{1}{\Omega}\right)^{-1}$ $R_{bc} = 8.40\ \Omega$ $R_{eq} = R_a + R_{bc} = 15.0\ \Omega + 8.40\ \Omega = \boxed{23.4\ \Omega}$

Givens | *Solutions*

2. $R_a = 25.0\ \Omega$

$R_b = 3.0\ \Omega$

$R_c = 40.0\ \Omega$

$R_d = 15.0\ \Omega$

$R_e = 18.0\ \Omega$

I

a. $$R_{ab} = \left(\frac{1}{R_a} + \frac{1}{R_b}\right)^{-1} = \left(\frac{1}{25.0\ \Omega} + \frac{1}{3.0\ \Omega}\right)^{-1}$$

$$R_{ab} = \left(0.0400\ \frac{1}{\Omega} + 0.33\ \frac{1}{\Omega}\right)^{-1} = \left(0.37\ \frac{1}{\Omega}\right)^{-1}$$

$$R_{ab} = 2.7\ \Omega$$

$$R_{de} = \left(\frac{1}{R_d} + \frac{1}{R_e}\right)^{-1} = \left(\frac{1}{15.0\ \Omega} + \frac{1}{18.0\ \Omega}\right)^{-1}$$

$$R_{de} = \left(0.0667\ \frac{1}{\Omega} + 0.0556\ \frac{1}{\Omega}\right)^{-1} = \left(0.1223\ \frac{1}{\Omega}\right)^{-1}$$

$$R_{de} = 8.177\ \Omega$$

$$R_{eq} = R_{ab} + R_c + R_{de} = 2.7\ \Omega + 40.0\ \Omega + 8.177\ \Omega = \boxed{50.9\ \Omega}$$

$R_a = 12.0\ \Omega$

$R_b = 35.0\ \Omega$

$R_c = 25.0\ \Omega$

$R_d = 50.0\ \Omega$

$R_e = 45.0\ \Omega$

b. $$R_{ab} = \left(\frac{1}{R_a} + \frac{1}{R_b}\right)^{-1} = \left(\frac{1}{12.0\ \Omega} + \frac{1}{35.0\ \Omega}\right)^{-1}$$

$$R_{ab} = \left(0.0833\ \frac{1}{\Omega} + 0.0286\ \frac{1}{\Omega}\right)^{-1} = \left(0.1119\ \frac{1}{\Omega}\right)^{-1}$$

$$R_{ab} = 8.937\ \Omega$$

$$R_{de} = \left(\frac{1}{R_d} + \frac{1}{R_e}\right)^{-1} = \left(\frac{1}{50.0\ \Omega} + \frac{1}{45.0\ \Omega}\right)^{-1}$$

$$R_{de} = \left(0.0200\ \frac{1}{\Omega} + 0.0222\ \frac{1}{\Omega}\right)^{-1} = \left(0.0422\ \frac{1}{\Omega}\right)^{-1}$$

$$R_{de} = 23.7\ \Omega$$

$$R_{eq} = R_{ab} + R_c + R_{de} = 8.937\ \Omega + 25.0\ \Omega + 23.7\ \Omega = \boxed{57.6\ \Omega}$$

Circuits and Circuit Elements, Practice D

Givens

$R_a = 5.0\ \Omega$

$R_b = 7.0\ \Omega$

$R_c = 4.0\ \Omega$

$R_d = 4.0\ \Omega$

$R_e = 4.0\ \Omega$

$R_f = 2.0\ \Omega$

$\Delta V = 14.0$ V

Solutions

$$R_{ab} = R_a + R_b = 5.0\ \Omega + 7.0\ \Omega = 12.0\ \Omega$$

$$R_{abc} = \left(\frac{1}{R_{ab}} + \frac{1}{R_c}\right)^{-1} = \left(\frac{1}{12.0\ \Omega} + \frac{1}{4.0\ \Omega}\right)^{-1}$$

$$R_{abc} = \left(0.0833\ \frac{1}{\Omega} + 0.25\ \frac{1}{\Omega}\right)^{-1} = \left(0.33\ \frac{1}{\Omega}\right)^{-1} = 3.0\ \Omega$$

$$R_{de} = \left(\frac{1}{R_d} + \frac{1}{R_e}\right)^{-1} = \left(\frac{1}{4.0\ \Omega} + \frac{1}{4.0\ \Omega}\right)^{-1}$$

$$R_{de} = \left(0.25\ \frac{1}{\Omega} + 0.25\ \frac{1}{\Omega}\right)^{-1} = \left(0.50\ \frac{1}{\Omega}\right)^{-1} = 2.0\ \Omega$$

$$R_{eq} = R_{abc} + R_{de} + R_f = 3.0\ \Omega + 2.0\ \Omega + 2.0\ \Omega = 7.0\ \Omega$$

$$I = \frac{\Delta V}{R_{eq}} = \frac{14.0\ \text{V}}{7.0\ \Omega} = 2.0\ \text{A}$$

$$\Delta V_{abc} = IR_{abc} = (2.0\ \text{A})(3.0\ \Omega) = 6.0\ \text{V}$$

$$I_{ab} = \frac{\Delta V_{abc}}{R_{ab}} = \frac{6.0\ \text{V}}{12.0\ \Omega} = 0.50\ \text{A}$$

R_a: $I_a = I_{ab} = \boxed{0.50\ \text{A}}$

$\Delta V_a = I_aR_a = (0.50\ \text{A})(5.0\ \Omega) = \boxed{2.5\ \text{V}}$

R_b: $I_b = I_{ab} = \boxed{0.50\ \text{A}}$

$\Delta V_b = I_bR_b = (0.50\ \text{A})(7.0\ \Omega) = \boxed{3.5\ \text{V}}$

R_c: $\Delta V_c = \Delta V_{abc} = \boxed{6.0\ \text{V}}$

$I_c = \dfrac{\Delta V_c}{R_c} = \dfrac{6.0\ \text{V}}{4.0\ \Omega} = \boxed{1.5\ \text{A}}$

$$\Delta V_{de} = IR_{de} = (2.0\ \text{A})(2.0\ \Omega) = 4.0\ \text{V}$$

R_d: $\Delta V_d = \Delta V_{de} = \boxed{4.0\ \text{V}}$

$I_d = \dfrac{\Delta V_d}{R_d} = \dfrac{4.0\ \text{V}}{4.0\ \Omega} = \boxed{1.0\ \text{A}}$

R_e: $\Delta V_e = \Delta V_{de} = \boxed{4.0\ \text{V}}$

$I_e = \dfrac{\Delta V_e}{R_e} = \dfrac{4.0\ \text{V}}{4.0\ \Omega} = \boxed{1.0\ \text{A}}$

R_f: $I_f = I = \boxed{2.0\ \text{A}}$

$\Delta V_f = I_fR_f = (2.0\ \text{A})(2.0\ \Omega) = \boxed{4.0\ \text{V}}$

Circuits and Circuit Elements, Section 3 Review

I

Givens | *Solutions*

1. $R_1 = 5.0\ \Omega$

$R_2 = 5.0\ \Omega$

$R_3 = 5.0\ \Omega$

$R_4 = 5.0\ \Omega$

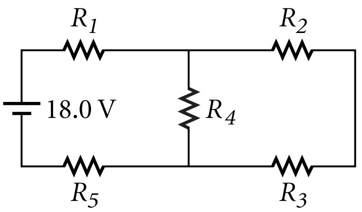
$R_5 = 1.5\ \Omega$

$$R_{23} = R_2 + R_3 = 5.0\ \Omega + 5.0\ \Omega = 10.0\ \Omega$$

$$R_{234} = \left(\frac{1}{R_{23}} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{5.0\ \Omega}\right)^{-1}$$

$$R_{234} = \left(0.100\ \frac{1}{\Omega} + 0.20\ \frac{1}{\Omega}\right)^{-1} = \left(0.30\ \frac{1}{\Omega}\right)^{-1} = 3.3\ \Omega$$

$$R_{eq} = R_1 + R_{234} + R_5 = 5.0\ \Omega + 3.3\ \Omega + 1.5\ \Omega = \boxed{9.8\ \Omega}$$



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2. $R_{eq} = 9.8\ \Omega$

$\Delta V = 18.0\ \text{V}$

$$I_5 = I = \frac{\Delta V}{R_{eq}} = \frac{18.0\ \text{V}}{9.8\ \Omega} = \boxed{1.8\ \text{A}}$$

---

3. $I_5 = 1.8\ \text{A}$

$R_5 = 1.5\ \Omega$

$$\Delta V_5 = I_5 R_5 = (1.8\ \text{A})(1.5\ \Omega) = \boxed{2.7\ \text{V}}$$

---

4. $R = 15.0\ \Omega$

$\Delta V = 120.0\ \text{V}$

$N = 35$ bulbs

$n = 3$ strands

$$R_{eq,\ strand} = NR = (35)(15.0\ \Omega) = 525\ \Omega$$

$$R_{eq} = \left(\frac{1}{R_{eq,\ strand}} + \frac{1}{R_{eq,\ strand}} + \frac{1}{R_{eq,\ strand}}\right)^{-1} = \left(\frac{1}{525\ \Omega} + \frac{1}{525\ \Omega} + \frac{1}{525\ \Omega}\right)^{-1}$$

$$R_{eq} = \left(0.0019\ \frac{1}{\Omega} + 0.0019\ \frac{1}{\Omega} + 0.0019\ \frac{1}{\Omega}\right)^{-1} = \left(0.0057\ \frac{1}{\Omega}\right)^{-1} = \boxed{175\ \Omega}$$

---

5. $\Delta V = 120.0\ \text{V}$

$R_{eq,\ strand} = 525\ \Omega$

$R = 15.0\ \Omega$

$$\Delta V_{strand} = \Delta V = 120.0\ \text{V}$$

$$I_{strand} = \frac{\Delta V_{strand}}{R_{eq,\ strand}} = \frac{120.0\ \text{V}}{525\ \Omega} = \boxed{0.229\ \text{A}}$$

$$\Delta V = I_{strand}R = (0.229\ \text{A})(15.0\ \Omega) = \boxed{3.44\ \text{V}}$$

---

6. $R_{eq,\ strand} = 510.\ \Omega$

$\Delta V = 120.0\ \text{V}$

$R = 15.0\ \Omega$

$$\Delta V_{strand} = \Delta V = 120.0\ \text{V}$$

$$I_{strand} = \frac{\Delta V_{strand}}{R_{eq,\ strand}} = \frac{120.0\ \text{V}}{510.\ \Omega} = \boxed{0.235\ \text{A}}$$

$$\Delta V = I_{strand}R = (0.235\ \text{A})(15.0\ \Omega) = \boxed{3.52\ \text{V}}$$

---

7. $\Delta V = 120\ \text{V}$

$R_T = 16.9\ \Omega$

$R_M = 8.0\ \Omega$

$R_P = 10.0\ \Omega$

$R_C = 0.01\ \Omega$

d. $$R_{TMP} = \left(\frac{1}{R_T} + \frac{1}{R_M} + \frac{1}{R_P}\right)^{-1} = \left(\frac{1}{16.9\ \Omega} + \frac{1}{8.0\ \Omega} + \frac{1}{10.0\ \Omega}\right)^{-1}$$

$$_{TMP} = \left(0.0592\ \frac{1}{\Omega} + 0.12\ \frac{1}{\Omega} + 0.100\ \frac{1}{\Omega}\right)^{-1} = \left(0.28\ \frac{1}{\Omega}\right)^{-1} = 3.6\ \Omega$$

$$R_{eq} = R_{TMP} + R_C = 3.6\ \Omega + 0.01\ \Omega = \boxed{3.6\ \Omega}$$

Givens	*Solutions*
$\Delta V = 120\text{ V}$ $R_{eq} = 3.6\ \Omega$ $R_{TMP} = 3.6\ \Omega$ $R_T = 16.9\ \Omega$	**e.** $I = \frac{\Delta V}{R_{eq}} = \frac{120\text{ V}}{3.6\ \Omega} = 33\text{ A}$ $\Delta V_T = \Delta V_{TMP} = IR_{TMP} = (33\text{ A})(3.6\ \Omega) = 120\text{ V}$ $I_T = \frac{\Delta V_T}{R_T} = \frac{120\text{ V}}{16.9\ \Omega} = \boxed{7.1\text{ A}}$

I

Circuits and Circuit Elements, Chapter Review

16. $R = 0.15\ \Omega$

$R_{eq} = 5R = 5(0.15\ \Omega) = \boxed{0.75\ \Omega}$

17. $R_1 = 4.0\ \Omega$, $R_2 = 8.0\ \Omega$, $R_3 = 12\ \Omega$, $\Delta V = 24\text{ V}$

a. $R_{eq} = R_1 + R_2 + R_3 = 4.0\ \Omega + 8.0\ \Omega + 12\ \Omega = \boxed{24\ \Omega}$

b. $I = \frac{\Delta V}{R_{eq}} = \frac{24\text{ V}}{24\ \Omega} = \boxed{1.0\text{ A}}$

18. $R_1 = 4.0\ \Omega$, $R_2 = 8.0\ \Omega$, $R_3 = 12\ \Omega$, $\Delta V = 24\text{ V}$

a. $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{4.0\ \Omega} + \frac{1}{8.0\ \Omega} + \frac{1}{12\ \Omega}\right)^{-1}$

$R_{eq} = \left(0.25\ \frac{1}{\Omega} + 0.12\ \frac{1}{\Omega} + 0.083\ \frac{1}{\Omega}\right)^{-1} = \left(0.45\ \frac{1}{\Omega}\right)^{-1} = \boxed{2.2\ \Omega}$

b. $I = \frac{\Delta V}{R_{eq}} = \frac{24\text{ V}}{2.2\ \Omega} = \boxed{11\text{ A}}$

19. $R_1 = 18.0\ \Omega$, $R_2 = 9.00\ \Omega$, $R_3 = 6.00\ \Omega$, $\Delta V = 12\text{ V}$

a. $R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{18.0\ \Omega} + \frac{1}{9.00\ \Omega} + \frac{1}{6.00\ \Omega}\right)^{-1}$

$R_{eq} = \left(0.0556\ \frac{1}{\Omega} + 0.111\ \frac{1}{\Omega} + 0.167\ \frac{1}{\Omega}\right)^{-1} = \left(0.334\ \frac{1}{\Omega}\right)^{-1} = \boxed{2.99\ \Omega}$

b. $I = \frac{\Delta V}{R_{eq}} = \frac{12\text{ V}}{2.99\ \Omega} = \boxed{4.0\text{ A}}$

23. $R_1 = 12\ \Omega$, $R_2 = 18\ \Omega$, $R_3 = 9.0\ \Omega$, $R_4 = 6.0\ \Omega$, $\Delta V = 30.0\text{ V}$

$R_{234} = \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{18\ \Omega} + \frac{1}{9.0\ \Omega} + \frac{1}{6.0\ \Omega}\right)^{-1}$

$R_{234} = \left(0.056\ \frac{1}{\Omega} + 0.11\ \frac{1}{\Omega} + 0.17\ \frac{1}{\Omega}\right)^{-1} = \left(0.34\ \frac{1}{\Omega}\right)^{-1} = 2.9\ \Omega$

$R_{eq} = R_1 + R_{234} = 12\ \Omega + 2.9\ \Omega = \boxed{15\ \Omega}$

24. $R_1 = 7.0\ \Omega$, $R_2 = 7.0\ \Omega$, $R_3 = 7.0\ \Omega$, $R_4 = 7.0\ \Omega$, $R_5 = 1.5\ \Omega$, $\Delta V = 12.0\text{ V}$

$R_{34} = R_3 + R_4 = 7.0\ \Omega + 7.0\ \Omega = 14.0\ \Omega$

$R_{234} = \left(\frac{1}{R_2} + \frac{1}{R_{34}}\right)^{-1} = \left(\frac{1}{7.0\ \Omega} + \frac{1}{14.0\ \Omega}\right)^{-1} = \left(0.14\ \frac{1}{\Omega} + 0.0714\ \frac{1}{\Omega}\right)^{-1} = 4.8\ \Omega$

$R_{eq} = R_1 + R_{234} + R_5 = 7.0\ \Omega + 4.8\ \Omega + 1.5\ \Omega = \boxed{13.3\ \Omega}$

I

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25. $R_1 = 6.0\ \Omega$ $R_2 = 9.0\ \Omega$ $R_3 = 3.0\ \Omega$ $\Delta V = 12$ V	Current:

$$\Delta V_{12} = IR_{12} = (1.8\text{ A})(3.6\ \Omega) = 6.5\text{ V}$$

$$I_1 = \frac{\Delta V_{12}}{R_1} = \frac{6.5\text{ V}}{6.0\ \Omega} = \boxed{1.1\text{ A}}$$

$$I_2 = \frac{\Delta V_{12}}{R_2} = \frac{6.5\text{ V}}{9.0\ \Omega} = \boxed{0.72\text{ A}}$$

$$R_{12} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{9.0\ \Omega}\right)^{-1}$$

$$R_{12} = \left(0.17\ \frac{1}{\Omega} + 0.11\ \frac{1}{\Omega}\right)^{-1} = \left(0.28\ \frac{1}{\Omega}\right)^{-1} = 3.6\ \Omega$$

$$R_{eq} = R_{12} + R_3 = 3.6\ \Omega + 3.0\ \Omega = 6.6\ \Omega$$

$$I = \frac{\Delta V}{R_{eq}} = \frac{12\text{ V}}{6.6\ \Omega} = 1.8\text{ A}$$

$$I_3 = \boxed{1.8\text{ A}}$$

Potential difference:

$$\Delta V_1 = \Delta V_2 = \Delta V_{12} = \boxed{6.5\text{ V}}$$

$$\Delta V_3 = I_3R_3 = (1.8\text{ A})(3.0\ \Omega) = \boxed{5.4\text{ V}}$$

---

26. $R_1 = 3.0\ \Omega$, $R_2 = 3.0\ \Omega$, $R_3 = 6.0\ \Omega$, $R_4 = 6.0\ \Omega$, $R_5 = 4.0\ \Omega$, $R_6 = 12.0\ \Omega$, $R_7 = 2.0\ \Omega$, $\Delta V = 18.0$ V

a. $$R_{34} = \left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{6.0\ \Omega}\right)^{-1} = \left(0.17\ \frac{1}{\Omega} + 0.17\ \frac{1}{\Omega}\right)^{-1} = \left(0.34\ \frac{1}{\Omega}\right)^{-1} = 2.9\ \Omega$$

$$R_{234} = R_2 + R_{34} = 3.0\ \Omega + 2.9\ \Omega = 5.9\ \Omega$$

$$R_{56} = \left(\frac{1}{R_5} + \frac{1}{R_6}\right)^{-1} = \left(\frac{1}{4.0\ \Omega} + \frac{1}{12.0\ \Omega}\right)^{-1}$$

$$R_{56} = \left(0.25\ \frac{1}{\Omega} + 0.0833\ \frac{1}{\Omega}\right)^{-1} = \left(0.33\ \frac{1}{\Omega}\right)^{-1} = 3.0\ \Omega$$

$$R_{567} = R_{56} + R_7 = 3.0\ \Omega + 2.0\ \Omega = 5.0\ \Omega$$

$$R_{234567} = \left(\frac{1}{R_{234}} + \frac{1}{R_{567}}\right)^{-1} = \left(\frac{1}{5.9\ \Omega} + \frac{1}{5.0\ \Omega}\right)^{-1}$$

$$R_{234567} = \left(0.17\ \frac{1}{\Omega} + 0.20\ \frac{1}{\Omega}\right)^{-1} = \left(0.37\ \frac{1}{\Omega}\right)^{-1} = 2.7\ \Omega$$

$$R_{eq} = R_1 + R_{234567} = 3.0\ \Omega + 2.7\ \Omega = 5.7\ \Omega$$

$$I = \frac{\Delta V}{R_{eq}} = \frac{18.0\text{ V}}{5.7\ \Omega} = 3.2\text{ A}$$

$$\Delta V_{234567} = IR_{234567} = (3.2\text{ A})(2.7\ \Omega) = 8.6\text{ V}$$

$$I_7 = I_{567} = \frac{\Delta V_{234567}}{R_{567}} = \frac{8.6\text{ V}}{5.0\ \Omega} = \boxed{1.7\text{ A}}$$

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	b. $\Delta V_7 = I_7 R_7 = (1.7\ \text{A})(2.0\ \Omega) = \boxed{3.4\ \text{V}}$
	c. $\Delta V_{56} = I_{567} R_{56} = (1.7\ \text{A})(3.0\ \Omega) = 5.1\ \text{V}$ $\Delta V_6 = \Delta V_{56} = \boxed{5.1\ \text{V}}$
	d. $I_6 = \dfrac{\Delta V_6}{R_6} = \dfrac{5.1\ \text{V}}{12.0\ \Omega} = \boxed{0.42\ \text{A}}$
27. $R_1 = 8.0\ \Omega$ $R_2 = 6.0\ \Omega$ $\Delta V_2 = 12\ \text{V}$	$R_{eq} = R_1 + R_2 = 8.0\ \Omega + 6.0\ \Omega = 14.0\ \Omega$ $I_2 = \dfrac{\Delta V_2}{R_2} = \dfrac{12\ \text{V}}{6.0\ \Omega} = 2.0\ \text{A}$ $\Delta V = I_2 R_{eq} = (2.0\ \text{A})(14.0\ \Omega) = \boxed{28\ \text{V}}$
28. $R_1 = 9.0\ \Omega$ $R_2 = 6.0\ \Omega$ $I_1 = 0.25\ \text{A}$	$\Delta V_1 = I_1 R_1 = (0.25\ \text{A})(9.0\ \Omega) = \boxed{2.2\ \text{V}}$
29. $R_1 = 9.0\ \Omega$ $R_2 = 6.0\ \Omega$ $I_1 = 0.25\ \text{A}$	$R_{eq} = R_1 + R_2 = 9.0\ \Omega + 6.0\ \Omega = 15.0\ \Omega$ $\Delta V = I_1 R_{eq} = (0.25\ \text{A})(15.0\ \Omega) = \boxed{3.8\ \text{V}}$
30. $R_1 = 9.0\ \Omega$ $R_2 = 6.0\ \Omega$ $\Delta V_2 = 12\ \text{V}$	$I = \dfrac{\Delta V_2}{R_2} = \dfrac{12\ \text{V}}{6.0\ \Omega} = 2.0\ \text{A}$ $R_{eq} = R_1 + R_2 = 9.0\ \Omega + 6.0\ \Omega = 15.0\ \Omega$ $\Delta V = IR_{eq} = (2.0\ \text{A})(15.0\ \Omega) = \boxed{3.0 \times 10^1\ \text{V}}$
31. $R_1 = 18.0\ \Omega$ $R_2 = 9.00\ \Omega$ $R_3 = 6.00\ \Omega$ $I_2 = 4.00\ \text{A}$	**a.** $R_{eq} = R_1 + R_2 + R_3 = 18.0\ \Omega + 9.00\ \Omega + 6.00\ \Omega = \boxed{33.0\ \Omega}$ **b.** $I = I_2 = 4.00\ \text{A}$ $\Delta V = IR_{eq} = (4.00\ \text{A})(33.0\ \Omega) = \boxed{132\ \text{V}}$ **c.** $I_1 = I_3 = I_2 = \boxed{4.00\ \text{A}}$
33. $R_1 = 90.0\ \Omega$ $R_2 = 10.0\ \Omega$ $R_3 = 10.0\ \Omega$ $R_4 = 90.0\ \Omega$ $R_{eq} = 60.0\ \Omega$	$R_{12} = R_1 + R_2 = 90.0\ \Omega + 10.0\ \Omega = 100.0\ \Omega$ $R_{34} = R_3 + R_4 = 10.0\ \Omega + 90.0\ \Omega = 100.0\ \Omega$ $R_{1234} = \left(\dfrac{1}{R_{12}} + \dfrac{1}{R_{34}}\right)^{-1} = \left(\dfrac{1}{100.0\ \Omega} + \dfrac{1}{100.0\ \Omega}\right)^{-1} = \left(0.01000\ \dfrac{1}{\Omega} + 0.01000\ \dfrac{1}{\Omega}\right)^{-1}$ $R_{1234} = \left(0.02000\ \dfrac{1}{\Omega}\right)^{-1} = 50.00\ \Omega$ $R_{eq} = R + R_{1234}$ $R = R_{eq} - R_{1234} = 60.0\ \Omega - 50.00\ \Omega = \boxed{10.0\ \Omega}$

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34. $R_{eq} = 150.0\ \Omega$

$\Delta V = 120.0$ V

$N = 25$

$$R_{eq,\ string} = \left(\frac{N}{R}\right)^{-1} = \left(\frac{25}{R}\right)^{-1} = \frac{R}{25}$$

$$R_{eq} = \frac{R}{25} + \frac{R}{25} = \frac{2R}{25} = 150.0\ \Omega$$

$$R = \frac{25(150.0\ \Omega)}{2} = \boxed{1875\ \Omega}$$

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35. $R = 6.0\ \Omega$

The following equations represent the circuits as listed.

(a) $R_{eq} = 2R = 2(6.0\ \Omega) = 12.0\ \Omega$

(b) $R_{eq} = \left(\frac{2}{R}\right)^{-1} = \left(\frac{2}{6.0\ \Omega}\right)^{-1} = 3.0\ \Omega$

(c) $R_{eq} = \left(\frac{3}{R}\right)^{-1} = \left(\frac{3}{6.0\ \Omega}\right)^{-1} = 2.0\ \Omega$

(d) $R_{eq} = \left(\frac{1}{R} + \frac{1}{2R}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{12.0\ \Omega}\right)^{-1}$

$R_{eq} = \left(0.17\ \frac{1}{\Omega} + 0.0833\ \frac{1}{\Omega}\right)^{-1} = \left(0.25\ \frac{1}{\Omega}\right)^{-1} = 4.0\ \Omega$

(e) $R_{eq} = \left(\frac{2}{R}\right)^{-1} + R = 3.0\ \Omega + 6.0\ \Omega = 9.0\ \Omega$

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36. $\Delta V = 9.0$ V

$R_1 = 4.5\ \Omega$

$R_2 = 3.0\ \Omega$

$R_3 = 2.0\ \Omega$

a. $R_{23} = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{3.0\ \Omega} + \frac{1}{2.0\ \Omega}\right)^{-1} = \left(0.83\ \frac{1}{\Omega}\right)^{-1} = 1.2\ \Omega$

$R_{eq} = R_1 + R_{23} = 4.5\ \Omega + 1.2\ \Omega = \boxed{5.7\ \Omega}$

b. $I = \frac{\Delta V}{R_{eq}} = \frac{9.0\ \text{V}}{5.7\ \Omega} = \boxed{1.6\ \text{A}}$

c. $I_1 = I = \boxed{1.6\ \text{A}}$

$\Delta V_{23} = IR_{23} = (1.6\ \text{A})(1.2\ \Omega) = 1.9$ V

$I_2 = \frac{\Delta V_{23}}{R_2} = \frac{1.9\ \text{V}}{3.0\ \Omega} = \boxed{0.63\ \text{A}}$

$I_3 = \frac{\Delta V_{23}}{R_3} = \frac{1.9\ \text{V}}{2.0\ \Omega} = \boxed{0.95\ \text{A}}$

d. $\Delta V_1 = I_1 R_1 = (1.6\ \text{A})(4.5\ \Omega) = \boxed{7.2\ \text{V}}$

$\Delta V_2 = \Delta V_3 = \Delta V_{23} = \boxed{1.9\ \text{V}}$

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37. $R_1 = 18.0\ \Omega$

$R_2 = 6.0\ \Omega$

$\Delta V = 18.0$ V

$R_{eq} = R_1 + R_2 = 18.0\ \Omega + 6.0\ \Omega = 24.0\ \Omega$

$$I_1 = I_2 = I = \frac{\Delta V}{R_{eq}} = \frac{18.0\ \text{V}}{24.0\ \Omega} = \boxed{0.750\ \text{A}}$$

$\Delta V_1 = I_1 R_1 = (0.750\ \text{A})(18.0\ \Omega) = \boxed{13.5\ \text{V}}$

$\Delta V_2 = I_2 R_2 = (0.750\ \text{A})(6.0\ \Omega) = \boxed{4.5\ \text{V}}$

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38. $R_1 = 30.0\ \Omega$

$R_2 = 15.0\ \Omega$

$R_3 = 5.00\ \Omega$

$\Delta V = 30.0$ V

b. $$R_{12} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{30.0\ \Omega} + \frac{1}{15.0\ \Omega}\right)^{-1}$$

$$R_{12} = \left(0.0333\ \frac{1}{\Omega} + 0.0667\ \frac{1}{\Omega}\right)^{-1} = \left(0.1000\ \frac{1}{\Omega}\right)^{-1} = 10.00\ \Omega$$

$R_{eq} = R_{12} + R_3 = 10.00\ \Omega + 5.00\ \Omega = \boxed{15.00\ \Omega}$

c. $$I_3 = I = \frac{\Delta V}{R_{eq}} = \frac{30.0\ \text{V}}{15.00\ \Omega} = \boxed{2.00\ \text{A}}$$

$\Delta V_{12} = IR_{12} = (2.00\ \text{A})(10.00\ \Omega) = 20.0$ V

$$I_1 = \frac{\Delta V_{12}}{R_1} = \frac{20.0\ \text{V}}{30.0\ \Omega} = \boxed{0.667\ \text{A}}$$

$$I_2 = \frac{\Delta V_{12}}{R_2} = \frac{20.0\ \text{V}}{15.0\ \Omega} = \boxed{1.33\ \text{A}}$$

d. $\Delta V_1 = \Delta V_2 = \Delta V_{12} = \boxed{20.0\ \text{V}}$

$\Delta V_3 = I_3 R_3 = (2.00\ \text{A})(5.00\ \Omega) = \boxed{10.0\ \text{V}}$

---

39. $R_2 = 12\ \Omega$

$\Delta V = 12$ V

$I_1 = 3.0$ A

$$R_1 = \frac{\Delta V}{I_1} = \frac{12\ \text{V}}{3.0\ \text{A}} = \boxed{4.0\ \Omega}$$

---

40. $R_1 = 18.0\ \Omega$

$R_2 = 6.0\ \Omega$

$\Delta V = 18.0$ V

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{18.0\ \Omega} + \frac{1}{6.0\ \Omega}\right)^{-1} = \left(0.0556\ \frac{1}{\Omega} + 0.17\ \frac{1}{\Omega}\right)^{-1} = \left(0.23\ \frac{1}{\Omega}\right)^{-1}$$

$R_{eq} = 4.3\ \Omega$

$\Delta V_1 = \Delta V_2 = \Delta V = \boxed{18.0\ \text{V}}$

$$I_1 = \frac{\Delta V_1}{R_1} = \frac{18.0\ \text{V}}{18.0\ \Omega} = \boxed{1.00\ \text{A}}$$

$$I_2 = \frac{\Delta V_2}{R_2} = \frac{18.0\ \text{V}}{6.0\ \Omega} = \boxed{3.0\ \text{A}}$$

I

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41. $R_1 = 90.0\ \Omega$

$R_2 = 10.0\ \Omega$

$R_3 = 10.0\ \Omega$

$R_4 = 90.0\ \Omega$

$R_{eq} = 2R_{eq,S}$

Switch open:

$$R_{12} = R_1 + R_2 = 90.0\ \Omega + 10.0\ \Omega = 100.0\ \Omega$$

$$R_{34} = R_3 + R_4 = 10.0\ \Omega + 90.0\ \Omega = 100.0\ \Omega$$

$$R_{1234} = \left(\frac{1}{R_{12}} + \frac{1}{R_{34}}\right)^{-1} = \left(\frac{1}{100.0\ \Omega} + \frac{1}{100.0\ \Omega}\right)^{-1} = \left(0.02000\ \frac{1}{\Omega}\right)^{-1} = 50.00\ \Omega$$

$$R_{eq} = R + R_{1234} = R + 50.00\ \Omega$$

Switch closed:

$$R_{13} = \left(\frac{1}{R_1} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{90.0\ \Omega} + \frac{1}{10.0\ \Omega}\right)^{-1}$$

$$R_{13} = \left(0.0111\ \frac{1}{\Omega} + 0.100\ \frac{1}{\Omega}\right)^{-1} = \left(0.111\ \frac{1}{\Omega}\right)^{-1} = 9.01\ \Omega$$

$$R_{24} = \left(\frac{1}{R_2} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{90.0\ \Omega}\right)^{-1} = 9.01\ \Omega$$

$$R_{eq,S} = R + R_{13} + R_{24} = R + 9.01\ \Omega + 9.01\ \Omega = R + 18.02\ \Omega$$

$$R_{eq} = 2R_{eq,S}$$

$$R + 50.00\ \Omega = 2(R + 18.02\ \Omega) = 2R + 36.04\ \Omega$$

$$2R - R = 50.00\ \Omega - 36.04\ \Omega$$

$$R = \boxed{13.96\ \Omega}$$

42. $R = 20.0\ \Omega$

a. Two resistors in series with two parallel resistors:

$$R_{eq} = R + R + \left(\frac{2}{R}\right)^{-1} = 20.0\ \Omega + 20.0\ \Omega + \left(\frac{2}{20.0\ \Omega}\right)^{-1} = 50.0\ \Omega$$

b. Four parallel resistors:

$$R_{eq} = \left(\frac{4}{R}\right)^{-1} = \frac{R}{4} = \frac{20.0\ \Omega}{4} = 5.00\ \Omega$$

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43. $\Delta V = 12.0$ V

$R_1 = 30.0\ \Omega$

$R_2 = 50.0\ \Omega$

$R_3 = 90.0\ \Omega$

$R_4 = 20.0\ \Omega$

a. $R_{12} = R_1 + R_2 = 30.0\ \Omega + 50.0\ \Omega = 80.0\ \Omega$

$$R_{123} = \left(\frac{1}{R_{12}} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{80.0\ \Omega} + \frac{1}{90.0\ \Omega}\right)^{-1}$$

$$R_{123} = \left(0.0125\ \frac{1}{\Omega} + 0.0111\ \frac{1}{\Omega}\right)^{-1} = \left(0.0236\ \frac{1}{\Omega}\right)^{-1} = 42.4\ \Omega$$

$$R_{eq} = R_{123} + R_4 = 42.4\ \Omega + 20.0\ \Omega = \boxed{62.4\ \Omega}$$

b. $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{12.0\ \text{V}}{62.4\ \Omega} = \boxed{0.192\ \text{A}}$

c. $\Delta V_{123} = IR_{123} = (0.192\ \text{A})(42.4\ \Omega) = 8.14$ V

$$I_{12} = \frac{\Delta V_{123}}{R_{12}} = \frac{8.14\ \text{V}}{80.0\ \Omega} = 0.102\ \text{A}$$

$$I_1 = I_{12} = \boxed{0.102\ \text{A}}$$

d. $\Delta V_2 = I_{12}R_2 = (0.102\ \text{A})(50.0\ \Omega) = 5.10$ V

$$P_2 = \frac{(\Delta V_2)^2}{R_2} = \frac{(5.10\ \text{V})^2}{50.0\ \Omega} = \boxed{0.520\ \text{W}}$$

e. $\Delta V_4 = IR_4 = (0.192\ \text{A})(20.0\ \Omega) = 3.84$ V

$$P_4 = \frac{(\Delta V_4)^2}{R_4} = \frac{(3.84\ \text{V})^2}{20.0\ \Omega} = \boxed{0.737\ \text{W}}$$

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44. $\Delta V = 6.0$ V

$\Delta V_A = 4.0$ V (series)

$I_B = 2.0$ A (parallel)

series:

$$\Delta V = \Delta V_A + \Delta V_B$$

$$\Delta V_B = \Delta V - \Delta V_A = 6.0\ \text{V} - 4.0\ \text{V} = 2.0\ \text{V}$$

$$I_B = \frac{\Delta V_B}{R_B} = \frac{2.0\ \text{V}}{3.0\ \Omega} = 0.67\ \text{A}$$

$$I_A = I_B = 0.67\ \text{A}$$

$$R_A = \frac{\Delta V_A}{I_A} = \frac{4.0\ \text{V}}{0.67\ \text{A}} = \boxed{6.0\ \Omega}$$

parallel:

$$\Delta V_A = \Delta V_B = 6.0\ \text{V}$$

$$R_B = \frac{\Delta V_B}{I_B} = \frac{6.0\ \text{V}}{2.0\ \text{A}} = \boxed{3.0\ \Omega}$$

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46. $R_1 = 5.0\ \Omega$
$R_2 = 10.0\ \Omega$
$R_3 = 4.0\ \Omega$
$R_4 = 3.0\ \Omega$
$R_5 = 10.0\ \Omega$
$R_6 = 2.0\ \Omega$
$R_7 = 3.0\ \Omega$
$R_8 = 4.0\ \Omega$
$R_9 = 3.0\ \Omega$
$\Delta V = 28\ \text{V}$

a. $R_{789} = R_7 + R_8 + R_9 = 3.0\ \Omega + 4.0\ \Omega + 3.0\ \Omega = 10.0\ \Omega$

$$R_{5789} = \left(\frac{1}{R_5} + \frac{1}{R_{789}}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{10.0\ \Omega}\right)^{-1} = \left(0.200\ \frac{1}{\Omega}\right)^{-1} = 5.00\ \Omega$$

$R_{456789} = R_4 + R_{5789} + R_6 = 3.0\ \Omega + 5.00\ \Omega + 2.0\ \Omega = 10.0\ \Omega$

$$R_{2456789} = \left(\frac{1}{R_2} + \frac{1}{R_{456789}}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{10.0\ \Omega}\right)^{-1} = \left(0.200\ \frac{1}{\Omega}\right)^{-1} = 5.00\ \Omega$$

$R_{eq} = R_1 + R_{2456789} + R_3 = 5.0\ \Omega + 5.00\ \Omega + 4.0\ \Omega = \boxed{14.0\ \Omega}$

b. $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{28\ \text{V}}{14.0\ \Omega} = 2.0\ \text{A}$

$I_1 = I = \boxed{2.0\ \text{A}}$

---

47. $P = 4.00\ \text{W}$
$R_1 = 3.0\ \Omega$
$R_2 = 10.0\ \Omega$
$R_3 = 5.0\ \Omega$
$R_4 = 4.0\ \Omega$
$R_5 = 3.0\ \Omega$

a. $$R_{23} = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{5.0\ \Omega}\right)^{-1}$$

$$R_{23} = \left(0.100\ \frac{1}{\Omega} + 0.20\ \frac{1}{\Omega}\right)^{-1} = \left(0.30\ \frac{1}{\Omega}\right)^{-1} = 3.3\ \Omega$$

$R_{234} = R_{23} + R_4 = 3.3\ \Omega + 4.0\ \Omega = 7.3\ \Omega$

$$R_{2345} = \left(\frac{1}{R_{234}} + \frac{1}{R_5}\right)^{-1} = \left(\frac{1}{7.3\ \Omega} + \frac{1}{3.0\ \Omega}\right)^{-1}$$

$$R_{2345} = \left(0.14\ \frac{1}{\Omega} + 0.33\ \frac{1}{\Omega}\right)^{-1} = \left(0.47\ \frac{1}{\Omega}\right)^{-1} = 2.1\ \Omega$$

$R_{eq} = R_1 + R_{2345} = 3.0\ \Omega + 2.1\ \Omega = \boxed{5.1\ \Omega}$

b. $\Delta V = \sqrt{PR_{eq}} = \sqrt{(4.00\ \text{W})(5.1\ \Omega)} = \boxed{4.5\ \text{V}}$

---

48. $P_T = 1200\ \text{W}$
$P_C = 1200\ \text{W}$
$\Delta V = 120\ \text{V}$
$I_{max} = 15\ \text{A}$

$P = I\Delta V$

$P_T + P_C = I\Delta V$

$I = \dfrac{2(1200\ \text{W})}{120\ \text{V}} = 20\ \text{A}$

$\boxed{\text{no, because } 20\ \text{A} > 15\ \text{A}}$

---

49. $P_H = 1300\ \text{W}$
$P_T = 1100\ \text{W}$
$P_G = 1500\ \text{W}$
$\Delta V = 120\ \text{V}$

a. heater: $I = \dfrac{P_H}{\Delta V} = \dfrac{1300\ \text{W}}{120\ \text{V}} = \boxed{11\ \text{A}}$

toaster: $I = \dfrac{P_T}{\Delta V} = \dfrac{1100\ \text{W}}{120\ \text{V}} = \boxed{9.2\ \text{A}}$

grill: $I = \dfrac{P_G}{\Delta V} = \dfrac{1500\ \text{W}}{120\ \text{V}} = \boxed{12\ \text{A}}$

b. $I_{tot} = 11\ \text{A} + 9.2\ \text{A} + 12\ \text{A} = \boxed{32.2\ \text{A}}$

Givens	*Solutions*
8. $R_1 = 2.0\ \Omega$ $R_2 = 2.0\ \Omega$ $R_3 = 2.0\ \Omega$ $\Delta V_{tot} = 12\ \text{V}$	$R_{eq} = R_1 + R_2 + R_3 = 2.0\ \Omega + 2.0\ \Omega + 2.0\ \Omega = 6.0\ \Omega$ $I_R = \frac{\Delta V_{tot}}{R_{eq}} = \frac{12\ \text{V}}{6.0\ \Omega} = 2.0\ \text{A}$ $\Delta V_R = I_R R = 2.0\ \text{A} \times 2.0\ \Omega = \boxed{4.0\ \text{V}}$
10. $R_{bulb} = 3.0\ \Omega$ $\Delta V = 9.0\ \text{V}$	$I = \frac{\Delta V}{R_{bulb}} = \frac{9.0\ \text{V}}{3.0\ \Omega} = \boxed{3.0\ \text{A}}$
11. $R_{bulb} = 3.0\ \Omega$ $\Delta V = 9.0\ \text{V}$	$R_{eq} = \left(\frac{1}{R_{bulb}} \times 6\right)^{-1} = \left(\frac{1}{3.0\ \Omega} \times 6\right)^{-1} = 0.50\ \Omega$ $I_{tot} = \frac{\Delta V}{R_{eq}} = \frac{9.0\ \text{V}}{0.50\ \Omega} = \boxed{18\ \text{A}}$
16. $R_1 = 1.5\ \Omega$ $R_2 = 6.0\ \Omega$ $R_{bulb} = 3.0\ \Omega$ $\Delta V = 12\ \text{V}$	**a.** $R_{12} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{1.5\ \Omega} + \frac{1}{6.0\ \Omega}\right)^{-1} = 1.2\ \Omega$ $R_{eq} = R_{12} + R_{bulb} = 1.2\ \Omega + 3.0\ \Omega = \boxed{4.2\ \Omega}$ **b.** $I = \frac{\Delta V}{R_{eq}} = \frac{12\ \text{V}}{4.2\ \Omega} = 2.9\ \text{A}$ $I_{bulb} = \boxed{2.9\ \text{A}}$
17. $R_1 = 1.5\ \Omega$ $R_{bulb} = 3.0\ \Omega$ $\Delta V_{tot} = 12\ \text{V}$	**a.** $R_{eq} = R_1 + R_{bulb} = 1.5\ \Omega + 3.0\ \Omega = 4.5\ \Omega$ **b.** $I = \frac{\Delta V}{R_{eq}} = \frac{12\ \text{V}}{4.5\ \Omega} = 2.7\ \text{A}$ $I_{bulb} = \boxed{2.7\ \text{A}}$

Givens	*Solutions*
18. $R_1 = 4.0\ \Omega$ $R_2 = 12.0\ \Omega$ $\Delta V = 4.0\text{ V}$	**a.** $R_{eq} = R_1 + R_2 = 4.0\ \Omega + 12.0\ \Omega = 16.0\ \Omega$ $I_1 = I_2 = I = \dfrac{\Delta V}{R_{eq}} = \dfrac{4.0\text{ V}}{16.0\ \Omega} = \boxed{0.25\text{ A}}$ $\Delta V_1 = I_1R_1 = (0.25\text{ A})(4.0\ \Omega) = \boxed{1.0\text{ V}}$ $\Delta V_2 = I_2R_2 = (0.25\text{ A})(12.0\ \Omega) = \boxed{3.0\text{ V}}$
$R_1 = 4.0\ \Omega$ $R_2 = 12.0\ \Omega$ $\Delta V = 4.0\text{ V}$	**b.** $R_{eq} = \left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)^{-1} = \left(\dfrac{1}{4.0\ \Omega} + \dfrac{1}{12.0\ \Omega}\right)^{-1}$ $R_{eq} = \left(0.25\ \dfrac{1}{\Omega} + 0.0833\ \dfrac{1}{\Omega}\right)^{-1} = \left(0.33\ \dfrac{1}{\Omega}\right)^{-1} = 3.0\ \Omega$ $\Delta V_1 = \Delta V_2 = \Delta V = \boxed{4.0\text{ V}}$ $I_1 = \dfrac{\Delta V_1}{R_1} = \dfrac{4.0\text{ V}}{4.0\ \Omega} = \boxed{1.0\text{ A}}$ $I_2 = \dfrac{\Delta V_2}{R_2} = \dfrac{4.0\text{ V}}{12.0\ \Omega} = \boxed{0.33\text{ A}}$
19. $R_1 = 150\ \Omega$ $R_2 = 180\ \Omega$ $\Delta V = 12\text{ V}$	**a.** $R_{eq} = R_1 + R_2 = 150\ \Omega + 180\ \Omega = 330\ \Omega$ $I_1 = I_2 = I = \dfrac{\Delta V}{R_{eq}} = \dfrac{12\text{ V}}{330\ \Omega} = \boxed{0.036\text{ A}}$ $\Delta V_1 = I_1R_1 = (0.036\text{ A})(150\ \Omega) = \boxed{5.4\text{ V}}$ $\Delta V_2 = I_2R_2 = (0.036\text{ A})(180\ \Omega) = \boxed{6.5\text{ V}}$
$R_1 = 150\ \Omega$ $R_2 = 180\ \Omega$ $\Delta V = 12\text{ V}$	**b.** $\Delta V_1 = \Delta V_2 = \Delta V = \boxed{12\text{ V}}$ $I_1 = \dfrac{\Delta V_1}{R_1} = \dfrac{12\text{ V}}{150\ \Omega} = \boxed{0.080\text{ A}}$ $I_2 = \dfrac{\Delta V_2}{R_2} = \dfrac{12\text{ V}}{180\ \Omega} = \boxed{0.067\text{ A}}$

Magnetism

Magnetism, Practice A

Givens	*Solutions*
1. $B = 4.20 \times 10^{-2}$ T $F_{magnetic} = 2.40 \times 10^{-14}$ N $q = 1.60 \times 10^{-19}$ C	$v = \dfrac{F_{magnetic}}{qB} = \dfrac{2.40 \times 10^{-14}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(4.20 \times 10^{-2}\ \text{T})} = \boxed{3.57 \times 10^{6}\ \text{m/s}}$
2. $F_{magnetic} = 2.0 \times 10^{-14}$ downward $B = 8.3 \times 10^{-2}$ T west $q = 1.60 \times 10^{-19}$ C	$v = \dfrac{F_{magnetic}}{qB} = \dfrac{2.0 \times 10^{-14}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(8.3 \times 10^{-2}\ \text{T})} = \boxed{1.5 \times 10^{6}\ \text{m/s north}}$
3. $B = 1.5$ T north $v = 2.5 \times 10^{7}$ m/s downward $q = 1.60 \times 10^{-19}$ C	$F_{magnetic} = qvB = (1.60 \times 10^{-19}\ \text{C})(2.5 \times 10^{7}\ \text{m/s})(1.5\ \text{T}) = \boxed{6.0 \times 10^{-12}\ \text{m/s N west}}$

Magnetism, Practice B

1. $\ell = 6.0$ m $I = 7.0$ A $F_{magnetic} = 7.0 \times 10^{-6}$ N	$B = \dfrac{F_{magnetic}}{I\ell} = \dfrac{7.0 \times 10^{-6}\ \text{N}}{(7.0\ \text{A})(6.0\ \text{m})} = \boxed{1.7 \times 10^{-7}\ \text{T in the } +z \text{ direction}}$
2. $\ell = 1.0$ m $F_{magnetic} = 0.50$ N $I = 10.0$ A	$B = \dfrac{F_{magnetic}}{I\ell} = \dfrac{0.50\ \text{N}}{(10.0\ \text{A})(1.0\ \text{m})} = \boxed{0.050\ \text{T}}$
3. $\ell = 0.15$ m $I = 4.5$ A $F_{magnetic} = 1.0$ N	$B = \dfrac{F_{magnetic}}{I\ell} = \dfrac{1.0\ \text{N}}{(4.5\ \text{A})(0.15\ \text{m})} = \boxed{1.5\ \text{T}}$
4. $B = 1.5$ T $F_{magnetic} = 4.4$ N $I = 5.0$ A	$\ell = \dfrac{F_{magnetic}}{IB} = \dfrac{4.4\ \text{N}}{(5.0\ \text{A})(1.5\ \text{T})} = \boxed{0.59\ \text{m}}$

Magnetism, Section 3 Review

Givens | *Solutions*

I

1. $q = 0.030$ C
$F_{magnetic} = 1.5$ N
$v = 620$ m/s

$$B = \frac{F_{magnetic}}{qv} = \frac{1.5\text{ N}}{(0.030\text{ C})(620\text{ m/s})} = \boxed{0.081\text{ T}}$$

3. $\ell = 25$ cm
$I = 5.0$ A
$B = 0.60$ T

$$F_{magnetic} = BI\ell = (0.60\text{ T})(5.0\text{ A})(0.25\text{ m}) = \boxed{0.75\text{ N}}$$

Magnetism, Chapter Review

30. $B = 5.0 \times 10^{-5}$ T North
$F_{magnetic} = 3.0 \times 10^{-11}$ N upward
$q = 4.0 \times 10^{-8}$ C

$$v = \frac{F_{magnetic}}{qB} = \frac{3.0 \times 10^{-11}\text{ N}}{(4.0 \times 10^{-8}\text{ C})(5.0 \times 10^{-5}\text{ T})} = \boxed{15\text{ m/s}}$$

31. $m = 1.673 \times 10^{-27}$ kg
$B = 5.0 \times 10^{-5}$ T
$q = 1.60 \times 10^{-19}$ C
$g = 9.81$ m/s^2

$$mg = qvB$$
$$v = \frac{mg}{qB} = \frac{(1.673 \times 10^{-27}\text{ kg})(9.81\text{ m/s}^2)}{(1.60 \times 10^{-19}\text{ C})(5.0 \times 10^{-5}\text{ T})} = \boxed{2.1 \times 10^{-3}\text{ m/s}}$$

32. $I = 10.0$ A
$\ell = 5.00$ m
$F_{magnetic} = 15.0$ N

$$B = \frac{F_{magnetic}}{I\ell} = \frac{15.0\text{ N}}{(10.0\text{ A})(5.00\text{ m})} = \boxed{0.300\text{ T}}$$

33. $\ell = 1.00$ m
$m = 50.0\text{ g} = 0.0500$ kg
$I = 0.245$ A
$g = 9.81$ m/s^2

$$mg = BI\ell$$
$$B = \frac{mg}{I\ell} = \frac{(0.0500\text{ kg})(9.81\text{ m/s}^2)}{(0.245\text{ A})(1.00\text{ m})} = \boxed{2.00\text{ T}}$$

34. $v = 2.50 \times 10^6$ m/s
$m = 1.673 \times 10^{-27}$ kg
$q = 1.60 \times 10^{-19}$ C
$g = 9.81$ m/s^2

a. $mg = qvB$
$$B = \frac{mg}{qv} = \frac{(1.673 \times 10^{-27}\text{ kg})(9.81\text{ m/s}^2)}{(1.60 \times 10^{-19}\text{ C})(2.50 \times 10^6\text{ m/s})} = \boxed{4.10 \times 10^{-14}\text{ T}}$$

38. $v = 2.0 \times 10^7$ m/s
$B = 0.10$ T
$m = 1.673 \times 10^{-27}$ kg
$q = 1.60 \times 10^{-19}$ C

$$ma = qvB$$
$$a = \frac{qvB}{m} = \frac{(1.60 \times 10^{-19}\text{ C})(2.0 \times 10^7\text{ m/s})(0.10\text{ T})}{1.673 \times 10^{-27}\text{ kg}} = \boxed{1.9 \times 10^{14}\text{ m/s}^2}$$

Givens / *Solutions*

39. $q = 1.60 \times 10^{-19}$ C
$a = 2.0 \times 10^{13}$ m/s^2
$v = 1.0 \times 10^7$ m/s
$m = 1.673 \times 10^{-27}$ kg

$ma = qvB$

$$B = \frac{ma}{qv} = \frac{(1.673 \times 10^{-27}\text{ kg})(2.0 \times 10^{13}\text{ m/s}^2)}{(1.60 \times 10^{-19}\text{ C})(1.0 \times 10^7\text{ m/s})}$$

$B = \boxed{2.1 \times 10^{-2}\text{ T, in the negative } y \text{ direction}}$

---

40. $v = 3.0 \times 10^6$ m/s
$\theta = 37°$
$B = 0.30$ T
$q = 1.60 \times 10^{-19}$ C
$m = 1.673 \times 10^{-27}$ kg

a. $F_{magnetic} = qvB(\sin\theta) = (1.60 \times 10^{-19}\text{ C})(3.0 \times 10^6\text{ m/s})(0.30\text{ T})(\sin 37°)$

$F_{magnetic} = \boxed{8.7 \times 10^{-14}\text{ N}}$

c. $$a = \frac{F}{m} = \frac{8.7 \times 10^{-14}\text{ N}}{1.673 \times 10^{-27}\text{ kg}} = \boxed{5.2 \times 10^{13}\text{ m/s}^2}$$

---

41. $\ell = 15$ cm
$I = 5.0$ A
$m = 0.15$ kg
$g = 9.81$ m/s^2

$mg = BI\ell$

$$B = \frac{mg}{I\ell} = \frac{(0.15\text{ kg})(9.81\text{ m/s}^2)}{(5.0\text{ A})(0.15\text{ m})} = \boxed{2.0\text{ T, out of the page}}$$

---

42. $I = 15$ A
$\frac{F_{magnetic}}{\ell} = 0.12$ N/m

Consider the force on a 1.0 m length of wire.

$$F_{magnetic} = \left(\frac{F_{magnetic}}{\ell}\right)(\ell) = (0.12\text{ N/m})(1.0\text{ m}) = 0.12\text{ N}$$

$F_{magnetic} = BI\ell$

$$B = \frac{F_{magnetic}}{I\ell} = \frac{0.12\text{ N}}{(15\text{ A})(1.0\text{ m})} = \boxed{8.0 \times 10^{-3}\text{ T, in the positive } z \text{ direction}}$$

---

43. $B = 3.5$ mT $= 3.5 \times 10^{-3}$ T
$F_{magnetic} = 4.5 \times 10^{-21}$ N
$q = q_p = 1.60 \times 10^{-19}$ C
$m = m_p = 1.67 \times 10^{-27}$ kg

a. $$v = \frac{F}{qB} = \frac{4.5 \times 10^{-21}\text{ N}}{(1.60 \times 10^{-19}\text{ C})(3.5\text{ mT})}$$

$v = \boxed{8.0\text{ m/s}}$

b. $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(1.67 \times 10^{-27}\text{ kg})(8.0\text{ m/s})^2$$

$KE = \boxed{5.4 \times 10^{-26}\text{ J}}$

---

44. $m = 6.68 \times 10^{-27}$ kg
$r = 3.00$ cm
$v = 1.00 \times 10^4$ m/s
$q = 1.60 \times 10^{-19}$ C

Use the equation for the force that maintains circular motion from Chapter 7.

$F_c = F_{magnetic}$

$$m\frac{v^2}{r} = qvB$$

$$B = \frac{mv}{qr} = \frac{(6.68 \times 10^{-27}\text{ kg})(1.00 \times 10^4\text{ m/s})}{(1.60 \times 10^{-19}\text{ C})(0.0300\text{ m})} = \boxed{1.39 \times 10^{-2}\text{ T, toward the observer}}$$

Givens | *Solutions*

I

45. $r = 1000.0$ km

$B = 4.00 \times 10^{-8}$ T

$q = 1.60 \times 10^{-19}$ C

$m = 1.673 \times 10^{-27}$ kg

$r_E = 6.37 \times 10^6$ m

Use the equation for the force that maintains circular motion from Chapter 7.

$F_c = F_{magnetic}$

$$m\frac{v^2}{r + r_E} = qvB$$

$$v = \frac{(r + r_E)qB}{m} = \frac{(1.0000 \times 10^6 \text{ m} + 6.37 \times 10^6 \text{ m})(1.60 \times 10^{-19} \text{ C})(4.00 \times 10^{-8} \text{ T})}{1.673 \times 10^{-27} \text{ kg}}$$

$$v = \boxed{2.82 \times 10^7 \text{ m/s}}$$

---

46. $q_e = -1.6 \times 10^{-19}$ C

$m_e = 9.1 \times 10^{-31}$ kg

$q_p = 1.6 \times 10^{-19}$ C

$c = 3.0 \times 10^8$ m/s

$k_c = 9.0 \times 10^9$ N•m^2/C^2

a. $v = 2.0\%\ c = (0.02)(3.8 \times 10^8 \text{ m/s}) = (6.0 \times 10^6 \text{ m/s})$

$B = 3.0$ T

$$F_{magnetic} = qvB = (-1.6 \times 10^{-19} \text{ C})(6.0 \times 10^6 \text{ m/s})(3.0 \text{ T})$$

$$F_{magnetic} = \boxed{-2.9 \times 10^{-12} \text{ N}}$$

b. $r = 3.0 \times 10^{-6}$ m

$$F_{electric} = kc\frac{q_eq_p}{r^2} = (9.0 \times 10^9 \text{ N•m}^2/\text{C}^2)\frac{(-1.6 \times 10^{-19} \text{ C})(1.6 \times 10^{-19} \text{ C})}{(3.0 \times 10^{-6} \text{ m})^2}$$

$$F_{electric} = \boxed{-2.6 \times 10^{-17} \text{ N}}$$

c. $g = 9.81$ m/s^2

$$F_{gravitational} = mg = (9.1 \times 10^{-31} \text{ kg})(9.81 \text{ m/s}^2)$$

$$F_{gravitational} = \boxed{8.9 \times 10^{-30} \text{ N}}$$

Magnetism, Standardized Test Prep

7. $q = 3.2 \times 10^{-19}$ C

$v = 2.5 \times 10^6$ m/s

$B = 2.0 \times 10^{-4}$ T

$$F_{magnetic} = qvB = (3.2 \times 10^{-19} \text{ C})(2.5 \times 10^6 \text{ m/s})(2.0 \times 10^{-4} \text{ T})$$

$$F_{magnetic} = \boxed{1.6 \times 10^{-16} \text{ N}}$$

---

8. $\ell = 25$ cm $= 0.25$ m

$I = 12$ A (east to west)

$B = 4.8 \times 10^{-5}$ T (south to north)

$$F_{magnetic} = BI\ell = (4.8 \times 10^{-5} \text{ T})(12 \text{ A})(0.25 \text{ m})$$

$$F_{magnetic} = \boxed{1.4 \times 10^{-4} \text{ N}}$$

---

16. $q = 1.6 \times 10^{-19}$ C

$m = 1.7 \times 10^{-27}$ kg

$B = 0.25$ T

$v = 2.8 \times 10^5$ m/s

$F_{centripetal} = F_{magnetic}$

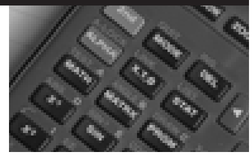
$$m\frac{v^2}{r} = qvB$$

$$r = m\frac{v^2}{qvB} = \frac{mv^2}{qvB} = \frac{mv}{qB}$$

$$r = \frac{(1.7 \times 10^{-27} \text{ kg})(2.8 \times 10^5 \text{ m/s})}{(1.6 \times 10^{-19} \text{ C})(0.25 \text{ T})}$$

$$r = 1.2 \times 10^{-2} \text{ m} = \boxed{1.2 \text{ cm}}$$

Student Edition Solutions



Electromagnetic Induction

I

Electromagnetic Induction, Practice A

Givens / *Solutions*

1. $r = 22$ cm

$B_i = 0.50$ T

$B_f = 0.00$ T

$\Delta t = 0.25$ s

$N = 1$

$\theta = 0.0°$

$$\text{emf} = -NA(\cos\theta)\frac{\Delta B}{\Delta t}$$

$$\Delta B = B_f - B_i = 0.00\text{ T} - 0.50\text{ T} = -0.50\text{ T}$$

$$A = \pi r^2$$

$$\text{emf} = -N\pi r^2(\cos\theta)\frac{\Delta B}{\Delta t} = -(1)(\pi)(0.22\text{ m})^2(\cos 0.0°)\left(\frac{-0.50\text{ T}}{0.25\text{ s}}\right)$$

$$\text{emf} = \boxed{0.30\text{ V}}$$

---

2. $N = 205$

$R = 23\ \Omega$

$A = 0.25\text{ m}^2$

$\theta = 0.0°$

$\Delta t = 0.25$ s

$B_i = 1.6$ T

$B_f = 0.0$ T

$$I = \frac{\text{emf}}{R}$$

$$\text{emf} = -NA(\cos\theta)\frac{\Delta B}{\Delta t}$$

$$\Delta B = B_f - B_i = 0.0\text{ T} - 1.6\text{ T} = -1.6\text{ T}$$

$$I = \frac{-NA(\cos\theta)\Delta B}{\Delta t R} = \frac{-(205)(0.25\text{ m}^2)(\cos 0.0°)(-1.6\text{ T})}{(0.25\text{ s})(23\ \Omega)}$$

$$I = \boxed{14\text{ A}}$$

---

3. $r = 0.33$ m

$B_i = 0.35$ T

$\theta = 0.0°$

$B_f = -0.25$ T

$\Delta t = 1.5$ s

$N = 1$

$$\text{emf} = -NA(\cos\theta)\frac{\Delta B}{\Delta t}$$

$$\Delta B = B_f - B_i = -0.25\text{ T} - 0.35\text{ T} = -0.60\text{ T}$$

$$A = \pi r^2$$

$$\text{emf} = -N\pi r^2(\cos\theta)\frac{\Delta B}{\Delta t} = \frac{-(1)(\pi)(0.33\text{ m})^2(\cos 0.0°)(-0.60\text{ T})}{1.5\text{ s}}$$

$$\text{emf} = \boxed{0.14\text{ V}}$$

---

4. $N = 505$

$d = 15.5$ cm

$\theta_i = 0.0°$

$\Delta t = 2.77$ ms

$\theta_f = 90.0°$

emf $= 0.166$ V

$$\Delta\cos\theta = \cos\theta_f - \cos\theta_i = \cos 90.0° - \cos 0.0° = 0 - 1 = -1$$

$$A = \pi\left(\frac{d}{2}\right)^2$$

$$B = \frac{(\text{emf})(\Delta t)}{-NA(\Delta\cos\theta)} = \frac{(0.166\text{ V})(2.77\times10^{-3}\text{ s})}{-(505)(\pi)\left(\frac{0.155\text{ m}}{2}\right)^2(-1)}$$

$$B = \boxed{4.83\times10^{-5}\text{ T}}$$

I

Electromagnetic Induction, Section 1 Review

Givens	*Solutions*
3. $N = 256$ $A = 0.0025\ \text{m}^2$ $B_i = 0.25\ \text{T}$ $\theta = 0.0°$ $\Delta t = 0.75\ \text{s}$ $B_f = 0.00\ \text{T}$	$\Delta B = B_f - B_i = 0.00\ \text{T} - 0.25\ \text{T} = -0.25\ \text{T}$ $\text{emf} = -NA(\cos\theta)\dfrac{\Delta B}{\Delta t} = \dfrac{-(256)(0.0025\ \text{m}^2)(\cos 0.0°)(-0.25\ \text{T})}{0.75\ \text{s}}$ $\text{emf} = \boxed{0.21\ \text{V}}$

Electromagnetic Induction, Section 2 Review

1. $A = 0.33\ \text{m}^2$ $\omega = 281\ \text{rad/s}$ $B = 0.035\ \text{T}$ $N = 37$	$\text{maximum emf} = NAB\omega = (37)(0.33\ \text{m}^2)(0.035\ \text{T})(281\ \text{rad/s})$ $\text{maximum emf} = \boxed{1.2 \times 10^2\ \text{V}}$
2. maximum emf $= 2.8\ \text{V}$ $N = 25$ $A = 36\ \text{cm}^2$ $f = 60.0\ \text{Hz}$	$B = \dfrac{\text{maximum emf}}{NA\omega} = \dfrac{\text{maximum emf}}{NA2\pi f} = \dfrac{2.8\ \text{V}}{(25)(0.0036\ \text{m}^2)(2\pi)(60.0\ \text{Hz})}$ $B = \boxed{8.3 \times 10^{-2}\ \text{T}}$

Electromagnetic Induction, Practice B

1. $R = 25\ \Omega$ $\Delta V_{rms} = 120\ \text{V}$	$I_{rms} = \dfrac{\Delta V_{rms}}{R} = \dfrac{120\ \text{V}}{25\ \Omega} = \boxed{4.8\ \text{A}}$ $I_{max} = \dfrac{I_{rms}}{0.707} = \dfrac{4.8\ \text{A}}{0.707} = \boxed{6.8\ \text{A}}$ $\Delta V_{max} = \dfrac{\Delta V_{rms}}{0.707} = \dfrac{120\ \text{V}}{0.707} = \boxed{170\ \text{V}}$
2. $I_{rms} = 5.5\ \text{A}$	$I_{max} = \dfrac{I_{rms}}{0.707} = \dfrac{5.5\ \text{A}}{0.707} = \boxed{7.8\ \text{A}}$
3. $\Delta V_{rms} = 110\ \text{V}$ $I_{max} = 10.5\ \text{A}$	**a.** $I_{rms} = (0.707)(I_{max}) = (0.707)(10.5\ \text{A}) = \boxed{7.42\ \text{A}}$ **b.** $R = \dfrac{\Delta V_{rms}}{I_{rms}} = \dfrac{110\ \text{V}}{7.42\ \text{A}} = \boxed{14.8\ \Omega}$
4. $\Delta V_{rms} = 15.0\ \text{V}$ $R = 10.4\ \Omega$	$I_{rms} = \dfrac{\Delta V_{rms}}{R} = \dfrac{15.0\ \text{V}}{10.4\ \Omega} = \boxed{1.44\ \text{A}}$ $I_{max} = \dfrac{I_{rms}}{0.707} = \dfrac{1.44\ \text{A}}{0.707} = \boxed{2.04\ \text{A}}$ $\Delta V_{max} = \dfrac{\Delta V_{rms}}{0.707} = \dfrac{15.0\ \text{V}}{0.707} = \boxed{21.2\ \text{V}}$

Givens | *Solutions*

5. $\Delta V_{max} = 155\ \text{V}$

$R = 53\ \Omega$

a. $\Delta V_{rms} = (0.707)(\Delta V_{max}) = (0.707)(155\ \text{V}) = \boxed{1.10 \times 10^2\ \text{V}}$

b. $I_{rms} = \dfrac{\Delta V_{rms}}{R} = \dfrac{1.10 \times 10^2\ \text{V}}{53\ \Omega} = \boxed{2.1\ \text{A}}$

6. $\Delta V_{max} = 451\ \text{V}$

$\Delta V_{rms} = (0.707)(\Delta V_{max}) = (0.707)(451\ \text{V}) = \boxed{319\ \text{V}}$

Electromagnetic Induction, Practice C

1. $N_1 = 2680$ turns

$\Delta V_1 = 5850\ \text{V}$

$\Delta V_2 = 120\ \text{V}$

$$N_2 = \frac{N_1 \Delta V_2}{\Delta V_1} = \frac{(2680\ \text{turns})(120\ \text{V})}{5850\ \text{V}} = \boxed{55.0\ \text{turns}}$$

2. $\Delta V_1 = 12\ \text{V}$

$\Delta V_2 = 2.0 \times 10^4\ \text{V}$

$N_1 = 21$ turns

$$N_2 = \frac{N_1 \Delta V_2}{\Delta V_1} = \frac{(21\ \text{turns})(2.0 \times 10^4\ \text{V})}{12\ \text{V}} = \boxed{3.5 \times 10^4\ \text{turns}}$$

3. $\Delta V_1 = 117\ \text{V}$

$\Delta V_2 = 119\ 340\ \text{V}$

$N_2 = 25\ 500$ turns

$$N_1 = \frac{N_2 \Delta V_1}{\Delta V_2} = \frac{(25\ 500\ \text{turns})(117\ \text{V})}{119\ 340\ \text{V}} = \boxed{25.0\ \text{turns}}$$

4. $\Delta V_1 = 117\ \text{V}$

$\Delta V_2 = 0.750\ \text{V}$

$$\frac{N_1}{N_2} = \frac{\Delta V_1}{\Delta V_2} = \frac{117\ \text{V}}{0.750\ \text{V}} = \boxed{\frac{156}{1}}$$

5. $N_1 = 12\ 500$ turns

$N_2 = 525$ turns

$\Delta V_1 = 3510\ \text{V}$

$$\Delta V_2 = \frac{N_2 \Delta V_1}{N_1} = \frac{(525\ \text{turns})(3510\ \text{V})}{12\ 500\ \text{turns}} = \boxed{147\ \text{V}}$$

Electromagnetic Induction, Section 3 Review

1. $I_{rms} = 0.025\ \text{mA}$

$R = 4.3\ \text{k}\Omega$

$$I_{max} = \frac{I_{rms}}{0.707} = \frac{0.025\ \text{mA}}{0.707} = \boxed{0.035\ \text{mA}}$$

$$\Delta V_{rms} = I_{rms} R = (0.025 \times 10^{-3}\ \text{A})(4.3 \times 10^3\ \Omega) = \boxed{0.11\ \text{V}}$$

$$\Delta V_{max} = I_{max} R = (0.035 \times 10^{-3}\ \text{A})(4.3 \times 10^3\ \Omega) = \boxed{0.15\ \text{V}}$$

2. $N_1 = 50$ turns

$N_2 = 7000$ turns

$\Delta V_1 = 120\ \text{V}$

$$\Delta V_2 = \frac{N_2 \Delta V_1}{N_1} = \frac{(7000\ \text{turns})(120\ \text{V})}{50\ \text{turns}} = \boxed{1.7 \times 10^4\ \text{V}}$$

3. $N_1 = 12$ turns

$N_2 = 2550$ turns

$\Delta V_1 = 120\ \text{V}$

$$\Delta V_2 = \frac{N_2 \Delta V_1}{N_1} = \frac{(2550\ \text{turns})(120\ \text{V})}{12\ \text{turns}} = \boxed{2.6 \times 10^4\ \text{V}}$$

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Givens	Solutions
10. $N = 1$ $r_i = 0.12$ m $B = 0.15$ T $A_f = 3 \times 10^{-3}$ m^2 $\Delta t = 0.20$ s $\theta = 0.0°$	$\text{emf} = \frac{-N(\cos\theta)B\Delta A}{\Delta t}$ $\Delta A = A_f - A_i = Af - \pi r_i^2 = (3 \times 10^{-3}\ \text{m}^2) - (\pi)(0.12\ \text{m})^2$ $\Delta A = (3 \times 10^{-3}\ \text{m}^2) - 0.045\ \text{m}^2 = -0.042\ \text{m}^2$ $\text{emf} = \frac{-(1)(\cos 0.0°)(0.15\ \text{T})(-0.042\ \text{m}^2)}{0.20\ \text{s}} = \boxed{3.2 \times 10^{-2}\ \text{V}}$
11. $A = (0.055\ \text{m})(0.085\ \text{m})$ $\theta = 0.0°$ $N = 75$ $R = 8.7\ \Omega$ $\frac{-\Delta B}{\Delta t} = 3.0$ T/s	$\text{emf} = -N\frac{\Delta[AB(\cos\theta)]}{\Delta t} = -NA(\cos\theta)\frac{\Delta B}{\Delta t}$ $\text{emf} = -(75)(0.055\ \text{m})(0.085\ \text{m})(\cos 0.0°)(-3.0\ \text{T/s}) = 1.05\ \text{V}$ $I = \frac{\text{emf}}{R} = \frac{1.05\ \text{V}}{8.7\ \Omega} = \boxed{0.12\ \text{A}}$
12. $N = 52$ $A = 5.5 \times 10^{-3}$ m^2 $B_i = 0.00$ T $B_f = 0.55$ T $\Delta t = 0.25$ s $\theta = 0.0°$	$\text{emf} = \frac{-NA(\cos\theta)\Delta B}{\Delta t}$ $\Delta B = B_f - B_i = 0.55\ \text{T} - 0.00\ \text{T} = 0.55\ \text{T}$ $\text{emf} = \frac{-(52)(5.5 \times 10^{-3}\ \text{m}^2)(\cos 0.0°)(0.55\ \text{T})}{0.25\ \text{s}} = \boxed{-0.63\ \text{V}}$
26. $\Delta V_{rms} = 220\ 000$ V	$\Delta V_{max} = \frac{\Delta V_{rms}}{0.707} = \frac{220\ 000\ \text{V}}{0.707} = \boxed{310\ 000\ \text{V} = 3.1 \times 10^5\ \text{V}}$
27. $\Delta V_{max} = 340$ V $R = 120\ \Omega$	**a.** $\Delta V_{rms} = (0.707)(\Delta V_{max}) = (0.707)(340\ \text{V}) = \boxed{2.4 \times 10^2\ \text{V}}$ **b.** $I_{rms} = \frac{\Delta V_{rms}}{R} = \frac{2.40 \times 10^2\ \text{V}}{120\ \Omega} = \boxed{2.0\ \text{A}}$
28. $I_{max} = 0.909$ A $R = 182\ \Omega$	**a.** $I_{rms} = (0.707)(I_{max}) = (0.707)(0.909\ \text{A}) = \boxed{0.643\ \text{A}}$ **b.** $\Delta V_{rms} = I_{rms}R = (0.643\ \text{A})(182\ \Omega) = \boxed{117\ \text{V}}$ **c.** $P = I_{rms}{}^2R = (0.643\ \text{A})^2(182\ \Omega) = \boxed{75.2\ \text{W}}$
29. $P = 996$ W $I_{max} = 11.8$ A	**a.** $I_{rms} = (0.707)(I_{max}) = (0.707)(11.8\ \text{A}) = \boxed{8.34\ \text{A}}$ **b.** $\Delta V_{rms} = \frac{P}{I_{rms}} = \frac{996\ \text{W}}{8.34\ \text{A}} = \boxed{119\ \text{V}}$

Givens | *Solutions*

34. $\Delta V_1 = 120$ V
$\Delta V_2 = 9.0$ V
$N_1 = 640$ turns

$$N_2 = \frac{\Delta V_2 N_1}{\Delta V_1} = \frac{(9.0\ \text{V})(640\ \text{turns})}{120\ \text{V}} = \boxed{48\ \text{turns}}$$

35. $\Delta V_2 = 9.00$ V
$\frac{N_1}{N_2} = \frac{24.6}{1}$

$$\Delta V_1 = \Delta V_2 \frac{N_1}{N_2}$$

$$\Delta V_1 = (9.00\ \text{V})\left(\frac{24.6}{1}\right) = \boxed{221\ \text{V}}$$

36. $\Delta V_1 = 120$ V
$\Delta V_2 = 6.3$ V
$N_1 = 210$ turns

$$N_2 = \frac{\Delta V_2 N_1}{\Delta V_1} = \frac{(6.3\ \text{V})(210\ \text{turns})}{120\ \text{V}} = \boxed{11\ \text{turns}}$$

37. $\Delta V_1 = 24\,000$ V
$N_1 = 60$ turns
$N_2 = 3$ turns

b. $$\Delta V_1 = \Delta V_2 \frac{N_1}{N_2}$$

$$\Delta V_1 = (24\,000\ \text{V})\left(\frac{3}{60}\right) = 1200\ \text{V} = \boxed{1.2 \times 10^3\ \text{V}}$$

42. $N = 1$
$B_i = 2.5 \times 10^{-2}$ T
$A = 7.54 \times 10^{-3}\ \text{m}^2$
emf $= 1.5$ V
$\theta = 0.0°$
$B_f = 0.000$ T

$$\Delta t = \frac{-NA(\cos\theta)\Delta B}{\text{emf}}$$

$$\Delta B = B_f - B_i = 0.000\ \text{T} - 2.5 \times 10^{-2}\ \text{T} = -2.5 \times 10^{-2}\ \text{T}$$

$$\Delta t = \frac{-(1)(7.54 \times 10^{-3}\ \text{m}^2)(\cos 0.0°)(-2.5 \times 10^{-2}\ \text{T})}{1.5\ \text{V}} = \boxed{1.3 \times 10^{-4}\ \text{s}}$$

43. $A = 1.886 \times 10^{-3}\ \text{m}^2$
$B_i = 2.5 \times 10^{-2}$ T
$\Delta t = 0.25$ s
emf $= 149$ mV
$B_f = 0.000$ T
$\theta = 0.0°$

$$N = \frac{(\text{emf})(\Delta t)}{-A(\cos\theta)\Delta B}$$

$$\Delta B = B_f - B_i = 0.000\ \text{T} - 2.5 \times 10^{-2}\ \text{T} = -2.5 \times 10^{-2}\ \text{T}$$

$$N = \frac{(149 \times 10^{-3}\ \text{V})(0.25\ \text{s})}{-(1.886 \times 10^{-3}\ \text{m}^2)(\cos 0.0°)(-2.5 \times 10^{-2}\ \text{T})} = \boxed{7.9 \times 10^2\ \text{turns}}$$

44. $N = 325$
$A = 19.5 \times 10^{-4}\ \text{m}^2$
$\theta = 45°$
$\Delta t = 1.25$ s
emf $= 15$ mV
$B_f = 0.0$ T

$$\Delta B = \frac{(\text{emf})(\Delta t)}{-NA(\cos\theta)} = \frac{(15 \times 10^{-3}\ \text{V})(1.25\ \text{s})}{-(325)(19.5 \times 10^{-4}\ \text{m}^2)(\cos 45°)} = -4.2 \times 10^{-2}\ \text{T}$$

$$B_i = B_f - \Delta B = 0.0\ \text{T} - (-4.2 \times 10^{-2}\ \text{T}) = \boxed{4.2 \times 10^{-2}\ \text{T}}$$

Givens	*Solutions*
45. $N_1 = 22$ turns $N_2 = 88$ turns $\Delta V_1 = 110$ V	**b.** $\Delta V_2 = \frac{N_2 \Delta V_1}{N_1} = \frac{(88 \text{ turns})(110 \text{ V})}{22 \text{ turns}} = \boxed{4.4 \times 10^2 \text{ V}}$
46. $N = 105$ $\theta = 0.0°$ $r = 0.833$ m $B_i = 4.72 \times 10^{-3}$ T $B_f = 0.00$ T $\Delta t = 10.5\ \mu$s	$\text{emf} = \frac{-NA(\cos\theta)\Delta B}{\Delta t} = \frac{-N\pi r^2(\cos\theta)\Delta B}{\Delta t}$ $\Delta B = B_f - B_i = 0.00 \text{ T} - 4.72 \times 10^{-3} \text{ T} = -4.72 \times 10^{-3} \text{ T}$ $\text{emf} = \frac{-(105)(\pi)(0.833 \text{ m})^2(\cos 0.0°)(-4.72 \times 10^{-3} \text{ T})}{10.5 \times 10^{-6} \text{ s}}$ $\text{emf} = \boxed{1.03 \times 10^5 \text{ V}}$
47. $\Delta V_1 = 20.0$ kV $\Delta V_2 = 117$ V	$\frac{N_1}{N_2} = \frac{\Delta V_1}{\Delta V_2} = \frac{20.0 \times 10^3 \text{ V}}{117 \text{ V}} = \boxed{\frac{171}{1}}$
48. emf = (245 V)sin 560t	$f = \frac{560}{2\pi} = \boxed{89 \text{ Hz}}$ maximum potential difference = $\boxed{245 \text{ V}}$
49. $-M = 1.06$ H $\Delta I = 9.50$ A $\Delta t = 0.0336$ s	$\text{emf} = -M\frac{\Delta I}{\Delta t} = 1.06 \text{ H} \times \frac{9.50 \text{ A}}{0.0336 \text{ s}} = \boxed{300 \text{ V}}$
50. $P = 5.0 \times 10^3$ kW $\Delta V_1 = 4500$ V $\Delta V_2 = 510$ kV $R = (4.5 \times 10^{-4}\ \Omega/\text{m})$ $(6.44 \times 10^5 \text{ m})$	**a.** $I = \frac{P}{\Delta V_2}$ $P_{dissipated} = I^2R = \left(\frac{P}{\Delta V_2}\right)^2 R = \left(\frac{5.0 \times 10^6 \text{ W}}{510 \times 10^3 \text{ V}}\right)^2 (4.5 \times 10^{-4}\ \Omega/\text{m})(6.44 \times 10^5 \text{ m})$ $P_{dissipated} = 28 \times 10^3 \text{ W} = \boxed{28 \text{ kW}}$ **b.** If the generator's output were not stepped up, $I = \frac{P}{\Delta V_1}$ $P_{dissipated} = I^2R = \left(\frac{P}{\Delta V_1}\right)^2 R = \left(\frac{5.0 \times 10^6 \text{ W}}{4500 \text{ V}}\right)^2 (4.5 \times 10^{-4}\ \Omega/\text{m})(6.44 \times 10^5 \text{ m})$ $P_{dissipated} = 3.6 \times 10^8 \text{ W} = \boxed{3.6 \times 10^5 \text{ kW}}$

Givens	*Solutions*
4.	$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$ $\frac{\Delta V_{rms}}{\Delta V_{max}} = \frac{1}{\sqrt{2}}$
6. $A_2 = 1.5A_1$ $B_2 = B_1$ $N_2 = 2N_1$ $\cos\theta_2 = \cos\theta_1$ $\Delta t_2 = 0.5\Delta t_1$	$\Delta V_1 = -\frac{N_1\Delta[A_1B_1\cos\theta_1]}{\Delta t_1}$ $\Delta V_2 = -\frac{N_2\Delta[A_2B_2\cos\theta_2]}{\Delta t_2}$ $\frac{\Delta V_2}{\Delta V_1} = \frac{N_2\Delta[A_2B_2\cos\theta_2]\Delta t_1}{N_1\Delta[A_1B_1\cos\theta_1]\Delta t_2}$ $\frac{\Delta V_2}{\Delta V_1} = \frac{N_2A_2\Delta t_1}{N_1A_1\Delta t_2} = \left(\frac{N_2}{N_1}\right)\left(\frac{A_2}{A_1}\right)\left(\frac{\Delta t_1}{\Delta t_2}\right)$ $\frac{\Delta V_2}{\Delta V_1} = \left(\frac{2N_1}{N_1}\right)\left(\frac{1.5A_1}{A_1}\right)\left(\frac{\Delta t_1}{0.5\Delta t_1}\right) = \left(\frac{2}{1}\right)\left(\frac{1.5}{1}\right)\left(\frac{1}{0.5}\right) = 6$ $\boxed{\Delta V_2 = 6 \times \Delta V_1}$
8. $\Delta V_1 = 240\ 000$ V $N_{1A} = 1000$ turns $N_{2A} = 50$ turns $N_{1B} = 600$ turns $N_{2B} = 20$ turns	$\Delta V_2 = \Delta V_1\left(\frac{N_{2A}}{N_{1A}}\right)\left(\frac{N_{2B}}{N_{1B}}\right)$ $\Delta V_2 = (240\ 000\text{V})\left(\frac{50\text{ turns}}{1000\text{ turns}}\right)\left(\frac{20\text{ turns}}{600\text{ turns}}\right) = \boxed{400\text{ V}}$
10. $I_{max} = 3.5$ A $\Delta V_{max} = 340$ V	$I_{rms} = 0.707I_{max} = (0.707)(3.5\text{ A}) = 2.5\text{ A}$ $\Delta V_{rms} = 0.707\Delta V_{max} = (0.707)(340\text{ V}) = 240\text{ V}$ $P_{dissipated} = \Delta V_{rms}I_{rms} = (240\text{ V})(2.5\text{ A}) = \boxed{600\text{ W}}$
11. $I_{max} = 12.0$ A	$I_{rms} = 0.707I_{max} = (0.707)(12.0\text{ A}) = \boxed{8.48\text{ A}}$
14. $N_1 = 150$ turns $N_2 = 75\ 000$ turns $\Delta V_1 = 120$ V	$\Delta V_2 = \Delta V_1\frac{N_2}{N_1} = (120\text{ V})\left(\frac{75\ 000\text{ turns}}{150\text{ turns}}\right)$ $\Delta V_2 = \boxed{6.0 \times 10^4\text{ V}}$
18. $\frac{\Delta B}{\Delta t} = 0.10$ T/s $r = 2.4$ cm $= 0.024$ m $N = 1$ $\theta = 180°$ (for maximum emf)	$\text{emf} = -N\frac{\Delta\Phi_M}{\Delta t} = -\frac{N\Delta[AB\cos\theta]}{\Delta t}$ $\text{emf} = -NA\cos\theta\frac{\Delta B}{\Delta t} = -N\pi r^2\cos\theta\frac{\Delta B}{\Delta t}$ $\text{emf} = -(1)(\pi)(0.024\text{ m})^2(\cos 180°)(0.10\text{ T/s})$ $\text{emf} = \boxed{1.8 \times 10^{-4}\text{ V}}$

Atomic Physics

Atomic Physics, Practice A

Givens	*Solutions*
1. $E = 8.1 \times 10^{-15}$ eV	$f = \dfrac{E}{h} = \dfrac{(8.1 \times 10^{-15}\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}} = \boxed{2.0\ \text{Hz}}$
2. $f = 0.56$ Hz	$E = hf = (6.63 \times 10^{-34}\ \text{J•s})(0.56\ \text{Hz}) = \boxed{3.7 \times 10^{-34}\ \text{J}}$
3. $E = 5.0$ eV	$f = \dfrac{E}{h} = \dfrac{(1.60 \times 10^{-19}\ \text{J/eV})(5.0\ \text{eV})}{6.63 \times 10^{-34}\ \text{J•s}} = \boxed{1.2 \times 10^{15}\ \text{Hz}}$
4. $\lambda = 940$ µm	**a.** $f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8}\ \text{m/s}}{940 \times 10^{-6}\ \text{m}} = \boxed{3.19 \times 10^{11}\ \text{Hz}}$ **c.** $E = hf = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(3.19 \times 10^{11}\ \text{Hz})}{1.60 \times 10^{-19}\ \text{J/eV}} = \boxed{1.32 \times 10^{-3}\ \text{eV}}$

Atomic Physics, Practice B

1. $E = 5.00$ eV

$KE_{max} = E - hf_t$

$$f_t = \frac{E - KE_{max}}{h} = \frac{[5.00\ \text{eV} - 3.00\ \text{eV}](1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$$

$f_t = \boxed{4.83 \times 10^{14}\ \text{Hz}}$

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2. $\lambda = 350$ nm

$KE_{max} = 1.3$ eV

work function $= hf - KE_{max}$

$$f = \frac{c}{\lambda}$$

$$\text{work function} = h\left(\frac{c}{\lambda}\right) - KE_{max}$$

$$\text{work function} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{J/eV})(350 \times 10^{-9}\ \text{m})} - 1.3\ \text{eV}$$

work function $= 3.6\ \text{eV} - 1.3\ \text{eV} = \boxed{2.3\ \text{eV}}$

$$f_t = \frac{\text{work function}}{h} = \frac{(2.3\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$$

$f_t = \boxed{5.6 \times 10^{14}\ \text{Hz}}$

Givens	*Solutions*
3. $f = 1.00 \times 10^{15}$ Hz	$KE_{max} = hf - hf_t$
$KE_{max} = 2.85 \times 10^{-19}$ J	$hf_t = hf - KE_{max}$
	$hf_t = (6.63 \times 10^{-34}\ \text{J•s})(1.00 \times 10^{15}\ \text{Hz}) - 2.85 \times 10^{-19}$ J
	$hf_t = 6.63 \times 10^{-19}\ \text{J} - 2.85 \times 10^{-19}$ J
	$hf_t = 3.78 \times 10^{-19}$ J
	Converting to electron-volts, $hf_t = \dfrac{3.78 \times 10^{-19}\ \text{J}}{1.60 \times 10^{-19}\ \text{J/eV}} = \boxed{2.36\ \text{eV}}$

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4. $f = 7.0 \times 10^{14}$ Hz	$E = hf = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(7.0 \times 10^{14}\ \text{Hz})}{1.60 \times 10^{-19}\ \text{J/eV}} = 2.9$ eV
$hf_{t,lithium} = 2.3$ eV	
$hf_{t,silver} = 4.7$ eV	The photoelectric effect will be observed if $E > hf_t$, which holds true for $\boxed{\text{lithium}}$
$hf_{t,cesium} = 2.14$ eV	and $\boxed{\text{cesium}}$.

Atomic Physics, Section 1 Review

2. $\lambda = 4.5 \times 10^{-7}$ m	$E = hf = \dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{J/eV})(4.5 \times 10^{-7}\ \text{m})}$
	$E = \boxed{2.8\ \text{eV}}$

5. $\lambda = 1.00 \times 10^{-7}$ m	$f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^{8}\ \text{m/s}}{1.00 \times 10^{-7}\ \text{m}} = 3.00 \times 10^{15}$ Hz
$hf_t = 4.6$ eV	$f_t = \dfrac{4.6\ \text{eV}}{h} = \dfrac{(4.6\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$
	$f_t = 1.1 \times 10^{15}$ Hz
	Because $f > f_t$, electrons are ejected.
	$KE_{max} = hf - hf_t$
	$KE_{max} = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{15}\ \text{Hz})}{1.60 \times 10^{-19}\ \text{J/eV}} - 4.6$ eV
	$KE_{max} = 12.4\ \text{eV} - 4.6\ \text{eV} = \boxed{7.8\ \text{eV}}$

Atomic Physics, Practice C

1. $E_3 = -1.51$ eV	$E = E_3 - E_2 = (-1.51\ \text{eV}) - (-3.40\ \text{eV}) = 1.89$ eV
$E_2 = -3.40$ eV	$f = \dfrac{E}{h} = \dfrac{(1.89\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$
	$f = \boxed{4.56 \times 10^{14}\ \text{Hz}}$

2. $E_6 = -0.378$ eV	$E = E_6 - E_3 = (-0.378\ \text{eV}) - (-1.51\ \text{eV}) = 1.13$ eV
$E_3 = -1.51$ eV	$f = \dfrac{E}{h} = \dfrac{(1.13\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$
	$f = \boxed{2.73 \times 10^{14}\ \text{Hz}}$

Givens	Solutions
3. $E_5 = 6.67$ eV $E_1 = 0$ eV	$E = E_5 - E_1 = (6.67 \text{ eV}) - (0 \text{ eV}) = 6.67 \text{ eV}$ $f = \frac{E}{h} = \frac{(6.67 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J•s}}$ $f = \boxed{1.61 \times 10^{15} \text{ Hz}}$
5. $f = 7.29 \times 10^{14}$ Hz	$E = hf = (6.63 \times 10^{-34} \text{ J•s})(7.29 \times 10^{14} \text{ Hz}) = 4.83 \times 10^{-19} \text{ J}$ $E = 4.83 \times 10^{-19} \text{ J} \times 1 \text{ eV}/1.60 \times 10^{-19} \text{ J} = \boxed{3.02 \text{ eV}}$

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Atomic Physics, Practice D

1. $m = 50.0\text{g} = 5.00 \times 10^{-2}$ kg $\lambda = 3.32 \times 10^{-34}$ m	$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.00 \times 10^{-2} \text{ kg})(3.32 \times 10^{-34} \text{ m})} = \boxed{39.9 \text{ m/s}}$
2. $\lambda = 5.00 \times 10^{-7}$ m $m = 9.109 \times 10^{-31}$ kg	$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.00 \times 10^{-7} \text{ m})(9.109 \times 10^{-31} \text{ kg})} = \boxed{1.46 \times 10^{3} \text{ m/s}}$
3. $m = 0.15$ kg $\lambda = 5.00 \times 10^{-7}$ m	$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.00 \times 10^{-7} \text{ m})(0.15 \text{ kg})} = \boxed{8.84 \times 10^{-27} \text{ m/s}}$
4. $m = 1375$ kg $v = 43$ km/h	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(1375 \text{ kg})(43 \times 10^{3} \text{ m/h})(1 \text{ h}/3600 \text{ s})} = \boxed{4.0 \times 10^{-38} \text{ m}}$
5. $v = 3.5$ µm/s $\lambda = 1.9 \times 10^{-13}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(1.9 \times 10^{-13} \text{ m})(3.5 \times 10^{-6} \text{ m/s})} = \boxed{1.0 \times 10^{-15} \text{ kg}}$

Atomic Physics, Section 3 Review

3. $v = 1.00 \times 10^{4}$ m/s $m = 1.673 \times 10^{-27}$ kg	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34} \text{ J•s}}{(1.673 \times 10^{-27} \text{ kg})(1.00 \times 10^{4} \text{ m/s})} = \boxed{3.96 \times 10^{-11} \text{ m}}$

Atomic Physics, Chapter Review

11. $E = 2.0$ keV	$f = \frac{E}{h} = \frac{(2.0 \times 10^{3} \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{6.63 \times 10^{-34} \text{ J•s}} = \boxed{4.8 \times 10^{17} \text{ Hz}}$
12. $\lambda_1 = 5.00$ cm	**a.** $E_1 = hf_1 = \frac{hc}{\lambda_1} = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^{8} \text{ m/s})}{(1.60 \times 10^{-19} \text{ J/eV})(5.00 \times 10^{-2} \text{ m})} = \boxed{2.49 \times 10^{-5} \text{ eV}}$
$\lambda_2 = 5.00 \times 10^{-7}$ m	**b.** $E_2 = hf_2 = \frac{hc}{\lambda_2} = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^{8} \text{ m/s})}{(1.60 \times 10^{-19} \text{ J/eV})(5.00 \times 10^{-7} \text{ m})} = \boxed{2.49 \text{ eV}}$
$\lambda_3 = 5.00 \times 10^{-8}$ m	**c.** $E_3 = hf_3 = \frac{hc}{\lambda_3} = \frac{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^{8} \text{ m/s})}{(1.60 \times 10^{-19} \text{ J/eV})(5.00 \times 10^{-8} \text{ m})} = \boxed{24.9 \text{ eV}}$

Givens	*Solutions*
13. $f = 1.5 \times 10^{15}$ Hz $KE_{max} = 1.2$ eV	$f_t = \dfrac{hf - KE_{max}}{h}$ $f_t = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(1.5 \times 10^{15}\ \text{Hz}) - (1.2\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f_t = \dfrac{(9.9 \times 10^{-19}\ \text{J} - 1.9 \times 10^{-19}\ \text{J})}{6.63 \times 10^{-34}\ \text{J•s}} = \boxed{1.2 \times 10^{15}\ \text{Hz}}$
14. $f_t = 1.14 \times 10^{15}$ Hz	work function $= hf_t = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(1.14 \times 10^{15}\ \text{Hz})}{1.60 \times 10^{-19}\ \text{J/eV}}$ work function $= \boxed{4.72\ \text{eV}}$
23. $E_1 = -13.6$ eV $E_2 = -3.40$ eV	**a.** $E = E_2 - E_1 = -3.40\ \text{eV} - (-13.6\ \text{eV}) = 10.2\ \text{eV}$ $f = \dfrac{E}{h} = \dfrac{(10.2\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f = \boxed{2.46 \times 10^{15}\ \text{Hz}}$
$E_1 = -13.6$ eV $E_3 = -1.51$ eV	**b.** $E = E_3 - E_1 = -1.51\ \text{eV} - (-13.6\ \text{eV}) = 12.1\ \text{eV}$ $f = \dfrac{E}{h} = \dfrac{(12.1\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f = \boxed{2.92 \times 10^{15}\ \text{Hz}}$
$E_1 = -13.6$ eV $E_4 = -0.850$ eV	**c.** $E = E_4 - E_1 = -0.850\ \text{eV} - (-13.6\ \text{eV}) = 12.8\ \text{eV}$ $f = \dfrac{E}{h} = \dfrac{(12.8\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f = \boxed{3.09 \times 10^{15}\ \text{Hz}}$
$E_1 = -13.6$ eV $E_5 = -0.544$ eV	**d.** $E = E_5 - E_1 = -0.544\ \text{eV} - (-13.6\ \text{eV}) = 13.1\ \text{eV}$ $f = \dfrac{E}{h} = \dfrac{(13.1\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f = \boxed{3.16 \times 10^{15}\ \text{Hz}}$
33. $\lambda = 5.2 \times 10^{-11}$ m	$v = \dfrac{h}{m\lambda} = \dfrac{6.63 \times 10^{-34}\ \text{J•s}}{(9.109 \times 10^{-31}\ \text{kg})(5.2 \times 10^{-11}\ \text{m})} = \boxed{1.4 \times 10^{7}\ \text{m/s}}$
34. $m = 0.15$ kg $v = 45$ m/s	$\lambda = \dfrac{h}{mv} = \dfrac{6.63 \times 10^{-34}\ \text{J•s}}{(0.15\ \text{kg})(45\ \text{m/s})} = \boxed{9.8 \times 10^{-35}\ \text{m}}$

Givens	*Solutions*

35. $\lambda_1 = \lambda$

$KE_{max,1} = 1.00$ eV

$\lambda_2 = \frac{1}{2}\lambda$

$KE_{max,2} = 4.00$ eV

$$\text{work function} = hf - KE_{max} = \frac{hc}{\lambda} - KE_{max}$$

$$\frac{hc}{\lambda} - KE_{max,1} = \frac{hc}{\frac{1}{2}\lambda} - KE_{max,2} = \frac{2hc}{\lambda} - KE_{max,2}$$

$$KE_{max,2} - KE_{max,1} = \frac{hc}{\lambda}$$

$$\frac{hc}{\lambda} = 4.00 \text{ eV} - 1.00 \text{ eV} = 3.00 \text{ eV}$$

$$\text{work function} = \frac{hc}{\lambda} - KE_{max,1} = 3.00 \text{ eV} - 1.00 \text{ eV} = \boxed{2.00 \text{ eV}}$$

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36. $m = 0.50$ kg

$h_m = 3.0$ m

$\lambda = 5.0 \times 10^{-7}$ m

$$PE = mgh_m = nhf = \frac{nhc}{\lambda}$$

$$n = \frac{\lambda mgh_m}{hc} = \frac{(5.0 \times 10^{-7} \text{ m})(0.50 \text{ kg})(9.81 \text{ m/s}^2)(3.0 \text{ m})}{(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})}$$

$$n = \boxed{3.7 \times 10^{19} \text{ photons}}$$

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37. $\lambda_1 = 670.0$ nm

$\lambda_2 = 520.0$ nm

$KE_{max,2} = (1.50)(KE_{max,1})$

$$KE_{max} = hf - hf_t = \frac{hc}{\lambda} - hf_t$$

For wavelength λ_1, $KE_{max,1} = \dfrac{hc}{\lambda_1} - hf_t$

For wavelength λ_2, $KE_{max,2} = \dfrac{hc}{\lambda_2} - hf_t$

$$KE_{max,2} = (1.50)(KE_{max,1})$$

$$\frac{hc}{\lambda_2} - hf_t = (1.50)\left(\frac{hc}{\lambda_1} - hf_t\right)$$

$$\frac{hc}{\lambda_2} - hf_t = \frac{(1.50)(hc)}{\lambda_1} - (1.50)(hf_t)$$

$$(1.50)(hf_t) - hf_t = \frac{(1.50)(hc)}{\lambda_1} - \frac{hc}{\lambda_2}$$

$$(0.50)(hf_t) = \frac{(1.50)(hc)}{\lambda_1} - \frac{hc}{\lambda_2}$$

$$hf_t = (2.0)\left(\frac{(1.50)(hc)}{\lambda_1} - \frac{hc}{\lambda_2}\right)$$

$$hf_t = (2.0)(hc)\left(\frac{1.50}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$hf_t = (2.0)(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})\left(\frac{1.50}{670.0 \times 10^{-9} \text{ m}} - \frac{1}{520.0 \times 10^{-9} \text{ m}}\right)$$

$$hf_t = (2.0)(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})(2.24 \times 10^6 \text{ m}^{-1} - 1.923 \times 10^6 \text{ m}^{-1})$$

$$hf_t = \frac{(2.0)(6.63 \times 10^{-34} \text{ J•s})(3.00 \times 10^8 \text{ m/s})(0.32 \times 10^6 \text{ m}^{-1})}{1.60 \times 10^{-19} \text{ J/eV}}$$

$$hf_t = \boxed{0.80 \text{ eV}}$$

Givens *Solutions*

38. $m = 0.200$ kg

$\Delta y = 50.0$ m

$$\lambda = \frac{h}{mv}$$

$$v = \sqrt{2g\Delta y}$$

$$\lambda = \frac{h}{m\sqrt{2g\Delta y}} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(0.200\ \text{kg})\sqrt{(2)(9.81\ \text{m/s}^2)(50.0\ \text{m})}} = \boxed{1.06 \times 10^{-34}\ \text{m}}$$

Atomic Physics, Standardized Test Prep

7. $E_5 = -0.544$ eV

$E_2 = -3.40$ eV

$$E = E_5 - E_2 = (-0.544\ \text{eV}) - (-3.40\ \text{eV}) = 2.86\ \text{eV}$$

$$f = \frac{E}{h} = \frac{(2.86\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$$

$$f = \boxed{6.90 \times 10^{14}\ \text{Hz}}$$

8. $E_3 = -1.51$ eV

$E_2 = -3.40$ eV

$$E = E_3 - E_2 = (-1.51\ \text{eV}) - (-3.40\ \text{eV}) = 1.89\ \text{eV}$$

$$f = \frac{E}{h} = \frac{(1.89\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$$

$$f = \boxed{4.56 \times 10^{14}\ \text{Hz}}$$

11. $\lambda = 4.00 \times 10^{-14}$ m

$m_p = 1.67 \times 10^{-27}$ kg

$$v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(1.67 \times 10^{-27}\ \text{kg})(4.00 \times 10^{-14}\ \text{m})} = \boxed{9.93 \times 10^{6}\ \text{m/s}}$$

13. $f = 2.80 \times 10^{14}$ Hz

$$E = hf = (6.63 \times 10^{-34}\ \text{J•s})(2.80 \times 10^{14}\ \text{Hz}) = \boxed{1.86 \times 10^{-19}\ \text{J}}$$

$$E = 1.86 \times 10^{-19}\ \text{J} \times 1\ \text{eV}/1.60 \times 10^{-19}\ \text{J} = \boxed{1.16\ \text{eV}}$$

14. $\lambda = 3.0 \times 10^{-7}$ m

$hf_{t,lithium} = 2.3$ eV

$hf_{t,iron} = 3.9$ eV

$hf_{t,mercury} = 4.5$ eV

a. $$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{J/eV})(3.0 \times 10^{-7}\ \text{m})} = 4.1\ \text{eV}$$

The photoelectric effect will be observed if $E > hf_t$, which holds true for $\boxed{\text{lithium}}$ and $\boxed{\text{iron}}$.

b. For lithium, $KE_{max} = E - hf_{t,lithium} = 4.1\ \text{eV} - 2.3\ \text{eV} = \boxed{1.8\ \text{eV}}$

For iron, $KE_{max} = E - hf_{t,iron} = 4.1\ \text{eV} - 3.9\ \text{eV} = \boxed{0.2\ \text{eV}}$

Givens | *Solutions*

17. $v_{max} = 4.6 \times 10^5$ m/s

$\lambda = 625$ nm

$m = 9.109 \times 10^{-31}$ kg

a. $hf_t = hf - KE_{max} = \dfrac{hc}{\lambda} - \frac{1}{2}m(v_{max})^2$

$$hf_t = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^8\ \text{m/s})}{625 \times 10^{-9}\ \text{m}} - (0.5)(9.109 \times 10^{-31}\ \text{kg})(4.6 \times 10^5\ \text{m/s})^2$$

$$hf_t = (3.18 \times 10^{-19}\ \text{J}) - (9.6 \times 10^{-20}\ \text{J}) = 22.2 \times 10^{-20}\ \text{J}$$

$$hf_t = \frac{22.2 \times 10^{-20}\ \text{J}}{1.60 \times 10^{-19}\ \text{J/eV}} = \boxed{1.39\ \text{eV}}$$

b. $f_t = \dfrac{\text{work function}}{h} = \dfrac{22.2 \times 10^{-20}\ \text{J}}{6.63 \times 10^{-34}\ \text{J•s}} = \boxed{3.35 \times 10^{14}\ \text{Hz}}$

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18. $\lambda = 1.0 \times 10^{-11}$ m

$m = 9.109 \times 10^{-31}$ kg

a. $\lambda = \dfrac{h}{mv}$

$$v = \frac{h}{\lambda m}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{h}{\lambda m}\right)^2 = \frac{h^2}{2\lambda^2 m}$$

$$KE = \frac{(6.63 \times 10^{-34}\ \text{J•s})^2}{(2)(1.0 \times 10^{-11}\ \text{m})^2(9.109 \times 10^{-31}\ \text{kg})(1.60 \times 10^{-19}\ \text{J/eV})}$$

$$KE = \boxed{1.5 \times 10^4\ \text{eV (15 keV)}}$$

b. $E = hf = \dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^8\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{J/eV})(1.0 \times 10^{-11}\ \text{m})}$

$$E = \boxed{1.2 \times 10^5\ \text{eV (120 keV)}}$$

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Student Edition Solutions

Subatomic Physics

Subatomic Physics, Practice A

Givens | *Solutions*

1. For $^{20}_{10}$Ne:

$Z = 10$

$A = 20$

atomic mass of Ne-20 = 19.992 435 u

atomic mass of H = 1.007 825 u

$m_n = 1.008\ 665$ u

$N = A - Z = 20 - 10 = 10$

$\Delta m = Z$(atomic mass of H) $+ Nm_n -$ atomic mass of Ne-20

$\Delta m = 10(1.007\ 825\ \text{u}) + 10(1.008\ 665\ \text{u}) - 19.992\ 435\ \text{u}$

$\Delta m = 10.078\ 250\ \text{u} + 10.086\ 650\ \text{u} - 19.992\ 435\ \text{u}$

$\Delta m = 0.172\ 465\ \text{u}$

$E_{bind} = (0.172\ 465\ \text{u})(931.49\ \text{MeV/u}) = \boxed{160.65\ \text{MeV}}$

For $^{40}_{20}$Ca:

$Z = 20$

$A = 40$

atomic mass of Ca-40 = 39.962 591 u

$N = A - Z = 40 - 20 = 20$

$\Delta m = Z$(atomic mass of H) $+ Nm_n -$ atomic mass of Ca-40

$\Delta m = 20(1.007\ 825\ \text{u}) + 20(1.008\ 665\ \text{u}) - 39.962\ 591\ \text{u}$

$\Delta m = 20.156\ 500\ \text{u} + 20.173\ 300\ \text{u} - 39.962\ 591\ \text{u}$

$\Delta m = 0.367\ 209\ \text{u}$

$E_{bind} = (0.367\ 209\ \text{u})(931.49\ \text{MeV/u}) = \boxed{342.05\ \text{MeV}}$

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2. For $^{3}_{1}$H:

$Z = 1$

$A = 3$

atomic mass of H-3 = 3.016 049 u

atomic mass of H = 1.007 825 u

$m_n = 1.008\ 665$ u

$N = A - Z = 3 - 1 = 2$

$\Delta m = Z$(atomic mass of H) $+ Nm_n -$ atomic mass of H-3

$\Delta m = 1(1.007\ 825\ \text{u}) + 2(1.008\ 665\ \text{u}) - 3.016\ 049\ \text{u}$

$\Delta m = 1.007\ 825\ \text{u} + 2.017\ 330\ \text{u} - 3.016\ 049\ \text{u}$

$\Delta m = 0.009\ 106\ \text{u}$

$E_{bind} = (0.009\ 106\ \text{u})(931.49\ \text{MeV/u}) = 8.482\ \text{MeV}$

For $^{3}_{2}$He:

$Z = 2$

$A = 3$

atomic mass of He-3 = 3.016 029 u

$N = A - Z = 3 - 2 = 1$

$\Delta m = Z$(atomic mass of H) $+ Nm_n -$ atomic mass of He-3

$\Delta m = 2(1.007\ 825\ \text{u}) + 1(1.008\ 665\ \text{u}) - 3.016\ 029\ \text{u}$

$\Delta m = 2.015\ 650\ \text{u} + 1.008\ 665\ \text{u} - 3.016\ 029\ \text{u}$

$\Delta m = 0.008\ 286\ \text{u}$

$E_{bind} = (0.008\ 286\ \text{u})(931.49\ \text{MeV/u}) = 7.718\ \text{MeV}$

The difference in binding energy is 8.482 MeV − 7.718 MeV = $\boxed{0.764\ \text{MeV}}$.

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Givens	*Solutions*
3. atomic mass of Ca-43 = 42.958 767 u	$\Delta m = m_{unbound} - m_{bound}$
m_n = 1.008 665 u	Δm = (atomic mass of Ca-42 + m_n) − (atomic mass of Ca-43)
atomic mass of Ca-42 = 41.958 618 u	Δm = 41.958 618 u + 1.008 665 u − 42.958 767 u
	Δm = 0.008 516 u
	E_{bind} of the last neutron = (0.008 516 u)(931.49 MeV/u) = $\boxed{7.933\text{ MeV}}$

4. For $^{238}_{92}$U:	$N = A - Z = 238 - 92 = 146$
$Z = 92$	$\Delta m = Z$(atomic mass of H) + Nm_n − atomic mass of U-238
$A = 238$	Δm = 92(1.007 825 u) + 146(1.008 665 u) − 238.050 784 u
atomic mass of U-238 = 238.050 784 u	Δm = 92.719 900 u + 147.265 090 u − 238.050 784 u
atomic mass of H = 1.007 825 u	Δm = 1.934 206 u
m_n = 1.008 665 u	$\dfrac{E_{bind}}{\text{nucleon}} = \dfrac{E_{bind}}{A} = \dfrac{(1.934\,206\text{ u})(931.49\text{ MeV/u})}{238} = \boxed{7.5701\text{ MeV/nucleon}}$

Subatomic Physics, Section 1 Review

6. atomic mass of H = 1.007 825 u	**a.** $N = A - Z = 93 - 41 = 52$
m_n = 1.008 665 u	$\Delta m = Z$(atomic mass of H) + Nm_n − atomic mass of Nb-93
For $^{93}_{41}$Nb:	Δm = 41(1.007 825 u) + 52(1.008 665 u) − 92.906 376 u
$Z = 41$	Δm = 41.320 825 u + 52.450 580 u − 92.906 376 u
$A = 93$	Δm = 0.865 029 u
atomic mass of Nb-93 = 92.906 376 u	E_{bind} = (0.865 029 u)(931.49 MeV/u) = $\boxed{805.77\text{ MeV}}$
For $^{197}_{79}$Au:	**b.** $N = A - Z = 197 - 79 = 118$
$Z = 79$	$\Delta m = Z$(atomic mass of H) + Nm_n − atomic mass of Au-197
$A = 197$	Δm = 79(1.007 825 u) + 118(1.008 665 u) − 196.966 543 u
atomic mass of Au-197 = 196.996 543 u	Δm = 79.618 175 u + 119.022 470 u − 196.966 543 u
	Δm = 1.674 102 u
	E_{bind} = (1.674 102 u)(931.49 MeV/u) = $\boxed{1559.4\text{ MeV}}$
For $^{27}_{13}$Al:	**c.** $N = A - Z = 27 - 13 = 14$
$Z = 13$	$\Delta m = Z$(atomic mass of H) + Nm_n − atomic mass of Al-27
$A = 27$	Δm = 13(1.007 825 u) + 14(1.008 665 u) − 26.981 534 u
atomic mass of Al-27 = 26.981 534 u	Δm = 13.101 725 u + 14.121 310 u − 26.981 534 u
	Δm = 0.241 501 u
	E_{bind} = (0.241 501 u)(931.49 MeV/u) = $\boxed{224.96\text{ MeV}}$

Givens	Solutions
8. For $^{23}_{11}\text{Na}$:	$N = A - Z = 23 - 11 = 12$
$Z = 11$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Na-23}$
$A = 23$	$\Delta m = 11(1.007\ 825\ \text{u}) + 12(1.008\ 665\ \text{u}) - 22.989\ 767\ \text{u}$
atomic mass of Na-23 = 22.989 767 u	$\Delta m = 11.086\ 08\ \text{u} + 12.103\ 98\ \text{u} - 22.989\ 767\ \text{u}$
atomic mass of H = 1.007 825 u	$\Delta m = 0.200\ 29\ \text{u}$
$m_n = 1.008\ 665$ u	$\dfrac{E_{bind}}{\text{nucleon}} = \dfrac{E_{bind}}{A} = \dfrac{(0.200\ 29\ \text{u})(931.49\ \text{MeV/u})}{23} = 8.1117\ \text{MeV/nucleon}$
For $^{23}_{12}\text{Mg}$:	$N = A - Z = 23 - 12 = 11$
$Z = 12$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Mg-23}$
$A = 23$	$\Delta m = 12(1.007\ 825\ \text{u}) + 11(1.008\ 665\ \text{u}) - 22.994\ 124\ \text{u}$
atomic mass of Mg-23 = 22.994 124 u	$\Delta m = 12.093\ 900\ \text{u} + 11.095\ 315\ \text{u} - 22.994\ 124\ \text{u}$
	$\Delta m = 0.195\ 091\ \text{u}$
	$\dfrac{E_{bind}}{\text{nucleon}} = \dfrac{E_{bind}}{A} = \dfrac{(0.195\ 091\ \text{u})(931.49\ \text{MeV/u})}{23} = 7.9011\ \text{MeV/nucleon}$
	The difference in binding energy per nucleon is
	$8.1117\ \text{MeV} - 7.9011\ \text{MeV} = \boxed{0.2106\ \text{MeV}}$.

Subatomic Physics, Practice B

1. $^{12}_{5}\text{B} \rightarrow ? + ^{0}_{-1}e + \overline{v}$

$A = 12 - 0 = 12$

$Z = 5 - (-1) = 6$, which is carbon, C

$? = \boxed{^{12}_{6}\text{C}}$

2. $^{212}_{83}\text{Bi} \rightarrow ? + ^{4}_{2}\text{He}$

$A = 212 - 4 = 208$

$Z = 83 - 2 = 81$, which is thallium, Tl

$? = \boxed{^{208}_{81}\text{Tl}}$

3. $? \rightarrow ^{14}_{7}\text{N} + ^{0}_{-1}e + \overline{v}$

$A = 14 + 0 = 14$

$Z = 7 + (-1) = 6$, which is carbon, C

$? = \boxed{^{14}_{6}\text{C}}$

4. $^{225}_{89}\text{Ac} \rightarrow ^{221}_{87}\text{Fr} + ?$

$A = 225 - 221 = 4$

$Z = 89 - 87 = 2$, which is helium, He

$? = \boxed{^{4}_{2}\text{He}}$

5. Nickel-63 decays by β^- to copper-63.

β^- decay involves an electron and an antineutrino.

$\boxed{^{63}_{28}\text{Ni} \rightarrow ^{63}_{29}\text{Cu} + ^{0}_{-1}e + \overline{v}}$

Givens	Solutions
6. ${}^{56}_{26}\text{Fe} \rightarrow {}^{56}_{27}\text{Co} + ?$	**a.** $A = 56 - 56 = 0$ $Z = 26 - 27 = -1$ $? = {}^{0}_{-1}e$, so the decay is $\boxed{\beta^-}$ **b.** β^- decay involves an electron and an antineutrino. $\boxed{{}^{56}_{26}\text{Fe} \rightarrow {}^{56}_{27}\text{Co} + {}^{0}_{-1}e + \overline{\nu}}$

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Subatomic Physics, Practice C

Givens	Solutions
1. $T_{1/2} = 164 \times 10^{-6}$ s $N = 2.0 \times 10^6$	$\lambda = \dfrac{0.693}{T_{1/2}} = \dfrac{0.693}{164 \times 10^{-6}\ \text{s}} = \boxed{4.23 \times 10^3\ \text{s}^{-1}}$ $\text{activity} = \lambda N = \dfrac{(4.23 \times 10^3\ \text{s}^{-1})(2.0 \times 10^6)}{3.7 \times 10^{10}\ \text{s}^{-1}/\text{Ci}} = \boxed{0.23\ \text{Ci}}$
2. $T_{1/2} = 19.7$ min $N = 2.0 \times 10^9$	$\lambda = \dfrac{0.693}{T_{1/2}} = \dfrac{0.693}{(19.7\ \text{min})(60\ \text{s/min})} = \boxed{5.86 \times 10^{-4}\ \text{s}^{-1}}$ $\text{activity} = \lambda N = \dfrac{(5.86 \times 10^{-4}\ \text{s}^{-1})(2.0 \times 10^9)}{3.7 \times 10^{10}\ \text{s}^{-1}/\text{Ci}} = \boxed{3.2 \times 10^{-5}\ \text{Ci}}$
3. $T_{1/2} = 8.07$ days $N = 2.5 \times 10^{10}$	$\lambda = \dfrac{0.693}{T_{1/2}} = \dfrac{0.693}{(8.07\ \text{days})(24\ \text{h/day})(3600\ \text{s/h})}$ $\lambda = \boxed{9.94 \times 10^{-7}\ \text{s}^{-1}}$ $\text{activity} = \lambda N = \dfrac{(9.94 \times 10^{-7}\ \text{s}^{-1})(2.5 \times 10^{10})}{3.7 \times 10^{10}\ \text{s}^{-1}/\text{Ci}} = \boxed{6.7 \times 10^{-7}\ \text{Ci}}$
4. $m_i = 1.00 \times 10^{-3}$ g $t = 2.0$ h $m_f = 0.25 \times 10^{-3}$ g	$\dfrac{m_f}{m_i} = \dfrac{0.25 \times 10^{-3}\ \text{g}}{1.00 \times 10^{-3}\ \text{g}} = \dfrac{1}{4}$ $2 \times \frac{1}{4} = \frac{1}{2}$, so we know that 2 half-lives have passed in 2.0 h. $T_{1/2} = \dfrac{2.0\ \text{h}}{2} = \boxed{1.0\ \text{h}}$
5. $T_{1/2} = 3.82$ days $N = 4.0 \times 10^8$	**a.** $\dfrac{12\ \text{days}}{3.82\ \text{days}} \approx 3$ half-lives $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$ $\frac{1}{8}(4.0 \times 10^8) = \boxed{5.0 \times 10^7\ \text{atoms}}$ **b.** $N_{decayed} = N - N_{remaining}$ $N_{decayed} = 4.0 \times 10^8\ \text{atoms} - 5.0 \times 10^7\ \text{atoms}$ $N_{decayed} = \boxed{3.5 \times 10^8\ \text{atoms}}$

Subatomic Physics, Section 2 Review

Givens	*Solutions*
2. $^{232}_{90}\text{Th} \rightarrow ? + ^{4}_{2}\text{He}$	**a.** $A = 232 - 4 = 228$ $Z = 90 - 2 = 88$, which is radium, Ra $? = \boxed{^{228}_{88}\text{Ra}}$
$^{12}_{5}\text{B} \rightarrow ? + ^{0}_{-1}e + \overline{v}$	**b.** $A = 12 - 0 = 12$ $Z = 5 - (-1) = 6$, which is carbon, C $? = \boxed{^{12}_{6}\text{C}}$
$? \rightarrow ^{4}_{2}\text{He} + ^{145}_{60}\text{Nd}$	**c.** $A = 4 + 145 = 149$ $Z = 2 + 60 = 62$, which is samarium, Sm $? = \boxed{^{149}_{62}\text{Sm}}$

3. $N = 5.3 \times 10^5$ nuclei

activity = 1 decay/4.2 h

a. $\lambda = \dfrac{\text{activity}}{N} = \dfrac{(1 \text{ decay}/4.2 \text{ h})(1 \text{ h}/3600 \text{ s})}{5.3 \times 10^5}$

$\lambda = \boxed{1.2 \times 10^{-10} \text{ s}^{-1}}$

b. $T_{1/2} = \dfrac{0.693}{\lambda} = \dfrac{0.693}{1.2 \times 10^{-10} \text{ s}^{-1}} = \boxed{5.8 \times 10^9 \text{ s}}$

or $(5.8 \times 10^9 \text{ s})(1 \text{ h}/3600 \text{ s})(1 \text{ day}/24 \text{ h})(1 \text{ year}/365.25 \text{ days}) = \boxed{180 \text{ years}}$

4. $T_{1/2} = 5715$ years

$^{14}\text{C} = (0.125)(\text{original } ^{14}\text{C})$

The ^{14}C has been reduced by $0.125 = \frac{1}{8} = \left(\frac{1}{2}\right)^3 = 3$ half-lives. Thus, the age of the site is $3T_{1/2} = (3)(5715 \text{ years}) = \boxed{17\,140 \text{ years}}$.

Subatomic Physics, Chapter Review

7. For $^{12}_{6}$C:

$Z = 6$

$A = 12$

atomic mass of C-12 = 12.000 000 u

atomic mass of H = 1.007 825 u

$m_n = 1.008\,665$ u

$N = A - Z = 12 - 6 = 6$

$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of C-12}$

$\Delta m = 6(1.007\,825 \text{ u}) + 6(1.008\,665 \text{ u}) - 12.000\,000 \text{ u}$

$\Delta m = 6.046\,950 \text{ u} + 6.051\,990 \text{ u} - 12.000\,000 \text{ u}$

$\Delta m = 0.098\,940 \text{ u}$

$E_{bind} = (0.098\,940 \text{ u})(931.49 \text{ MeV/u}) = \boxed{92.162 \text{ MeV}}$

8. For $^{3}_{1}$H:

$Z = 1$

$A = 3$

atomic mass of H-3 = 3.016 049 u

atomic mass of H = 1.007 825 u

$m_n = 1.008\,625$ u

$N = A - Z = 3 - 1 = 2$

$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of H-3}$

$\Delta m = 1(1.007\,825 \text{ u}) + 2(1.008\,665 \text{ u}) - 3.016\,049 \text{ u}$

$\Delta m = 1.007\,825 \text{ u} + 2.017\,330 \text{ u} - 3.016\,049 \text{ u}$

$\Delta m = 0.009\,106 \text{ u}$

$E_{bind} = (0.009\,106 \text{ u})(931.49 \text{ MeV/u}) = \boxed{8.482 \text{ MeV}}$

Givens	*Solutions*
For $^{3}_{2}He$: $Z = 2$, $A = 3$, atomic mass of He-3 = 3.016 029 u	$N = A - Z = 3 - 2 = 1$ $\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of He-3}$ $\Delta m = 2(1.007\ 825\ \text{u}) + 1(1.008\ 665\ \text{u}) - 3.016\ 029\ \text{u}$ $\Delta m = 2.015\ 650\ \text{u} + 1.008\ 665\ \text{u} - 3.016\ 029\ \text{u}$ $\Delta m = 0.008\ 286\ \text{u}$ $E_{bind} = (0.008\ 286\ \text{u})(931.49\ \text{MeV/u}) = \boxed{7.718\ \text{MeV}}$

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9. For $^{24}_{12}Mg$:
$Z = 12$
$A = 24$
atomic mass of Mg-24 = 23.985 042 u
atomic mass of H = 1.007 825 u
$m_n = 1.008\ 665$ u

$N = A - Z = 24 - 12 = 12$

$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Mg-24}$

$\Delta m = 12(1.007\ 825\ \text{u}) + 12(1.008\ 665\ \text{u}) - 23.985\ 042\ \text{u}$

$\Delta m = 12.093\ 900\ \text{u} + 12.103\ 980\ \text{u} - 23.985\ 042\ \text{u}$

$\Delta m = 0.212\ 838\ \text{u}$

$$\frac{E_{bind}}{\text{nucleon}} = \frac{E_{bind}}{A} = \frac{(0.212\ 838\ \text{u})(931.49\ \text{MeV/u})}{24} = \boxed{8.2607\ \text{MeV/nucleon}}$$

For $^{85}_{37}Rb$:
$Z = 37$
$A = 85$
atomic mass of Rb-85 = 84.911 793 u

$N = A - Z = 85 - 37 = 48$

$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Rb-85}$

$\Delta m = 37(1.007\ 825\ \text{u}) + 48(1.008\ 665\ \text{u}) - 84.911\ 793\ \text{u}$

$\Delta m = 37.289\ 525\ \text{u} + 48.415\ 920\ \text{u} - 84.911\ 793\ \text{u}$

$\Delta m = 0.793\ 652\ \text{u}$

$$\frac{E_{bind}}{\text{nucleon}} = \frac{E_{bind}}{A} = \frac{(0.793\ 652\ \text{u})(931.49\ \text{MeV/u})}{85} = \boxed{8.6974\ \text{MeV/nucleon}}$$

20. $^{7}_{3}Li + ^{4}_{2}He \rightarrow ? + ^{1}_{0}n$

$A = 7 + 4 - 1 = 10$

$Z = 3 + 2 = 5$, which is Boron, B

$? = \boxed{^{10}_{5}B}$

21. $? + ^{14}_{7}N \rightarrow ^{1}_{1}H + ^{17}_{8}O$

a. $A = 1 + 17 - 14 = 4$

$Z = 1 + 8 - 7 = 2$, which is helium, He

$? = \boxed{^{4}_{2}He}$

$^{7}_{3}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ?$

b. $A = 7 + 1 - 4 = 4$

$Z = 3 + 1 - 2 = 2$, which is helium, He

$? = \boxed{^{4}_{2}He}$

22. $T_{1/2} = 2.42$ min
$N = 1.67 \times 10^{11}$

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{(2.42\ \text{min})(60.0\ \text{s/min})} = \boxed{4.77 \times 10^{-3}\ \text{s}^{-1}}$$

$$\text{activity} = \lambda N = \frac{(4.77 \times 10^{-3}\ \text{s}^{-1})(1.67 \times 10^{11})}{3.7 \times 10^{10}\ \text{s}^{-1}/\text{Ci}} = \boxed{2.2 \times 10^{-2}\ \text{Ci}}$$

Givens	Solutions
23. $T_{1/2} = 140$ days $N_f = \frac{1}{16}N_i$	$\frac{1}{16} = \left(\frac{1}{2}\right)^4$, so 4 half-lives have passed. $4T_{1/2} = (4)(140 \text{ days}) = \boxed{560 \text{ days}}$
24. ${}^{14}_{6}\text{C} = (0.0625)(\text{original } {}^{14}_{6}\text{C})$ $T_{1/2} = 5715$ years	$\left(\frac{1}{2}\right)^x = 0.0625$ $x = 4$, so 4 half-lives have passed. $4T_{1/2} = (4)(5715 \text{ years}) = \boxed{22\,860 \text{ years}}$
32. ${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow ? + {}^{30}_{15}\text{P}$	**a.** $A = 27 + 4 - 30 = 1$ $Z = 13 + 2 - 15 = 0$ $? = \boxed{{}^{1}_{0}n}$
33. $r_H = 0.53 \times 10^{-10}$ m $\rho_{nuclear} = 2.3 \times 10^{17}$ kg/m^3 $m_H \approx m_p = 1.673 \times 10^{-27}$ kg	$\frac{\rho_{atomic}}{\rho_{nuclear}} = \frac{\frac{m_H}{V_H}}{\rho_{nuclear}} = \frac{\frac{m_H}{\frac{4}{3}\pi(r_H)^3}}{\rho_{nuclear}} = \frac{3m_H}{4\pi(r_H)^3\rho_{nuclear}}$ $\frac{\rho_{atomic}}{\rho_{nuclear}} = \frac{(3)(1.673 \times 10^{-27} \text{ kg})}{(4\pi)(0.53 \times 10^{-10} \text{ m})^3(2.3 \times 10^{17} \text{ kg/m}^3)} = \boxed{1.2 \times 10^{-14}}$
34. $m = 1.99 \times 10^{30}$ kg $\rho = 2.3 \times 10^{17}$ kg/m^3	$m = V\rho = \frac{4}{3}\pi r^3 \rho$ $r = \left(\frac{3m}{4\pi\rho}\right)^{1/3} = \left(\frac{(3)(1.99 \times 10^{30} \text{ kg})}{(4)(\pi)(2.3 \times 10^{17} \text{ kg/m}^3)}\right)^{1/3} = \boxed{1.3 \times 10^4 \text{ m}}$
35. atomic mass of H = 1.007 825 u $m_n = 1.008\,665$ u atomic mass of O-15 = 15.003 065 u For ${}^{15}_{8}$O: $Z = 8$ $A = 15$	$N = A - Z = 15 - 8 = 7$ $\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of O-15}$ $\Delta m = 8(1.007\,825 \text{ u}) + 7(1.008\,665 \text{ u}) - 15.003\,065 \text{ u}$ $\Delta m = 8.062\,600 \text{ u} + 7.060\,655 \text{ u} - 15.003\,065 \text{ u}$ $\Delta m = 0.120\,190$ u $E_{bind} = (0.120\,190 \text{ u})(931.49 \text{ MeV/u}) = 111.96 \text{ MeV}$
atomic mass of N-15 = 15.000 108 u For ${}^{15}_{7}$N: $Z = 7$ $A = 15$	$N = A - Z = 15 - 7 = 8$ $\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } N\text{-15}$ $\Delta m = 7(1.007\,825 \text{ u}) + 8(1.008\,665 \text{ u}) - 15.000\,108 \text{ u}$ $\Delta m = 7.054\,775 \text{ u} + 8.069\,320 \text{ u} - 15.000\,108 \text{ u}$ $\Delta m = 0.123\,987$ u $E_{bind} = (0.123\,987 \text{ u})(931.49 \text{ MeV/u}) = 115.49 \text{ MeV}$ The difference in binding energy is 115.49 MeV − 111.96 MeV = $\boxed{3.53 \text{ MeV}}$.

Givens	*Solutions*
36. $N = 7.96 \times 10^{10}$ atoms $T_{1/2} = 5715$ years	**a.** $\lambda = \dfrac{0.693}{T_{1/2}} = \dfrac{0.693}{(5715\text{ years})(365.25\text{ days/year})(24\text{ h/day})(60\text{ min/h})}$ $\lambda = 2.31 \times 10^{-10}\text{ min}^{-1}$ $\lambda N = (2.31 \times 10^{-10}\text{ min}^{-1})(7.96 \times 10^{10}) = \boxed{18.4\text{ decays/min}}$
37. ${}^{1}_{0}n + {}^{197}_{79}\text{Au} \rightarrow ? + {}^{0}_{-1}e + \overline{v}$	**a.** $A = 197 + 1 = 198$ $Z = 79 - (-1) = 80$, which is mercury, Hg $? = {}^{198}_{80}\text{Hg}$ $\boxed{{}^{1}_{0}n + {}^{197}_{79}\text{Au} \rightarrow {}^{198}_{80}\text{Hg} + {}^{0}_{-1}e + \overline{v}}$
atomic mass of Au-197 = 196.966 543 u atomic mass of Hg-198 = 197.966 743 u $m_n = 1.008\ 665$ u	**b.** $\Delta m = m_{unbound} - m_{bound}$ Δm = (atomic mass of Au-197 + m_n) − (atomic mass of Hg-198) $\Delta m = 196.966\ 543\text{ u} + 1.008\ 665\text{ u} - 197.966\ 743\text{ u}$ $\Delta m = 0.008\ 465$ u $E = (0.008\ 465\text{ u})(931.49\text{ MeV/u}) = \boxed{7.885\text{ MeV}}$
38. ${}^{140}\text{Xe}$ and ${}^{94}\text{Sr}$ are released as fission fragments.	**a.** ${}^{235}\text{U} + {}^{1}_{0}n \rightarrow {}^{140}\text{Xe} + {}^{94}\text{Sr} + ?$ $A = 235 + 1 - (140 + 94) = 2$ $? = \boxed{2\,{}^{1}_{0}n}$
${}^{132}\text{Sn}$ and ${}^{101}\text{Mo}$ are released as fission fragments.	**b.** ${}^{235}\text{U} + {}^{1}_{0}n \rightarrow {}^{132}\text{Sn} + {}^{101}\text{Mo} + ?$ $A = 235 + 1 - (132 + 101) = 3$ $? = \boxed{3\,{}^{1}_{0}n}$
39. ${}^{6}_{3}\text{Li} + {}^{1}_{1}p \rightarrow {}^{4}_{2}\text{He} + ?$	$A = 6 + 1 - 4 = 3$ $Z = 3 + 1 - 2 = 2$, which is helium, He $? = \boxed{{}^{3}_{2}\text{He}}$
40. ${}^{10}_{5}\text{B} + {}^{4}_{2}\text{He} \rightarrow {}^{1}_{1}p + ?$	$A = 10 + 4 - 1 = 13$ $Z = 5 + 2 - 1 = 6$, which is carbon, C $? = \boxed{{}^{13}_{6}\text{C}}$
41. $P = 2.0 \times 10^{3}$ kW•h/month conversion efficiency = 100.0% $E = 208$ MeV/fission event $\Delta t = 1$ year	$E = P\Delta t = (N)(208\text{ MeV})$ $N = \dfrac{P\Delta t}{208\text{ MeV}} = \dfrac{(2.0 \times 10^{6}\text{ W•h/month})(12\text{ months})(3600\text{ s/h})}{(208 \times 10^{6}\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})}$ $N = \boxed{2.6 \times 10^{21}\text{ atoms}}$
42. ${}^{18}_{8}\text{O} + {}^{1}_{1}p \rightarrow {}^{18}_{9}\text{F} + ?$	$A = 18 + 1 - 18 = 1$ $Z = 8 + 1 - 9 = 0$ $? = \boxed{{}^{1}_{0}n}$

Givens	*Solutions*
43. $2\,{}^4_2\text{He} \rightarrow \text{nucleus A} + \gamma$	**a.** $A = 2(4) = 8$ $Z = 2(2) = 4$, which is beryllium, Be nucleus A = $\boxed{{}^8_4\text{Be}}$
${}^8_4\text{Be} + {}^4_2\text{He} \rightarrow \text{nucleus B} + \gamma$	**b.** $A = 8 + 4 = 12$ $Z = 4 + 2 = 6$, which is carbon, C nucleus B = $\boxed{{}^{12}_6\text{C}}$
44. $\lambda N = 240.0$ mCi $T_{1/2} = 14$ days	$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{(14\text{ days})(24\text{ h/day})(3600\text{ s/h})}$ $\lambda = 5.7 \times 10^{-7}\text{ s}^{-1}$ $N = \frac{\lambda N}{\lambda} = \frac{(240.0 \times 10^{-3}\text{ Ci})(3.7 \times 10^{10}\text{ s}^{-1}\text{/Ci})}{5.7 \times 10^{-7}\text{ s}^{-1}}$ $N = \boxed{1.6 \times 10^{16}\text{ nuclei}}$
45. activity = 5.0 μCi $N = 1.0 \times 10^9$	$\lambda = \frac{\text{activity}}{N} = \frac{(5.0 \times 10^{-6}\text{ Ci})(3.7 \times 10^{10}\text{ s}^{-1}\text{/Ci})}{1.0 \times 10^9} = 1.8 \times 10^{-4}\text{ s}^{-1}$ $T_{1/2} = \frac{0.693}{\lambda}$ $T_{1/2} = \frac{0.693}{1.8 \times 10^{-4}\text{ s}^{-1}} = \boxed{3.8 \times 10^3\text{ s}}$
46. $m_{tot} = (9.1 \times 10^{11}\text{ kg})(0.0070)$ atomic mass of U-235 = 3.9×10^{-25} kg $P = 7.0 \times 10^{12}$ J/s $E = 208$ MeV/fission event	$N = \frac{m_{tot}}{\text{atomic mass}}$ $E = N(208\text{ MeV})$ $\Delta t = \frac{E}{P} = \frac{N(208\text{ MeV})}{P} = \frac{(m_{tot})(208\text{ MeV})}{(\text{atomic mass})(P)}$ $\Delta t = \frac{(9.1 \times 10^{11}\text{ kg})(0.0070)(208 \times 10^6\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})}{(3.9 \times 10^{-25}\text{ kg})(7.0 \times 10^{12}\text{ J/s})}$ $\Delta t = \boxed{7.8 \times 10^{10}\text{ s}}$ or $(7.8 \times 10^{10}\text{ s})(1\text{ h/3600 s})(1\text{ d/24 h})(1\text{ year/365.25 d}) = \boxed{2500\text{ years}}$
47. $E = 208$ MeV/fission event $P = 100.0$ W $\Delta t = 1.0$ h	$E_{tot} = P\Delta t = N(208\text{ MeV})$ $N = \frac{P\Delta t}{208\text{ MeV}} = \frac{(100.0\text{ W})(1.0\text{ h})(3600\text{ s/h})}{(208 \times 10^6\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})}$ $N = \boxed{1.1 \times 10^{16}\text{ fission events}}$

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Givens	Solutions
48. $P = 1.0 \times 10^3$ MW E = 208 MeV/fission event conversion efficiency = 30.0% Δt = 24 h	$E = P\Delta t = (N)(208\text{ MeV})(0.300)$ $N = \dfrac{P\Delta t}{(208\text{ MeV})(0.300)} = \dfrac{(1.0 \times 10^9\text{ W})(24\text{ h})(3600\text{ s/h})}{(208 \times 10^6\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})(0.300)}$ $N = \boxed{8.7 \times 10^{24}\text{ atoms}}$

Subatomic Physics, Standardized Test Prep

2. $m = 1.66 \times 10^{-27}$ kg $c = 3.00 \times 10^8$ m/s	$E_R = mc^2 = (1.66 \times 10^{-27}\text{ kg})(3.00 \times 10^8\text{ m/s})^2 = \boxed{1.49 \times 10^{-10}\text{ J}}$
5. ${}^4_2\text{He} + {}^9_4\text{Be} \rightarrow {}^{12}_6\text{C} + \text{X}$	$A = 4 + 9 - 12 = 1$ $Z = 2 + 4 - 6 = 0$ $\text{X} = \boxed{{}^1_0 n}$
7. age of the material = 23 000 years $T_{1/2}$ = 5715 years	$\dfrac{23\,000\text{ years}}{5715\text{ years}} \approx 4.0$ half-lives $\left(\dfrac{1}{2}\right)^4 = 0.0625$ Approximately 6% of the material remains, hence about 100% – 6% = $\boxed{94\%}$ of the material has decayed.
8. $T_{1/2}$ = 5.76 years $N = 2.0 \times 10^9$	$\lambda = \dfrac{0.693}{T_{1/2}} = \dfrac{0.693}{(5.76\text{ years})(3.156 \times 10^7\text{ s/year})} = \boxed{3.81 \times 10^{-9}\text{ s}^{-1}}$ $\text{activity} = \lambda N = \dfrac{(3.81 \times 10^{-9}\text{ s}^{-1})(2.0 \times 10^9)}{3.7 \times 10^{10}\text{ s}^{-1}/\text{Ci}} = \boxed{2.1 \times 10^{-10}\text{ Ci}}$
15. ${}^1_0 n + ? \rightarrow {}^4_2\text{He} + {}^7_3\text{Li}$	$A = 4 + 7 - 1 = 10$ $Z = 2 + 3 - 0 = 5$, which is boron, B $? = \boxed{{}^{10}_5\text{B}}$
16. $T_{1/2}$ = 432 years	It takes 10 half-lives to reach 0.1% of its original activity. Total length of time to reach 0.1% is (432 years)(10) = $\boxed{4320\text{ years}}$
17. $Z = 26$ $A = 56$ atomic mass of Fe-56 = 55.934 940 u atomic mass of H = 1.007 825 u m_n = 1.008 665 u	**a.** $N = A - Z = 56 - 26 = 30$ $\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Fe-56}$ $\Delta m = 26(1.007\,825\text{ u}) + 30(1.008\,665\text{ u}) - 55.934\,940\text{ u}$ $\Delta m = 26.203\,450\text{ u} + 30.259\,950\text{ u} - 55.934\,940\text{ u}$ $\Delta m = \boxed{0.528\,460\text{ u}}$ **b.** $E_{bind} = (0.528\,460\text{ u})(931.49\text{ MeV/u})$ $E_{bind} = \boxed{492.26\text{ MeV}}$

Givens | *Solutions*

18. m of U-238 = 238.050 784 u

m of Th-234 = 234.043 593 u

m of He-4 = 4.002 602 u

$\Delta m = m_{unbound} - m_{bound}$

$\Delta m = (m \text{ of U-238}) - (m \text{ of Th-234} + m \text{ of He-4})$

$\Delta m = 238.050\,784 \text{ u} - (234.043\,593 \text{ u} + 4.002\,602 \text{ u})$

$\Delta m = 0.004\,589 \text{ u}$

$E = (0.004\,589 \text{ u})(931.49 \text{ MeV/u}) = \boxed{4.275 \text{ MeV}}$

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Appendix I Additional Problems

I

The Science of Physics

Givens	*Solutions*
1. depth $= 1.168 \times 10^3$ cm	$\text{depth} = 1.168 \times 10^3 \text{ cm} \times \dfrac{1 \text{ m}}{10^2 \text{ cm}} = \boxed{1.168 \times 10^1 \text{ m} = 11.68 \text{ m}}$
2. area $= 1$ acre $= 4.0469 \times 10^3$ m^2	$\text{area} = 1 \text{ acre} = 4.0469 \times 10^3 \text{ m}^2 \times \left(\dfrac{1 \text{ km}}{10^3 \text{ m}}\right)^2$ $\text{area} = 4.0469 \times 10^3 \text{ m}^2 \times \dfrac{1 \text{ km}^2}{10^6 \text{ m}^2} = \boxed{4.0469 \times 10^{-3} \text{ km}^2}$
3. Volume $= 6.4 \times 10^4$ cm^3	$\text{volume} = 6.4 \times 10^4 \text{ cm}^3 \times \left(\dfrac{1 \text{ m}}{10^2 \text{ cm}}\right)^3 = 6.4 \times 10^4 \text{ cm}^3 \times \dfrac{1 \text{ m}^3}{10^6 \text{ cm}^3} = \boxed{6.4 \times 10^{-2} \text{ m}^3}$
4. mass $= 6.0 \times 10^3$ kg	$\text{mass} = 6.0 \times 10^3 \text{ kg} \times \dfrac{10^3 \text{ g}}{1 \text{ kg}} \times \dfrac{1 \text{ mg}}{10^{-3} \text{ g}} = \boxed{6.0 \times 10^9 \text{ mg}}$
5. time $= 6.7 \times 10^{-17}$ s	$\text{time} = 6.7 \times 10^{-17} \text{ s} \times \left(\dfrac{10^{12} \text{ ps}}{1 \text{ s}}\right) = \boxed{6.7 \times 10^{-5} \text{ ps}}$

Motion In One Dimension

Givens	*Solutions*
6. $\Delta x = 15.0$ km west $\Delta t = 15.3$ s	$v_{avg} = \dfrac{\Delta x}{\Delta t} = \dfrac{15.0 \text{ km}}{(15.3 \text{ s})\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)} = \dfrac{15.0 \text{ km}}{4.25 \times 10^{-3} \text{ h}} = \boxed{3.53 \times 10^3 \text{ km/h west}}$
7. $v = 89.5$ km/h north $v_{avg} = 77.8$ km/h north $\Delta t_{rest} = 22.0$ min	$\Delta x = v_{avg}\Delta t = v(\Delta t - \Delta t_{rest})$ $\Delta t(v_{avg} - v) = -v\Delta t_{rest}$ $\Delta t = \dfrac{v\Delta t_{rest}}{v - v_{avg}} = \dfrac{(89.5 \text{ km/h})(22.0 \text{ min})\left(\dfrac{1 \text{ h}}{60 \text{ min}}\right)}{89.5 \text{ km/h} - 77.8 \text{ km/h}}$ $\Delta t = \boxed{2.80 \text{ h} = 2 \text{ h, } 48 \text{ min}}$
8. $\Delta x = 1220$ km $v_i = 11.1$ km/s $v_f = 11.7$ km/s	$\Delta t = \dfrac{2\Delta x}{v_i + v_f} = \dfrac{(2)(1220 \text{ km})}{11.1 \text{ km/s} + 11.7 \text{ km/s}} = \dfrac{2440 \text{ km}}{22.8 \text{ km/s}} = \boxed{107 \text{ s}}$

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Givens	*Solutions*
9. $v_i = 4.0$ m/s $\Delta t = 18$ s $\Delta x = 135$ m	$v_f = \frac{2\Delta x}{\Delta t} - v_i = \frac{(2)(135\text{ m})}{18\text{ s}} - 4.0\text{ m/s} = 15\text{ m/s} - 4.0\text{ m/s} = \boxed{11\text{ m/s}}$ $v_f = (11\text{ m/s})\left(\frac{3600\text{ s}}{1\text{ h}}\right)\left(\frac{1\text{ km}}{10^3\text{ m}}\right)$ $v_f = \boxed{4.0 \times 10^1\text{ km/h}}$
10. $v_i = 7.0$ km/h $v_f = 34.5$ km/h $\Delta x = 95$ m	$a = \frac{v_f^2 - v_i^2}{2\Delta x} = \frac{[(34.5\text{ km/h})^2 - (7.0\text{ km/h})^2]\left(\frac{1\text{ h}}{3600\text{ s}}\right)^2\left(\frac{10^3\text{ m}}{1\text{ km}}\right)^2}{(2)(95\text{ m})}$ $a = \frac{(1190\text{ km}^2/\text{h}^2 - 49\text{ km}^2/\text{h}^2)\left(\frac{1\text{ h}}{3600\text{ s}}\right)^2\left(\frac{10^3\text{ m}}{1\text{ km}}\right)^2}{190\text{ m}}$ $a = \frac{(1140\text{ km}^2/\text{h}^2)\left(\frac{1\text{ h}}{3600\text{ s}}\right)^2\left(\frac{10^3\text{ m}}{1\text{ km}}\right)^2}{190\text{ m}} = \boxed{0.46\text{ m/s}^2}$
11. $\Delta x = 4.0$ m $\Delta t = 5.0$ min	$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{4.0\text{ m}}{(5.0\text{ min})\left(\frac{1\text{ h}}{60\text{ min}}\right)} = \boxed{48\text{ m/h}}$
12. $\Delta t = 28$ s $a = 0.035$ m/s^2 $v_i = 0.76$ m/s	$v_f = a\Delta t + v_i = (0.035\text{ m/s}^2)(28.0\text{ s}) + 0.76\text{ m/s} = 0.98\text{ m/s} + 0.76\text{ m/s} = \boxed{1.74\text{ m/s}}$
13. $\Delta t_{tot} = 5.10$ s $a = -9.81$ m/s^2 $\Delta x_{tot} = 0$ m	$\Delta t_{tot} = v_i \Delta\ t_{tot} + \frac{1}{2}a\Delta t_{tot}{}^2$ Because $\Delta x_{tot} = 0$, $v_i = -\frac{1}{2}\text{a}\Delta t_{tot} = -\frac{1}{2}(-9.81\text{ m/s}^2)(5.10\text{ s}) = +25.0\text{ m/s} = \boxed{25.0\text{ m/s upward}}$
14. $a_{avg} = -0.870$ m/s^2 $\Delta t = 3.80$ s	$a_{avg} = \frac{\Delta v_{avg}}{\Delta t}$ $\Delta v_{avg} = a_{avg}\Delta t = (-0.870\text{ m/s}^2)(3.80\text{ s}) = \boxed{-3.31\text{ m/s}}$
15. $\Delta x = 55.0$ m $\Delta t = 1.25$ s $v_f = 43.2$ m/s	$v_i = \frac{2\Delta x}{\Delta t} - v_f = \frac{(2)(55.0\text{ m})}{1.25\text{ s}} - 43.2\text{ m/s} = 88.0\text{ m/s} - 43.2\text{ m/s} = \boxed{44.8\text{ m/s}}$
16. $\Delta x = 12.4$ m upward $\Delta t = 2.0$ s $v_i = 0$ m/s	Because $v_i = 0$ m/s, $a = \frac{2\Delta x}{\Delta t^2} = \frac{(2)(12.4\text{ m})}{(2.0\text{ s})^2} = \boxed{6.2\text{ m/s}^2\text{ upward}}$

Givens	Solutions
17. $\Delta x = +42.0$ m $v_i = +153.0$ km/h $v_f = 0$ km/h	$a = \dfrac{v_f^2 - v_i^2}{2\Delta x} = \dfrac{[(0\ \text{km/h})^2 - (153.0\ \text{km/h})^2]\left(\dfrac{1\ \text{h}}{3600\ \text{s}}\right)^2\left(\dfrac{10^3\ \text{m}}{1\ \text{km}}\right)^2}{(2)\ (42.0\ \text{m})}$ $a = \dfrac{-(2.34 \times 10^4\ \text{km}^2/\text{h}^2)\left(\dfrac{1\ \text{h}}{3600\ \text{s}}\right)^2\left(\dfrac{10^3\ \text{m}}{1\ \text{km}}\right)^2}{(84.0\ \text{m})} = \boxed{-21.5\ \text{m/s}^2}$
18. $v_i = 17.5$ m/s $v_f = 0.0$ m/s $\Delta t_{tot} = 3.60$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$ $\Delta t_{top} = \dfrac{\Delta t_{tot}}{2} = \dfrac{3.60\ \text{s}}{2} = 1.80$ s $\Delta x = \frac{1}{2}(17.5\ \text{m/s} + 0.0\ \text{m/s})(1.80\ \text{s}) = \boxed{15.8\ \text{m}}$
19. $\Delta t = 5.50$ s $v_i = 0.0$ m/s $v_f = 14.0$ m/s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0.0\ \text{m/s} + 14.0\ \text{m/s})(5.50\ \text{s}) = \boxed{38.5\ \text{m}}$
20. $v = 6.50$ m/s downward $= -6.50$ m/s $\Delta t = 34.0$ s	$\Delta x = v\Delta t = (-6.50\ \text{m/s})(34.0\ \text{s}) = \boxed{-221\ \text{m} = 221\ \text{m downward}}$
21. $v_t = 10.0$ cm/s $v_h = 20\ v_t = 2.00 \times 10^2$ cm/s $\Delta t_{race} = \Delta t_t$ $\Delta t_h = \Delta t_t - 2.00$ min $\Delta x_t = \Delta x_h + 20.0\ \text{cm} = \Delta x_{race}$	$\Delta x_t = v_t\Delta t_t$ $\Delta x_h = v_h\Delta t_h = v_h\ (\Delta t_t - 2.00\ \text{min})$ $\Delta x_t = \Delta x_{race} = \Delta x_h + 20.0$ cm $v_t\ \Delta t_t = v_h\ (\Delta t_t - 2.00\ \text{min}) + 20.0$ cm $\Delta t_t\ (v_t - v_h) = -v_h\ (2.00\ \text{min}) + 20.0$ cm $\Delta t_t = \dfrac{20.0\ \text{cm} - v_h\ (2.00\ \text{min})}{v_t - v_h}$ $\Delta t_{race} = \Delta t_t = \dfrac{20.0\ \text{cm} - (2.00 \times 10^2\ \text{cm/s})(2.00\ \text{min})(60\ \text{s/min})}{10.0\ \text{cm/s} - 2.00 \times 10^2\ \text{cm/s}}$ $\Delta t_{race} = \dfrac{20.0\ \text{cm} - 2.40 \times 10^4\ \text{cm}}{-1.90 \times 10^2\ \text{cm/s}} = \dfrac{-2.40 \times 10^4\ \text{cm}}{-1.90 \times 10^2\ \text{cm/s}}$ $\Delta t_{race} = \boxed{126\ \text{s}}$
22. $\Delta x_{race} = \Delta x_t$ $v_t = 10.0$ cm/s $\Delta t_t = 126$ s	$\Delta x_{race} = \Delta x_t = v_t\Delta t_t = (10.0\ \text{cm/s})(126\ \text{s}) = \boxed{1.26 \times 10^3\ \text{cm} = 12.6\ \text{m}}$
23. $v_i = 12.5$ m/s up, $v_i = +12.5$ m/s $v_f = 0$ m/s $a = 9.81\ \text{m/s}^2$ down, $a = -9.81\ \text{m/s}^2$	$v_f = v_i + a\Delta t$ $\Delta t = \dfrac{v_f - v_i}{a} = \dfrac{0\ \text{m/s} - 12.5\ \text{m/s}}{-9.81\ \text{m/s}^2} = \boxed{1.27\ \text{s}}$

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Givens	*Solutions*
24. $\Delta t = 0.910$ s $\Delta x = 7.19$ km $v_i = 0$ km/s	$v_f = \frac{2\Delta x}{\Delta t} - v_i = \frac{(2)(7.19 \text{ km})}{0.910 \text{ s}} - 0 \text{ km/s} = \boxed{15.8 \text{ km/s}}$
25. $a = 3.0$ m/s^2 $\Delta t = 4.1$ s $v_f = 55.0$ km/h	$v_f = v_i + a\Delta t$ $v_i = v_f - a\Delta t = \left(\frac{55.0 \text{ km}}{\text{h}}\right) - (3.0 \text{ m/s}^2)(4.1 \text{ s})\left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)$ $v_i = 55.0 \text{ km/h} - 44 \text{ km/h} = \boxed{11 \text{ km/h}}$
26. $\Delta t = 1.5$ s $v_i = 2.8$ km/h $v_f = 32.0$ km/h	$a = \frac{v_f - v_i}{\Delta t} = \frac{(32.0 \text{ km/h} - 2.8 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{\text{km}}\right)}{1.5 \text{ s}}$ $a = \frac{(29.2 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{1.5 \text{ s}} = \boxed{5.4 \text{ m/s}^2}$
27. $a = 4.88$ m/s^2 $\Delta x = 18.3$ m $v_i = 0$ m/s	Because $v_i = 0$ m/s, $\Delta t = \sqrt{\frac{2\Delta x}{a}} = \sqrt{\frac{(2)(18.3 \text{ m})}{(4.88 \text{ m/s}^2)}} = \boxed{2.74 \text{ s}}$
28. $a_{avg} = 16.5$ m/s^2 $v_i = 0$ km/h $v_f = 386.0$ km/h	$\Delta t = \frac{\Delta v}{a_{avg}} = \frac{v_f - v_i}{a_{avg}} = \frac{(386.0 \text{ km/h} - 0 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{16.5 \text{ m/s}^2}$ $\Delta t = \frac{107.2 \text{ m/s}}{16.5 \text{ m/s}^2} = \boxed{6.50 \text{ s}}$
29. $v_i = 50.0$ km/h forward $= +50.0$ km/h $v_f = 0$ km/h $a = 9.20$ m/s^2 backward $= -9.20$ m/s^2	$\Delta x = \frac{v_f^2 - v_i^2}{2a} = \frac{[(0 \text{ km/h})^2 - (50.0 \text{ km/h})^2]\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(-9.20 \text{ m/s}^2)}$ $\Delta x = \frac{-(2.50 \times 10^3 \text{ km}^2/\text{h}^2)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{-18.4 \text{ m/s}^2}$ $\Delta x = 10.5 \text{ m} = \boxed{10.5 \text{ m forward}}$
30. $v_i = -4.0$ m/s $a_{avg} = -0.27$ m/s^2 $\Delta t = 17$ s	$v_f = a_{avg}\Delta t + v_i$ $v_f = (-0.27 \text{ m/s}^2)(17 \text{ s}) + (-4.0 \text{ m/s}) = -4.6 \text{ m/s} - 4.0 \text{ m/s} = \boxed{-8.6 \text{ m/s}}$
31. $v_i = +4.42$ m/s $v_f = 0$ m/s $a = -0.75$ m/s^2	$\Delta t = \frac{v_f - v_i}{a} = \frac{0 \text{ m/s} - 4.42 \text{ m/s}}{-0.75 \text{ m/s}^2} = \frac{-4.42 \text{ m/s}}{-0.75 \text{ m/s}^2} = \boxed{5.9 \text{ s}}$

Givens	*Solutions*
32. $v_i = 4.42$ m/s $a = -0.75$ m/s^2 $\Delta t = 5.9$ s	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (4.42 \text{ m/s})(5.9 \text{ s}) + \frac{1}{2}(-0.75 \text{ m/s}^2)(5.9 \text{ s})^2$ $\Delta x = 26 \text{ m} - 13 \text{ m} = \boxed{13 \text{ m}}$
33. $v_i = 25$ m/s west $v_f = 35$ m/s west $\Delta x = 250$ m west	$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(250 \text{ m})}{25 \text{ m/s} + 35 \text{ m/s}} = \frac{5.0 \times 10^2 \text{ m}}{6.0 \times 10^1 \text{ m/s}} = \boxed{8.3 \text{ s}}$
34. $a = -7.6 \times 10^{-2}$ m/s^2 $\Delta x = 255$ m $\Delta t = 82.0$ s	$v_i = v_f - a\Delta t = 0.0 \text{ m/s} - (-7.6 \times 10^{-2} \text{ m/s}^2)(82.0 \text{ s}) = \boxed{6.2 \text{ m/s}}$
35. $v_i = 4.5$ m/s $v_f = 10.8$ m/s $a_{avg} = 0.85$ m/s^2	$\Delta t = \frac{\Delta v}{a_{avg}} = \frac{v_f - v_i}{a_{avg}} = \frac{10.8 \text{ m/s} - 4.5 \text{ m/s}}{0.85 \text{ m/s}^2} = \frac{6.3 \text{ m/s}}{0.85 \text{ m/s}^2} = \boxed{7.4 \text{ s}}$
36. $v_i = 0.0$ m/s $v_f = -49.5$ m/s $a = -9.81$ m/s^2	$\Delta x = \frac{v_f^2 - v_i^2}{2a} = \frac{(-49.5 \text{ m/s})^2 - (0.0 \text{ m/s})^2}{2(-9.81 \text{ m/s}^2)} = \frac{2.45 \times 10^3 \text{ m}^2/\text{s}^2}{-19.6 \text{ m/s}^2}$ $\Delta x = \boxed{-125 \text{ m or } 125 \text{ m downward}}$
37. $v_i = +320$ km/h $v_f = 0$ km/h $\Delta t = 0.18$ s	$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{(0 \text{ km/h} - 320 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{0.18 \text{ s}}$ $a_{avg} = \frac{-89 \text{ m/s}}{0.18 \text{ s}} = \boxed{-490 \text{ m/s}^2}$
38. $a = 7.56$ m/s^2 $\Delta x = 19.0$ m $v_i = 0$ m/s	$v_f = \sqrt{v_i^2 + 2a\Delta x} = \sqrt{(0 \text{ m/s})^2 + (2)(7.56 \text{ m/s}^2)(19.0 \text{ m})}$ $v_f = \sqrt{287 \text{ m}^2/\text{s}^2} = \pm 16.9 \text{ m/s} = \boxed{16.9 \text{ m/s}}$
39. $v_i = 85.1$ m/s upward $= +85.1$ m/s $a = -9.81$ m/s^2 $\Delta x = 0$ m	Because $\Delta x = 0$ m, $v_i\,\Delta t + \frac{1}{2}a\Delta t^2 = 0$ $\Delta t = -\frac{2v_i}{a} = -\frac{(2)(85.1 \text{ m/s})}{(-9.81 \text{ m/s}^2)} = \boxed{17.3 \text{ s}}$
40. $v_i = 13.7$ m/s forward $= +13.7$ m/s $v_f = 11.5$ m/s backward $= -11.5$ m/s $\Delta t = 0.021$ s	$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{(-11.5 \text{ m/s}) - (13.7 \text{ m/s})}{0.021 \text{ s}} = \frac{-25.2 \text{ m/s}}{0.021 \text{ s}}$ $a_{avg} = \boxed{-1200 \text{ m/s}^2\text{, or } 1200 \text{ m/s}^2 \text{ backward}}$
41. $v_i = 1.8$ m/s $v_f = 9.4$ m/s $a = 6.1$ m/s^2	$\Delta x = \frac{v_f^2 - v_i^2}{2a} = \frac{(9.4 \text{ m/s})^2 - (1.8 \text{ m/s})^2}{(2)(6.1 \text{ m/s}^2)} = \frac{88 \text{ m}^2/\text{s}^2 - 3.2 \text{ m}^2/\text{s}^2}{(2)(6.1 \text{ m/s}^2)}$ $\Delta x = \frac{85 \text{ m}^2/\text{s}^2}{(2)(6.1 \text{ m/s}^2)} = \boxed{7.0 \text{ m}}$

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Givens	*Solutions*
42. $v_i = 0$ m/s $\Delta t = 2.0$ s $a = -9.81$ m/s^2	Because $v_i = 0$ m/s, $\Delta x = \frac{1}{2}a\Delta t^2 = \frac{1}{2}(-9.81 \text{ m/s}^2)(2.0 \text{ s})^2 = -2.0 \times 10^1$ m distance of bag below balloon = $\boxed{2.0 \times 10^1 \text{ m}}$
43. $a = 0.678$ m/s^2 $v_f = 8.33$ m/s $\Delta x = 46.3$ m	$v_i = \sqrt{v_f^2 - 2a\Delta x} = \sqrt{(8.33 \text{ m/s})^2 - (2)(0.678 \text{ m/s}^2)(46.3 \text{ m})}$ $v_i = \sqrt{69.4 \text{ m}^2/\text{s}^2 - 62.8 \text{ m}^2/\text{s}^2} = \sqrt{6.6 \text{ m}^2/\text{s}^2} = \pm 2.6 \text{ m/s} = \boxed{2.6 \text{ m/s}}$
44. $v_i = 7.5$ m/s $v_f = 0.0$ m/s $a = -9.81$ m/s^2	$v_f = v_i + a\Delta t$ $\Delta \text{t} = \frac{v_f - v_i}{a} = \frac{0.0 \text{ m/s} - 7.5 \text{ m/s}}{-9.81 \text{ m/s}^2} = \boxed{0.76 \text{ s}}$
45. $v_i = 0.0$ m/s $a = -3.70$ m/s^2 $\Delta x = -17.6$ m	$v_f^2 = v_i^2 + 2a\Delta x = (0.0 \text{ m/s})^2 + 2(-3.70 \text{ m/s}^2)(-17.6\text{m}) = 130 \text{ m}^2/\text{s}^2$ $v_f = \sqrt{130 \text{ m}^2/\text{s}^2} = \boxed{11.4 \text{ m/s down}}$

Two-Dimensional Motion and Vectors

46. $d = 599$ m $\Delta y = 89$ m north	$d^2 = \Delta x^2 + \Delta y^2$ $\Delta x = \sqrt{d^2 - \Delta y^2} = \sqrt{(599 \text{ m})^2 - (89 \text{ m})^2} = \sqrt{3.59 \times 10^5 \text{ m}^2 - 7.9 \times 10^3 \text{ m}^2}$ $\Delta x = \sqrt{3.51 \times 10^5 \text{ m}^2}$ $\Delta x = \boxed{592 \text{ m, east}}$
47. $d = 599$ m $\Delta y = 89$ m north	$\theta = \sin^{-1}\left(\frac{\Delta y}{d}\right) = \sin^{-1}\left(\frac{89 \text{ m}}{599 \text{ m}}\right)$ $\theta = \boxed{8.5^\circ \text{ north of east}}$

Givens	*Solutions*
48. $d = 478$ km $\Delta y = 42$ km, south $= -42$ km	$d^2 = \Delta x^2 + \Delta y^2$ $\Delta x = \sqrt{d^2 - \Delta y^2} = \sqrt{(478\text{ km})^2 - (-42\text{ km})^2}\ \sqrt{2.28 \times 10^5\text{ km}^2 - 1.8 \times 10^3\text{ km}^2}$ $\Delta x = \sqrt{2.26 \times 10^5\text{ km}^2} = -475$ km $\Delta x = \boxed{475\text{ km, west}}$
49. $d = 478$ km $\Delta y = 42$ km, south $= -42$ km	$\theta = \sin^{-1}\left(\frac{\Delta y}{d}\right) = \sin^{-1}\left(\frac{-42\text{ km}}{478\text{ km}}\right)$ $\theta = \boxed{5.0° \text{ south of west}}$
50. $d = 7400$ km $\theta = 26°$ south of west $\Delta y = 3200$ km, south $= -3200$ km	$\mathrm{d}^2 = \Delta x^2 = \Delta y^2$ $\Delta x = \sqrt{d^2 - \Delta y^2} = \sqrt{(7400\text{ km})^2 - (-3200\text{ km})^2} = \sqrt{5.5 \times 10^7\text{ km}^2 - 1.0 \times 10^7\text{ km}^2}$ $\Delta x = \sqrt{4.5 \times 10^7\text{ km}^2} = -6700$ km $\Delta x = \boxed{6700\text{ km, west}}$
51. $d = 5.3$ km $\theta = 8.4°$ above horizontal	$\Delta y = d(\sin\theta) = (5.3\text{ km})(\sin 8.4°)$ $\Delta y = 0.77$ km $= 770$ m $\boxed{\text{the mountain's height} = 770\text{ m}}$
52. $d = 113$ m $\theta = 82.4°$ above the horizontal south	$\Delta x = d(\cos\theta) = (113\text{ m})(\cos 82.4°)$ $\boxed{\Delta x = 14.9\text{ m, south}}$
53. $v = 55$ km/h $\theta = 37°$ below the horizontal $= -37°$	$v_y = v(\sin\theta) = (55\text{ km/h})[\sin(-37°)]$ $v_y = -33$ km/h $= \boxed{33\text{ km/h, downward}}$

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Givens | *Solutions*

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54. $d_1 = 55$ km

$\theta_1 = 37$ north of east

$d_2 = 66$ km

$\theta_2 = 0.0°$ (due east)

$\Delta x_1 = d_1(\cos\theta_1) = (55\text{ km})(\cos 37°) = 44\text{ km}$

$\Delta y_1 = d_1(\sin\theta_1) = (55\text{ km})(\sin 37°) = 33\text{ km}$

$\Delta x_2 = d_2(\cos\theta_2) = (66\text{ km})(\cos 0.0°) = 66\text{ km}$

$\Delta y_2 = d_2(\sin\theta_2) = (66\text{ km})(\sin 0.0°) = 0\text{ km}$

$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 44\text{ km} + 66\text{ km} = 110\text{ km}$

$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 33\text{ km} + 0\text{ km} = 33\text{ km}$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(110\text{ km})^2 + (33\text{ km})^2}$$

$$= \sqrt{1.21\times 10^4\text{ km}^2 + 1.1\times 10^3\text{ km}^2} = \sqrt{1.32\times 10^4\text{ km}^2}$$

$$d = \boxed{115\text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{33\text{ km}}{110\text{ km}}\right)$$

$$\theta = \boxed{17°\text{ north of east}}$$

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55. $d_1 = 4.1$ km

$\theta_1 = 180°$ (due west)

$d_2 = 17.3$ km

$\theta_2 = 90.0°$ (due north)

$d_3 = 1.2$ km

$\theta_3 = 24.6°$ west of north $= 90.0° + 24.6° = 114.6°$

$\Delta x_1 = d_1(\cos\Delta_1) = (4.1\text{ km})(\cos 180°) = -4.1\text{ km}$

$\Delta y_1 = d_1(\sin\theta_1) = (4.1\text{ km})(\sin 180°) = 0\text{ km}$

$\Delta x_2 = d_2(\cos\theta_2) = (17.3\text{ km})(\cos 90.0°) = 0\text{ km}$

$\Delta y_2 = d_2(\sin\theta_2) = (17.3\text{ km})(\sin 90.0°) = 17.3\text{ km}$

$\Delta x_3 = d_3(\cos\theta_3) = (1.2\text{ km})(\cos 114.6°) = -0.42\text{ km}$

$\Delta y_3 = d_3(\sin\theta_3) = (1.2\text{ km})(\sin 114.6°) = 1.1\text{ km}$

$\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 = -4.1\text{ km} + 0\text{ km} + (-0.42\text{ km}) = -4.5\text{ km}$

$\Delta y_{tot} = \Delta y_1 + \Delta y_2 + \Delta y_3 = 0\text{ km} + 17.3\text{ km} + 1.1\text{ km} = 18.4\text{ km}$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(-4.5\text{ km})^2 + (18.4\text{ km})^2}$$

$$= \sqrt{2.0\times 10^1\text{ km}^2 + 339\text{ km}^2} = \sqrt{359\text{ km}^2}$$

$$d = \boxed{18.9\text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{18.4\text{ km}}{-4.5\text{ km}}\right) = -76° = \boxed{76°\text{ north of west}}$$

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56. $\Delta x = 125$ m

$v_x = 90.0$ m/s

$\Delta x = v_x\Delta t$

$$\Delta t = \frac{\Delta x}{v_x} = \frac{(125\text{ m})}{(90\text{ m/s})} = \boxed{1.39\text{ s}}$$

Givens	Solutions
57. $v_x = 10.0$ cm/s $\Delta x = 18.6$ cm $g = 9.81$ m/s^2	$\Delta t = \dfrac{\Delta x}{v_x}$ $\Delta y = -\frac{1}{2}g\Delta t^2$ $\Delta y = -\frac{1}{2}g\left(\dfrac{\Delta x}{v_x}\right)^2 = -\frac{1}{2}(9.81 \text{ m/s}^2)\left(\dfrac{18.6 \text{ cm}}{10.0 \text{ cm/s}}\right)^2 = -17.0 \text{ m}$ $\boxed{\text{squirrel's height} = 17.0 \text{ m}}$
58. $v_i = 250$ m/s $\theta = 35°$ $g = 9.81$ m/s^2	At the maximum height $v_{y,f} = v_{y,i} - g\Delta t = 0$ $v_{y,i} = v_i(\sin\theta) = g\Delta t$ $\Delta t = \dfrac{v_i(\sin\theta)}{g} = \dfrac{(250 \text{ m/s})(\sin 35°)}{9.81 \text{ m/s}^2}$ $\Delta t = \boxed{15 \text{ s}}$
59. $v_i = 23.1$ m/s $\Delta y_{max} = 16.9$ m $g = 9.81$ m/s^2	$v_{y,f}{}^2 - v_{y,i}{}^2 = -2g\Delta y$ At maximum height, $v_{y,f}$ $v_{y,i} = v_i(\sin\theta) = \sqrt{2g\Delta y_{max}}$ $\theta = \sin^{-1}\left(\dfrac{\sqrt{2g\Delta y_{max}}}{v_i}\right) = \sin^{-1}\left[\dfrac{\sqrt{(2)(9.81 \text{ m/s}^2)(16.9 \text{ m})}}{23.1 \text{ m/s}}\right]$ $\theta = \boxed{52.0°}$
60. $\mathbf{v_{bw}} = 58.0$ km/h, forward $= +58.0$ km/h $\mathbf{v_{we}} = 55.0$ km/h, backward $= -55.0$ km/h	$\mathbf{v_{be}} = \mathbf{v_{bw}} + \mathbf{v_{we}} = +58.0 \text{ km/h} + (-55.0 \text{ km/h}) = +3.0 \text{ km/h}$ $\Delta t = \dfrac{\Delta x}{v_{be}} = \dfrac{1.4 \text{ km}}{3.0 \text{ km/h}}$ $\Delta t = \boxed{0.47 \text{ h} = 28 \text{ min}}$
61. $\mathbf{v_{1e}} = 286$ km/h, forward $\mathbf{v_{2e}} = 252$ km/h, forward $\Delta x = 0.750$ km	$\mathbf{v_{12}} + \mathbf{v_{2e}} = \mathbf{v_{1e}}$ $\mathbf{v_{12}} = \mathbf{v_{1e}} - \mathbf{v_{2e}}$ $v_{12} = v_{1e} - v_{2e} = 286 \text{ km/h} - 252 \text{ km/h} = 34 \text{ km/h}$ $\Delta t = \dfrac{\Delta x}{v_{12}} - \dfrac{0.750 \text{ km}}{34 \text{ km/h}} = 2.2 \times 10^{-2} \text{ h}$ $\Delta t = (2.2 \times 10^{-2} \text{ h})\left(\dfrac{3600 \text{ s}}{1 \text{ h}}\right) = \boxed{79 \text{ s}}$
62. $\Delta x = 165$ m $\Delta y = -45$ m	$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(165 \text{ m})^2 + (-45 \text{ m})^2}\ \sqrt{2.72 \times 10^4 \text{ m}^2 + 2.0 \times 10^3 \text{ m}^2} = \sqrt{2.92 \times 10^4 \text{ m}^2}$ $d = \boxed{171 \text{ m}}$ $\theta \tan^{-1}\left(\dfrac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\dfrac{-45 \text{ m}}{165 \text{ m}}\right)$ $\theta = -15° = \boxed{15° \text{ below the horizontal}}$

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Givens	*Solutions*
63. $\Delta y = -13.0$ m $\Delta x = 9.0$ m	$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(9.0 \text{ m})^2 + (-13.0 \text{ m})^2} = \sqrt{81 \text{ m}^2 + 169 \text{ m}^2} = \sqrt{2.50 \times 10^2 \text{ m}^2}$ $d = \boxed{15.8 \text{ m}}$ $\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) \tan^{-1}\left(\frac{-13.0 \text{ m}}{9.0 \text{ m}}\right)$ $\theta = -55° = \boxed{55° \text{ below the horizontal}}$
64. $d = 2.7$ m $\theta = 13°$ from the table's length	$\Delta x = d(\cos\theta) = (2.7 \text{ m})(\cos 13°)$ $\Delta x = \boxed{2.6 \text{ m along the table's length}}$ $\Delta y = d(\sin\theta) = (2.7 \text{ m})(\sin 13°)$ $\Delta y = \boxed{0.61 \text{ m along the table's width}}$
65. $v = 1.20$ m/s $\theta = 14.0°$ east of north	$v_x = v(\sin\theta) = (1.20 \text{ m/s})(\sin 14.0°)$ $v_x = \boxed{0.290 \text{ m/s, east}}$ $v_y = v(\cos\theta) = (1.20 \text{ m/s})(\cos 14.0°)$ $v_y = \boxed{1.16 \text{ m/s, north}}$
66. $v = 55.0$ km/h $\theta = 13.0°$ above horizontal	$v_y = v(\sin\theta) = (55.0 \text{ km/h})(\sin 13.0°)$ $v_y = \boxed{12.4 \text{ km/h, upward}}$ $v_x = v(\cos\theta) = (55.0 \text{ km/h})(\cos 13.0°)$ $v_x = \boxed{53.6 \text{ km/h, forward}}$
67. $d = 3.88$ km $\Delta x = 3.45$ km $h_1 = 0.8$ km	$d^2 = \Delta x^2 + \Delta y^2$ $\Delta y = \sqrt{d^2 - \Delta x^2} = \sqrt{(3.88 \text{ km})^2 - (3.45 \text{ km})^2} = \sqrt{15.1 \text{ km}^2 - 11.9 \text{ km}^2} = \sqrt{3.2 \text{ km}^2}$ $\Delta y = 1.8$ km height of mountain $= h = \Delta y + h_1 = 1.8 \text{ km} + 0.8 \text{ km}$ $\boxed{h = 2.6 \text{ km}}$
68. $d_1 = 850$ m $\theta_1 = 0.0°$ $d_2 = 640$ m $\theta_2 = 36°$	$\Delta x_1 = d_1(\cos\theta_1) = (850 \text{ m})(\cos 0.0°) = 850$ m $\Delta y_1 = d_1(\sin\theta_1) = (850 \text{ m})(\sin 0.0°) = 0$ m $\Delta x_2 = d_2(\cos\theta_2) = (640 \text{ m})(\cos 36°) = 520$ m $\Delta y_2 = d_2(\sin\theta_2) = (640 \text{ m})(\sin 36°) = 380$ m $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 850 \text{ m} + 520 \text{ m} = 1370$ m $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 0 \text{ m} + 380 \text{ m} = 380$ m $d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(1370 \text{ m})^2 + (380 \text{ m})^2} = \sqrt{1.88 \times 10^6 \text{ m}^2 + 1.4 \times 10^5 \text{ m}^2}$ $= \sqrt{2.02 \times 10^6 \text{ m}^2} = 1420 \text{ m} = \boxed{1.42 \times 10^3 \text{ m}}$ $\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{380 \text{ m}}{1370 \text{ m}}\right)$ $= \boxed{16° \text{ to the side of the initial dispacement}}$

Givens	Solutions
69. $d_1 = 46$ km $\theta_1 = 15°$ south of east $= -15°$ $d_2 = 22$ km $\theta_2 = 13°$ east of south $= -77°$ $d_3 = 14$ km $\theta_3 = 14°$ west of south $= -90.0° - 14° = -104°$	$\Delta x_1 = d_1(\cos\theta_1) = (46\text{ km})[\cos(-15°)] = 44\text{ km}$ $\Delta y_1 = d_1(\sin\theta_1) = (46\text{ km})[\sin(-15°)] = -12\text{ km}$ $\Delta x_2 = d_2(\cos\theta_2) = (22\text{ km})[\cos(-77°)] = 4.9\text{ km}$ $\Delta y_2 = d_2(\sin\theta_2) = (22\text{ km})[\sin(-77°)] = -21\text{ km}$ $\Delta x_3 = d_3(\cos\theta_3) = (14\text{ km})[\cos(-104°)] = -3.4\text{ km}$ $\Delta y_3 = d_3(\sin\theta_3) = (14\text{ km})[\sin(-104°)] = -14\text{ km}$ $\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 = 44\text{ km} + 4.9\text{ km} + (-3.4\text{ km}) = 46\text{ km}$ $\Delta y_{tot} = \Delta y_1 + \Delta y_2 + \Delta y_3 = -12\text{ km} + (-21\text{ km}) + (-14\text{ km}) = -47\text{ km}$ $d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(46\text{ km})^2 + (-47\text{ km})^2} = \sqrt{2.1\times 10^3\text{ km}^2 + 2.2\times 10^3\text{ km}^2}$ $= \sqrt{4.3\times 10^3\text{ km}^2}$ $d = \boxed{66\text{ km}}$ $\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{-47\text{ km}}{46\text{ km}}\right) = -46°$ $\theta = \boxed{46°\text{ south of east}}$
70. $v_x = 9.37$ m/s $\Delta x = 85.0$ m $g = 9.81\text{ m/s}^2$	$\Delta t = \frac{\Delta x}{v_x}$ $\Delta y = -\frac{1}{2}g\Delta t^2$ $\Delta y = -\frac{1}{2}g\left(\frac{\Delta x}{v_x}\right)^2 = -\frac{1}{2}(9.81\text{ m/s}^2)\left(\frac{85.0\text{ m}}{9.37\text{ m/s}}\right)^2 = -404\text{ m}$ $\boxed{\text{mountain's height} = 404\text{ m}}$
71. $\Delta y = -2.50\times 10^2$ m $v_x = 1.50$ m/s $g = 9.81\text{ m/s}^2$	$\Delta x = v_x\Delta t$ $\Delta y = -\frac{1}{2}g\Delta t^2$ $\Delta t = \sqrt{\frac{2\Delta y}{-g}}$ $\Delta x = v_x\sqrt{\frac{2\Delta y}{-g}} = (1.50\text{ m/s})\sqrt{\frac{(2)(-2.50\times 10^2\text{ m})}{-9.81\text{ m/s}^2}}$ $\Delta x = \boxed{10.7\text{ m}}$
72. $v_x = 1.50$ m/s $\Delta y = -2.50\times 10^2$ m $g = 9.81\text{ m/s}^2$	$v_{y,f}^2 = -2g\Delta y + v_{y,i}^2$ $v_{y,i} = 0$ m/s, so $v_{y,f} = v_y = \sqrt{-2g\Delta y} = \sqrt{-(2)(9.81\text{ m/s}^2)(-2.50\times 10^2\text{ m})}$ $v_y = 70.0$ m/s $v = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.50\text{ m/s})^2 + (70.0\text{ m/s})^2} = \sqrt{2.25\text{ m}^2/\text{s}^2 + 4.90\times 10^3\text{ m}^2/\text{s}^2}$ $= \sqrt{4.90\times 10^3\text{ m}^2/\text{s}^2}$ $v = \boxed{70.0\text{ m/s}}$ $\theta = \tan^{-1}\left(\frac{v_x}{v_y}\right) = \tan^{-1}\left(\frac{1.50\text{ m/s}}{70.0\text{ m/s}}\right)$ $\theta = \boxed{1.23°\text{ from the vertical}}$

Givens	Solutions

Givens

73. $\theta = -30.0°$

$v_i = 2.0$ m/s

$\Delta y = -45$ m

$g = 9.81$ m/s^2

Solutions

$\Delta y = v_i(\sin\theta)\Delta t - \frac{1}{2}g\Delta t^2$

$\left(\frac{g}{2}\right)\Delta t^2 - [v_i(\sin\theta)]\Delta t + \Delta y = 0$

Solving for Δt using the quadratic equation,

$$\Delta t = \frac{v_i(\sin\theta) \pm \sqrt{[-v_i(\sin\theta)]^2 - 4\left(\frac{g}{2}\right)(\Delta y)}}{2\left(\frac{g}{2}\right)}$$

$$\Delta t = \frac{(2.0 \text{ m/s})[\sin(-30.0°)] \pm \sqrt{[(-2.0 \text{ m/s})[\sin(-30.0°)]^2 - (2)(9.81 \text{ m/s}^2)(-45 \text{ m})}}{9.81 \text{ m/s}^2}$$

$$\Delta t = \frac{-1.0 \text{ m/s} \pm \sqrt{1.0 \text{ m}^2/\text{s}^2 + 8.8\times10^2 \text{ m}^2/\text{s}^2}}{9.81 \text{ m/s}^2} = \frac{-1.0 \text{ m/s} \pm \sqrt{8.8\times10^2 \text{ m}^2/\text{s}^2}}{9.81 \text{ m/s}^2}$$

$$\Delta t = \frac{-1.0 \text{ m/s} \pm 3.0\times10^1 \text{ m/s}}{9.81 \text{ m/s}^2}$$

Δt must be positive, so the positive root must be chosen.

$$\Delta t = \frac{29 \text{ m/s}}{9.81 \text{ m/s}^2} = \boxed{3.0 \text{ s}}$$

Givens

74. $v_i = 10.0$ m/s

$\theta = 37.0°$

$\Delta t = 2.5$ s

$g = 9.81$ m/s^2

Solutions

$\Delta x = v_i(\cos\theta)\Delta t = (10.0 \text{ m/s})(\cos 37.0°)(2.5 \text{ s})$

$\Delta x = \boxed{2.0 \times 10^1 \text{ m}}$

$\Delta y = v_i(\sin\theta)\Delta t - \frac{1}{2}g\Delta t^2 = (10.0 \text{ m/s})(\sin 37.0°)(2.5 \text{ s}) - \frac{1}{2}(9.81 \text{ m/s}^2)(2.5 \text{ s})^2$

$= 15 \text{ m} - 31 \text{ m}$

$\Delta y = \boxed{-16 \text{ m}}$

Givens

75. $\mathbf{v_{aw}} = 55.0$ km/h, north

$\mathbf{v_{we}} = 40.0$ km/h at 17.0° north of west

Solutions

$\mathbf{v_{ae}} = \mathbf{v_{aw}} + \mathbf{v_{we}}$

$v_{x,\,ae} = v_{x,\,aw} + v_{x,\,we} = v_{we}(\cos\theta_{we})$

$v_{y,\,ae} = v_{y,\,aw} + v_{y,\,we} = v_{aw} + v_{we}(\sin\theta_{we})$

$\theta_{we} = 180.0° - 17.0° = 163.0°$

$v_{x,\,ae} = (40.0 \text{ km/h})(\cos 163.0°) = -38.3$ km/h

$v_{y,\,ae} = 55.0 \text{ km/h} + (40.0 \text{ km/h})(\sin 163.0°) = 55.0 \text{ km/h} + 11.7 \text{ km/h} = 66.7$ km/h

$v_{ae} = \sqrt{(v_{x,\,ae})^2 + (v_{y,\,ae}0^2} = \sqrt{(-38.3 \text{ km/h})^2 + (66.7 \text{ km/h})^2}$

$v_{ae} = \sqrt{1.47\times10^3 \text{ km}^2/\text{h}^2 + 4.45\times10^3 \text{ km}^2/\text{h}^2} = \sqrt{5.92\times10^3 \text{ km}^2/\text{h}^2}$

$v_{ae} = \boxed{76.9 \text{ km/h}}$

$\theta = \tan^{-1}\left(\frac{v_{y,ae}}{v_{x,ae}}\right) = \tan^{-1}\left(\frac{66.7 \text{ km/h}}{-38.3 \text{ km/h}}\right) = -60.1°$

$\theta = \boxed{60.1° \text{ west of north}}$

Givens	Solutions
76. $\mathbf{v_{ae}} = 76.9$ km/h at 29.9° west of north	$\Delta x = v_{ae}(\cos\theta_{ae})\Delta t$
	$\Delta y = v_{ae}(\sin\theta_{ae})\Delta t$
$\Delta t = 15.0$ min	$\theta_{ae} = 90.0° + 29.9° = 119.9°$
	$\Delta x = (76.9 \text{ km/h})(\cos 119.9°)(15.0 \text{ min})(1 \text{ h}/60 \text{ min}) = -9.58 \text{ km}$
	$\Delta y = (76.9 \text{ km/h})(\sin 119.9°)(15.0 \text{ min})(1 \text{ h}/60 \text{ min}) = 16.7 \text{ km}$
	$\Delta x = \boxed{9.58 \text{ km, west}}$
	$\Delta y = \boxed{16.7 \text{ km, north}}$

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Givens	Solutions
77. $d_1 = 2.00 \times 10^2$ m	$\Delta x_1 = d_1(\cos\theta_1) = (2.00 \times 10^2 \text{ m})(\cos 0.0^2) = 2.0 \times 10^2 \text{ m}$
$\theta_1 = 0.0°$	$\Delta y_1 = d_1(\sin\theta_1) = (2.00 \times 10^2 \text{ m})(\sin 0.0°) = 0 \text{ m}$
$d_2 = 3.00 \times 10^2$ m	$\Delta x_2 = d_2(\cos\theta_2) = (3.00 \times 10^2 \text{ m})(\cos 3.0°) = 3.0 \times 10^2 \text{ m}$
$\theta_2 = 3.0°$	$\Delta y_2 = d_2(\sin\theta_2) = (3.00 \times 10^2 \text{ m})(\sin 3.0°) = 16 \text{ m}$
$d_3 = 2.00 \times 10^2$ m	$\Delta x_3 = d_3(\cos\theta_3) = (2.00 \times 10^2 \text{ m})(\cos 8.8°) = 2.0 \times 10^2 \text{ m}$
$\theta_3 = 8.8°$	$\Delta y_3 = d_3(\sin\theta_3) = (2.00 \times 10^2 \text{ m})(\sin 8.8°) = 31 \text{ m}$
	$\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 = 2.0 \times 10^2 \text{ m} + 3.0 \times 10^2 \text{ m} + 2.0 \times 10^2 \text{ m} = 7.0 \times 10^2 \text{ m}$
	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 + \Delta y_3 = 0 \text{ m} + 16 \text{ m} + 31 \text{ m} = 47 \text{ m}$
	$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(7.0 \times 10^2 \text{ m})^2 + (47 \text{ m})^2} = \sqrt{4.9 \times 10^5 \text{ m}^2 + 2.2 \times 10^3 \text{ m}^2}$
	$= \sqrt{4.9 \times 10^5 \text{ m}^2}$
	$d = \boxed{7.0 \times 10^2 \text{ m}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{47 \text{ m}}{7.0 \times 10^2 \text{ m}}\right)$
	$\theta = \boxed{3.8° \text{ above the horizontal}}$

Givens	Solutions
78. $d_1 = 79$ km	$\Delta x_1 = d_1(\cos\theta_1) = (790 \text{ km})(\cos 162°) = -750 \text{ km}$
$\theta_1 = 18°$ north of west $180.0° - 18° = 162°$	$\Delta y_1 = d_1(\sin\theta_1) = (790 \text{ km})(\sin 162°) = 24 \text{ km}$
$d_2 = 150$ km	$\Delta x_2 = d_2(\cos\theta_2) = (150 \text{ km})(\cos 180.0°) = -150 \text{ km}$
$\theta_2 = 180.0°$ due west	$\Delta y_2 = d_2(\sin\theta_2) = (150 \text{ km})(\sin 180.0°) = 0 \text{ km}$
$d_3 = 470$ km	$\Delta x_3 = d_3(\cos\theta_3) = (470 \text{ km})(\cos 90.0°) = 0 \text{ km}$
$\theta_3 = 90.0°$ due north	$\Delta y_3 = d_3(\sin\theta_3) = (470 \text{ km})(\sin 90.0°) = 470 \text{ km}$
$d_4 = 240$ km	$\Delta x_4 = d_4(\cos\theta_4) = (240 \text{ km})(\cos 75°) = 62 \text{ km}$
$\theta_4 = 15°$ east of north $90.0° - 15° = 75°$	$\Delta y_4 = d_4(\sin\theta_4) = (240 \text{ km})(\sin 75°) = 230 \text{ km}$
	$\Delta x_{tot} = \Delta x_1 + \Delta x_2 + \Delta x_3 + \Delta x_4 = (-750 \text{ km}) + (-150 \text{ km}) + 0 \text{ km} + 62 \text{ km} = -840 \text{ km}$
	$\Delta y_{tot} = \Delta y_1 + \Delta y_2 + \Delta y_3 + \Delta y_4 = 240 \text{ km} + 0 \text{ km} + 470 \text{ km} + 230 \text{ km} = 940 \text{ km}$
	$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(-840 \text{ km})^2 + (940 \text{ km})^2} = \sqrt{7.1 \times 10^5 \text{ km}^2 + 8.8 \times 10^5 \text{ km}^2}$
	$= \sqrt{15.9 \times 10^5 \text{ km}^2}$
	$d = \boxed{1260 \text{ km}}$
	$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{940 \text{ km}}{-840 \text{ km}}\right) = -48°$
	$\theta = \boxed{48° \text{ north of west}}$

Givens | *Solutions*

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79. $v_x = 85.3$ m/s

$\Delta y = -1.50$ m

$g = 9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{-g}} = \frac{\Delta x}{v_x}$$

$$\Delta x = v_x\sqrt{\frac{2\Delta y}{-g}} = (85.3 \text{ m/s})\sqrt{\frac{(2)(-1.50 \text{ m})}{-9.81 \text{ m/s}^2}} = 47.2 \text{ m}$$

$$\boxed{\text{range of arrow} = 47.2 \text{ m}}$$

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80. $\Delta t = 0.50$ s

$\Delta x = 1.5$ m

$\theta = 33°$

$$\Delta x = v_i(\cos\theta)\Delta t$$

$$v_i = \frac{\Delta x}{(\cos\theta)\Delta t} = \frac{1.5 \text{ m}}{(\cos 33°)(0.50 \text{ s})} = \boxed{3.6 \text{ m/s}}$$

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81. $\Delta x_1 = 0.46$ m

$\Delta x_2 = 4.00$ m

$\theta = 41.0°$

$\Delta y = -0.35$ m

$g = 9.81$ m/s^2

$$\Delta x_{tot} = \Delta x_1 + \Delta x_2$$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

$$\Delta y = v_i(\sin\theta)\Delta t - \tfrac{1}{2}g\Delta t^2 = v_i(\sin\theta)\left[\frac{\Delta x_i + \Delta x_2}{v_i(\cos\theta)}\right] - \tfrac{1}{2}g\left[\frac{\Delta x_1 + \Delta x_2}{v_i(\cos\theta)}\right]^2$$

$$\Delta y = (\Delta x_1 + \Delta x_2)(\tan\theta) - \frac{g(\Delta x_1 + \Delta x_2)^2}{2\,v_i^2(\cos\theta)^2}$$

$$v_i = \sqrt{\frac{g(\Delta x_1 + \Delta x_2)^2}{2(\cos\theta)^2[(\Delta x_1 + \Delta x_2)(\tan\theta) - \Delta y]}}$$

$$v_i = \sqrt{\frac{(9.81 \text{ m/s}^2)(0.46 \text{ m} + 4.00 \text{ m})^2}{(2)(\cos 41.0°)^2\,[(0.46 \text{ m} + 4.00 \text{ m})(\tan 41.0°) - (-0.35 \text{ m})]}}$$

$$v_i = \sqrt{\frac{(9.81 \text{ m/s}^2)(4.46 \text{ m})^2}{(2)(\cos 41.0°)^2(3.88 \text{ m} + 0.35 \text{ m})}}$$

$$v_i = \sqrt{\frac{(9.81 \text{ m/s}^2)(4.46 \text{ m})^2}{(2)(\cos 41.0°)^2\,(4.23 \text{ m})}}$$

$$v_i = \boxed{6.36 \text{ m/s}}$$

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82. $\mathbf{v_{fc}} = 87$ km/h, west

$\mathbf{v_{ce}} = 145$ km/h, north

$\Delta t = 0.45$ s

$$\mathbf{v_{fe}} = \mathbf{v_{fc}} + \mathbf{v_{ce}}$$

$$v_{x,\,fe} = v_{x,\,fc} + v_{x,\,ce} = v_{fc} = -87 \text{ km/h}$$

$$v_{y,\,fe} = v_{y,\,fc} + v_{y,\,ce} = v_{ce} = +145 \text{ km/h}$$

$$\Delta x = v_{x,\,fe}\,\Delta t = (-87 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})(0.45 \text{ s}) = -11 \text{ m}$$

$$\Delta x = \boxed{11\text{m, west}}$$

$$\Delta y = v_{y,\,fe}\,\Delta t = (145 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})(0.45 \text{ s})$$

$$\Delta y = \boxed{18 \text{ m, north}}$$

Givens	Solutions
83. $\mathbf{v_{bw}} = 12.0$ km/h, south $\mathbf{v_{we}} = 4.0$ km/h at 15.0° south of east	$\mathbf{v_{be}} = \mathbf{v_{bw}} + \mathbf{v_{we}}$ $v_{x,\,be} = v_{x,\,bw} + v_{x,\,we} = v_{we}(\cos\theta_{we})$ $v_{y,\,be} = v_{y,\,bw} + v_{y,\,we} = v_{bw} + v_{we}(\sin\theta_{we})$ $\theta_{we} = -15.0°$ $v_{x,\,be} = (4.0 \text{ km/h})[\cos(-15.0°)] = 3.9 \text{ km/h}$ $v_{y,\,be} = (-12.0 \text{ km/h}) + (4.0 \text{ km/h})[\sin(-15.0°)] = (-12.0 \text{ km/h}) + (-1.0 \text{ km/h}) = -13.0 \text{ km/h}$ $v_{be} = \sqrt{(v_{x,\,be})^2 + v_{y,\,be})^2} = \sqrt{(3.9 \text{ km/h})^2 + (-13.0 \text{ km/h})^2}$ $v_{be} = \sqrt{15 \text{ km}^2/\text{h}^2 + 169 \text{ km}^2/\text{h}^2} = \sqrt{184 \text{ km}^2/\text{h}^2}$ $v_{be} = \boxed{13.6 \text{ km/h}}$ $\theta = \tan^{-1}\left(\frac{v_{y,\,be}}{v_{x,\,be}}\right) = \tan^{-1}\left(\frac{-13.0 \text{ km/h}}{3.9 \text{ km/h}}\right) = -73°$ $\theta = \boxed{73° \text{ south of east}}$

Forces and the Laws of Motion

84. $\mathbf{F_1} = 7.5 \times 10^4$ N north $\mathbf{F_2} = 9.5 \times 10^4$ N at 15.0° north of west $\theta_1 = 90.0°$ $\theta_2 = 180.0° - 15.0° = 165.0°$	$F_{x,net} = \Sigma F_x = F_1(\cos\theta_1) + F_2(\cos\theta_2)$ $F_{x,net} = (7.5 \times 10^4 \text{ N})(\cos 90.0°) + (9.5 \times 10^4 \text{ N})(\cos 165.0°)$ $F_{x,net} = -9.2 \times 10^4 \text{ N}$ $F_{y,net} = \Sigma F_y = F_1(\sin\theta_1) + F_2(\sin\theta_2)$ $F_{y,net} = (7.5 \times 10^4 \text{ N})(\sin 90.0°) + (9.5 \times 10^4 \text{ N})(\sin 165.0°)$ $F_{y,net} = 7.5 \times 10^4 \text{ N} + 2.5 \times 10^4 \text{ N} = 10.0 \times 10^4 \text{ N}$ $\theta = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right) = \tan^{-1}\left(\frac{10.0 \times 10^4 \text{ N}}{-9.2 \times 10^4}\right) = -47°$ $\theta = \boxed{47° \text{ north of west}}$
85. $F = 76$ N $\theta = 40.0°$	$F_x = F(\cos\theta) = (76 \text{ N})(\cos 40.0°)$ $F_x = \boxed{58 \text{ N}}$
86. $F = 76$ N $\theta = 40.0°$	$F_y = F(\sin\theta) = (76 \text{ N})(\sin 40.0°)$ $F_y = \boxed{49 \text{ N}}$
87. $\mathbf{F_1} = 6.0$ N $\mathbf{F_2} = 8.0$ N	$F_{max} = F_1 + F_2 = 6.0 \text{ N} + 8.0 \text{ N}$ $F_{max} = \boxed{14.0 \text{ N}}$ $F_{min} = F_2 - F_1 = 8.0 \text{ N} - 6.0 \text{ N}$ $F_{min} = \boxed{2.0 \text{ N}}$
88. $m = 214$ kg $F_{buoyant} = 790$ N $g = 9.81$ m/s^2	$F_{net} = F_{buoyant} - \text{mg} = 790 \text{ N} - (214 \text{ kg})(9.81 \text{ m/s}^2)$ $F_{net} = 790 \text{ N} - 2.10 \times 10^3 \text{ N} = -1310 \text{ N}$ $a_{net} = \frac{F_{net}}{m} = \frac{-1310 \text{ N}}{214 \text{ kg}} = \boxed{-6.12 \text{ m/s}^2}$

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Givens | *Solutions*

89. $F_{net} = 2850$ N
$v_f = 15$ cm/s
$v_i = 0$ cm/s
$\Delta t = 5.0$ s

$$a_{net} = \frac{v_f - v_i}{\Delta t} = \frac{15 \text{ cm/s} - 0 \text{ cm/s}}{5.0 \text{ s}} = 3.0 \text{ cm/s}^2 = 3.0 \times 10^{-2} \text{ m/s}^2$$

$$F_{net} = m\,a_{net}$$

$$m = \frac{F_{net}}{a_{net}} = \frac{2850 \text{ N}}{3.0 \times 10^{-2} \text{ m/s}^2}$$

$$m = \boxed{9.5 \times 10^4 \text{ kg}}$$

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90. $m = 8.0$ kg
$\Delta y = 20.0$ cm
$\Delta t = 0.50$ s
$v_i = 0$ m/s
$g = 9.81$ m/s^2

$$\Delta y = v_i \Delta t + \frac{1}{2} a_{net}\,\Delta t^2$$

Because $v_i = 0$ m/s, $a_{net} = \dfrac{2\Delta y}{\Delta t^2} = \dfrac{(2)(20.0 \times 10^{-2} \text{ m})}{(0.50 \text{ s})^2} = 1.6 \text{ m/s}^2$

$$F_{net} = m\,a_{net} = (8.0 \text{ kg})(1.6 \text{ m/s}^2) = 13 \text{ N}$$

$$F_{net} = \boxed{\text{13 N upward}}$$

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91. $m = 90.0$ kg
$\theta = 17.0°$
$g = 9.81$ m/s^2

$$F_{net} = mg(\sin\theta) - F_k = 0$$

$$F_k = mg(\sin\theta) = (90.0 \text{ kg})(9.81 \text{ m/s}^2)(\sin 17.0°) = 258 \text{ N}$$

$$F_k = \boxed{\text{258 N up the slope}}$$

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92. $\theta = 5.0°$

$$F_{net} = mg(\sin\theta) - F_k = 0$$

$$F_k = \mu_k F_n = \mu_k\,mg(\cos\theta)$$

$$\mu_k = \frac{mg(\sin\theta)}{mg(\cos\theta)} = \tan\theta = \tan 5.0°$$

$$\mu_k = \boxed{0.087}$$

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93. $m = 2.00$ kg
$\theta = 36.0°$
$a_g = 9.81$ m/s^2

$$F_n = ma_g\cos\theta = (2.00 \text{ kg})(9.81 \text{ m/s}^2)(\cos 36.0°) = \boxed{15.9 \text{ N}}$$

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94. $m = 1.8 \times 10^3$ kg
$\theta = 15.0°$
$F_{s,max} = 1.25 \times 10^4$ N
$g = 9.81$ m/s^2

$$F_{s,max} = \mu_s F_n = \mu_s\,mg(\cos\theta)$$

$$\mu_s = \frac{F_{s,max}}{mg(\cos\theta)} = \frac{1.25 \times 10^4 \text{ N}}{(1.8 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\cos 15.0°)}$$

$$\mu_s = \boxed{0.73}$$

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95. $\mu_k = 0.20$
$g = 9.81$ m/s^2

$$F_{net} = m\,a_{net} = F_k$$

$$F_k = \mu_k F_h = \mu_k mg$$

$$a_{net} = \frac{\mu_k mg}{m} = \mu_k g = (0.20)(9.81 \text{ m/s}^2)$$

$$a_{net} = \boxed{2.0 \text{ m/s}^2}$$

Givens	Solutions
96. $F_{applied} = 5.0$ N to the left $m = 1.35$ kg $a_{net} = 0.76$ m/s^2 to the left	$F_{net} = m\,a_{net} = F_{applied} - F_k$ $F_k = F_{applied} - m\,a_{net}$ $F_k = 5.0 \text{ N} - (1.35 \text{ kg})(0.76 \text{ m/s}^2) = 5.0 \text{ N} - 1.0 \text{ N} = 4.0 \text{ N}$ $F_k = \boxed{4.0 \text{ N to the right}}$
97. $F_1 = 15.0$ N $\theta = 55.0°$	$F_y = F(\sin\theta) = (15.0 \text{ N})(\sin 55.0°)$ $F_y = \boxed{12.3 \text{ N}}$ $F_x = F(\cos\theta) = (15.0 \text{ N})(\cos 55.0°)$ $F_x = \boxed{8.60 \text{ N}}$
98. $\mathbf{F_1} = 6.00 \times 10^2$ N north $\mathbf{F_2} = 7.50 \times 10^2$ N east $\mathbf{F_3} = 6.75 \times 10^2$ N at 30.0° south of east $\theta_1 = 90.0°$ $\theta_2 = 0.00°$ $\theta_3 = -30.0°$	$F_{x,net} = \Sigma F_x = F_1(\cos\theta_1) + F_2(\cos\theta_2) + F_3(\cos\theta_3) = (6.00 \times 10^2 \text{ N})(\cos 90.0°)$ $+ (7.50 \times 10^2 \text{ N})(\cos 0.00°) + (6.75 \times 10^2 \text{ N})[\cos(-30.0°)]$ $F_{x,net} = 7.50 \times 10^2 \text{ N} + 5.85 \times 10^2 \text{ N} = 13.35 \times 10^2 \text{ N}$ $F_{y,net} = \Sigma F_y = F_1(\sin\theta_1) + F_2(\sin\theta_2) + F_3(\sin\theta_3) = (6.00 \times 10^2 \text{ N})(\sin 90.0°)$ $+ (7.50 \times 10^2 \text{ N})(\sin 0.00°) + (6.75 \times 10^2 \text{ N})[\sin(-30.0°)]$ $F_{y,net} = 6.00 \times 10^2 \text{ N} + (-3.38 \times 10^2 \text{ N}) = 2.62 \times 10^2 \text{ N}$ $\theta = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right) = \tan^{-1}\left(\frac{2.62 \times 10^2 \text{ N}}{13.35 \times 10^2 \text{ N}}\right)$ $\theta = \boxed{11.1° \text{ north of east}}$
99. $F_{net} = -65.0$ N $m = 0.145$ kg	$a_{net} = \frac{F_{net}}{m} = \frac{-65.0 \text{ N}}{0.145 \text{ kg}} = \boxed{-448 \text{ m/s}^2}$
100. $m = 2.0$ kg $\Delta y = 1.9$ m $\Delta t = 2.4$ s $v_i = 0$ m/s	$\Delta y = v_i\Delta t + \frac{1}{2}a_{net}\,\Delta t^2$ Because $v_i = 0$ m/s, $a_{net} = \frac{2\Delta y}{\Delta t^2} = \frac{(2)(1.9 \text{ m})}{(2.4 \text{ s})^2} = 0.66 \text{ m/s}^2$ $F_{net} = m\,a_{net} = (2.0 \text{ kg})(0.66 \text{ m/s}) = 1.3 \text{ N}$ $F_{net} = \boxed{1.3 \text{ N upward}}$
101. $\Delta t = 1.0$ m/s $\Delta t = 5.0$ s $F_{downhill} = 18.0$ N $F_{uphill} = 15.0$ N	$a_{net} = \frac{\Delta v}{\Delta t} = \frac{1.0 \text{ m/s}}{5.0 \text{ s}} = 0.20 \text{ m/s}^2$ $F_{net} = m\,a_{net} = F_{downhill} - F_{uphill} = 18.0 \text{ N} - 15.0 \text{ N} = 3.0 \text{ N}$ $m = \frac{F_{net}}{a_{net}} = \frac{3.0 \text{ N}}{0.20 \text{ m/s}^2} = \boxed{15 \text{ kg}}$
102. $m_{sled} = 47$ kg $m_{supplies} = 33$ kg $\mu_k = 0.075$ $\theta = 15°$	$F_k = \mu_k F_n = \mu_k(m_{sled} + m_{supplies})g(\cos\theta) = (0.075)(47 \text{ kg} + 33 \text{ kg})(9.81 \text{ m/s}^2)(\cos 15°)$ $F_k = (0.075)(8.0 \times 10^1 \text{ kg})(9.81 \text{ m/s}^2)(\cos 15°) = \boxed{57 \text{ N}}$

Givens | *Solutions*

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103. $a_{net} = 1.22\ m/s^2$
$\theta = 12.0°$
$g = 9.81\ m/s^2$

$F_{net} = m\,a_{net} = mg(\sin\theta) - F_k$

$F_k = \mu_k F_n = \mu_k\, mg(\cos\theta)$

$m\,a_{net} + \mu_k\, mg(\cos\theta) = mg(\sin\theta)$

$$\mu_k = \frac{g(\sin\theta) - a_{net}}{g(\cos\theta)} = \frac{(9.81\ m/s^2)(\sin 12.0°) - 1.22\ m/s^2}{(9.81\ m/s^2)(\cos 12.0°)} = \frac{2.04\ m/s^2 - 1.22\ m/s^2}{(9.81\ m/s^2)(\cos 12.0°)}$$

$$\mu_k = \frac{0.82\ m/s^2}{(9.81\ m/s^2)(\cos 12.0°)} = \boxed{0.085}$$

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104. $F_{applied} = 1760\ N$
$\theta = 17.0°$
$m = 266\ kg$
$g = 9.81\ m/s^2$

$F_{net} = F_{applied} - mg(\sin\theta) - F_{s,max} = 0$

$F_{s,max} = \mu_s F_n = \mu_s\, mg(\cos\theta)$

$\mu_s\, mg(\cos\theta) = F_{applied} - mg(\sin\theta)$

$$\mu_s = \frac{F_{applied} - mg(\sin\theta)}{mg(\cos\theta)} = \frac{1760 - (266\ kg)(9.81\ m/s^2)(\sin 17°)}{(266\ kg)(9.81\ m/s^2)(\cos 17°)}$$

$$\mu_s = \frac{1760 - 760\ N}{(266\ kg)(9.81\ m/s^2)(\cos 17°)} = \frac{1.00 \times 10^3\ N}{(266\ kg)(9.81\ m/s^2)(\cos 17°)}$$

$$\mu_s = \boxed{0.40}$$

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105. $F_{downward} = 4.26 \times 10^7\ N$
$\mu_k = 0.25$

$F_{net} = F_{downward} - F_k = 0$

$F_k = \mu_k F_n = F_{downward}$

$$F_n = \frac{F_{downward}}{\mu_k} = \frac{4.26 \times 10^7\ N}{0.25} = \boxed{1.7 \times 10^8\ N}$$

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106. $F_n = 1.7 \times 10^8\ N$
$\theta = 10.0°$
$g = 9.81\ m/s^2$

$F_n = mg(\cos\theta)$

$$m = \frac{F_n}{g(\cos\theta)} = \frac{1.7 \times 10^8\ N}{(9.81\ m/s^2)(\cos 10.0°)} = \boxed{1.8 \times 10^7\ kg}$$

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107. $F_{applied} = 2.50 \times 10^2\ N$
$m = 65.0\ kg$
$\theta = 18.0°$
$a_{net} = 0.44\ m/s^2$

$F_{net} = m\,a_{net} = F_{applied} - mg(\sin\theta) - F_k$

$F_k = F_{applied} - mg(\sin\theta) - ma_{net}$

$F_k = 2.50 \times 10^2\ N - (65.0\ kg)(9.81\ m/s^2)(\sin 18.0°) - (65.0\ kg)(0.44\ m/s^2)$

$F_k = 2.50 \times 10^2\ N - 197\ N - 29\ N = 24\ N = \boxed{24\ N\ \text{downhill}}$

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108. $\mathbf{F_1} = 2280.0$ N upward
$\mathbf{F_2} = 2250.0$ N downward
$\mathbf{F_3} = 85.0$ N west
$\mathbf{F_4} = 12.0$ N east

$F_{y,net} = \Sigma F_y = F_1 + F_2 = 2280.0\ N + (-2250.0\ N) = 30.0\ N$

$F_{x,net} = \Sigma F_x = F_3 + F_4 = -85.0\ N + 12.0\ N = -73.0\ N$

$$\theta = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right) = \tan^{-1}\left(\frac{30.0\ N}{-73.0\ N}\right) = -22.3°$$

$\theta = \boxed{22.3°\ \text{up from west}}$

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109. $F_1 = 7.50 \times 10^2\ N$
$\theta_1 = 40.0°$
$F_2 = 7.50 \times 10^2\ N$
$\theta_2 = -40.0°$

$F_{y,net} = F_g = F_1(\cos\theta_1) + F_2(\cos\theta_2)$

$F_{y,net} = (7.50 \times 10^2\ N)(\cos 40.0°) + (7.50 \times 10^2\ N)\,[\cos(-40.0°)]$

$F_g = 575\ N + 575\ N = \boxed{1.150 \times 10^3\ N}$

Givens	*Solutions*
110. $F_{max} = 4.5 \times 10^4$ N $a_{net} = 3.5$ m/s^2 $g = 9.81$ m/s^2	$F_{net} = m\,a_{net} = F_{max} - mg$ $m(a_{net} + g) = F_{max}$ $m = \dfrac{F_{max}}{a_{net} + g} = \dfrac{4.5 \times 10^4\text{ N}}{3.5\text{ m/s}^2 + 9.81\text{ m/s}^2} = \dfrac{4.5 \times 10^4\text{ N}}{13.3\text{ m/s}^2} = \boxed{3.4 \times 10^3\text{ kg}}$
111. $F_{s,max} = 2400$ N $\mu s = 0.20$ $\theta = 30.0°$ $g = 9.81$ m/s^2	$F_{s,max} = \mu_s F_n$ $F_n = \dfrac{F_{s,max}}{\mu_s} = \dfrac{2400\text{ N}}{0.20} = 1.2 \times 10^4$ N $F_n = \boxed{1.2 \times 10^4\text{ N perpendicular to and away from the incline}}$
112. $F_{s,max} = 2400$ N $\mu s = 0.20$ $\theta = 30.0°$ $g = 9.81$ m/s^2	$F_n = mg(\cos\theta)$ $m = \dfrac{F_n}{g(\cos\theta)} = \dfrac{1.2 \times 10^4\text{ N}}{(9.81\text{ m/s}^2)(\cos 30.0°)} = \boxed{1400\text{ kg}}$
113. $m = 5.1 \times 10^2$ kg $\theta = 14°$ $F_{applied} = 4.1 \times 10^3$ N $g = 9.81$ m/s^2	$F_{net} = F_{applied} - mg(\sin\theta) - F_{s,max} = 0$ $F_{s,max} = \mu_s F_n = \mu_s\,mg(\cos\theta)$ $\mu_s\,mg(\cos\theta) = F_{applied} - mg(\sin\theta)$ $\mu_s = \dfrac{F_{applied} - mg(\sin\theta)}{mg(\cos\theta)} = \dfrac{4.1 \times 10^3\text{ N} - (5.1 \times 10^2\text{ kg})(9.81\text{ m/s}^2)(\sin 14°)}{(5.1 \times 10^2\text{ kg})(9.81\text{ m/s}^2)(\cos 14°)}$ $\mu_s = \dfrac{4.1 \times 10^3\text{ N} - 1.2 \times 10^3\text{ N}}{(5.1 \times 10^2\text{ kg})(9.81\text{ m/s}^2)(\cos 14°)} = \dfrac{2.9 \times 10^3\text{ N}}{(5.1 \times 10^2\text{ kg})(9.81\text{ m/s}^2)(\cos 14°)}$ $\mu_s = \boxed{0.60}$

Work and Energy

114. $d = 3.00 \times 10^2$ m $W = 2.13 \times 10^6$ J $\theta = 0°$	$F = \dfrac{W}{d(\cos\theta)} = \dfrac{2.13 \times 10^6\text{ J}}{(3.00 \times 10^2\text{ m})(\cos 0°)} = \boxed{7.10 \times {}^3\text{ N}}$
115. $F = 715$ N $W = 2.72 \times 10^4$ J $\theta = 0°$	$d = \dfrac{W}{F(\cos\theta)} = \dfrac{2.72 \times 10^4\text{ J}}{(715\text{ N})(\cos 0°)} = \boxed{38.0\text{ m}}$
116. $v_1 = 88.9$ m/s $v_f = 0$ m/s $\Delta t = 0.181$ s $d = 8.05$ m $m = 70.0$ kg $\theta = 180°$	$W = Fd(\cos\theta)$ $F = ma$ $a = \dfrac{\Delta v}{\Delta t} = \dfrac{v_f - v_i}{\Delta t}$ $W = \dfrac{m(v_f - v_i)}{\Delta t}d(\cos\theta) = \dfrac{(70.0\text{ kg})(0\text{ m/s} - 88.9\text{ m/s})}{(0.181\text{ s})}(8.05\text{ m})(\cos 180°)$ $W = \dfrac{(70.0\text{ kg})(88.9\text{ m/s})(8.05\text{ m})}{(0.181\text{ s})}$ $W = \boxed{2.77 \times 10^5\text{ J}}$

Givens	*Solutions*
117. $v = 15.8$ km/s $m = 0.20$ g	$KE = \frac{1}{2}mv^2 = \frac{1}{2}(0.20 \times 10^{-3}\ \text{kg})(15.8 \times 10^3\ \text{m/s})^2$ $KE = \boxed{2.5 \times 10^4\ \text{J}}$
118. $v = 35.0$ km/h $m = 9.00 \times 10^2$ kg	$KE = \frac{1}{2}mv^2 = \frac{1}{2}(9.00 \times 10^2\ \text{kg})\ [(35.0\ \text{km/h})(10^3\ \text{m/km})(1\ \text{h/3600 s})]^2$ $KE = \boxed{4.25 \times 10^4\ \text{J}}$
119. $KE = 1433$ J $m = 47.0$ g	$v = \sqrt{\frac{2\ KE}{m}} = \sqrt{\frac{(2)(1433\ \text{J})}{47.0 \times 10^{-3}\ \text{kg}}} = \boxed{247\ \text{m/s}}$
120. $v = 9.78$ m/s $KE = 6.08 \times 10^4$ J	$m = \frac{2\ KE}{v^2} = \frac{(2)(6.08 \times 10^4\ \text{J})}{(9.78\ \text{m/s})^2} = \boxed{1.27 \times 10^3\ \text{kg}}$
121. $m = 50.0$ kg $v_i = 47.00$ m/s $v_f = 5.00$ m/s	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}(50.0\ \text{kg})[(5.00\ \text{m/s})^2 - (47.00\ \text{m/s})^2]$ $W_{net} = \frac{1}{2}(50.0\ \text{kg})(25.0\ \text{m}^2/\text{s}^2 - 2209\ \text{m}^2/\text{s}^2) = \frac{1}{2}(50.0\ \text{kg})(-2184\ \text{m}^2/\text{s}^2)$ $W_{net} = \boxed{-5.46 \times 10^4\ \text{J}}$
122. $m = 1100$ kg $v_i = 48.0$ km/h $v_f = 59.0$ km/h $d = 100$ m	$v_i = \left(\frac{48.0\ \text{km}}{\text{h}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 13.3\ \text{m/s}$ $v_f = \left(\frac{59.0\ \text{km}}{\text{h}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 16.4\ \text{m/s}$ $\Delta KE = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}(1100\ \text{kg})[(16.4)^2 - (13.3)^2]$ $\Delta KE = (550\ \text{kg})(269\ \text{m}^2/\text{s}^2 - 177\ \text{m}^2/\text{s}^2) = (550\ \text{kg})(92\ \text{m}^2/\text{s}^2) = 5.1 \times 10^4\ \text{J}$ $F = \frac{W}{d} = \frac{\Delta KE}{d} = \frac{5.1 \times 10^4\ \text{J}}{100\ \text{m}} = \boxed{5.1 \times 10^2\ \text{N}}$
123. $h = 5334$ m $m = 64.0$ kg $g = 9.81\ \text{m/s}^2$	$PE_g = mgh = (64.0\ \text{kg})(9.81\ \text{m/s}^2)(5334\ \text{m}) = \boxed{3.35 \times 10^6\ \text{J}}$
124. $k = 550$ N/m $x = -1.2$ cm	$PE_{elastic} = \frac{1}{2}kx^2 = \frac{1}{2}(550\ \text{N/m})(-1.2 \times 10^{-2}\ \text{m})^2 = \boxed{4.0 \times 10^{-2}\ \text{J}}$
125. $m = 0.500$ g $h = 0.250$ km $g = 9.81\ \text{m/s}^2$	$PE_i = KE_f$ $mgh = KE_f$ $KE_f = (0.500 \times 10^{-3}\ \text{kg})(9.81\ \text{m/s}^2)(0.250 \times 10^3\ \text{m}) = \boxed{1.23\ \text{J}}$

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126. $m = 50.0$ g

$v_i = 3.00 \times 10^2$ m/s

$v_f = 89.0$ m/s

$ME_i + \Delta ME = ME_f$

$ME_i = KE_i = \frac{1}{2}mv_i^2$

$ME_f = KE_f = \frac{1}{2}mv_f^2$

$\Delta ME = ME_f - ME_i = \frac{1}{2}m(v_f^2 - v_i^2)$

$\Delta ME = \frac{1}{2}(50.0 \times 10^{-3}\text{ kg})[(89.0\text{ m/s})^2 - (3.00 \times 10^2\text{ m/s})^2]$

$\Delta ME = \frac{1}{2}(5.00 \times 10^{-2}\text{ kg})(7.92 \times 10^3\text{ m}^2/\text{s}^2 - 9.00 \times 10^4\text{ m}^2/\text{s}^2)$

$\Delta ME = \frac{1}{2}(5.00 \times 10^{-2}\text{ kg})(-8.21 \times 10^4\text{ m}^2/\text{s}^2)$

$\Delta ME = \boxed{-2.05 \times 10^3\text{ J}}$

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127. $P = 380.3$ kW

$W = 4.5 \times 10^6$ J

$$\Delta t = \frac{W}{P} = \frac{4.5 \times 10^6\text{ J}}{380.3 \times 10^3\text{ W}} = \boxed{12\text{ s}}$$

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128. $P = 13.0$ MW

$\Delta t = 15.0$ min

$$W = P\Delta t = (13.0 \times 10^6\text{ W})(15.0\text{ min})(60\text{ s/min}) = \boxed{1.17 \times 10^{10}\text{ J}}$$

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129. $F_{net} = 7.25 \times 10^{-2}$ N

$W_{net} = 4.35 \times 10^{-2}$ J

$\theta = 0°$

$$d = \frac{W_{net}}{F_{net}(\cos\theta)} = \frac{4.35 \times 10^{-2}\text{ J}}{(7.25 \times 10^{-2}\text{ N})(\cos 0°)} = \boxed{0.600\text{ m}}$$

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130. $d = 76.2$ m

$W_{net} = 1.31 \times 10^3$ J

$\theta = 0°$

$$F_{net} = \frac{W_{net}}{d(\cos\theta)} = \frac{1.31 \times 10^3\text{ J}}{(76.2\text{ m})(\cos 0°)} = \boxed{17.2\text{ N}}$$

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131. $d = 15.0$ m

$F_{applied} = 35.0$ N

$\theta_1 = 20.0°$

$F_k = 24.0$ N

$\theta_2 = 180°$

$W_{net} = F_{applied}\, d(\cos\theta_1) + F_k\, d(\cos\theta_2)$

$W_{net} = (35.0\text{ N})(15.0\text{ m})(\cos 20.0°) + (24.0\text{ N})(15.0\text{ m})(\cos 180°)$

$W_{net} = 493\text{ J} + (-3.60 \times 10^2\text{ J})$

$W_{net} = \boxed{133\text{J}}$

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132. $m = 7.5 \times 10^7$ kg

$v = 57$ km/h

$KE = \frac{1}{2}mv^2 = \frac{1}{2}(7.5 \times 10^7\text{ kg})[(57\text{ km/h})(10^3\text{ m/km})(1\text{h}/3600\text{ s})]^2$

$KE = \boxed{9.4 \times 10^9\text{ J}}$

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133. $KE = 7.81 \times 10^4$ J

$m = 55.0$ kg

$$v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{(2)(7.81 \times 10^4\text{ J})}{55.0\text{ kg}}} = \boxed{53.3\text{ m/s}}$$

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Givens	Solutions
134. $v_i = 8.0$ m/s $v_f = 0$ m/s $d = 45$ m $F_k = 0.12$ N $\theta = 180°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $W_{net} = F_{net}d(\cos\theta) = F_k d(\cos\theta)$ $\frac{1}{2}m(v_f^2 - v_i^2) = F_k d(\cos\theta)$ $m = \frac{2F_k d(\cos\theta)}{v_f^2 - v_i^2} = \frac{(2)(0.12\text{ N})(45\text{ m})(\cos 180°)}{(0\text{ m/s})^2 - (8.0\text{ m/s})^2} = \frac{-(2)(0.12\text{ N})(45\text{ m})}{-64\text{ m}^2/\text{s}^2}$ $m = \boxed{0.17\text{ kg}}$
135. $v_i = 2.40 \times 10^2$ km/h $v_f = 0$ km/h $a_{net} = 30.8$ m/s^2 $m = 1.30 \times 10^4$ kg $\theta = 180°$	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - v_i^2$ $W_{net} = F_{net}\,d\,(\cos\theta) = ma_{net}\,d(\cos\theta)$ $ma_{net}d(\cos\theta) = \frac{1}{2}m(v_f^2 - v_i^2)$ $d = \frac{v_f^2 - v_i^2}{2\,a_{net}\,(\cos\theta)} = \frac{[(0\text{ km/h})^2 - (2.40 \times 10^2\text{ km/h})^2]\,(10^3\text{ m/km})^2(1\text{h}/3600\text{ s})^2}{(2)(30.8\text{ m/s}^2)(\cos 180°)}$ $d = \frac{(-5.76 \times 10^4\text{ km}^2/\text{h}^2)(10^3\text{ m/km})^2\,(1\text{h}/3600\text{ s})^2}{-(2)(30.8\text{ m/s}^2)} = \boxed{72.2\text{ m}}$
136. $h = 7.0$ m $PE_g = 6.6 \times 10^4$ J $g = 9.81$ m/s^2	$PE_g = mgh$ $m = \frac{PE_g}{gh} = \frac{6.6 \times 10^4\text{ J}}{(9.81\text{ m/s}^2)(7.0\text{ m})}$ $m = \boxed{9.6 \times 10^2\text{ kg}}$
137. $k = 1.5 \times 10^4$ N/m $PE_{elastic} = 120$ J	$PE_{elastic} = \frac{1}{2}kx^2$ $x = \pm\sqrt{\frac{2\,PE_{elastic}}{k}} = \pm\sqrt{\frac{(2)(120\text{ J})}{1.5 \times 10^4\text{ N/m}}}$ Spring is compressed, so negative root is selected. $x = \boxed{-0.13\text{ m} = -13\text{ cm}}$
138. $m = 100.0$ g $x = 30.0$ cm $k = 1250$ N/m	$PE_{elastic} = KE$ $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ $v = \sqrt{\frac{kx^2}{m}} = \sqrt{\frac{(1250\text{ N/m})(30.0 \times 10^{-2}\text{ m})^2}{100.0 \times 10^{-3}\text{ kg}}}$ $v = \boxed{33.5\text{ m/s}}$
139. $h = 3.0$ m $g = 9.81$ m/s^2	$PE_i = KE_f$ $mgh = \frac{1}{2}mv_f^2$ $v_f = \sqrt{2gh} = \sqrt{(2)(9.81\text{ m/s}^2)(3.0\text{ m})}$ $v_f = \boxed{7.7\text{ m/s}}$
140. $W = 1.4 \times 10^{13}$ J $\Delta t = 8.5$ min	$P = \frac{W}{\Delta t} = \frac{1.4 \times 10^{13}\text{ J}}{(8.5\text{ min})(60\text{ s/min})} = \boxed{2.7 \times 10^{10}\text{ W} = 27\text{ GW}}$

Givens	Solutions

141. $F = 334$ N

$d = 50.0$ m

$\theta = 0°$

$P = 2100$ W

$W = Fd(\cos\theta)$

$$\Delta t = \frac{W}{P} = \frac{Fd(\cos\theta)}{P} = \frac{(334\text{ N})(50.0\text{ m})(\cos 0°)}{2100\text{ W}} = \boxed{8.0\text{ s}}$$

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142. $P = (4)(300.0$ kW)

$\Delta t = 25$ s

$$W = P\,\Delta t = (4)(300.0 \times 10^3\text{ W})(25\text{ s}) = \boxed{3.0 \times 10^7\text{ J}}$$

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143. $F_{applied} = 92$ N

$m = 18$ kg

$\mu_k = 0.35$

$d = 7.6$ m

$g = 9.81$ m/s^2

$\theta = 0°$

$KE_i = 0$ J

$W_{net} = \Delta KE = KE_f - KE_i = KE_f$

$W_{net} = F_{net}\,d\,(\cos\theta)$

$F_{net} = F_{applied} - F_k = F_{applied} - \mu_k\,mg$

$KE_f = (F_{applied} - \mu_k\,mg)\,d\,(\cos\theta)$

$= [92\text{ N} - (0.35)(18\text{ kg})(9.81\text{ m/s}^2)](7.6\text{ m})(\cos 0°)$

$KE_f = (92\text{ N} - 62\text{ N})(7.6\text{ m}) = (3.0 \times 10^1\text{ N})(7.6\text{ m})$

$KE_f = \boxed{230\text{ J}}$

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144. $x = 5.00$ cm

$KE_{car} = 1.09 \times 10^{-4}$ J

Assuming all of the kinetic energy becomes stored elastic potential energy,

$KE_{car} = PE_{elastic} = \frac{1}{2}kx^2$

$$k = \frac{2\,PE_{elastic}}{x^2} = \frac{(2)(1.09 \times 10^4\text{ J})}{(5.00 \times 10^{-2}\text{ m})^2}$$

$k = \boxed{8.72 \times 10^6\text{ N/m}}$

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145. $m = 25.0$ kg

$v = 12.5$ m/s

$g = 9.81$ m/s^2

$PE_i = KE_f$

$mgh = \frac{1}{2}mv^2$

$$h = \frac{v^2}{2\,g} = \frac{(12.5\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)} = \boxed{7.96\text{ m}}$$

---

146. $m = 5.0$ kg

$\theta = 25.0°$

$PE_g = 2.4 \times 10^2$ J

$PE_g = mgh = mgd(\sin\theta)$

$$d = \frac{PE_g}{mg\,(\sin\theta)} = \frac{2.4 \times 10^2\text{ J}}{(5.0\text{ kg})(9.81\text{ m/s}^2)(\sin 25.0°)}$$

$d = \boxed{12\text{ m}}$

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147. $m = 2.00 \times 10^2$ kg

$F_{wind} = 4.00 \times 10^2$ N

$d = 0.90$ km

$v_i = 0$ m/s

$\theta = 0°$

$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$W_{net} = F_{net}\,d\,(\cos\theta) = F_{wind}\,d(\cos\theta)$

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = F_{wind}\,d\,(\cos\theta)$

$$v_f = \sqrt{\frac{2F_{wind}\,d\,(\cos\theta)}{m} + v_i^2} = \sqrt{\frac{(2)(4.00 \times 10^2\text{ N})(0.90 \times 10^3\text{ m})(\cos 0°)}{2.00 \times 10^2\text{ kg}} + (0\text{ m/s})^2}$$

$$v_f = \sqrt{\frac{(2)(4.00 \times 10^2\text{ N})(9.0 \times 10^2\text{ m})}{2.00 \times 10^2\text{ kg}}}$$

$v_f = \boxed{6.0 \times 10^1\text{ m/s}}$

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148. $m = 50.0$ kg

$k = 3.4 \times 10^4$ N/m

$x = 0.65$ m

$h_f = 1.00 \text{ m} - 0.65 \text{ m} = 0.35$ m

$PE_{g,i} = PE_{elastic,f} + PE_{g,f}$

$mgh_i = \frac{1}{2}kx^2 + mgh_f$

$h_i = h_f + \dfrac{kx^2}{2\,mg} = 0.35 \text{ m} + \dfrac{(3.4 \times 10^4 \text{ N/m})(0.65 \text{ m})^2}{(2)(50.0 \text{ kg})(9.81 \text{ m/s}^2)} = 0.35 \text{ m} + 15 \text{ m}$

$h_i = \boxed{15 \text{ m}}$

Momentum and Collisions

149. $\Delta\mathbf{x} = 274$ m to the north

$\Delta t = 8.65$ s

$m = 50.0$ kg

$\mathbf{v_{avg}} = \dfrac{\Delta\mathbf{x}}{\Delta t} = \dfrac{274 \text{ m}}{8.65 \text{ s}} = 31.7$ m/s to the north

$\mathbf{p} = m\mathbf{v}$

$\mathbf{p_{avg}} = m\mathbf{v_{avg}} = (50.0 \text{ kg})(31.7 \text{ m/s}) = \boxed{1.58 \times 10^3 \text{ kg•m/s to the north}}$

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150. $m = 1.46 \times 10^5$ kg

$\mathbf{p} = 9.73 \times 10^5$ kg•m/s to the south

$\mathbf{v} = \dfrac{\mathbf{p}}{m} = \dfrac{9.73 \times 10^5 \text{ kg•m/s}}{1.46 \times 10^5 \text{ kg}}$

$\mathbf{v} = \boxed{6.66 \text{ m/s to the south}}$

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151. $v = 255$ km/s

$p = 8.62 \times 10^{36}$ kg•m/s

$m = \dfrac{p}{v} = \dfrac{8.62 \times 10^{36} \text{ kg•m/s}}{255 \times 10^3 \text{ m/s}} = \boxed{3.38 \times 10^{31} \text{ kg}}$

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152. $m = 5.00$ g

$\mathbf{v_i} = 255$ m/s to the right

$\mathbf{v_f} = 0$ m/s

$\Delta t = 1.45$ s

$\Delta\mathbf{p} = m\mathbf{v_f} - m\mathbf{v_i} = \mathbf{F}\Delta t$

$F = \dfrac{mv_f - mv_i}{\Delta t} = \dfrac{(5.00 \times 10^{-3} \text{ kg})(0 \text{ m/s}) - (5.00 \times 10^{-3} \text{ kg})(255 \text{ m/s})}{1.45 \text{ s}} = -0.879 \text{ N}$

$\mathbf{F} = \boxed{0.879 \text{ N to the left}}$

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153. $m = 0.17$ kg

$\Delta v = -9.0$ m/s

$g = 9.81 \text{ m/s}^2$

$\mu_k = 0.050$

$F\Delta t = \Delta p = m\Delta v$

$F = F_k = -mg\mu_k$

$\Delta t = \dfrac{m\Delta v}{-mg\mu_k} = \dfrac{\Delta v}{-g\mu_k} = \dfrac{-9.0 \text{ m/s}}{-(9.81 \text{ m/s}^2)(0.050)}$

$\Delta t = \boxed{18 \text{ s}}$

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154. $\mathbf{v_i} = 382$ km/h to the right

$\mathbf{v_f} = 0$ km/h

$m_c = 705$ kg

$m_d = 65$ kg

$\Delta t = 12.0$ s

$\mathbf{F} = \dfrac{\Delta\mathbf{p}}{\Delta t} = \dfrac{(m_c + m_d)\mathbf{v_f} - (m_c + m_d)\mathbf{v_i}}{\Delta t}$

$\mathbf{F} = \dfrac{[(705 \text{ kg} + 65 \text{ kg})(0 \text{ km/h}) - (705 \text{ kg} + 65 \text{ kg})(382 \text{ km/h})](10^3 \text{ m//km})(1 \text{ h/3600 s})}{12.0 \text{ s}}$

$\mathbf{F} = \dfrac{-(7.70 \times 10^2 \text{ kg})(382 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h/3600 s})}{12.0 \text{ s}} = -6.81 \times 10^3 \text{ N}$

$\mathbf{F} = \boxed{6.81 \times 10^3 \text{ N to the left}}$

Givens	*Solutions*
155. $\mathbf{v_i}$ = 382 km/h to the right $\mathbf{v_f}$ = 0 km/h Δt = 12.0 s	$\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \frac{1}{2}(382 \text{ km/h} + 0 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})(12.0 \text{ s})$ $\Delta\mathbf{x} = \boxed{637 \text{ m to the right}}$
156. m_1 = 50.0 g $\mathbf{v_{1,i}}$ = 0 m/s $\mathbf{v_{1,f}}$ = 400.0 m/s forward m_2 = 3.00 kg $\mathbf{v_{2,i}}$ = 0 m/s	Because the initial velocities for both rifle and projectile are zero, the momentum conservation equation takes the following form: $m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} = 0$ $\mathbf{v_{2,f}} = \frac{-m_1\mathbf{v_{1,f}}}{m_2} = \frac{-(50.0 \times 10^{-3} \text{ kg})(400.0 \text{ m/s})}{3.00 \text{ kg}} = -6.67 \text{ m/s}$ $\mathbf{v_{2,f}} = \boxed{6.67 \text{ m/s backward}}$
157. $\mathbf{v_{1,i}}$ = 0 cm/s $\mathbf{v_{1,f}}$ = 1.2 cm/s forward = +1.2 cm/s $\mathbf{v_{2,i}}$ = 0 cm/s $\mathbf{v_{2,f}}$ = 0.40 cm/s backward = −0.40 cm/s m_1 = 2.5 g	$m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} = 0$ $m_2 = \frac{-m_1\mathbf{v_{1,f}}}{\mathbf{v_{2,f}}} = \frac{-(2.5 \text{ g})(1.2 \text{ cm/s})}{-0.40 \text{ cm/s}}$ $m_2 = \boxed{7.5 \text{ g}}$
158. m_s = 25.0 kg m_c = 42.0 kg $v_{1,i}$ = 3.50 m/s $v_{2,i}$ = 0 m/s v_f = 2.90 m/s	m_1 = mass of child and sled = $m_s + m_c$ = 25.0 kg + 42.0 kg = 67.0 kg $m_1v_{1,i} + m_2v_{2,i} = (m_1 + m_2)v_f$ $m_2 = \frac{m_1v_{1,i} - m_1v_f}{v_f - v_{2,i}} = \frac{(67.0 \text{ kg})(3.50 \text{ m/s}) - (67.0 \text{ kg})(2.90 \text{ m/s})}{2.90 \text{ m/s} - 0 \text{ m/s}}$ $m_2 = \frac{234 \text{ kg}\bullet\text{m/s} + 938 \text{ kg}\bullet\text{m/s}}{2.90 \text{ m/s}} = \frac{40 \text{ kg}\bullet\text{m/s}}{2.90 \text{ m/s}} = \boxed{14 \text{ kg}}$
159. m_1 = 8500 kg $\mathbf{v_{1,i}}$ = 4.5 m/s to the right = +4.5 m/s m_2 = 9800 kg $\mathbf{v_{2,i}}$ = 3.9 m/s to the left = −3.9 m/s	$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2}$ $\mathbf{v_f} = \frac{(8500 \text{ kg})(4.5 \text{ m/s}) + (9800 \text{ kg})(-3.9 \text{ m/s})}{8500 \text{ kg} + 9800 \text{ kg}} = \frac{3.8 \times 10^4 \text{ kg}\bullet\text{m/s} - 3.8 \times 10^4 \text{ kg}\bullet\text{m/s}}{1.83 \times 10^4 \text{ kg}}$ $\mathbf{v_f} = \boxed{0.0 \text{ m/s}}$
160. m_1 = 8500 kg $v_{1,i}$ = 4.5 m/s m_2 = 9800 kg $v_{2,i}$ = −3.9 m/s v_f = 0 m/s	$KE_i = \frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}(8500 \text{ kg})(4.5 \text{ m/s})^2 + \frac{1}{2}(9800 \text{ kg})(-3.9 \text{ m/s})^2$ $KE_i = 8.6 \times 10^4 \text{ J} + 7.5 \times 10^4 \text{ J} = 16.1 \times 10^4 \text{ J} = 1.61 \times 10^5 \text{ J}$ $KE_f = \frac{1}{2}(m_1 + m_2)v_f^2 = \frac{1}{2}(8500 \text{ kg} + 9800 \text{ kg})(0 \text{ m/s})^2 = 0 \text{ J}$ $\Delta KE = KE_f - KE_i = 0 \text{ J} - 1.61 \times 10^5 \text{ J} = \boxed{-1.61 \times 10^5 \text{ J}}$

Givens | *Solutions*

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161. $m_1 = 55$ g

$v_{1,i} = 1.5$ m/s

$m_2 = 55$ g

$v_{2,i} = 0$ m/s

$$v_f = \frac{m_1v_{1,i} + m_2v_{2,i}}{m_1 + m_2} = \frac{(55\text{ g})(1.5\text{ m/s}) + (55\text{ g})(0\text{ m/s})}{55\text{ g} + 55\text{ g}} = \frac{(55\text{ g})(1.5\text{ m/s})}{1.10\times 10^2\text{ g}}$$

$v_f = 0.75$ m/s

$$\text{percent decrease of } KE = \frac{\Delta KE}{KE_i}\times 100 = \frac{KE_f - KE_i}{KE_i}\times 100 = \left(\frac{KE_f}{KE_i} - 1\right)\times 100$$

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}(55\times 10^{-3}\text{ kg})(1.5\text{ m/s})^2 + \tfrac{1}{2}(55\times 10^{-3}\text{ kg})(0\text{ m/s})^2$$

$KE_i = 6.2\times 10^{-2}\text{ J} + 0\text{ J} = 6.2\times 10^{-2}$ J

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(55\text{ g} + 55\text{ g})(10^{-3}\text{ kg/g})(0.75\text{ m/s})^3$$

$KE_f = 3.1\times 10^{-2}$ J

$$\text{percent decrease of } \mathbf{KE} = \left[\left(\frac{3.1\times 10^{-2}\text{ J}}{6.2\times 10^{-2}\text{ J}}\right) - 1\right]\times 100 = (0.50 - 1)\times 100 = (-0.50)\times 100$$

percent decrease of **KE** = $\boxed{-5.0\times 10^1 \text{ percent}}$

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162 $m_1 = m_2 = 45$ g

$v_{2,i} = 0$ m/s

$v_{1,f} = 0$ m/s

$v_{2,f} = 3.0$ m/s

Momentum conservation

$m_1v_{1,i} + m_2v_{2,i} = m_1v_{1,f} + m_2v_{2,f}$

$v_{1,i} = v_{1,f} + v_{2,f} - v_{2,i} = 0\text{ m/s} + 3.0\text{ m/s} - 0\text{ m/s}$

$v_{1,i} = \boxed{3.0\text{ m/s}}$

Conservation of kinetic energy (check)

$\tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}m_2v_{2,f}^2$

$v_{1,i}^2 + v_{2,i}^2 = v_{1,f}^2 + v_{2,f}^2$

$(3.0\text{ m/s})^2 + (0\text{ m/s})^2 = (0\text{ m/s})^2 + (3.0\text{ m/s})^2$

$9.0\text{ m}^2/\text{s}^2 = 9.0\text{ m}^2/\text{s}^2$

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163. $m = 5.00\times 10^2$ kg

$\mathbf{p} = 8.22\times 10^3$ kg•m/s to the west

$$\mathbf{v} = \frac{\mathbf{p}}{m} = \frac{8.22\times 10^3\text{ kg•m/s}}{5.00\times 10^2\text{ kg}}$$

$\mathbf{v} = \boxed{16.4\text{ m/s to the west}}$

Givens	*Solutions*
164. $m_1 = 3.0 \times 10^7$ kg $m_2 = 2.5 \times 10^7$ kg $\mathbf{v_{2,i}} = 4.0$ km/h to the north $= +4.0$ km/h $\mathbf{v_{1,f}} = 3.1$ km/h to the north $= +3.1$ km/h $\mathbf{v_{2,f}} = 6.9$ km/h to the south $= -6.9$ km/h	Momentum conservation $m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $\mathbf{v_{1,i}} = \dfrac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}}{m_1}$ $\dfrac{(3.0 \times 10^7 \text{ kg})(3.1 \text{ km/h}) + (2.5 \times 10^7 \text{ kg})(-6.9 \text{ km/h}) - (2.5 \times 10^7 \text{ kg})(4.0 \text{ km/h})}{3.0 \times 10^7 \text{ kg}}$ $\mathbf{v_{1,i}} = \dfrac{9.3 \times 10^7 \text{ kg•km/h} - 1.7 \times 10^8 \text{ kg•km/h} - 1.0 \times 10^8 \text{ kg•km/h}}{3.0 \times 10^7 \text{ kg}}$ $\mathbf{v_{1,i}} = \dfrac{-1.8 \times 10^8 \text{ kg•km/h}}{3.0 \times 10^7 \text{ kg}} = -6.0$ km/h $\mathbf{v_{1,i}} = \boxed{6.0 \text{ km/h to the south}}$ Conservation of kinetic energy (check) $\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$ $\frac{1}{2}(3.0 \times 10^7 \text{ kg})[(-6.0 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})]^2 + \frac{1}{2}(2.5 \times 10^7 \text{ kg})[(4.0 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})]^2$ $= \frac{1}{2}(3.0 \times 10^7 \text{ kg})[(3.1 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})]^2 + \frac{1}{2}(2.7 \times 10^7 \text{ kg})[(-6.9 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})]^2$ $4.2 \times 10^7 \text{ J} + 1.5 \times 10^7 \text{ J} = 1.1 \times 10^7 \text{ J} + 4.6 \times 10^7 \text{ J}$ $5.7 \times 10^7 \text{ J} = 5.7 \times 10^7 \text{ J}$
165. $m = 7.10 \times 10^5$ kg $v = 270$ km/h	$p = mv = (7.10 \times 10^5 \text{ kg})(270 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})$ $p = \boxed{5.33 \times 10^7 \text{ kg•m/s}}$
166. $v = 50.0$ km/h $p = 0.278$ kg•m/s	$m = \dfrac{p}{v} = \dfrac{0.278 \text{ kg•m/s}}{(50.0 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})}$ $m = \boxed{2.00 \times 10^{-2} \text{ kg} = 20.0 \text{ g}}$
167. $F = 75$ N $m = 55$ kg $\Delta t = 7.5$ s $v_i = 0$ m/s	$\Delta p = mv_f - mv_i = F\Delta t$ $v_f = \dfrac{F\Delta t + mv_i}{m} = \dfrac{(75 \text{ N})(7.5 \text{ s}) + (55 \text{ kg})(0 \text{ m/s})}{55 \text{ kg}}$ $v_f = \boxed{1.0 \times 10^1 \text{ m/s}}$
168. $m = 60.0$ g $F = -1.5$ N $\Delta t = 0.25$ s $v_f = 0$ m/s	$\Delta p = mv_f - mv_i = F\Delta t$ $v_i = \dfrac{mv_f - F\Delta t}{m} = \dfrac{(60.0 \times 10^{-3} \text{ kg})(0 \text{ m/s}) - (-1.5 \text{ N})(0.25 \text{ s})}{60.0 \times 10^{-3} \text{ kg}} = \dfrac{(1.5 \text{ N})(0.25 \text{ s})}{60.0 \times 10^{-3} \text{ kg}}$ $v_i = \boxed{6.2 \text{ m/s}}$
169. $m = 1.1 \times 10^3$ kg $\mathbf{v_f} = 9.7$ m/s to the east $\mathbf{v_i} = 0$ m/s $\Delta t = 19$ s	$\mathbf{F} = \dfrac{\Delta \mathbf{p}}{\Delta t} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t}$ $\mathbf{F} = \dfrac{(1.1 \times 10^3 \text{ kg})(9.7 \text{ m/s}) - (1.1 \times 10^3 \text{ kg})(0 \text{ m/s})}{19 \text{ s}} = 560$ N $\mathbf{F} = \boxed{560 \text{ N to the east}}$

Givens | *Solutions*

170. $m = 12.0$ kg

$F_{applied} = 15.0$ N

$\theta = 20.0°$

$F_{friction} = 11.0$ N

$v_i = 0$ m/s

$v_f = 4.50$ m/s

$$F = F_{applied}(\cos\theta) - F_{friction}$$

$$\Delta t = \frac{\Delta p}{F} = \frac{mv_f - mv_i}{F_{applied}(\cos\theta) - F_{friction}} = \frac{(12.0 \text{ kg})(4.50 \text{ m/s}) - (12.0 \text{ kg})(0 \text{ m/s})}{(15.0 \text{ N})(\cos 20.0°) - 11.0 \text{ N}}$$

$$\Delta t = \frac{54.0 \text{ kg}\bullet\text{m/s} - 0 \text{ kg}\bullet\text{m/s}}{14.1 \text{ N} - 11.0 \text{ N}} = \frac{54.0 \text{ kg}\bullet\text{m/s}}{3.1 \text{ N}}$$

$$\Delta t = \boxed{17 \text{ s}}$$

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171. $v_i = 7.82 \times 10^3$ m/s

$v_f = 0$ m/s

$m = 42$ g

$\Delta t = 1.0 \times 10^{-6}$ s

$$\mathbf{F} = \frac{\Delta \mathbf{p}}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$$

$$F = \frac{(42 \times 10^{-3} \text{ kg})(0 \text{ m/s}) - (42 \times 10^{-3} \text{ kg})(7.82 \times 10^3 \text{ m/s})}{1.0 \times 10^{-6} \text{ s}}$$

$$F = \frac{-(42 \times 10^{-3} \text{ kg})(7.82 \times 10^3 \text{ m/s})}{1.0 \times 10^{-6} \text{ s}}$$

$$F = \boxed{-3.3 \times 10^8 \text{ N}}$$

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172. $m = 455$ kg

$\Delta t = 12.2$ s

$\mu_k = 0.071$

$g = 9.81$ m/s^2

$v_f = 0$ m/s

$$\Delta \mathbf{p} = \mathbf{F}\Delta t$$

$$\mathbf{F} = \mathbf{F_k} = -mg\mu_k$$

$$\Delta \mathbf{p} = -mg\mu_k\Delta t = -(455 \text{ kg})(9.81 \text{ m/s}^2)(0.071)(12.2 \text{ s}) = -3.9 \times 10^3 \text{ kg}\bullet\text{ms}$$

$$\Delta \mathbf{p} = \boxed{3.9 \times 10^3 \text{ kg}\bullet\text{ms opposite the polar bear's motion}}$$

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173. $m = 455$ kg

$\Delta t = 12.2$ s

$\mu_k = 0.071$

$g = 9.81$ m/s^2

$v_f = 0$ m/s

$$v_i = \frac{mv_f - \Delta p}{m} = \frac{(455 \text{ kg})(0 \text{ m/s}) - (-3.9 \times 10^3 \text{ kg}\bullet\text{ms})}{455 \text{ kg}}$$

$$v_i = \frac{3.9 \times 10^3 \text{ kg}\bullet\text{ms}}{455 \text{ kg}} = 8.6 \text{ m/s}$$

$$\Delta x = \tfrac{1}{2}(v_i + v_f)\Delta t = \tfrac{1}{2}(8.6 \text{ m/s} + 0 \text{ m/s})(12.2 \text{ s})$$

$$\Delta x = \boxed{52 \text{ m}}$$

Givens	*Solutions*
174. $m = 2.30 \times 10^3$ kg $v_i = 22.2$ m/s $v_f = 0$ m/s $F = -1.26 \times 10^4$ N	$\Delta t = \frac{\Delta p}{F} = \frac{mv_f - mv_i}{F}$ $\Delta t = \frac{(2.30 \times 10^3 \text{ kg})(0 \text{ m/s}) - (2.30 \times 10^3 \text{ kg})(22.2 \text{ m/s})}{-1.26 \times 10^4 \text{ N}} = \frac{-5.11 \times 10^4 \text{ kg•m/s}}{-1.26 \times 10^4 \text{ N}}$ $\Delta t = \boxed{4.06 \text{ s}}$
175. $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 5.4$ m/s to the north $\mathbf{v_{1,f}} = 1.5$ m/s to the north $\mathbf{v_{2,f}} = 1.5$ m/s to the north $m_1 = 63$ kg	$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $m_2 = \frac{m_1\mathbf{v_{1,f}} - m_1\mathbf{v_{1,i}}}{\mathbf{v_{2,i}} - \mathbf{v_{2,f}}} = \frac{(63 \text{ kg})(1.5 \text{ m/s}) - (63 \text{ kg})(0 \text{ m/s})}{5.4 \text{ m/s} - 1.5 \text{ m/s}} = \frac{(63 \text{ kg})(1.5 \text{ m/s})}{3.9 \text{ m/s}}$ $m_2 = \boxed{24 \text{ kg}}$
176. $m_i = 1.36 \times 10^4$ kg $m_2 = 8.4 \times 10^3$ kg $v_{2,i} = 0$ m/s $v_{1,f} = v_{2,f} = 1.3$ m/s	$m_1v_{1,i} + m_2v_{2,i} = m_1 v_{1,f} + m_2v_{2,f}$ $v_{1,i} = \frac{m_1v_{1,f} + m_2v_{2,f} - m_2v_{2,i}}{m_1}$ $v_{1,i} = \frac{(1.36 \times 10^4 \text{ kg})(1.3 \text{ m/s}) + (8.4 \times 10^3 \text{ kg})(1.3 \text{ m/s}) - (8.4 \times 10^3 \text{ kg})(0 \text{ m/s})}{1.36 \times 10^4 \text{ kg}}$ $v_{1,i} = \frac{1.8 \times 10^4 \text{ kg•m/s} + 1.1 \times 10^4 \text{ kg•m/s}}{1.36 \times 10^4 \text{ kg}} = \frac{2.9 \times 10^4 \text{ kg•m/s}}{1.36 \times 10^4 \text{ kg}}$ $v_{1,i} = \boxed{2.1 \text{ m/s}}$
177. $m_i = 1292$ kg $\mathbf{v_i} = 88.0$ km/h to the east $m_f = 1255$ kg	$m_i\mathbf{v_i} = m_f\mathbf{v_f}$ $\mathbf{v_f} = \frac{m_i\mathbf{v_i}}{m_f} = \frac{(1292 \text{ kg})(88.0 \text{ km/h})}{1255 \text{ kg}}$ $\mathbf{v_f} = \boxed{90.6 \text{ km/h to the east}}$
178. $m_1 = 68$ kg $m_2 = 68$ kg $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{1,f}} = 0.85$ m/s to the west $= -0.85$ m/s $\mathbf{v_{2,f}} = 0.85$ m/s to the west $= -0.85$ m/s	$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $\mathbf{v_{1,i}} = \frac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}}{m_i} = \frac{(68 \text{ kg})(-0.85 \text{ m/s}) + (68 \text{ kg})(-0.85 \text{ m/s}) - (68 \text{ kg})(0 \text{ m/s})}{68 \text{ kg}}$ $\mathbf{v_{1,i}} = -0.85 \text{ m/s} + (-0.85 \text{ m/s}) = -1.7 \text{ m/s}$ $\mathbf{v_{1,i}} = \boxed{1.7 \text{ m/s to the west}}$

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Givens	Solutions

I

179. $m_1 = 1400$ kg

$\mathbf{v_{1,i}} = 45$ km/h to the north

$m_2 = 2500$ kg

$\mathbf{v_{2,i}} = 33$ km/h to the east

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2}$$

The component of $\mathbf{v_f}$ in the x-direction is given by

$$v_{f,x} = \frac{m_2 v_{2,i}}{m_1 + m_2} = \frac{(2500\text{ kg})(33\text{ km/h})}{1400\text{ kg} + 2500\text{ kg}} = \frac{(2500\text{ kg})(33\text{ km/h})}{3900\text{ kg}}$$

$v_{f,x} = 21$ km/h

The component of $\mathbf{v_f}$ in the y-direction is given by

$$v_{f,y} = \frac{m_1 v_{1,i}}{m_1 + m_2} = \frac{(1400\text{ kg})(45\text{ km/h})}{1400\text{ kg} + 2500\text{ kg}} = \frac{(1400\text{ kg})(45\text{ km/h})}{3900\text{ kg}}$$

$v_{f,y} = 16$ km/h

$$v_f = \sqrt{v_{f,x}^2 + v_{f,y}^2} = \sqrt{(21\text{ km/h})^2 + (16\text{ km/h})^2}$$

$$v_f = \sqrt{440\text{ km}^2/\text{h}^2 + 260\text{ km}^2/\text{h}^2} = \sqrt{7.0\times 10^2\text{ km}^2/\text{h}^2}$$

$v_f = 26$ km/h

$$\theta = \tan^{-1}\left(\frac{v_{f,y}}{v_{f,x}}\right) = \tan^{-1}\left(\frac{16\text{ km/h}}{21\text{ km/h}}\right) = 37°$$

$$\mathbf{v_f} = \boxed{26\text{ km/h at }37°\text{ north of east}}$$

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180. $m_1 = 4.5$ kg

$v_{1,i} = 0$ m/s

$m_2 = 1.3$ kg

$v_f = 0.83$ m/s

$$v_{2,i} = \frac{(m_1 + m_2)v_f - m_1 v_{1,i}}{m_2} = \frac{(4.5\text{ kg} + 1.3\text{ kg})(0.83\text{ m/s}) - (4.5\text{ kg})(0\text{ m/s})}{1.3\text{ kg}}$$

$$v_{2,i} = \frac{(5.8\text{ kg})(0.83\text{ m/s})}{1.3\text{ kg}} = 3.7\text{ m/s}$$

$$KE_i = \tfrac{1}{2}m_1 v_{1,i}^2 + \tfrac{1}{2}m_2 v_{2,i}^2 = \tfrac{1}{2}(4.5\text{ kg})(0\text{ m/s})^2 + \tfrac{1}{2}(1.3\text{ kg})(3.7\text{ m/s})^2$$

$KE_i = 0\text{ J} + 8.9\text{ J} = 8.9$ J

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(4.5\text{ kg} + 1.3\text{ kg})(0.83\text{ m/s})^2 = \tfrac{1}{2}(5.8\text{ kg})(0.83\text{ m/s})^2$$

$KE_f = 2.0$ J

$$\Delta KE = KE_f - KE_i = 2.0\text{ J} - 8.9\text{ J} = \boxed{-6.9\text{ J}}$$

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181. $m_1 = 0.650$ kg

$\mathbf{v_{1,i}} = 15.0$ m/s to the right
$= +15.0$ m/s

$m_2 = 0.950$ kg

$\mathbf{v_{2,i}} = 13.5$ m/s to the left
$= -13.5$ m/s

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(0.650\text{ kg})(15.0\text{ m/s}) + (0.950\text{ kg})(-13.5\text{ m/s})}{0.650\text{ kg} + 0.950\text{ kg}}$$

$$\mathbf{v_f} = \frac{9.75\text{ kg•m/s} - 12.8\text{ kg•m/s}}{1.600\text{ kg}} = \frac{-3.0\text{ kg•m/s}}{1.600\text{ kg}} = -1.91\text{ m/s}$$

$\mathbf{v_f} = 1.91$ m/s to the left

$$KE_i = \tfrac{1}{2}m_1 v_{1,i}^2 + \tfrac{1}{2}m_2 v_{2,i}^2 = \tfrac{1}{2}(0.650\text{ kg})(15.0\text{ m/s})^2 + \tfrac{1}{2}(0.950\text{ kg})(-13.5\text{ m/s})^2$$

$KE_i = 73.1\text{ J} + 86.6\text{ J} = 159.7$ J

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(0.650\text{ kg} + 0.950\text{ kg})(1.91\text{ m/s})^2 = \tfrac{1}{2}(1.600\text{ kg})(1.91\text{ m/s})^2$$

$KE_f = 2.92$ J

$$\Delta KE = KE_f - KE_i = 2.92\text{ J} - 159.7\text{ J} = \boxed{-1.57\times 10^2\text{ J}}$$

Givens | *Solutions*

182. $m_1 = 10.0$ kg

$m_2 = 2.5$ kg

$v_{1,i} = 6.0$ m/s

$v_{2,i} = -3.0$ m/s

$$v_f = \frac{m_1 v_{1,i} + m_2 v_{2,i}}{m_1 + m_2} = \frac{(10.0\ \text{kg})(6.0\ \text{m/s}) + (2.5\ \text{kg})(-3.0\ \text{m/s})}{10.0\ \text{kg} + 2.5\ \text{kg}}$$

$$v_f = \frac{6.0 \times 10^1\ \text{kg•m/s} - 7.5\ \text{kg•m/s}}{12.5\ \text{kg}} = \frac{52\ \text{kg•m/s}}{12.5\ \text{kg}} = \boxed{4.2\ \text{m/s}}$$

---

183. $\mathbf{v_{1,i}} = 6.00$ m/s to the right $= +6.00$ m/s

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_{1,f}} = 4.90$ m/s to the left $= -4.90$ m/s

$\mathbf{v_{2,f}} = 1.09$ m/s to the right $= +1.09$ m/s

$m_2 = 1.25$ kg

Momentum conservation

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$$

$$m_1 = \frac{m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}}{\mathbf{v_{1,i}} - \mathbf{v_{1,f}}} = \frac{(1.25\ \text{kg})(1.09\ \text{m/s}) - (1.25\ \text{kg})(0\ \text{m/s})}{6.00\ \text{m/s} - (-4.90\ \text{m/s})} = \frac{1.36\ \text{kg•m/s}}{10.90\ \text{m/s}}$$

$$m_1 = \boxed{0.125\ \text{kg}}$$

Conservation of kinetic energy (check)

$$\tfrac{1}{2}m_1 v_{1,i}^2 + \tfrac{1}{2}m_2 v_{2,i}^2 = \tfrac{1}{2}m_1 v_{1,f}^2 + \tfrac{1}{2}m_2 v_{2,f}^2$$

$$\tfrac{1}{2}(0.125\ \text{kg})(6.00\ \text{m/s})^2 + \tfrac{1}{2}(1.25\ \text{kg})(0\ \text{m/s})^2 = \tfrac{1}{2}(0.125\ \text{kg})(-4.90\ \text{m/s})^2 + \tfrac{1}{2}(1.25\ \text{kg})(1.09\ \text{m/s})^2$$

$$2.25\ \text{J} + 0\ \text{J} = 1.50\ \text{J} + 0.74\ \text{J}$$

$$2.25\ \text{J} = 2.24\ \text{J}$$

The slight difference arises from rounding.

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184. $m_1 = 2150$ kg

$\mathbf{v_{1,i}} = 10.0$ m/s to the east

$m_2 = 3250$ kg

$\mathbf{v_f} = 5.22$ m/s to the east

$$\mathbf{v_{2,i}} = \frac{(m_1 + m_2)\mathbf{v_f} - m_1\mathbf{v_{1,i}}}{m_2}$$

$$\mathbf{v_{2,i}} = \frac{(2150\ \text{kg} + 3250\ \text{kg})(5.22\ \text{m/s}) - (2150\ \text{kg})(10.0\ \text{m/s})}{3250\ \text{kg}}$$

$$\mathbf{v_{2,i}} = \frac{(5.40 \times 10^3\ \text{kg})(5.22\ \text{m/s}) - (2150\ \text{kg})(10.0\ \text{m/s})}{3250\ \text{kg}}$$

$$\mathbf{v_{2,i}} = \frac{2.82 \times 10^4\ \text{kg•m/s} - 2.15 \times 10^4\ \text{kg•m/s}}{3250\ \text{kg}} = \frac{6700\ \text{kg•m/s}}{3250\ \text{kg}}$$

$$\mathbf{v_{2,i}} = \boxed{2.1\ \text{m/s to the east}}$$

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185. $m_1 = 2150$ kg

$\mathbf{v_{1,i}} = 10.0$ m/s to the east

$m_2 = 3250$ kg

$\mathbf{v_f} = 5.22$ m/s to the east

$\mathbf{v_{2,i}} = 2.1$ m/s to the east

$$\Delta KE = KE_f - KE_i$$

$$KE_i = \tfrac{1}{2}m_1 v_{1,i}^2 + \tfrac{1}{2}m_2 v_{2,i}^2 = \tfrac{1}{2}(2150\ \text{kg})(10.0\ \text{m/s})^2 + \tfrac{1}{2}(3250\ \text{kg})(2.1\ \text{m/s})^2$$

$$KE_i = 1.08 \times 10^5\ \text{J} + 7.2 \times 10^3\ \text{J} = 1.15 \times 10^5\ \text{J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(2150\ \text{kg} + 3250\ \text{kg})(5.22\ \text{m/s})^2$$

$$KE_f = \tfrac{1}{2}(5.40 \times 10^3\ \text{kg})(5.22\ \text{m/s})^2 = 7.36 \times 10^4\ \text{J}$$

$$\Delta KE = KE_f - KE_i = 7.36 \times 10^4\ \text{J} - 1.15 \times 10^5\ \text{J} = -4.1 \times 10^4\ \text{J}$$

The kinetic energy decreases by $\boxed{4.1 \times 10^4\ \text{J}}$.

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Givens	*Solutions*

186. $m_1 = 15.0$ g

$\mathbf{v_{1,i}} = 20.0$ cm/s to the right $= +20.0$ cm/s

$m_2 = 20.0$ g

$\mathbf{v_{2,i}} = 30.0$ cm/s to the left $= -30.0$ cm/s

$\mathbf{v_{1,f}} = 37.1$ cm/s to the left $= -37.1$ cm/s

$$\mathbf{v_{2,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_1\mathbf{v_{1,f}}}{m_2}$$

$$\mathbf{v_{2,f}} = \frac{(15.0\text{ g})(20.0\text{ cm/s}) + (20.0\text{ g})(-30.0\text{ cm/s}) - (15.0\text{ g})(-37.1\text{ cm/s})}{20.0\text{ g}}$$

$$\mathbf{v_{2,f}} = \frac{3.00\times10^2\text{ g•cm/s} - 6.00\times10^2\text{ g•cm/s} + 5.56\times10^2\text{ g•cm/s}}{20.0\text{ g}}$$

$$\mathbf{v_{2,f}} = \frac{256\text{ g•cm/s}}{20.0\text{ g}} = \boxed{12.8\text{ cm/s to the right}}$$

187. $\mathbf{v_{1,i}} = 5.0$ m/s to the right $= +5.0$ m/s

$\mathbf{v_{2,i}} = 7.00$ m/s to the left $= -7.00$ m/s

$\mathbf{v_f} = 6.25$ m/s to the left $= -6.25$ m/s

$m_2 = 150.0$ kg

$$m_1 = \frac{m_2\mathbf{v_{2,i}} - m_2\mathbf{v_f}}{\mathbf{v_f} - \mathbf{v_{1,i}}} = \frac{(150.0\text{ kg})(-7.00\text{ m/s}) - (150.0\text{ kg})(-6.25\text{ m/s})}{-6.25\text{ m/s} - 5.0\text{ m/s}}$$

$$m_1 = \frac{-1050\text{ kg•m/s} + 938\text{ kg•m/s}}{-11.2\text{ m/s}} = \frac{-110\text{ kg•m/s}}{-11.2\text{ m/s}}$$

$$m_1 = \boxed{9.8\text{ kg}}$$

188. $m_1 = 6.5\times10^{12}$ kg

$v_1 = 420$ m/s

$m_2 = 1.50\times10^{13}$ kg

$v_2 = 250$ m/s

Conservation of Momentum gives:

$$m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f$$

$$v_f = \frac{m_1v_{1i} + m_2v_{2i}}{m_1 + m_2}$$

The change in Kinetic Energy is:

$$\Delta KE = KE_f - KE_i = \frac{1}{2}(m_1 + m_2)v_f^2 - \left(\frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2f}^2\right)$$

$$2\Delta KE = (m_1 + m_2)\left(\frac{m_1v_{1i} + m_2v_{2i}}{m_1 + m_2}\right)^2 - (m_1v_{1i}^2 + m_2v_{2i}^2)$$

$$(m_1 + m_2)2\Delta KE = m_1^2v_{1i}^2 + 2m_1m_2v_{1i}v_{2i} + m_2^2v_{2i}^2 - (m_1 + m_2)m_1v_{1i}^2 + (m_1 + m_2)m_2v_{2i}^2$$

$$2(m_1 + m_2)\Delta KE = 2m_1m_2v_{1i}v_{2i} - m_1m_2v_{1i}^2 - m_1m_2v_{2i}^2$$

$$2(m_1 + m_2)\Delta KE = -m_1m_2(v_{1i}^2 - 2v_{1i}v_{2i} + v_{2i}^2) = -m_1m_2(v_{1i} - v_{2i})^2$$

$$\Delta KE = -\frac{1}{2}\left(\frac{m_1m_2}{m_1 + m_2}\right)(v_{1i} - v_{2i})^2$$

$$\Delta KE = -\frac{1}{2}\left(\frac{(6.5\times10^{12}\text{ kg})(1.50\times10^{13}\text{ kg})}{6.5\times10^{12}\text{ kg} + 1.50\times10^{13}\text{ kg}}\right)(420\text{ m/s} - 250\text{ m/s})^2$$

$$\Delta KE = -\frac{1}{2}\left(\frac{(6.5\times10^{12}\text{ kg})(1.50\times10^{13}\text{ kg})}{2.15\times10^{13}\text{ kg}}\right)(170\text{ m/s})^2 = -6.6\times10^{16}\text{ kg•m}^2\text{/s}^2$$

$$\Delta KE = \boxed{-6.6\times10^{16}\text{ J}}$$

Givens	*Solutions*

189. $m_1 = 7.00$ kg

$\mathbf{v_{1,i}} = 2.00$ m/s to the east (at 0°)

$m_2 = 7.00$ kg

$\mathbf{v_{1,i}} = 0$ m/s

$\mathbf{v_{1,f}} = 1.73$ m/s at 30.0° north of east

Momentum conservation

In the *x*-direction:

$m_1v_{1,i}(\cos\theta_{1,i}) + m_2v_{2,i}(\cos\theta_{2,i}) = m_1v_{1,f}(\cos\theta_{1,f}) + m_2v_{2,f}(\cos\theta_{2,f})$

$v_{2,f}(\cos\theta_{2,f}) = v_{1,i}(\cos\theta_{1,i}) + v_{2,i}(\cos\theta_{2,i}) - v_{i,f}(\cos\theta_{1,f})$

$v_{2,f}(\cos\theta_{2,f}) = (2.00 \text{ m/s})(\cos 0°) + 0 \text{ m/s} - (1.73 \text{ m/s})(\cos 30.0°)$

$v_{2,f} = 2.00 \text{ m/s} - 1.50 \text{ m/s} = 0.50 \text{ m/s}$

In the *y*-direction:

$m_1v_{1,i}(\sin\theta_{1,i}) + m_2v_{2,i}(\sin\theta_{2,i}) = m_1v_{1,f}(\sin\theta_{1,i})\ m_2v_{2,f}(\sin\theta_{2,f})$

$v_{2,f}(\sin\theta_{2,f}) = v_{1,i}(\sin\theta_{1,i}) + v_{2,i}(\sin\theta_{2,i}) - v_{2,f}(\sin\theta_{2,f})$

$v_{2,f}(\sin\theta_{2,f}) = (2.00 \text{ m/s})(\sin 0°) + 0 \text{ m/s} - (1.73 \text{ m/s})(\sin 30.0°) = -0.865 \text{ m/s}$

$$\frac{v_{2,f}(\sin\theta_{2,f})}{v_{2,f}(\cos\theta_{2,f})} = \frac{-0.865 \text{ m/s}}{0.50 \text{ m/s}}$$

$\tan\theta_{2,f} = -1.7$

$\theta_{2,f} = \tan^{-1}(-1.7) = (-6.0 \times 10^1)°$

$$v_{2,f} = \frac{0.50 \text{ m/s}}{\cos(-6.0 \times 10^1)°} = 1.0 \text{ m/s}$$

$\mathbf{v_{2,f}} = \boxed{1.0 \text{ m/s at } (6.0 \times 10^1)° \text{ south of east}}$

Conservation of kinetic energy (check)

$\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$\frac{1}{2}(7.00 \text{ kg})(2.00 \text{ m/s})^2 + \frac{1}{2}(7.00 \text{ kg})(0 \text{ m/s})^2 = \frac{1}{2}(7.00 \text{ kg})(1.73 \text{ m/s})^2 + \frac{1}{2}(7.00 \text{ kg})(1.0 \text{ m/s})^2$

$14.0 \text{ J} + 0 \text{ J} = 10.5 \text{ J} + 3.5 \text{ J}$

$14.0 \text{ J} = 14.0 \text{ J}$

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190. $m_1 = 2.0$ kg

$v_{1,i} = 8.0$ m/s

$v_{2,i} = 0$ m/s

$v_{1,f} = 2.0$ m/s

$m_1v_{1,i} + m_2v_{2,i} = m_1v_{1,f} + m_2v_{2,f}$

$\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$$m_2 = \frac{m_1v_{1,f} - m_1v_{1,i}}{v_{2,i} - v_{2,f}}$$

$$\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}\left[\frac{m_1v_{1,f} - m_1v_{1,i}}{v_{2,i} - v_{2,f}}\right]v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}\left(\frac{m_1v_{1,f} - m_1v_{1,i}}{v_{2,i} - v_{2,f}}\right)v_{2,f}^2$$

$v_{1,i}^2(v_{2,i} - v_{2,f}) + (v_{1,f} - v_{1,i})v_{2,i}^2 = v_{1,f}^2(v_{2,i} - v_{2,f}) + (v_{1,f} - v_{1,i})v_{2,f}^2$

$(v_{1,i}^2v_{2,i} + v_{1,f}v_{2,i}^2 - v_{1,i}v_{2,i}^2 - v_{1,f}^2v_{2,i} + v_{2,f}(v_{1,f}^2 - v_{1,i}^2) = v_{2,f}^2(v_{1,f} - v_{1,i})$

Because $v_{2,i} = 0$, the above equation simplifies to

$v_{1,f}^2 - v_{1,i}^2 = v_{2,f}(v_{1,f} - v_{1,i})$

$v_{2,f} = v_{1,f} + v_{1,i} = 2.0 \text{ m/s} + 8.0 \text{ m/s} = 10.0 \text{ m/s}$

$$m_2 = \frac{(2.0 \text{ kg})(2.0 \text{ m/s}) - (2.0 \text{ m/s})(8.0 \text{ m/s})}{0 \text{ m/s} - 10.0 \text{ m/s}} = \frac{4.0 \text{ kg•m/s} - 16 \text{ kg•m/s}}{-10.0 \text{ m/s}} = \frac{-12 \text{ kg•m/s}}{-10.0 \text{ m/s}}$$

$m_2 = \boxed{1.2 \text{ kg}}$

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Givens	*Solutions*
191. $r = 3.81$ m $v_t = 124$ m/s	$a_c = \dfrac{v_t^2}{r} = \dfrac{(124 \text{ m/s})^2}{3.81 \text{ m}} = \boxed{4.04 \times 10^3 \text{ m/s}^2}$
192. $v_t = 75.0$ m/s $a_c = 22.0$ m/s^2	$r = \dfrac{v_t^2}{a_c} = \dfrac{(75.0 \text{ m/s})^2}{22.0 \text{ m/s}^2} = \boxed{256 \text{ m}}$
193. $r = 8.9$ m $a_c = (20.0)\ g$ $g = 9.81$ m/s^2	$v_t = \sqrt{ra_c} = \sqrt{(8.9 \text{ m})(20.0)(9.81 \text{ m/s}^2)} = \boxed{42 \text{ m/s}}$
194. $m = 1250$ kg $v_t = 48.0$ km/h $r = 35.0$ m	$F_c = m\dfrac{v_t^2}{r} = (1250 \text{ kg})\dfrac{[(48.0 \text{ km/h})(1000 \text{ m/km})(1\text{h}/3600 \text{ s})]^2}{35.0 \text{ m}}$ $F_c = 6350 \text{ kg}\bullet\text{m/s}^2 = \boxed{6350 \text{ N}}$
195. $F_c = 8.00 \times 10^2$ N $r = 0.40$ m $v_t = 6.0$ m/s	$m = \dfrac{F_c r}{v_t^2} = \dfrac{(8.00 \times 10^2 \text{ N})(0.40 \text{ m})}{(6.0 \text{ m/s})^2} = \boxed{8.9 \text{ kg}}$
196. $m = 7.55 \times 10^{13}$ kg $v_t = 0.173$ km/s $F_c = 505$ N	$r = \dfrac{mv_t^2}{F_c} = \dfrac{(7.55 \times 10^{13} \text{ kg})(0.173 \times 10^3 \text{ m/s})^2}{505 \text{ N}} = \boxed{4.47 \times 10^{15} \text{ m}}$
197. $m = 2.05 \times 10^8$ kg $r = 7378$ km $F_c = 3.00 \times 10^9$ N	$v_t = \sqrt{\dfrac{F_c r}{m}} = \sqrt{\dfrac{(3.00 \times 10^9 \text{ N})(7378 \times 10^3 \text{ m})}{2.05 \times 10^8 \text{ kg}}}$ $v_t = \boxed{1.04 \times 10^4 \text{ m/s} = 10.4 \text{ km/s}}$
198. $m_1 = 0.500$ kg $m_2 = 2.50 \times 10^{12}$ kg $r = 10.0$ km $G = 6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$	$F_g = G\dfrac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\dfrac{(0.500 \text{ kg})(2.50 \times 10^{12} \text{ kg})}{(10.0 \times 10^3 \text{ m})^2} = \boxed{8.34 \times 10^{-7} \text{ N}}$
199. $F_g = 1.636 \times 10^{22}$ N $m_1 = 1.90 \times 10^{27}$ kg $r = 1.071 \times 10^6$ km $G = 6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$	$m_2 = \dfrac{F_g r^2}{Gm_1} = \dfrac{(1.636 \times 10^{22} \text{ N})(1.071 \times 10^9 \text{ m})^2}{\left(6.673 \times 10^{-11} \dfrac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)(1.90 \times 10^{27} \text{ kg})} = \boxed{1.48 \times 10^{23} \text{ kg}}$

Givens | *Solutions*

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200. $m_1 = 1.00$ kg

$m_2 = 1.99 \times 10^{30}$ kg

$F_g = 274$ N

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \sqrt{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.00 \text{ kg})(1.99 \times 10^{30} \text{ kg})}{274 \text{ N}}} = \boxed{6.96 \times 10^8 \text{ m}}$$

201. $m_1 = 1.00$ kg

$m_2 = 3.98 \times 10^{31}$ kg

$F_g = 2.19 \times 10^{-3}$ N

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \sqrt{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.00 \text{ kg})(3.98 \times 10^{31} \text{ kg})}{2.19 \times 10^{-3} \text{ N}}} = \boxed{1.10 \times 10^{12} \text{ m}}$$

202. $m = 8.6 \times 10^{25}$ kg

$r = 1.3 \times 10^5$ km $= 1.3 \times 10^8$ m

$G = 6.673 \times 10^{-11}$ N•m^2/kg^2

$$T = 2\pi\sqrt{\frac{r^3}{Gm}} = 2\pi\sqrt{\frac{(1.3 \times 10^8 \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(8.6 \times 10^{25} \text{ kg})}} = \boxed{1.2 \times 10^5 \text{ m}}$$

$$T = 1.2 \times 10^5 \text{ s}\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = \boxed{34 \text{ h}}$$

203. $m = 8.6 \times 10^{25}$ kg

$r = 1.3 \times 10^5$ km $= 1.3 \times 10^8$ m

$G = 6.673 \times 10^{-11}$ N•m^2/kg^2

$$v_t = \sqrt{\frac{Gm}{r}} = \sqrt{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(8.6 \times 10^{25} \text{ kg})}{(1.3 \times 10^8 \text{ m})}}$$

$$v_t = \boxed{6.6 \times 10^3 \text{ m/s} = 6.6 \text{ km/s}}$$

204. $F_{max} = 2.27 \times 10^5$ N • m

$r = 0.660$ m

$d = \frac{1}{2}r$

$$\tau_{max} = F_{max}d = \frac{F_{max}r}{2}$$

$$\tau_{max} = \frac{(2.27 \times 10^5 \text{ N • m})(0.660 \text{ m})}{2} = \boxed{7.49 \times 10^4 \text{ N • m}}$$

205. $\tau = 0.46$ N • m

$F = 0.53$ N

$\theta = 90°$

$$d = \frac{\tau}{F(\sin\theta)} = \frac{0.46 \text{ N • m}}{(0.53 \text{ N})(\sin 90°)}$$

$$d = \boxed{0.87 \text{ m}}$$

206. $m = 6.42 \times 10^{23}$ kg

$T = 30.3$ h

$G = 6.673 \times 10^{-11}$ N•m^2/kg^2

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}} = \sqrt[3]{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(6.42 \times 10^{23} \text{ kg})[(30.3 \text{ h})(3600 \text{ s/h})]^2}{4\pi^2}}$$

$$r = \sqrt[3]{1.29 \times 10^{22} \text{ m}^3} = \boxed{2.35 \times 10^7 \text{ m} = 2.35 \times 10^4 \text{ km}}$$

207. $d = 1.60$ m

$\tau = 4.00 \times 10^2$ N • m

$\theta = 80.0°$

$$F = \frac{\tau}{d(\sin\theta)} = \frac{4.00 \times 10^2 \text{ N • m}}{(1.60 \text{ m})(\sin 80.0°)}$$

$$F = \boxed{254 \text{ N}}$$

208. $r = 11$ m

$v_t = 1.92 \times 10^{-2}$ m/s

$$a_c = \frac{v_t^2}{r} = \frac{(1.92 \times 10^{-2} \text{ m/s})^2}{11 \text{ m}} = \boxed{3.4 \times 10^{-5} \text{ m/s}^2}$$

Givens	*Solutions*
209. $v_t = 0.35$ m/s $a_c = 0.29$ m/s^2	$r = \frac{v_t^2}{a_c} = \frac{(0.35 \text{ m/s})^2}{0.29 \text{ m/s}^2} = \boxed{0.42 \text{ m} = 42 \text{ cm}}$
210. $a_c = g = 9.81$ m/s^2 $r = 150$ m	$v_t = \sqrt{ra_c} = \sqrt{(150 \text{ m})(9.81 \text{ m/s}^2)} = \boxed{38 \text{ m/s}}$
211. $r = 0.25$ m $v_t = 5.6$ m/s $m = 0.20$ kg	$F_c = m\frac{v_t^2}{r} = (0.20 \text{ kg})\frac{(5.6 \text{ m/s})^2}{0.25 \text{ m}} = \boxed{25 \text{ N}}$
212. $m = 1250$ kg $r = 35.0$ m $\theta = 9.50°$ $g = 9.81$ m/s^2 $\mu_k = 0.500$	$F = F_f + mg(\sin\theta) = \mu_k F_n + mg(\sin\theta) = \mu_k mg(\cos\theta) + mg(\sin\theta)$ $F = (0.500)(1250 \text{ kg})(9.81 \text{ m/s}^2)(\cos 9.50°) + (1250 \text{ kg})(9.81 \text{ m/s}^2)(\sin 9.50°)$ $F = 6.05 \times 10^3 \text{ N} + 2.02 \times 10^3 \text{ N}$ $F = \boxed{8.07 \times 10^3 \text{ N}}$ $Fc = \text{F} = 8.07 \times 10^3$ N $v_t = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{(8.07 \times 10^3 \text{ N})(35.0 \text{ m})}{1250 \text{ kg}}}$ $v_t = \boxed{15.0 \text{ m/s} = 54.0 \text{ km/h}}$
213. $F_g = 2.77 \times 10^{-3}$ N $r = 2.50 \times 10^{-2}$ m $m_1 = 157$ kg $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$m_2 = \frac{F_g r^2}{Gm_1} = \frac{(2.77 \times 10^{-3} \text{ N})(2.50 \times 10^{-2} \text{ m})^2}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(157 \text{ kg})} = \boxed{165 \text{ kg}}$
214. $m_1 = 2.04 \times 10^4$ kg $m_2 = 1.81 \times 10^5$ kg $r = 1.5$ m $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$F_g = G\frac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(2.04 \times 10^4 \text{ kg})(1.81 \times 10^5 \text{ kg})}{(1.5 \text{ m})^2} = \boxed{0.11 \text{ N}}$
215. $r = 3.56 \times 10^5$ km $= 3.56 \times 10^8$ m $m = 1.03 \times 10^{26}$ kg $G = 6.673 \times 10^{-11}$ N•m^2/kg^2	$T = 2\pi\sqrt{\frac{r^3}{Gm}} = 2\pi\sqrt{\frac{(3.56 \times 10^8 \text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(1.03 \times 10^{26} \text{ kg})}}$ $T = 5.09 \times 10^5 \text{ s}\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = \boxed{141 \text{ h}}$
216. $r = 3.56 \times 10^5$ km $= 3.56 \times 10^8$ m $m = 1.03 \times 10^{26}$ kg $G = 6.673 \times 10^{-11}$ N•m^2/kg^2	$v_t = \sqrt{\frac{Gm}{r}} = \sqrt{\frac{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(1.03 \times 10^{26} \text{ kg})}{(3.56 \times 10^8 \text{ m})}}$ $v_t = \boxed{4.39 \times 10^3 \text{ m/s} = 4.39 \text{ km/s}}$

Givens	Solutions
217. $m = 1.0 \times 10^{26}$ kg $T = 365$ days $G = 6.673 \times 10^{-11}$ $N \bullet m^2/kg^2$	$r = \sqrt[3]{\dfrac{GmT^2}{4\pi^2}} = \sqrt[3]{\dfrac{(6.673 \times 10^{-11}\ N{\bullet}m^2/kg^2)(1.0 \times 10^{26}\ kg)[(365\ days)(24\ h/day)(3600\ s/h)]^2}{4\pi^2}}$ $r = \boxed{5.5 \times 10^9\ m = 5.5 \times 10^6\ km}$
218. $\tau = 1.4$ N • m $d = 0.40$ m $\theta = 60.0°$	$F = \dfrac{\tau}{d(\sin\theta)} = \dfrac{1.4\ N \bullet m}{(0.40\ m)(\sin 60.0°)}$ $F = \boxed{4.0\ N}$
219. $F = 4.0$ N $d = 0.40$ m	τ_{max} is produced when $\theta = 90°$, or $\tau_{max} = Fd = (4.0\ N)(0.40\ m) = \boxed{1.6\ N \bullet m}$
220. $\tau = 8.25 \times 10^3$ N • m $F = 587$ N $\theta = 65.0°$	$d = \dfrac{\tau}{F(\sin\theta)} = \dfrac{8.25 \times 10^3\ N \bullet m}{(587\ N)(\sin 65.0°)}$ $d = \boxed{15.5\ m}$

Fluid Mechanics

Givens	Solutions
221. $\rho_{gasoline} = 675\ kg/m^3$ $V_s = 1.00\ m^3$ $g = 9.81\ m/s^2$	$F_B = F_g \dfrac{\rho_{gasoline}}{\rho_s} = \dfrac{m_s g}{\rho_s}\rho_{gasoline} = V_s g \rho_{gasoline}$ $F_B = (1.00\ m^3)(9.81\ m/s^2)(675\ kg/m^3) = \boxed{6.62 \times 10^3\ N}$
222. $\rho_r = 2.053 \times 10^4 kg/m^3$ $V_r = (10.0\ cm)^3$ $g = 9.81\ m/s^2$ apparent weight = 192 N	$F_B = F_g -$ apparent weight $F_B = m_r g -$ apparent weight $= \rho_r V_r g -$ apparent weight $F_B = (2.053 \times 10^4\ kg/m^3)(10.0\ cm)^3(10^{-2}\ m/cm)^3(9.81\ m/s^2) - 192\ N = 201\ N - 192\ N$ $F_B = \boxed{9\ N}$
223. $m_h = 1.47 \times 10^6$ kg $A_h = 2.50 \times 10^3\ m^2$ $\rho_{sw} = 1.025 \times 10^3\ kg/m^3$ $g = 9.81\ m/s^2$	$F_B = F_g = m_h g$ $F_B = (1.47 \times 10^6\ kg)(9.81\ m/s^2) = 1.44 \times 10^7$ N volume of hull submerged $= V_{sw} = \dfrac{m_{sw}}{\rho_{sw}} = \dfrac{m_h}{\rho_{sw}}$ $h = \dfrac{V_{sw}}{A_h} = \dfrac{m_h}{A_h \rho_{sw}}$ $h = \dfrac{1.47 \times 10^6\ kg}{(2.50 \times 10^3\ m^2)(1.025 \times 10^3\ kg/m^3)} = \boxed{0.574\ m}$
224. $A = 1.54\ m^2$ $P = 1.013 \times 10^3$ Pa	$F = PA = (1.013 \times 10^3\ Pa)(1.54\ m^2) = \boxed{1.56 \times 10^3\ N}$

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Givens | *Solutions*

225. $P = 1.50 \times 10^6$ Pa

$F = 1.22 \times 10^4$ N

$$A = \frac{F}{P} = \frac{1.22 \times 10^4 \text{ N}}{1.50 \times 10^6 \text{ Pa}} = \boxed{8.13 \times 10^{-3} \text{ m}^2}$$

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226. $h = 760$ mm

$\rho = 13.6 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$P = \frac{F}{A} = \frac{mg}{A} = \frac{mgh}{Ah} = \frac{mgh}{V} = \rho gh$$

$$P = (13.6 \times 10^3 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(760 \times 10^{-3} \text{ m}) = \boxed{1.0 \times 10^5 \text{ Pa}}$$

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227. $V = 166$ cm^3

apparent weight = 35.0 N

$\rho_w = 1.00 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$F_g = F_B + \text{apparent weight}$$

$$\rho_{osmium} Vg = \rho_w Vg + \text{apparent weight}$$

$$\rho_{osmium} = \rho_w + \frac{\text{apparent weight}}{Vg}$$

$$\rho_{osmium} = 1.00 \times 10^3 \text{ kg/m}^3 + \frac{35.0 \text{ N}}{(166 \text{ cm}^3)(10^{-6} \text{ m}^3/\text{cm}^3)(9.81 \text{ m/s}^2)}$$

$$\rho_{osmium} = 1.00 \times 10^3 \text{ kg/m}^3 + 2.15 \times 10^4 \text{ kg/m}^3$$

$$\rho_{osmium} = \boxed{2.25 \times 10^4 \text{ kg/m}^3}$$

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228. $V = 2.5 \times 10^{-3}$ m^3

apparent weight = 7.4 N

$\rho_w = 1.0 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$$F_g = F_B + \text{apparent weight}$$

$$\rho_{ebony} V_g = \rho_w V_g + \text{apparent weight}$$

$$\rho_{ebony} = \rho_w + \frac{\text{apparent weight}}{V_g}$$

$$\rho_{ebony} = 1.0 \times 10^3 \text{ kg/m}^3 + \frac{7.4 \text{ N}}{(2.5 \times 10^{-3} \text{ m}^3)(9.81 \text{ m/s}^2)}$$

$$= 1.0 \times 10^3 \text{ kg/m}^3 + 3.0 \times 10^2 \text{ kg/m}^3$$

$$\rho_{ebony} = \boxed{1.3 \times 10^3 \text{ kg/m}^3}$$

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229. $m = 1.40 \times 10^3$ kg

$h = 0.076$ m

$\rho_{ice} = 917$ kg/m^3

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{mg}{A_1} = \frac{m_{ice}g}{A_2} = \frac{m_{ice}hg}{V_{ice}} = \rho_{ice}hg$$

$$A_1 = \frac{m}{\rho_{ice}h} = \frac{1.40 \times 10^3 \text{ kg}}{(917 \text{ kg/m}^3)(0.076 \text{ m})} = \boxed{2.0 \times 10^1 \text{ m}^2}$$

---

230. $F_1 = 4.45 \times 10^4$ N

$h_1 = 448$ m

$h_2 = 8.00$ m

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_1h_1}{A_1h_1} = \frac{F_1h_1}{V} = \frac{F_2h_2}{A_2h_2} = \frac{F_2h_2}{V}$$

$$F_2 = \frac{F_1h_1}{h_2} = \frac{(4.45 \times 10^4 \text{ N})(448 \text{ m})}{8.00 \text{ m}}$$

$$F_2 = \boxed{2.49 \times 10^6 \text{ N}}$$

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231. $\rho_{platinum} = 21.5\ g/cm^3$

$\rho_w = 1.00\ g/cm^3$

apparent weight = 40.2 N

$g = 9.81\ m/s^2$

$F_g = F_B + \text{apparent weight}$

$$mg = \rho_w V g + \text{apparent weight} = \rho_w\left(\frac{m}{\rho_{platinum}}\right)g + \text{apparent weight}$$

$$mg\left(1 - \frac{\rho_w}{\rho_{platinum}}\right) = \text{apparent weight}$$

$$m = \frac{\text{apparent weight}}{g\left(1 - \frac{\rho_w}{\rho_{platinum}}\right)} = \frac{40.2\ N}{(9.81\ m/s^2)\left(1 - \frac{1.00\ g/cm^3}{21.5\ g/cm^3}\right)}$$

$$m = \frac{40.2\ N}{(9.81\ m/s^2)(1 - 0.047)} = \frac{40.2\ N}{(9.81\ m/s^2)(0.953)}$$

$$m = \boxed{4.30\ kg}$$

Heat

232. $T_1 = 463\ K$

$T_2 = 93\ K$

$$T_{C,1} = (T - 273)°C = (463 - 273)°C = \boxed{1.90 \times 10^2\ °C}$$

$$T_{C,2} = (T - 273)°C = (93 - 273)°C = \boxed{-180 \times 10^2\ °C}$$

233. $T_1 = 463\ K$

$T_2 = 93\ K$

$$T_{F,1} = \frac{9}{5}\ T_{C,1} + 32 = \frac{9}{5}\ (1.90 \times 10^2)°F + 32°F = 342°F + 32°F = \boxed{374°F}$$

$$T_{F,2} = \frac{9}{5}\ T_{C,2} + 32 = \frac{9}{5}\ (-1.80 \times 10^2)°F + 32°F = -324°F + 32°F = \boxed{-292°F}$$

234. $T_{F,i} = -5\ °F$

$T_{F,f} = +37°F$

$$T_{C,i} = \frac{5}{9}(T_{F,i} - 32)°C = \frac{5}{9}(-5 - 32)°C = \frac{5}{9}(-37)°C = -21°C$$

$$T_{C,f} = \frac{5}{9}(T_{F,f} - 32)°C = \frac{5}{9}(37 - 32)°C = \frac{5}{9}(5)°C = 3°C$$

$$\Delta T = (T_{C,f} + 273\ K) - (T_{C,i} + 273\ K) = T_{C,f} - T_{C,i}$$

$$\Delta T = [3 - (-21)]\ K = \boxed{24\ K}$$

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235. Givens: $h = 9.5$ m; $g = 9.81$ m/s^2; $\Delta U_{acorn} = (0.85)\Delta U$; $k/m = \dfrac{1200 \text{ J/kg}}{1.0°\text{C}}$

$\Delta PE + \Delta KE + \Delta U = 0$

The change in kinetic energy from before the acorn is dropped to after it has landed is zero, as is PE_f.

$\Delta PE + \Delta KE + \Delta U = PE_f - PE_i + 0 + \Delta U = -PE_i + \Delta U = 0$

$\Delta U = PE_i = mgh$

$\Delta U_{acorn} = (0.85)\ \Delta U = (0.85)mgh$

$$\Delta T = \frac{\Delta U_{acorn}}{k} = \frac{(0.85)mgh}{k} = \frac{(0.85)gh}{(k/m)}$$

$$\Delta T = \frac{(0.85)(9.81 \text{ m/s}^2)(9.5 \text{ m})}{\left(\dfrac{1200 \text{ J/kg}}{1.0°\text{C}}\right)} = \boxed{6.6 \times 10^{-2}\ °\text{C}}$$

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236. Givens: $v_f = 0$ m/s; $v_i = 13.4$ m/s; $\Delta U = 5836$ J

$\Delta PE + \Delta KE + \Delta U = 0$

The bicyclist remains on the bicycle, which does not change elevation, so $\Delta PE = 0$ J.

$\Delta KE = KE_f - KE_i = 0 - \frac{1}{2}mv_i^2 = -\Delta U$

$$m = \frac{2\Delta U}{v_i^2} = \frac{(2)(5836 \text{ J})}{(13.4 \text{ m/s})^2} = \boxed{65.0 \text{ kg}}$$

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237. Givens: $v_i = 20.5$ m/s; $v_f = 0$ m/s; $m = 61.4$ kg

$\Delta PE + \Delta E + \Delta U = 0$

The height of the skater does not change, so $\Delta PE = 0$ J.

$\Delta KE = KE_f - KE_i = 0 - \frac{1}{2}mv_i^2$

$\Delta U = -\Delta KF = -(-\frac{1}{2}mv_i^2) = \frac{1}{2}(61.4 \text{ kg})(20.5 \text{ m/s})^2 = \boxed{1.29 \times 10^4 \text{ J}}$

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238. Givens: $m_t = 0.225$ kg; $c_{p,t} = 2.2 \times 10^3$ J/kg • °C; $Q = -3.9 \times 10^4$ J

$$c_{p,t} = \frac{Q}{m_t \Delta T_t}$$

$$\Delta T_t = \frac{Q}{m_t c_{p,t}} = \frac{-3.9 \times 10^4 \text{ J}}{(0.225 \text{ kg})(2.2 \times 10^3 \text{ J/kg} \bullet °\text{C})} = \boxed{-79°\text{C}}$$

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239. Givens: $c_{p,b} = 121$ J/kg • °C; $Q = 25$ J; $\Delta T_b = 5.0°$C

$$c_{p,b} = \frac{Q}{m_b \Delta T_b}$$

$$m_b = \frac{Q}{c_{p,b}\Delta T_b} = \frac{25 \text{ J}}{(121 \text{ J/kg} \bullet °\text{C})(5.0°\text{C})} = \boxed{4.1 \times 10^{-2} \text{ kg}}$$

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240. Givens: $m_a = 0.250$ kg; $m_w = 1.00$ kg; $\Delta T_w = 1.00°$ C; $\Delta T_a = -17.5°$ C; $c_{p,w} = 4186$ J/kg • °C

$-c_{p,a}m_a\Delta T_a = c_{p,w}m_w\Delta T_w$

$$c_{pa} = -\frac{c_{p,w}m_w\Delta T_w}{m_a\Delta T_a} = -\frac{(4186 \text{ J/kg} \bullet °\text{C})(1.00 \text{ kg})(1.00°\text{C})}{(0.25 \text{ kg})(-17.5°\text{ C})}$$

$c_{p,a} = \boxed{957 \text{ J/kg} \bullet °\text{C}}$

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241. Givens: $T_F = 2192°$F

$$T_C = \frac{5}{9}(T_F - 32)°\text{C} = \frac{5}{9}(2192 - 32)°\text{C} = \frac{5}{9}(2.160 \times 10^3)°\text{C}$$

$T_C = \boxed{1.200 \times 10^3 °\text{C}}$

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242. Givens: $T = 2.70$ K

$T_C = (T - 273)°\text{C} = (2.70 - 273)°\text{C} = \boxed{-270°\text{C}}$

Givens	Solutions

243. $T = 42°C$

$T = (T + 273)K = (42 + 273)\ K = \boxed{315\ K}$

244. $\Delta KE = 2.15 \times 10^4\ J$
$\Delta U_{air} = 33\% \Delta KE$
$\Delta PE = 0\ J$

$\Delta PE + \Delta KE + \Delta U = 0$

$\Delta PE + \Delta KE - \Delta U_{sticks} - \Delta U_{air} = 0$

$\Delta U_{sticks} = \Delta KE - \Delta U_{air} = \Delta KE - 0.33\Delta KE = 0.67\Delta KE$

$\Delta U_{sticks} = 0.667(2.15 \times 10^4\ J) = \boxed{1.4 \times 10^4\ J}$

245. $h = 561.7\ m$
$\Delta U = 105\ J$
$g = 9.81\ m/s^2$

$\Delta PE = \Delta KE + \Delta U = 0$

When the stone lands, its kinetic energy is transferred to the internal energy of the stone and the ground. Therefore, overall, $\Delta KE = 0\ J$

$\Delta PE = PE_f - PE_e = 0 - mgh = -\Delta U$

$$m = \frac{\Delta U}{gh} = \frac{105\ J}{(9.81\ m/s^2)(561.7\ m)} = 1.91 \times 10^{-2}\ kg = \boxed{19.1\ g}$$

246. $m = 2.5\ kg$
$v_i = 5.7\ m/s$
3.3×10^5 J melts 1.0 kg of ice

$\Delta U = KE_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(2.5\ kg)(5.7\ m/s)^2 = 41\ J$

$$\text{ice melted} = \frac{(41\ J)(1.0\ kg)}{3.3 \times 10^5\ J} = \boxed{1.2 \times 10^{-4}\ kg}$$

247. $m_i = 3.0\ kg$
$m_w = 5.0\ kg$
$\Delta T_w = 2.25°\ C$
$\Delta T_i = -29.6°\ C$
$c_{p,w} = 4186\ J/kg \bullet °C$

$-c_{p,i}m_i\Delta T_i = c_{p,w}m_w\Delta T_w$

$$c_{p,i} = -\frac{c_{p,w}m_w\Delta T_w}{m_i\Delta T_i} = -\frac{(4186\ J/kg \bullet °C)(5.0\ kg)(2.25°C)}{(3.0\ kg)(-29.6°C)}$$

$c_{p,i} = \boxed{530\ J/kg \bullet °C}$

248. $Q = 45 \times 10^6\ J$
$\Delta T_a = 55°\ C$
$c_{p,a} = 1.0 \times 10^3\ J/kg \bullet °C$

$$c_{p,a} = \frac{Q}{m_a\Delta T_a}$$

$$m_a = \frac{Q}{c_{p,a}\Delta T_a} = \frac{45 \times 10^6\ J}{(1.0 \times 10^3\ J/kg \bullet °C)(55°C)}_a = \boxed{820\ kg}$$

249. $c_{p,t} = 140\ J/kg \bullet °C$
$m_t = 0.23\ kg$
$Q = -3.0 \times 10^4\ J$

$$c_{p,t} = \frac{Q}{m_t\Delta T_t}$$

$$\Delta T_t = \frac{Q}{m_t c_{p,t}} = \frac{-3.0 \times 10^4\ J}{(0.23\ kg)(140\ J/kg \bullet °C)} = \boxed{-930°C}$$

Thermodynamics

250. $P = 2.07 \times 10^7\ Pa$
$\Delta V = 0.227\ m^3$

$W = P\Delta V = (2.07 \times 10^7\ Pa)(0.227\ m^3) = \boxed{4.70 \times 10^6\ J}$

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Givens	*Solutions*
251. $W = 3.29 \times 10^6$ J $\Delta V = 2190$ m^3	$P = \frac{W}{\Delta V} = \frac{3.29 \times 10^6 \text{ J}}{2190 \text{ m}^3} = 1.50 \times 10^3 \text{ Pa} = \boxed{1.50 \text{ kPa}}$
252. $W = 472.5$ J $P = 25.0 \text{ kPa} = 2.50 \times 10^4$ Pa	$\Delta V = \frac{W}{P} = \frac{472.5 \text{ J}}{2.50 \times 10^4 \text{ Pa}} = \boxed{1.89 \times 10^{-2} \text{ m}^3}$
253. $\Delta U = 873$ J	$\Delta V = 0$, so $W = 0$ J $\Delta U = Q - W$ $Q = \Delta U + W = 873 \text{ J} + 0 \text{ J} = \boxed{873 \text{ J}}$
254. $U_i = 39$ J $U_f = 163$ J $Q = 114$ J	$\Delta U = U_f - U_i = Q - W$ $W = Q - \Delta U = Q - (U_f - U_i) = Q - U_f + U_i$ $W = 114 \text{ J} - 163 \text{ J} + 39 \text{ J} = \boxed{-10 \text{ J}}$
255. $Q = 867$ J $W = 623$ J	$\Delta U = Q - W = 867 \text{ J} - 623 \text{ J} = \boxed{244 \text{ J}}$
256. $eff = 0.29$ $Q_h = 693$ J	$W_{net} = eff\, Q_h = (0.29)(693 \text{ J}) = \boxed{2.0 \times 10^2 \text{ J}}$
257. $eff = 0.19$ $W_{net} = 998$ J	$Q_h = \frac{W_{net}}{eff} = \frac{998 \text{ J}}{0.19} = \boxed{5.3 \times 10^3 \text{ J}}$
258. $Q_h = 571$ J $Q_c = 463$ J	$eff = 1 - \frac{Q_c}{Q_h} = 1 - \frac{463 \text{ J}}{571 \text{ J}} = 1 - 0.811 = \boxed{0.189}$
259. $W = 1.3$ J $\Delta V = 5.4 \times 10^{-4}$ m^3	$P = \frac{W}{\Delta V} = \frac{1.3 \text{ J}}{5.4 \times 10^{-4} \text{ m}^3} = 2.4 \times 10^3 \text{ Pa} = \boxed{2.4 \text{ kPa}}$
260. $W = 393$ J $P = 655 \text{ kPa} = 6.55 \times 10^5$ Pa	$\Delta V = \frac{W}{P} = \frac{393 \text{ J}}{6.55 \times 10^5 \text{ Pa}} = \boxed{6.00 \times 10^{-4} \text{ m}^3}$
261. $U_i = 8093$ J $U_f = 2.092 \times 10^4$ J $Q = 6932$ J	$\Delta U = U_f - U_i = Q - W$ $W = Q - \Delta U = Q - (U_f - U_i) = Q - U_f + U_i$ $W = 6932 \text{ J} - 2.092 \times 10^4 \text{ J} + 8093 \text{ J} = \boxed{-5895 \text{ J}}$
262. $W = 192$ kJ $\Delta U = 786$ kJ	$\Delta U = Q - W$ $Q = \Delta U + W = 786 \text{ kJ} + 192 \text{ kJ} = \boxed{978 \text{ kJ}}$
263. $Q = 632$ kJ $W = 102$ kJ	$\Delta U = Q - W = 632 \text{ kJ} - 102 \text{ kJ} = 5.30 \times 10^2 \text{ kJ} = \boxed{5.30 \times 10^5 \text{ J}}$

Givens	*Solutions*
264. $eff = 0.35$ $Q_h = 7.37 \times 10^8$ J	$W_{net} = eff\, Q_h = (0.35)(7.37 \times 10^8\ \text{J}) = \boxed{2.6 \times 10^8\ \text{J}}$
265. $eff = 0.11$ $W_{net} = 1150$ J	$Q_h = \dfrac{W_{net}}{eff} = \dfrac{1150\ \text{J}}{0.11} = \boxed{1.0 \times 10^4\ \text{J}}$
266. $W_{net} = 128$ J $Q_h = 581$ J	$eff = \dfrac{W_{net}}{Q_h} = \dfrac{128\ \text{J}}{581\ \text{J}} = \boxed{0.220}$

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Vibrations and Waves

267. $k = 420$ N/m $x = 4.3 \times 10^{-2}$ m	$F_{elastic} = -kx = -(420\ \text{N/m})(4.3 \times 10^{-2}\ \text{m}) = \boxed{-18\ \text{N}}$
268. $F_g = -669$ N $x = -6.5 \times 10^{-2}$ m	$F_{net} = 0 = F_{elastic} + F_g = -kx + F_g$ $F_g = kx$ $k = \dfrac{F_g}{x} = \dfrac{-669\ \text{N}}{-6.5 \times 10^{-2}\ \text{m}} = \boxed{1.0 \times 10^4\ \text{N/m}}$
269. $F_{elastic} = 52$ N $k = 490$ N/m	$F_{elastic} = -kx$ $x = -\dfrac{F_{elastic}}{k} = -\dfrac{52\ \text{N}}{490\ \text{N/m}} = -0.11\ \text{m} = \boxed{-11\ \text{cm}}$
270. $L = 1.14$ m $T = 3.55$ s	$T = 2\pi\sqrt{\dfrac{L}{g}}$ $T^2 = \dfrac{4\pi^2 L}{g}$ $g = \dfrac{4\pi^2 L}{T^2} = \dfrac{(4\pi^2)(1.14\ \text{m})}{(3.55\ \text{s})^2} = \boxed{3.57\ \text{m/s}^2}$
271. $f = 2.5$ Hz $g = 9.81$ m/s^2	$T = 2\pi\sqrt{\dfrac{L}{g}} = \dfrac{1}{f}$ $\dfrac{1}{f^2} = \dfrac{4\pi^2 L}{g}$ $L = \dfrac{g}{4\pi^2 f^2} = \dfrac{9.81\ \text{m/s}^2}{(4\pi^2)(2.5\ \text{s}^{-1})^2} = \boxed{4.0 \times 10^{-2}\ \text{m}}$
272. $L = 6.200$ m $g = 9.819$ m/s^2	$T = 2\pi\sqrt{\dfrac{L}{g}} = 2\pi\sqrt{\dfrac{6.200\ \text{m}}{9.819\ \text{m/s}^2}} = \boxed{4.993\ \text{s}}$

Givens | *Solutions*

273. $L = 6.200$ m

$g = 9.819$ m/s^2

$$f = \frac{1}{T} = \frac{1}{4.993\text{ s}} = \boxed{0.2003\text{ Hz}}$$

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274. $k = 364$ N/m

$m = 24$ kg

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{24\text{ kg}}{364\text{ N/m}}} = \boxed{1.6\text{ s}}$$

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275. $F = 32$ N

$T = 0.42$ s

$g = 9.81$ m/s^2

$$F = mg$$

$$m = \frac{F}{g} = \frac{32\text{ N}}{9.81\text{ m/s}^2} = 3.3\text{ kg}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T^2 = \frac{4\pi^2 m}{k}$$

$$k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2 F}{gT^2} = \frac{4\pi^2\,(32\text{ N})}{(9.81\text{ m/s}^2)(0.42\text{ s})^2} = \boxed{730\text{ N/m}}$$

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276. $T = 0.079$ s

$k = 63$ N/m

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T^2 = \frac{4\pi^2 m}{k}$$

$$m = \frac{kT^2}{4\pi^2} = \frac{(63\text{ N/m})\,(0.079\text{ s})^2}{4\pi^2} = \boxed{1.0 \times 10^{-2}\text{ kg}}$$

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277. $f = 2.8 \times 10^5$ Hz

$\lambda = 0.51\text{ cm} = 5.1 \times 10^{-3}$ m

$$v = f\lambda = (2.8 \times 10^5\text{ Hz})(5.1 \times 10^{-3}\text{ m}) = \boxed{1.4 \times 10^3\text{ m/s}}$$

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278. $f = 20.0$ Hz

$v = 331$ m/s

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{331\text{ m/s}}{20.0\text{ Hz}} = \boxed{16.6\text{ m}}$$

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279. $\lambda = 1.1$ m

$v = 2.42 \times 10^4$ m/s

$$v = f\lambda$$

$$f = \frac{v}{\lambda} = \frac{2.42 \times 10^4\text{ m/s}}{1.1\text{ m}} = \boxed{2.2 \times 10^4\text{ Hz}}$$

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280. $k = 65$ N/m

$x = -1.5 \times 10^{-1}$ m

$$F_{elastic} = -kx = -(65\text{ N/m})(-1.5 \times 10^{-1}\text{ m}) = \boxed{9.8\text{ N}}$$

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281. $F_g = 620$ N

$x = 7.2 \times 10^{-2}$ m

$$F_{net} = 0 = F_{elastic} + F_g = -kx + F_g$$

$$F_g = kx$$

$$k = \frac{F_g}{x} = \frac{620\text{ N}}{7.2 \times 10^{-2}\text{ m}} = \boxed{8.6 \times 10^3\text{ N/m}}$$

Givens	Solutions
282. $m = 3.0$ kg $g = 9.81$ m/s^2 $k = 36$ N/m	$F_{net} = 0 = F_{elastic} + F_g = -kx - mg$ $mg = -kx$ $x = -\frac{mg}{k} = -\frac{(3.0\text{ kg})(9.81\text{ m/s}^2)}{36\text{ N/m}} = -0.82\text{ m} = \boxed{-82\text{ cm}}$
283. $L = 2.500$ m $g = 9.780$ m/s^2	$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{2.500\text{ m}}{9.780\text{ m/s}^2}} = \boxed{3.177\text{ s}}$
284. $f = 0.50$ Hz $g = 9.81$ m/s^2	$T = 2\pi\sqrt{\frac{L}{g}} = \frac{1}{f}$ $\frac{1}{f^2} = \frac{4\pi^2 L}{g}$ $L = \frac{g}{4\pi^2 f^2} = \frac{9.81\text{ m/s}^2}{(4\pi^2)(0.50\text{ s}^{-1})^2} = 0.99\text{ m} = \boxed{99\text{ cm}}$
285. $k = 2.03 \times 10^3$ N/m $f = 0.79$ Hz	$T = 2\pi\sqrt{\frac{m}{k}} = \frac{1}{f}$ $\frac{1}{f^2} = \frac{4\pi^2 m}{k}$ $m = \frac{k}{4\pi^2 f^2} = \frac{2.03 \times 10^3\text{ N/m}}{(4\pi^2)(0.79\text{ Hz})^2} = \boxed{82\text{ kg}}$
286. $f = 87$ N $T = 0.64$ s $g = 9.81$ m/s^2	$k = m\left(\frac{2\pi}{T}\right)^2 = \left(\frac{f}{g}\right)\left(\frac{2\pi}{T}\right)^2 = \left(\frac{87\text{ N}}{9.81\text{ m/s}^2}\right)\left(\frac{2\pi}{0.64\text{ s}}\right)^2 = \boxed{850\text{ N/m}}$
287. $m = 8.2$ kg $k = 221$ N/m	$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{8.2\text{ kg}}{221\text{ N/m}}} = \boxed{1.2\text{ s}}$
288. $\lambda = 10.6$ m $v = 331$ m/s	$v = f\lambda$ $f = \frac{v}{\lambda} = \frac{331\text{ m/s}}{10.6\text{ m}} = \boxed{31.2\text{ Hz}}$
289. $\lambda = 2.3 \times 10^4$ m $f = 0.065$ Hz	$v = f\lambda = (0.065\text{ Hz})(2.3 \times 10^4\text{ m}) = \boxed{1.5 \times 10^3\text{ m/s}}$

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Givens	*Solutions*
290. $P = 5.88 \times 10^{-5}$ W $Intensity = 3.9 \times 10^{-6}$ W/m^2	$Intensity = \dfrac{P}{4\pi r^2}$ $r = \sqrt{\dfrac{P}{(4\pi)(Intensity)}} = \sqrt{\dfrac{5.88 \times 10^{-5}\text{ W}}{(4\pi)\ (3.9 \times 10^{-6}\text{ W/m}^2)}}$ $r = \boxed{1.1\text{ m}}$
291. $P = 3.5$ W $r = 0.50$ m	$Intensity = \dfrac{P}{4\pi r^2} = \dfrac{3.5\text{ W}}{(4\pi)(0.50\text{ m})^2} = \boxed{1.1\text{ W/m}^2}$
292. $Intensity = 4.5 \times 10^{-4}$ W/m^2 $r = 1.5$ m	$Intensity = \dfrac{P}{4\pi r^2}$ $P = 4\pi r^2\ Intensity = (4\pi)\ (1.5\text{ m})^2\ (4.5 \times 10^{-4}\text{ W/m}^2)$ $P = \boxed{1.3 \times 10^{-2}\text{ W}}$
293. $n = 1$ $v = 499$ m/s $L = 0.850$ m	$f_n = \dfrac{nv}{2\,L}$ $f_1 = \dfrac{(1)(499\text{ m/s})}{(2)(0.85\text{ m})} = \boxed{294\text{ Hz}}$
294. $n = 1$ $f_n = f_1 = 392$ Hz $v = 329$ m/s	$L = n\dfrac{v}{2f} = (1)\dfrac{(329\text{ m/s})}{2(392\text{ s}^{-1})} = \boxed{0.420\text{ Hz}}$
295. $n = 7$ $f_1 = 466.2$ Hz $L = 1.53$ m	$f_n = \dfrac{nv}{4\,L}$ $v = \dfrac{4\,Lf_n}{n} = \dfrac{(4)(1.53\text{ m})(466.2\text{ Hz})}{7} = \boxed{408\text{ m/s}}$
296. $n = 1$ $f_1 = 125$ Hz $L = 1.32$ m	$f_n = \dfrac{nv}{2\,L}$ $v = \dfrac{2Lf_n}{n} = \dfrac{(2)(1.32\text{ m})(125\text{ Hz})}{1} = \boxed{330\text{ m/s}}$
297. $P = 1.57 \times 10^{-3}$ W $Intensity = 5.20 \times 10^{-3}$ W/m^2	$Intensity = \dfrac{P}{4\pi r^2}$ $r = \sqrt{\dfrac{P}{(4\pi)(Intensity)}} = \sqrt{\dfrac{1.57 \times 10^{-3}\text{ W}}{(4\pi)(5.20 \times 10^{-3}\text{ W/m}^2)}}$ $r = \boxed{0.155\text{ m}}$
298. $Intensity = 9.3 \times 10^{-8}$ W/m^2 $r = 0.21$ m	$Intensity = \dfrac{P}{4\pi r^2}$ $P = 4\pi r^2\ Intensity = (4\pi)(0.21\text{ m})^2\ (9.3 \times 10^{-8}\text{ W/m}^2)$ $P = \boxed{5.2 \times 10^{-8}\text{ W}}$

Givens	Solutions
299. $n = 1$ $f_1 = 392.0$ Hz $v = 331$ m/s	$f_n = \frac{nv}{4L}$ $L = \frac{nv}{4f_n} = \frac{(1)(331 \text{ m/s})}{(4)(392.0 \text{ Hz})} = 0.211 \text{ m} = \boxed{21.1 \text{ cm}}$
300. $n = 1$ $f_1 = 370.0$ Hz $v = 331$ m/s	$f_n = \frac{nv}{2L}$ $L = \frac{nv}{2f_n} = \frac{(1)(331 \text{ m/s})}{(2)(370.0 \text{ Hz})} = 0.447 \text{ m} = \boxed{44.7 \text{ cm}}$

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Light and Reflection

301. $f = 7.6270 \times 10^8$ Hz $\lambda = 3.9296 \times 10^{-1}$ m	$c = f\lambda = (7.6270 \times 10^8 \text{ s}^{-1})(3.9296 \times 10^{-1} \text{ m}) = \boxed{2.9971 \times 10^8 \text{ m/s}}$ The radio wave travels through Earth's atmosphere.
302. $\lambda = 3.2 \times 10^{-9}$ m	$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{3.2 \times 10^{-9} \text{ m}} = \boxed{9.4 \times 10^{16} \text{ Hz}}$
303. $f = 9.5 \times 10^{14}$ Hz	$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8 \text{ m/s}}{9.5 \times 10^{14} \text{ s}^{-1}} = 3.2 \times 10^{-7} \text{ m} = \boxed{320 \text{ nm}}$
304. $f = 17$ cm $q = 23$ cm	$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{17 \text{ cm}} - \frac{1}{23 \text{ cm}} = \frac{23 \text{ cm} - 17 \text{ cm}}{(17 \text{ cm})(23 \text{ cm})} = \frac{6 \text{ cm}}{(17 \text{ cm})(23 \text{ cm})}$ $p = \boxed{65 \text{ cm}}$
305. $f = 17$ cm $q = 23$ cm $h = 2.7$ cm	$h' = -\frac{qh}{p} = -\frac{(23 \text{ cm})(2.7 \text{ cm})}{62 \text{ cm}} = \boxed{-0.96 \text{ cm}}$
306. $f = 9.50$ cm $q = 15.5$ cm	$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{9.5 \text{ cm}} - \frac{1}{15.5 \text{ cm}} = 0.105 \text{ cm}^{-1} - 0.0645 \text{ cm}^{-1} = 0.0405 \text{ cm}^{-1}$ $p = \boxed{24.7 \text{ cm}}$
307. $h = 3.0$ cm	$h' = -\frac{qh}{p} = -\frac{(15.5 \text{ cm})(3.0 \text{ cm})}{25 \text{ cm}} = \boxed{-1.9 \text{ cm}}$
308. $h = 1.75$ m $M = 0.11$ $q = -42 \text{ cm} = -0.42$ m	$M = \frac{h'}{h} = -\frac{q}{p}$ $h' = Mh = (0.11)(1.75 \text{ m}) = \boxed{0.19 \text{ m}}$
309. $M = 0.11$ $q = -42 \text{ cm} = -0.42$ m	$p = -\frac{q}{M} = -\frac{0.42 \text{ m}}{0.11} = \boxed{3.8 \text{ m}}$

Givens | *Solutions*

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310. $f = -12$ cm
$q = -9.0$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-12\text{ cm}} - \frac{1}{-9.0\text{ cm}} = \frac{0.083}{1\text{ cm}} + \frac{0.111}{1\text{ cm}} = \frac{0.028}{1\text{ cm}}$$

$$p = \boxed{36\text{ cm}}$$

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311. $f = -12$ cm
$q = -9.0$ cm

$$M = -\frac{q}{p} = -\frac{9.0\text{ cm}}{36\text{ cm}} = \boxed{0.25}$$

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312. $p = 35$ cm
$q = 42$ cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{2}{R} = \frac{1}{35\text{ cm}} + \frac{1}{42\text{ cm}}$$

$$\frac{1}{f} = \frac{0.029}{1\text{ cm}} + \frac{0.024}{1\text{ cm}} = \frac{0.053}{1\text{ cm}}$$

$$f = \boxed{19\text{ cm}}$$

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313. $p = 35$ cm
$q = 42$ cm

$$\frac{2}{R} = \frac{1}{f}$$

$$R = 2f = (2)(19\text{ cm}) = \boxed{38\text{ cm}}$$

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314. $f = 60.0$ cm
$p = 35.0$ cm

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{60.0\text{ cm}} - \frac{1}{35.0\text{ cm}} = \frac{0.0167}{1\text{ cm}} - \frac{0.0286}{1\text{ cm}} = \frac{-0.0119}{1\text{ cm}}$$

$$q = \boxed{-84.0\text{ cm}}$$

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315. $q = -84.0$ cm
$p = 35.0$ cm

$$M = -\frac{q}{p} = -\frac{-84.0\text{ cm}}{35.0\text{ cm}} = \boxed{2.40}$$

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316. $q = -5.2$ cm
$p = 17$ cm

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{17\text{ cm}} + \frac{1}{-5.2\text{ cm}} = \frac{0.059}{1\text{ cm}} - \frac{0.19}{1\text{ cm}} = \frac{-0.13}{1\text{ cm}}$$

$$f = \boxed{-7.7\text{ cm}}$$

Givens	Solutions
317. $q = -5.2$ cm $p = 17$ cm $h = 3.2$ cm	$h' = -\frac{qh}{p} = -\frac{(-5.2\text{ cm})(3.2\text{ cm})}{17\text{ cm}} = \boxed{0.98\text{ cm}}$
318. $\lambda = 5.291\ 770 \times 10^{-11}$ m	$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8\text{ m/s}}{5.291\ 770 \times 10^{-11}\text{ m}} = \boxed{5.67 \times 10^{18}\text{ Hz}}$
319. $f = 2.85 \times 10^9$ Hz	$\lambda = \frac{c}{f} = \frac{3.00 \times 10^8\text{ m/s}}{2.85 \times 10^9\text{ s}^{-1}} = 0.105\text{ m} = \boxed{10.5\text{ cm}}$
320. $f_1 = 1800$ MHz $= 1.8 \times 10^9$ Hz $f_2 = 2000$ MHz $= 2.0 \times 10^9$ Hz	$\lambda_1 = \frac{c}{f_1} = \frac{3.00 \times 10^8\text{ m/s}}{1.8 \times 10^9\text{ s}^{-1}} = 0.17\text{ m} = \boxed{17\text{ cm}}$ $\lambda_2 = \frac{c}{f_2} = \frac{3.00 \times 10^8\text{ m/s}}{2.0 \times 10^9\text{ s}^{-1}} = 0.15\text{ m} = \boxed{15\text{ cm}}$
321. $f = 32.0$ cm	You want to appear to be shaking hands with yourself, so the image must appear to be where your hand is. So $p = q$ $\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{2}{p}$ $p = 2f = (2)(32.0\text{ cm}) = \boxed{64.0\text{ cm}}$ $q = p = \boxed{64.0\text{ cm}}$
322. $p = 5.0$ cm	A car's beam has rays that are parallel, so $q = \infty$. $\frac{1}{q} = \frac{1}{\infty} = 0$ $\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} + 0 = \frac{1}{p}$ $f = p = 5.0$ cm $\frac{2}{R} = \frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $R = 2f = (2)(5.0\text{ cm}) = \boxed{1.0 \times 10^1\text{ cm}}$
323. $p = 19$ cm $q = 14$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{19\text{ cm}} + \frac{1}{14\text{ cm}}$ $\frac{1}{f} = \frac{0.053}{1\text{ cm}} + \frac{0.071}{1\text{ cm}} = \frac{0.12}{1\text{ cm}}$ $f = \boxed{8.3\text{ cm}}$
324. $f = -27$ cm $p = 43$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-27\text{ cm}} - \frac{1}{43\text{ cm}} = \frac{-0.037}{1\text{ cm}} - \frac{0.023}{1\text{ cm}} = \frac{-0.060}{1\text{ cm}}$ $q = \boxed{-17\text{ cm}}$

Givens	Solutions
325. $q = -17$ cm $p = 43$ cm	$M = -\frac{q}{p} = -\frac{-17 \text{ cm}}{43 \text{ cm}} = \boxed{0.40}$
326. $f = -8.2$ cm $p = 18$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-8.2 \text{ cm}} - \frac{1}{18 \text{ cm}} = \frac{-0.122}{1 \text{ cm}} - \frac{0.056}{1 \text{ cm}} = \frac{-0.18}{1 \text{ cm}}$ $q = \boxed{-5.6 \text{ cm}}$
327. $f = -39$ cm $p = 16$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-39 \text{ cm}} - \frac{1}{16 \text{ cm}} = \frac{-0.026}{1 \text{ cm}} - \frac{0.062}{1 \text{ cm}} = \frac{-0.088}{1 \text{ cm}}$ $q = \boxed{-11 \text{ cm}}$
328. $h = 6.0$ cm	$M = \frac{h'}{h} = -\frac{q}{p}$ $h' = -\frac{qh}{p} = -\frac{(-11 \text{ cm})(6.0 \text{ cm})}{16 \text{ cm}} = \boxed{4.1 \text{ cm}}$
329. $f = 1.17306 \times 10^{11}$ Hz $\lambda = 2.5556 \times 10^{-3}$ m	$c = f\lambda = (1.17306 \times 10^{11} \text{ s}^{-1})(2.5556 \times 10^{-3} \text{ m}) = \boxed{2.9979 \times 10^{8} \text{ m/s}}$
330. $f = 2.5 \times 10^{10}$ Hz	$\lambda = \frac{c}{f} = \frac{3.00 \times 10^{8} \text{ m/s}}{2.5 \times 10^{10} \text{ s}^{-1}} = 1.2 \times 10^{-2} \text{ m} = \boxed{1.2 \text{ cm}}$
331. $p = 3.00$ cm $= 3.00 \times 10^{2}$ cm $f = 30.0$ cm	$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{30.0 \text{ cm}} - \frac{1}{3.00 \times 10^{2} \text{ cm}}$ $\frac{1}{q} = \frac{0.0333}{1 \text{ cm}} - \frac{0.00333}{1 \text{ cm}} = \frac{0.0300}{1 \text{ cm}}$ $q = \boxed{33.3 \text{ cm}}$
332. $f = -6.3$ cm $q = -5.1$ cm	$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-6.3 \text{ cm}} - \frac{1}{-5.1 \text{ cm}} = \frac{0.159}{1 \text{ cm}} - \frac{0.196}{1 \text{ cm}} = \frac{0.037}{1 \text{ cm}}$ $p = \boxed{27 \text{ cm}}$
333. $p = 27$ cm $q = -5.1$ cm	$M = \frac{-q}{p} = \frac{-(-5.1 \text{ cm})}{27 \text{ cm}} = \boxed{0.19}$

Refraction

334. $\theta_r = 35°$ $n_r = 1.553$ $n_i = 1.000$	$\theta_i = \sin^{-1}\left[\frac{n_r(\sin \theta_r)}{n_i}\right] = \sin^{-1}\left[\frac{(1.553)(\sin 35°)}{1.000}\right] = \boxed{63°}$

Givens	Solutions
335. $\theta_i = 59.2°$ $n_r = 1.61$ $n_i = 1.00$	$\theta_r = \sin^{-1}\left[\frac{n_i(\sin\theta_i)}{n_r}\right] = \sin^{-1}\left[\frac{(1.00)(\sin 59.2°)}{1.61}\right] = \boxed{32.2°}$
336. $c = 3.00 \times 10^8$ m/s $v = 1.97 \times 10^8$ m/s	$n = \frac{c}{v} = \frac{3.00 \times 10^8 \text{ m/s}}{1.97 \times 10^8 \text{ m/s}} = \boxed{1.52}$
337. $f = -13.0$ cm $M = 5.00$	$M = -\frac{q}{p}$ $q = -Mp = -(5.00)p$ $\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} + \frac{1}{-(5.00)p} = \frac{-5.00 + 1.00}{-(5.00)p} = \frac{-4.00}{-(5.00)p} = \frac{4.00}{(5.00)p}$ $M = \frac{h'}{h} = -\frac{q}{p}$ $p = \frac{(4.00)f}{5.00} = \frac{(4.00)(-13.0 \text{ cm})}{5.00} = \boxed{-10.4 \text{ cm}}$
338. $h = 18$ cm $h' = -9.0$ cm $f = 6.0$ cm	$M = \frac{h'}{h} = \frac{-9.0 \text{ cm}}{18 \text{ cm}} = \boxed{-0.50}$
339. $h = 18$ cm $h' = -9.0$ cm $f = 6.0$ cm	$M = -\frac{q}{p}$ $q = -Mp = -(-0.50)p = (0.50)p$ $\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} + \frac{1}{(0.50)p} = \frac{0.50}{(0.50)p} + \frac{1}{(0.50)p} = \frac{1.50}{(0.50)p} = \frac{3.0}{p}$ $p = (3.0)f = (3.0)(6.0 \text{ cm}) = \boxed{18 \text{ cm}}$
340. $M = -0.50$ $p = 18$ cm	$q = -Mp = (0.50)(18 \text{ cm}) = \boxed{9.0 \text{ cm}}$
341. $\theta_c = 37.8°$ $n_r = 1.00$	$\sin\theta_c = \frac{n_r}{n_i}$ $n_i = \frac{n_r}{\sin\theta_c} = \frac{1.00}{\sin 37.8°} = \boxed{1.63}$
342. n_i- $= 1.766$ $n_r = 1.000$	$\sin\theta_c = \frac{n_r}{n_i}$ $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.000}{1.766}\right) = \boxed{34.49°}$
343. $n_i = 1.576$ $n_r = 1.000$	$\sin\theta_c = \frac{n_r}{n_i}$ $\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{1.000}{1.576}\right) = \boxed{39.38°}$

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Givens	Solutions
344. $\theta_i = 35.2°$ $n_i = 1.00$ $n_{r,1} = 1.91$ $n_{r,2} = 1.66$	$\theta_{r,1} = \sin^{-1}\left[\frac{n_i(\sin\theta_i)}{n_{r,1}}\right] = \sin^{-1}\left[\frac{(1.00)(\sin 35.2°)}{1.91}\right] = \boxed{17.6°}$ $\theta_{r,2} = \sin^{-1}\left[\frac{n_i(\sin\theta_i)}{n_{r,2}}\right] = \sin^{-1}\left[\frac{(1.00)(\sin 35.2°)}{1.66}\right] = \boxed{20.3°}$
345. $\theta_r = 33°$ $n_r = 1.555$ $n_i = 1.000$	$\theta_i = \sin^{-1}\left[\frac{n_r(\sin\theta_r)}{n_i}\right] = \sin^{-1}\left[\frac{(1.555)(\sin 33°)}{1.000}\right] = \boxed{58°}$
346. $\theta_c = 39.18°$ $n_r = 1.000$	$\sin\theta_c = \frac{n_r}{n_i}$ $n_i = \frac{n_r}{\sin\theta_c} = \frac{1.000}{\sin 39.18} = \boxed{1.583}$
347. $p = 44$ cm $q = -14$ cm $h = 15$ cm	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{44\text{ cm}} + \frac{1}{-14\text{ cm}} = \frac{0.023}{1\text{ cm}} + \frac{0.071}{1\text{ cm}} = \frac{-0.048}{1\text{cm}}$ $f = \boxed{-21\text{ cm}}$
348. $p = 44$ cm $q = -14$ cm $h = 15$ cm	$M = \frac{h'}{h} = -\frac{q}{p}$ $h' = -\frac{qh}{p} = -\frac{(-14\text{ cm})(15\text{ cm})}{44\text{ cm}} = \boxed{4.8\text{ cm}}$
349. $p = 4$ m $f = 4$ m	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$, but $f = p$, so $\frac{1}{q} = 0$. That means $q = \boxed{\infty}$
350. $p = 4$ m $f = 4$ m	$M = -\frac{q}{p} = -\frac{\infty}{4\text{ m}} = \boxed{\infty}$ The rays are parallel, and the light can be seen from very far away.
351. $n_i = 1.670$ $\theta_c = 62.85°$	$\sin\theta_c = \frac{n_r}{n_i}$ $n_r = n_i(\sin\theta_c) = (1.670)(\sin 62.85°) = \boxed{1.486}$
352. $c = 3.00 \times 10^8$ m/s $v = 2.07 \times 10^8$ m/s	$n = \frac{c}{v} = \frac{3.00 \times 10^8\text{ m/s}}{2.07 \times 10^8\text{ m/s}} = \boxed{1.45}$
353. $c = 3.00 \times 10^8$ m/s $v = 1.95 \times 10^8$ m/s	$n = \frac{c}{v} = \frac{3.00 \times 10^8\text{ m/s}}{1.95 \times 10^8\text{ m/s}} = \boxed{1.54}$
354. $p = 0.5$ m $f = 0.5$ m	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ $p = f$, so $\frac{1}{q} = 0$, and $q = \boxed{\infty}$

Givens | *Solutions*

355. $f = 3.6$ cm

$q = 15.2$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{3.6\text{ cm}} - \frac{1}{15.2\text{ cm}} = \frac{0.28}{1\text{ cm}} - \frac{0.066}{1\text{ cm}} = \frac{0.21}{1\text{ cm}}$$

$$p = \boxed{4.8\text{ cm}}$$

356. $q = -12$ cm

$f = -44$ cm

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-44\text{ cm}} - \frac{1}{-12\text{ cm}} = \left(\frac{-0.023}{1\text{ cm}}\right) - \left(\frac{-0.083}{1\text{ cm}}\right) = \frac{0.060}{1\text{ cm}}$$

$$p = \boxed{17\text{ cm}}$$

357. $\theta_{c,1} = 35.3°$

$\theta_{c,2} = 33.1°$

$n_r = 1.00$

$$\sin\theta_c = \frac{n_r}{n_i}$$

$$n_{i,1} = \frac{n_r}{\sin\theta_{c,1}} = \frac{1.00}{\sin 35.3°} = \boxed{1.73}$$

$$n_{i,2} = \frac{n_r}{\sin\theta_{c,2}} = \frac{1.00}{\sin 33.1°} = \boxed{1.83}$$

358. $n_i = 1.64$

$\theta_c = 69.9°$

$$\sin\theta_c = \frac{n_r}{n_i}$$

$$n_r = n_i(\sin\theta_c) = (1.64)(\sin 69.9°) = \boxed{1.54}$$

Interference and Diffraction

359. $\lambda = 5.875 \times 10^{-7}$ m

$m = 2$

$\theta = 0.130°$

$$d = \frac{m\lambda}{\sin\theta} = \frac{2(5.875 \times 10^{-7}\text{ m})}{\sin(0.130°)} = 5.18 \times 10^{-4}\text{ m}$$

$$d = \boxed{0.518\text{ mm}}$$

360. $d = 8.04 \times 10^{-6}$ m

$m = 3$

$\theta = 13.1°$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(8.04 \times 10^{-6}\text{ m})\sin(13.1°)}{3} = 6.07 \times 10^{-7}\text{ m}$$

$$\lambda = \boxed{607\text{ nm}}$$

361. $d = 2.20 \times 10^{-4}$ m

$\lambda = 5.27 \times 10^{-7}$ m

$m = 1$

$$\theta = \sin^{-1}(m\lambda/d)$$

$$\theta = \sin^{-1}[(1)(5.27 \times 10^{-7}\text{ m}) \div (2.20 \times 10^{-4}\text{ m})] = \boxed{0.137°}$$

362. $\lambda = 5.461 \times 10^{-7}$ m

$m = 1$

$\theta = 75.76°$

$$d = \frac{m\lambda}{\sin\theta} = \frac{(1)(5.461 \times 10^{-7}\text{ m})}{\sin(75.76°)} = 5.634 \times 10^{-7}\text{ m}$$

$$d = 5.634 \times 10^{-5}\text{ cm}$$

$$\#\text{ lines/cm} = (5.634 \times 10^{-5}\text{ cm})^{-1} = \boxed{1.775 \times 10^4\text{ lines/cm}}$$

363. 3600 lines/cm

$m = 3$

$\theta = 76.54°$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(360\,000\text{ m})^{-1}\sin(76.54°)}{3} = \boxed{9.0 \times 10^{-7} = 9.0 \times 10^2\text{ nm}}$$

Givens | *Solutions*

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364. 1950 lines/cm

$\lambda = 4.973 \times 10^{-7}$ m

$m = 1$

$m = 1$: $\theta_1 = \sin^{-1}(m\lambda/d)$

$\theta_1 = \sin^{-1}[(1)(4.973 \times 10^{-7}\text{ m}) \div (195\,000\text{ lines/m})^{-1}]$

$\theta_1 = \boxed{5.56°}$

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365. 1950 lines/cm

$\lambda = 4.973 \times 10^{-7}$ m

$m = 2$

$m = 1$: $\theta_1 = \sin^{-1}(m\lambda/d)$

$m = 2$: $\theta_2 = \sin^{-1}[(2)(4.973 \times 10^{-7}\text{ m}) \div (195\,000\text{ lines/m})^{-1}]$

$\theta_2 = \boxed{11.2°}$

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366. $d = 3.92 \times 10^{-6}$ m

$m = 2$

$\theta = 13.1°$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(3.92 \times 10^{-6}\text{ m})\sin(13.1°)}{2} = 4.44 \times 10^{-7}\text{ m}$$

$\lambda = \boxed{444\text{ nm}}$

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367. $\lambda = 430.8$ nm

$d = 0.163$ mm

$m = 1$

$$\theta = \sin^{-1}\frac{\left(m + \frac{1}{2}\right)\lambda}{d} = \sin^{-1}\frac{\left(1 + \frac{1}{2}\right)(430.8 \times 10^{-9}\text{ nm})}{0.163 \times 10^{-3}\text{ m}}$$

$\theta = \sin^{-1} 0.00396 = \boxed{0.227°}$

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368. $\lambda = 656.3$ nm

$m = 3$

$\theta = 0.548°$

$$d = \frac{\left(m + \frac{1}{2}\right)\lambda}{\sin\theta} = \frac{\left(3 + \frac{1}{2}\right)(656.3 \times 10^{-9}\text{ m})}{\sin 0.548°}$$

$d = \boxed{2.40 \times {}^{-4}\text{ m} = 0.240\text{ mm}}$

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369. $\lambda = 4.471 \times 10^{-7}$ m

$m = 1$

$\theta = 40.25°$

$$d = \frac{m\lambda}{\sin\theta} = \frac{(1)(4.471 \times 10^{-7}\text{ m})}{\sin(40.25°)} = 6.920 \times 10^{-7}\text{ m}$$

$d = 6.920 \times 10^{-7}$ cm

lines/cm = $(6.920 \times 10^{-7}\text{ cm})^{-1} = \boxed{1.445 \times 10^4\text{ lines/cm}}$

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370. 9550 lines/cm

$m = 2$

$\theta = 54.58°$

$$\lambda = \frac{d(\sin\theta)}{m} = \frac{(955\,000\text{ m})^{-1}\sin(54.58°)}{2} = \boxed{4.27 \times 10^{-7}\text{ m} = 427\text{ nm}}$$

Electric Forces and Fields

371. $q_1 = -5.3\ \mu\text{C} = -5.3 \times 10^{-6}$ C

$q_2 = +5.3\ \mu\text{C} = 5.3 \times 10^{-6}$ C

$r = 4.2\text{ cm} = 4.2 \times 10^{-2}$ m

$k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$

$$F_{electric} = \frac{k_C q_1 q_2}{r^2}$$

$$F_{electric} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(5.3 \times 10^{-6}\text{ C})^2}{(4.2 \times 10^{-2}\text{ m})^2}$$

$F_{electric} = \boxed{140\text{ N attractive}}$

Givens	Solutions
372. $q_1 = -8.0 \times 10^{-9}$ C $q_2 = +8.0 \times 10^{-9}$ C $r = 2.0 \times 10^{-2}$ m $k_C = 8.99 \times 10^9$ N•m²/C²	$F_{electric} = \dfrac{k_C q_1 q_2}{r^2}$ $F_{electric} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(-8.0 \times 10^{-9}\text{ C})(8.0 \times 10^{-9}\text{ C})}{(2.0 \times 10^{-2}\text{ m})^2}$ $F_{electric} = \boxed{1.4 \times 10^{-3}\text{ N}}$
373. $r = 6.5 \times 10^{-11}$ m $F_{electric} = 9.92 \times 10^{-4}$ N $k_C = 8.99 \times 10^9$ N•m²/C²	$F_{electric} = \dfrac{k_C q_1 q_2}{r^2} = \dfrac{k_C q_2}{r^2}$ $q = \sqrt{\dfrac{F_{electric} r^2}{k_C}} = \sqrt{\dfrac{(9.92 \times 10^{-4}\text{ N})(6.5 \times 10^{-11}\text{ m})^2}{8.99 \times 10^9 \text{ N•m}^2/\text{C}^2}}$ $q = \boxed{2.2 \times 10^{-17}\text{ C}}$
374. $q_1 = -1.30 \times 10^{-5}$ C $q_2 = -1.60 \times 10^{-5}$ C $F_{electric} = 12.5$ N $k_C = 8.99 \times 10^9$ N•m²/C²	$F_{electric} = \dfrac{k_C q_1 q_2}{r^2}$ $r = \sqrt{\dfrac{k_C q_1 q_2}{F_{electric}}} = \sqrt{\dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(-1.30 \times 10^{-5}\text{ C})(-1.60 \times 10^{-5}\text{ C})}{12.5\text{ N}}}$ $r = 0.387\text{ m} = \boxed{38.7\text{ cm}}$
375. $q_1 = q_2 = q_3 = 4.00 \times 10^{-9}$ C $k_C = 8.99 \times 10^9$ N•m²/C² $r_{2,1} = r_{2,3} = 4.00$ m	$F_{12} = \dfrac{k_C q_1 q_2}{r^2} = (8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)\dfrac{(4.00 \times 10^{-9}\text{ C})^2}{(4.00\text{ m})^2}$ $F_{12} = 5.99 \times 10^{-9}$ N to the right, $F_{12} = 5.99 \times 10^{-9}$ N $F_{23} = k_C \dfrac{q_2 q_3}{r^2} = (8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)\dfrac{(4.00 \times 10^{-9}\text{ C})^2}{(4.00\text{ m})^2}$ $F_{12} = 5.99 \times 10^{-9}$ N to the left, $F_{23} = -5.99 \times 10^{-9}$ N $F_{net} = F_{12} + F_{23} = 5.99 \times 10^{-9}\text{ N} - 5.99 \times 10^{-9}\text{ N} = \boxed{0.00\text{ N}}$
376. $q_p = 1.60 \times 10^{-19}$ C $r_{4,1} = r_{2,1} = 1.52 \times 10^{-9}$ m $k_C = 8.99 \times 10^9$ N•m²/C²	$q_p = q_1 = q_2 = q_3 = q_4$ $r_{3,2} = \sqrt{(1.52 \times 10^{-9}\text{ m})^2 + (1.52 \times 10^{-9}\text{ m})^2} = 2.15 \times 10^{-9}$ m $F_{2,1} = \dfrac{k_C q_p^2}{r_{2,1}^2} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(1.52 \times 10^{-9}\text{ m})^2} = 9.96 \times 10^{-11}$ N $F_{3,1} = \dfrac{k_C q_p^2}{r_{3,1}^2} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(2.15 \times 10^{-9}\text{ m})^2} = 4.98 \times 10^{-11}$ N $F_{4,1} = \dfrac{k_C q_p^2}{r_{4,1}^2} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.60 \times 10^{-19}\text{ C})^2}{(1.52 \times 10^{-9}\text{ m})^2} = 9.96 \times 10^{-11}$ N $\varphi = \tan^{-1}\left(\dfrac{1.52 \times 10^{-9}\text{ m}}{1.52 \times 10^{-9}\text{ m}}\right) = 45°$ $F_{2,1}$: $F_x = 0$ N $F_y = 9.96 \times 10^{-11}$ N $F_{3,1}$: $F_x = F_{3,1}\cos 45° = (4.98 \times 10^{-11}\text{ N})(\cos 45°) = 3.52 \times 10^{-11}$ N $F_y = F_{3,1}\sin 45° = (4.98 \times 10^{-11}\text{ N})(\sin 45°) = 3.52 \times 10^{-11}$ N $F_{4,1}$: $F_x = 9.96 \times 10^{-11}$ N $F_y = 0$ N

Givens | *Solutions*

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$$F_{x,tot} = 0\text{ N} + 3.52 \times 10^{-11} + 9.96 \times 10^{-11} = 1.35 \times 10^{-10}\text{ N}$$

$$F_{y,tot} = 9.96 \times 10^{-10}\text{ N} + 3.52 \times 10^{-11}\text{ N} + 0\text{ N} = 1.35 \times 10^{-10}\text{ N}$$

$$F_{tot} = \sqrt{(F_{x,tot})^2 + (F_{y,tot})^2} = \sqrt{(1.35 \times 10^{-10}\text{ N})^2 + (1.35 \times 10^{-10}\text{ N})^2}$$

$$F_{tot} = \boxed{1.91 \times 10^{-10}\text{ N}}$$

$$\varphi = \tan^{-1}\left(\frac{1.35 \times 10^{-10}\text{ N}}{1.35 \times 10^{-10}\text{ N}}\right) = \boxed{45.0°}$$

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377. $q_1 = q_2 = q_3 = 2.0 \times 10^{-9}$ C

$r_{1,2} = 1.0$ m

$r_{1,3} = \sqrt{(1.0\text{ m})^2 + (2.0\text{ m})^2} = 2.24$ m

$k_C = 8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2$

$$F_{12} = \frac{k_C q_1 q_2}{r_{12}^2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-9}\text{ C})^2}{(1.0\text{ m})^2} = 3.6 \times 10^{-8}\text{ N}$$

Components of F_{12}: $F_{12,x} = 3.6 \times 10^{-8}$ N

$F_{12,y} = 0$ N

$$F_{13} = \frac{k_C q_1 q_3}{r_{13}^2} = \frac{(8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-9}\text{ C})^2}{(2.24\text{ m})^2} = 7.2 \times 10^{-8}\text{ N}$$

$$\varphi_{13} = \tan^{-1}\left(\frac{2.0\text{ m}}{1.0\text{ m}}\right) = 63°$$

Components of F_{13}:

$$F_{13,x} = F_{13}\cos\theta = (7.2 \times 10^{-9}\text{ N})\cos(63.4°) = 3.2 \times 10^{-9}\text{ N}$$

$$F_{13,y} = F_{13}\sin\theta = (7.2 \times 10^{-9}\text{ N})\sin(63.4°) = 6.4 \times 10^{-9}\text{ N}$$

$$F_{x,tot} = F_{12,x} + F_{13,x} = 7.2 \times 10^{-8}\text{ N} + 3.2 \times 10^{-9}\text{ N} = 3.9 \times 10^{-8}\text{ N}$$

$$F_{y,tot} = F_{12,y} + F_{13,y} = 0\text{ N} + 6.4 \times 10^{-9}\text{ N} = 6.4 \times 10^{-9}\text{ N}$$

$$F_{tot} = \sqrt{(F_{x,tot})^2 + (F_{y,tot})^2} = \sqrt{(3.9 \times 10^{-8}\text{ N})^2 + (6.4 \times 10^{-9}\text{ N})^2}$$

$$F_{tot} = \boxed{4.0 \times 10^{-8}\text{ N}}$$

$$\varphi = \tan^{-1}\left(\frac{F_{y.tot}}{F_{x.tot}}\right) = \tan^{-1}\left(\frac{6.4 \times 10^{-9}\text{ N}}{3.9 \times 10^{-8}\text{ N}}\right) = \boxed{9.3°}$$

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378. $q_1 = 7.2$ nC

$q_2 = 6.7$ nC

$q_3 = -3.0$ nC

$k_C = 8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2$

$r_{1,2} = 3.2 \times 10^{-1}\text{ m} = 0.32$ m

The charge, q_3, must be between the charges to achieve electrostatic equilibrium.

$$F_{1,3} + F_{1,2} = \frac{k_C q_1 q_3}{x^2} - \frac{k_C q_2 q_3}{(x - 0.32\text{ m})^2} = 0$$

$$(q_1 - q_2)x^2 - (0.64\text{ m})q_1 x + (0.32\text{ m})^2 q_1 x = 0$$

$$x = \frac{(0.64\text{ m})(7.2\text{ nC}) \pm \sqrt{(0.64\text{ m})^2(7.2\text{ nC})^2 - 4(7.2\text{ nC} - 6.7\text{ nC})(0.32\text{ m})^2(7.2\text{ nC})}}{2(7.2\text{ nC} - 6.7\text{ nC})}$$

$$x = \boxed{16\text{ cm}}$$

Givens *Solutions*

379. $q_1 = 6.0\ \mu C$

$q_2 = -12.0\ \mu C$

$q_3 = 6.0\ \mu C$

$k_C = 8.99 \times 10^9\ N{\bullet}m^2/C^2$

$r_{1,0} = 5.0 \times 10^{-2}\ m$

$$F_{2,3} = -F_{1,2} = \frac{-k_C q_1 q_2}{r_{1,2}^2} = \frac{-(8.99 \times 10^9\ N{\bullet}m^2/C^2)(6.0 \times 10^{-6}\ C)(-12.0 \times 10^{-6}\ C)}{(5.0 \times 10^{-2}\ m)^2}$$

$$F_{2,3} = \boxed{260\ N}$$

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380. $E_x = 9.0\ N/C$

$q = -6.0\ C$

$$E_x = \frac{F_{electric}}{q}$$

$$F_{electric} = E_x q = (9.0\ N/C)(-6.0\ C)$$

$$F_{electric} = \boxed{-54\ N \text{ in the } -x \text{ direction}}$$

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381. $E = 4.0 \times 10^3\ N/C$

$F_{electric} = 6.43 \times 10^{-9}\ N$

$$E = \frac{F_{electric}}{q}$$

$$q = \frac{F_{electric}}{E} = \frac{6.43 \times 10^{-9}\ N}{4.0 \times 10^3\ N/C} = \boxed{1.6 \times 10^{-12}\ C}$$

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382. $q_1 = 1.50 \times 10^{-5}\ C$

$q_2 = 5.00 \times 10^{-6}\ C$

$k_C = 8.99 \times 10^9\ N{\bullet}m^2/C^2$

$r_1 = 1.00\ m$

$r_2 = 0.500\ m$

$$E_1 = E_{y,1} = \frac{k_C q_1}{r_1^2} = \frac{(8.99 \times 10^9\ N{\bullet}m^2/C^2)(1.50 \times 10^{-5}\ C)}{(1.00\ m)^2} = 1.35 \times 10^5\ N/C$$

$$E_2 = E_{y,2} = \frac{k_C q_2}{r_2^2} = \frac{(8.99 \times 10^9\ N{\bullet}m^2/C^2)(5.00 \times 10^{-6}\ C)}{(0.500\ m)^2} = 1.80 \times 10^5\ N/C$$

$$E_{y,tot} = E_{tot} = 1.35 \times 10^5\ N/C + 1.80 \times 10^5\ N/C = \boxed{3.15 \times 10^5\ N/C}$$

The electric field points along the *y*-axis.

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383. $q_1 = 9.99 \times 10^{-5}\ C$

$q_2 = 3.33 \times 10^{-5}\ C$

$F_{electric} = 87.3\ N$

$k_C = 8.99 \times 10^9\ N{\bullet}m^2/C^2$

$$F_{electric} = \frac{k_C q_1 q_2}{r^2}$$

$$r = \sqrt{\frac{k_C q_1 q_2}{F_{electric}}} = \sqrt{\frac{(8.99 \times 10^9\ N{\bullet}m^2/C^2)(9.99 \times 10^{-5}\ C)(3.33 \times 10^{-5}\ C)^1}{87.3\ N}}$$

$$r = 0.585\ m = \boxed{58.5\ cm}$$

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384. $r = 9.30 \times 10^{-11}\ m$

$F_{electric} = 2.66 \times 10^{-8}\ N$

$k_C = 8.99 \times 10^9\ N{\bullet}m^2/C^2$

$$F_{electric} = \frac{k_C q_1 q_2}{r^2} = \frac{k_C q^2}{r^2}$$

$$q = \sqrt{\frac{F_{electric} r^2}{k_C}} = \sqrt{\frac{(2.66 \times 10^{-8}\ N)(9.30 \times 10^{-11}\ m)^2}{8.99 \times 10^9\ N{\bullet}m^2/C^2}}$$

$$q = \boxed{1.60 \times 10^{-19}\ C}$$

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Givens	Solutions
385. $q_1 = -2.34 \times 10^{-8}$ C $q_2 = 4.65 \times 10^{-9}$ C $q_3 = 2.99 \times 10^{-10}$ C $r_{1,2} = 0.500$ m $r_{1,3} = 1.00$ m $k_C = 8.99 \times 10^9$ N•m²/C²	see below

385. Givens: $q_1 = -2.34 \times 10^{-8}$ C; $q_2 = 4.65 \times 10^{-9}$ C; $q_3 = 2.99 \times 10^{-10}$ C; $r_{1,2} = 0.500$ m; $r_{1,3} = 1.00$ m; $k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$

$$F_{1,2} = \frac{k_C q_1 q_2}{r_{1,2}^2} = \frac{(8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(-2.34 \times 10^{-8}\ \text{C})(4.65 \times 10^{-9}\ \text{C})}{(0.500\ \text{m})^2}$$

$F_{1,2} = F_y = -3.91 \times 10^{-6}$ N

$$F_{1,3} = \frac{k_C q_1 q_3}{r_{1,3}^2} = \frac{(8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(-2.34 \times 10^{-8}\ \text{C})(2.99 \times 10^{-10}\ \text{C})}{(1.00\ \text{m})^2}$$

$F_{1,3} = F_y = -\,6.29 \times 10^{-8}$ N

$F_{y,tot} = -3.91 \times 10^{-6}\ \text{N} + -6.29 \times 10^{-8}\ \text{N} = 3.97 \times 10^{-6}$ N

There are no x-components of the electrical force, so the magnitude of the electrical force is $\sqrt{(F_{y,tot})^2}$.

$F_{tot} = \boxed{3.97 \times 10^{-6}\ \text{N upward}}$

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386. Givens: $q_1 = -9.00 \times 10^{-9}$ C; $q_2 = -8.00 \times 10^{-9}$ C; $q_3 = 7.00 \times 10^{-9}$ C; $r_{1,2} = 2.00$ m; $r_{1,3} = 3.00$ m; $k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$

$$F_{1,2} = \frac{k_C q_1 q_2}{r_{1,2}^2} = \frac{(8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(-9.00 \times 10^{-9}\ \text{C})(-8.00 \times 10^{-9}\ \text{C})}{(2.00\ \text{m})^2} = 1.62 \times 10^{-7}\ \text{N}$$

$$F_{1,3} = \frac{k_C q_1 q_3}{r_{1,3}^2} = \frac{(8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(-9.00 \times 10^{-9}\ \text{C})(-7.00 \times 10^{-9}\ \text{C})}{(3.00\ \text{m})^2} = -6.29 \times 10^{-8}\ \text{N}$$

$F_{1,2}$: $F_x = 4.05 \times 10^{-8}$ N

$F_y = 0$ N

$F_{1,3}$: $F_x = 0$ N

$F_y = -6.29 \times 10^{-8}$ N

$F_{tot} = \sqrt{(1.62 \times 10^{-7}\ \text{N})^2 + (-6.29 \times 10^{-8}\ \text{N})^2} = \boxed{1.74 \times 10^{-7}\ \text{N}}$

F_{tot} is negative because the larger, y-component of the force is negative.

$$\varphi = \tan^{-1}\left(\frac{-6.29 \times 10^{-8}\ \text{N}}{1.62 \times 10^{-7}\ \text{N}}\right) = \boxed{-21.2°}$$

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387. Givens: $q_1 = -2.5$ nC; $q_2 = -\,7.5$ nC; $q_3 = 5.0$ nC; $k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$; $r_{1,2} = 20.0$ cm

The charge, q_3, must be between the charges to achieve electrostatic equilibrium.

$$F_{1,3} + F_{1,2} = \frac{k_C q_1 q_3}{x^2} - \frac{k_C q_2 q_3}{(x - 20.0\ \text{cm})^2} = 0$$

$(q_1 - q_2)x^2 - (40.0\ \text{cm})q_1 x + (20.0\ \text{cm})^2 q_1 x = 0$

$$x = \frac{(40.0\ \text{cm})(-2.5\ \text{nC}) \pm \sqrt{(40.0\ \text{cm})^2(-2.5\ \text{nC})^2 - 4(-2.5\ \text{nC} + 7.5\ \text{nC})(20.0\ \text{cm})^2(-2.5\ \text{nC})}}{2(-2.5\ \text{nC} + 7.5\ \text{nC})}$$

$x = \boxed{7.3\ \text{cm}}$

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388. Givens: $q_1 = -2.3$ C; $q_3 = -4.6$ C; $r_{1,2} = r_{3,1} = 2.0$ m; $r_{3,2} = 4.0$ m; $k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$

$$F_{3,1} + F_{3,2} = \frac{-k_C q_3 q_1}{r_{3,1}^2} - \frac{k_C q_3 q_2}{r_{3,2}} = 0$$

$$q_2 = \frac{-q_1 r_{3,2}^2}{r_{3,1}^2} = \frac{-(-2.3\ \text{C})(4.0\ \text{m})^2}{(2.0\ \text{m})^2} = \boxed{9.2\ \text{C}}$$

Givens	*Solutions*
389. $E_y = 1500$ N/C $q = 5.0 \times 10^{-9}$ C	$E_y = \dfrac{F_{electric}}{q}$ $F_{electric} = E_y q = (1500 \text{ N/C})(5.0 \times 10^{-9} \text{ C})$ $F_{electric} = \boxed{7.5 \times 10^{-6} \text{ N in the } +y \text{ direction}}$

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390. $E = 1663$ N/C $F_{electric} = 8.4 \times 10^{-9}$ N	$E = \dfrac{F_{electric}}{q}$ $q = \dfrac{F_{electric}}{E} = \dfrac{8.42 \times 10^{-9} \text{ N}}{1663 \text{ N/C}} = \boxed{5.06 \times 10^{-12} \text{ C}}$

391. $q_q = 3.00 \times 10^{-6}$ C

$q_2 = 3.00 \times 10^{-6}$ C

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$r_1 = 0.250$ m

$$r_2 = \sqrt{(2.00 \text{ m})^2 + (2.00 \text{ m})^2} = 2.02 \text{ m}$$

$$E_1 = E_y = E_y = \frac{k_C q_1}{r_1^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(3.00 \times 10^{-6} \text{ C})}{(0.250 \text{ m})^2}$$

$$E_1 = E_{y,1} = 4.32 \times 10^5 \text{ N/C}$$

$$E_2 = \frac{k_C q_2}{r_2^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(3.00 \times 10^{-6} \text{ C})}{(2.02 \text{ m})^2} = 6.61 \times 10^3 \text{ N/C}$$

$$\varphi = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{0.250 \text{ m}}{2.00 \text{ m}}\right) = 7.12°$$

$$E_{x,2} = E_2 \cos 7.12° = (6.61 \times 10^3 \text{ N/C})(\cos 7.12°) = 6.56 \times 10^3 \text{ N/C}$$

$$E_{y,2} = E_2 \sin 7.12° = (6.61 \times 10^3 \text{ N/C})(\sin 7.12°) = 8.19 \times 10^3 \text{ N/C}$$

$$E_{x,tot} = 0 \text{ N/C} + 6.56 \times 10^3 \text{ N/C} = 6.56 \times 10^3 \text{ N/C}$$

$$E_{y,tot} = 4.32 \times 10^5 \text{ N/C} + 8.19 \times 10^3 \text{ N/C} = 4.40 \times 10^5 \text{ N/C}$$

$$E_{tot} = \sqrt{(E_{x,tot}{}^2 + (E_{y,tot})^2}$$

$$E_{tot} = \sqrt{(6.56 \times 10^3 \text{ N/C})^2 + (4.40 \times 10^5 \text{ N/C})^2}$$

$$E_{tot} = \boxed{4.40 \times 10^5 \text{ N/C}}$$

$$\tan \varphi = \frac{E_{y,tot}}{E_{x,tot}} = \frac{4.40 \times 10^5 \text{ N/C}}{6.56 \times 10^3 \text{ N/C}}$$

$$\varphi = \boxed{89.1°}$$

392. $q_1 = -1.6 \times 10^{-19}$ C

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$q_2 = -1.60 \times 10^{-19}$ C

$q_3 = 1.60 \times 10^{-19}$ C

$r_1 = 3.00 \times 10^{-10}$ m

$r_2 = 2.00 \times 10^{-10}$ m

$$F_{x,tot} = \frac{k_C q_1}{r^2} + \frac{k_C q_2}{r_2^2} + \frac{k_C q_3}{x^2} = 0$$

$$q_1 = q_2 = -q_3$$

$$k_C q_1 \left(\frac{1}{r_1^2} + \frac{1}{r_2^2} - \frac{1}{x^2}\right) = 0$$

$$k_C q_1 \left(\frac{1}{r_1^2} + \frac{1}{r_2^2}\right) = \frac{k_C q_1}{x^2}$$

$$x^2 = \frac{1}{\dfrac{1}{r_1^2} + \dfrac{1}{r_2^2}} = \frac{1}{\dfrac{1}{(3.00 \times 10^{-10} \text{ m})^2} + \dfrac{1}{(2.00 \times 10^{-10} \text{ m})}}$$

$$x = \boxed{1.66 \times 10^{-10} \text{ m}}$$

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393. $q_1 = -7.0$ C

$x_1 = 0$

$q_2 = 49$ C

$x_2 = 18$ m

$x_3 = 25$ m

To remain in equilibrium, the force on q_2 by q_1 (F_{21}, which is in the negative direction) must equal the force on q_2 by q_3 (F_{23}, which must be in the positive direction).

$$-\frac{k_C q_2 q_1}{r_{12}^2} = \frac{k_C q_2 q_3}{r_{23}^2}$$

$$-\frac{q_2}{r_{12}^2} = \frac{q_3}{r_{23}^2}$$

$$q_3 = -q_2\frac{r_{23}^2}{r_{12}^2} = -(49 \text{ C})\left(\frac{(25 \text{ m} - 18 \text{ m})^2}{(18 \text{ m} - 0 \text{ m})^2}\right) = \boxed{-7.4 \text{ C}}$$

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394. $r = 8.3 \times 10^{-10}$ m

$F_{electric} = 3.34 \times 10^{-10}$ N

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F_{electric} = \frac{k_C q_1 q_2}{r^2} = \frac{k_C q^2}{r^2}$$

$$q = \sqrt{\frac{F_{electric} r^2}{k_C}} = \sqrt{\frac{(3.34 \times 10^{-10} \text{ N})(8.3 \times 10^{-10} \text{ N})^2}{8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2}}$$

$$q = \boxed{1.6 \times 10^{-19} \text{ C}}$$

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395. $r = 6.4 \times 10^{-8}$ m

$F_{electric} = 5.62 \times 10^{-14}$ N

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F_{electric} = \frac{k_C q_1 q_2}{r^2} = \frac{k_C q_2}{r^2}$$

$$q = \sqrt{\frac{F_{electric} r^2}{k_C}} = \sqrt{\frac{(5.62 \times 10^{-14} \text{ N})(6.4 \times 10^{-8} \text{ m})^2}{8.99 \times 10^9 \text{ N}\bullet\text{m}^2\text{C}^2}}$$

$$q = \boxed{1.6 \times 10^{-19} \text{ C}}$$

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396. $q_e = -1.60 \times 10^{-19}$ C

$r_{2,3} = r_{4,3} = 3.02 \times 10^{-5}$ m

$r_{1,3} = \sqrt{2(3.02 \times 10^{-5} \text{ m})^2} = 4.27 \times 10^{-5}$ m

$k_C = 8.99 \times 10^9$ N•m²/C²

$$q_e = q_1 = q_2 = q_3 = q_4$$

$$F_{3,2} = F_x = \frac{k_C q_2 e}{r_{3,2}^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(-1.60 \times 10^{-19} \text{ C})^2}{(3.02 \times 10^{-5} \text{ m})^2} = 2.52 \times 10^{-19} \text{ N}$$

$$F_{3,4} = F_y = \frac{k_C q e^2}{r_{3,4}^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(-1.60 \times 10^{-19} \text{ C})^2}{(3.02 \times 10^{-5} \text{ m})^2} = 2.52 \times 10^{-19} \text{ N}$$

$$F_{3,1} = \frac{k_C q_e^2}{r_{3,1}^2} = \frac{(8.99 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2)(-1.60 \times 10^{-19} \text{ C})^2}{(4.27 \times 10^{-5} \text{ m})^2} = 1.26 \times 10^{-19} \text{ N}$$

$$\varphi = \tan^{-1}\left(\frac{3.02 \times 10^{-5} \text{ m}}{3.02 \times 10^{-5} \text{ m}}\right) = 45°$$

$$F_{3,1}\text{: } F_x = F_{3,1} \cos 45° = (1.26 \times 10^{-19} \text{ N}) \cos 45° = 8.91 \times 10^{-20} \text{ N}$$

$$F_y = F_{3,1} \sin 45° = (1.26 \times 10^{-19} \text{ N}) \sin 45° = 8.91 \times 10^{-20} \text{ N}$$

$$F_{x,tot} = 8.91 \times 10^{-20} \text{ N} + 2.52 \times 10^{-19} \text{ N} + 0 \text{ N} = 3.41 \times 10^{-19} \text{ N}$$

$$F_{y,tot} = 8.91 \times 10^{-20} \text{ N} + 0 \text{ N} + 2.52 \times 10^{-19} \text{ N} = 3.41 \times 10^{-19} \text{ N}$$

$$F_{tot} = \sqrt{(F_{x,tot})^2 + (F_{y,tot})^2} = \sqrt{(3.41 \times 10^{-19} \text{ N})^2 (3.41 \times 10^{-19} \text{ N})^2}$$

$$F_{tot} = \boxed{4.82 \times 10^{-19} \text{ N}}$$

$$\varphi = \tan^{-1}\left(\frac{F_{y,tot}}{F_{x,tot}}\right) = \tan^{-1}\left(\frac{3.41 \times 10^{-19} \text{ N}}{3.41 \times 10^{-19} \text{ N}}\right) = \boxed{45°}$$

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397. $q_1 = 5.5$ nC
$q_2 = 11$ nC
$q_3 = -22$ nC
$k_C = 8.99 \times 10^9$ N•m^2/C^2
$r_{1,2} = 88$ cm

The charge, q_3, must be between the charges to achieve electrostatic equilibrium.

$$F_{1,3} + F_{1,2} = \frac{k_C q_1 q_3}{x^2} - \frac{k_C q_2 q_3}{(x - 88\text{ cm})^2} = 0$$

$$(q_1 - q_2)x^2 - (176\text{ cm})q_1 x + (88\text{ cm})^2 q_1 x = 0$$

$$x = \frac{(176\text{ cm})(5.5\text{ nC}) \pm \sqrt{(176\text{ cm})^2(5.5\text{ nC})^2 - 4(5.5\text{ nC} - 11\text{ nC})(88\text{ cm})^2(5.5\text{ nC})}}{2(5.5\text{ nC} - 11\text{ nC})}$$

$$x = \boxed{36\text{ cm}}$$

398. $q_1 = 72$ C
$q_3 = -8.0$ C
$r_{1,2} = 15$ mm $= 1.5 \times 10^{-2}$ m
$r_{3,1} = -9.0$ mm $= -9.0 \times 10^{-3}$ m
$r_{3,2} = 2.4 \times 10^{-2}$ m

$$F_{3,1} + F_{3,2} = \frac{-k_C q_3 q_1}{r_{3,1}^2} - \frac{k_C q_3 q_2}{r_{3,2}^2} = 0$$

$$q_2 = \frac{-q_1 r_{3,2}^2}{r_{3,1}^2} = \frac{-(72\text{ C})(2.4 \times 10^{-2}\text{ m})^2}{(-9.0 \times 10^{-3}\text{ m})^2} = \boxed{-512\text{ C}}$$

Electrical Energy and Current

399. $q = 1.45 \times 10^{-8}$ C
$E = 105$ N/C
$d = 290$ m

$$PE_{electric} = -qEd = -(1.45 \times 10^{-8}\text{ C})(-105\text{ N/C})(290\text{ m})$$

$$PE_{electric} = \boxed{4.4 \times 10^{-4}\text{ J}}$$

400. $PE_{electric} = -1.39 \times 10^{11}$ J
$E = 3.4 \times 10^5$ N/C
$d = 7300$ m

$$q = \frac{-PE_{electric}}{Ed} = \frac{-(-1.39 \times 10^{11}\text{ J})}{(3.4 \times 10^5\text{ N/C})(7300\text{ m})}$$

$$q = \boxed{56\text{ C}}$$

401. $R = 6.4 \times 10^6$ m

$$C_{sphere} = \frac{R}{k_c} = \frac{6.4 \times 10^6\text{ m}}{8.99 \times 10^9\text{N•m}^2/\text{C}^2} = \boxed{7.1 \times 10^{-4}\text{ F}}$$

402. $C = 5.0 \times 10^{-13}$ F
$\Delta V = 1.5$ V

$$Q = C\Delta V = (5 \times 10^{-13}\text{ F})(1.5\text{ V}) = \boxed{7.5 \times 10^{-13}\text{ C}}$$

403. $\Delta Q = 76$ C
$\Delta t = 19$ s

$$I = \frac{\Delta Q}{\Delta t} = \frac{76\text{ C}}{19\text{ s}} = \boxed{4.0\text{ A}}$$

404. $\Delta Q = 98$ C
$I = 1.4$ A

$$\Delta t = \frac{\Delta Q}{I} = \frac{98\text{ C}}{1.4\text{ A}} = \boxed{70\text{ s}}$$

405. $I = 0.75$ A
$\Delta V = 120$ V

$$R = \frac{\Delta V}{I} = \frac{120\text{ V}}{0.75\text{A}} = \boxed{1.6 \times 10^2\ \Omega}$$

406. $\Delta V = 120$ V
$R = 12.2\ \Omega$

$$I = \frac{\Delta V}{R} = \frac{120\text{ V}}{12.2\ \Omega} = \boxed{9.84\text{ A}}$$

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407. $\Delta V = 720$ V, $R = 0.30\ \Omega$

$$P = \frac{(\Delta V)^2}{R} = \frac{(720\ \text{V})^2}{0.30\ \Omega} = \boxed{1.7 \times 10^6\ \text{W}}$$

408. $\Delta V = 120$ V, $P = 1750$ W

$$R = \frac{(\Delta V)^2}{P} = \frac{(120\ \text{V})^2}{1750\ \text{W}} = \boxed{8.23\ \Omega}$$

409. $q = 64\ \text{nC} = 64 \times 10^9\ \text{C}$, $d = 0.95$ m, $\Delta PE_{electric} = -\,3.88 \times 10^{-5}$ J

$$E = -\frac{\Delta PE_{electric}}{qd} = -\frac{-3.88 \times 10^{-5}\ 5\ \text{J}}{(64 \times 10^9\ \text{C})(0.95)}$$

$$E = \boxed{6.4 \times 10^2\ \text{N/C}}$$

410. $q = -\,14\ \text{nC} = -\,14 \times 10^{-9}\ \text{C}$, $E = 156$ N/C, $\Delta PE_{electric} = 2.1 \times 10^{-6}$ J

$$d = \frac{\Delta PE_{electric}}{-qE} = \frac{2.1 \times 10^{-6}\ \text{J}}{-(-14 \times 10^{-9}\ \text{C})(156\ \text{N/C})}$$

$$d = \boxed{0.96\ \text{m} = 96\ \text{cm}}$$

411. $C = 5.0 \times 10^{-5}$ F, $Q = 6.0 \times 10^{-4}$ C

$$\Delta V = \frac{Q}{C} = \frac{6.0 \times 10^{-4}\ \text{C}}{5.0 \times 10^{-5}\ \text{F}} = \boxed{12\ \text{V}}$$

412. $Q = 3 \times 10^{-2}$ C, $\Delta V = 30$ kV

$$C = \frac{Q}{\Delta V} = \frac{3 \times 10^{-2}\ \text{C}}{30 \times 10^3\ \text{V}} = \boxed{1 \times 10^{-6}\ \text{F} = 1\ \mu\text{F}}$$

413. $\text{A} = 6.4 \times 10^{-3}\ \text{m}^2$, $C = 4.55 \times 10^{-9}$ F

$$d = \frac{\varepsilon_0 \text{A}}{C} = \frac{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(6.4 \times 10^{-3}\ \text{m}^2)}{4.55 \times 10^{-9}\ \text{F}}$$

$$d = \boxed{1.2 \times 10^{-5}\ \text{m}}$$

414. $C = 1.4 \times 10^{-5}$ F, $\Delta V = 1.5 \times 10^4$ V

$$Q = C\Delta V = (1.4 \times 10^{-5}\ \text{F})(1.5 \times 10^4\ \text{V}) = \boxed{0.21\ \text{C}}$$

415. $\Delta t = 15$ s, $I = 9.3$ A

$$\Delta Q = I\Delta t = (9.3\ \text{A})\ (15\ \text{s}) = \boxed{1.4 \times 10^2\ \text{C}}$$

416. $\Delta Q = 1.14 \times 10^{-4}$ C, $\Delta t = 0.36$ s

$$I = \frac{\Delta Q}{\Delta t} = \frac{1.14 \times 10^{-4}\ \text{C}}{0.36\ \text{s}} = \boxed{0.32\ \text{mA}}$$

417. $\Delta Q = 56$ C, $I = 7.8$ A

$$\Delta t = \frac{\Delta Q}{I} = \frac{56\ \text{C}}{7.8\ \text{A}} = \boxed{7.2\ \text{s}}$$

418. $\Delta t = 2.0\ \text{min} = 120$ s, $I = 3.0$ A

$$\Delta Q = I\Delta t = (3.0\ \text{A})\ (120\ \text{s}) = \boxed{3.6 \times 10^2\ \text{C}}$$

419. $I = 0.75$ A, $R = 6.4\ \Omega$

$$\Delta V = IR = (0.75\ \text{A})\ (6.4\ \Omega) = \boxed{4.8\ \text{V}}$$

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420. $\Delta V = 650$ V, $R = 1.0 \times 10^2\ \Omega$

$$I = \frac{\Delta V}{R} = \frac{650\ \text{V}}{1.0 \times 10^2\ \Omega} = \boxed{6.5\ \text{A}}$$

421. $I = 4.66$ A, $R = 25.0\ \Omega$

$$\Delta V = IR = (4.66\ \text{A})(25.0\ \Omega) = \boxed{116\ \text{V}}$$

422. $I = 0.545$ A, $\Delta V = 120$ V

$$R = \frac{\Delta V}{I} = \frac{120\ \text{V}}{0.545\ \text{A}} = \boxed{220\ \Omega}$$

423. $\Delta V = 2.5 \times 10^4$ V, $I = 20.0$ A

$$P = I\Delta V = (20.0\ \text{A})(2.5 \times 10^4\ \text{V}) = \boxed{5.0 \times 10^5\ \text{W}}$$

424. $P = 230$ W, $R = 91\ \Omega$

$$I^2 = \frac{P}{R} \qquad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{230\ \text{W}}{91\ \Omega}} = \boxed{1.59\ \text{A}}$$

425. $I = 8.0 \times 10^6$ A, $P = 6.0 \times 10^{13}$ W

$$\Delta V = \frac{P}{I} = \frac{6.0 \times 10^{13}\ \text{W}}{8.0 \times 10^6\ \text{A}} = \boxed{7.5 \times 10^6\ \text{V}}$$

426. $P = 350$ W, $R = 75\ \Omega$

$$I^2 = \frac{P}{R} \qquad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{350\ \text{W}}{75\ \Omega}} = \boxed{2.2\ \text{A}}$$

Circuits and Circuit Elements

427. 25 speakers, $R_{each\ speaker} = 12.0\ \Omega$

$R_{eq} = \Sigma R_{each\ speaker}$ All speakers have equal resistance.

$$R_{eq} = (25)(12.0\ \Omega) = \boxed{3.00 \times 10^2\ \Omega}$$

428. 57 lights, $R_{each\ light} = 2.0\ \Omega$

$R_{eq} = \Sigma R_{each\ light}$ All lights have equal resistance.

$$R_{eq} = (57)(2.0\ \Omega) = \boxed{114\ \Omega}$$

429. $R_1 = 39\ \Omega$, $R_2 = 82\ \Omega$, $R_3 = 12\ \Omega$, $R_4 = 22\ \Omega$, $\Delta V = 3.0$ V

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{39\ \Omega} + \frac{1}{82\ \Omega} + \frac{1}{12\ \Omega} + \frac{1}{22\ \Omega}$$

$$\frac{1}{R_{eq}} = \frac{0.026}{1\ \Omega} + \frac{0.012}{1\ \Omega} + \frac{0.083}{1\ \Omega} + \frac{0.045}{1\ \Omega} = \frac{0.17}{1\ \Omega}$$

$$R_{eq} = \boxed{6.0\ \Omega}$$

430. $R_1 = 33\ \Omega$, $R_2 = 39\ \Omega$, $R_3 = 47\ \Omega$, $R_4 = 68\ \Omega$, $V = 1.5$ V

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{33\ \Omega} + \frac{1}{39\ \Omega} + \frac{1}{47\ \Omega} + \frac{1}{68\ \Omega}$$

$$\frac{1}{R_{eq}} = \frac{0.030}{1\ \Omega} + \frac{0.026}{1\ \Omega} + \frac{0.021}{1\ \Omega} + \frac{0.015}{1\ \Omega}$$

$$R_{eq} = \boxed{11\ \Omega}$$

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431. $\Delta V = 12\ \text{V}$ $R_1 = 16\ \Omega$ $I = 0.42\ \text{A}$	$R_2 = \frac{\Delta V}{I} - R_1 = \frac{12\ \text{V}}{0.42\ \text{A}} - 16\ \Omega = 29\ \Omega - 16\ \Omega = \boxed{13\ \Omega}$
432. $\Delta V = 3.0\ \text{V}$ $R_1 = 24\Omega$ $I = 0.062\ \text{A}$	$R_2 = \frac{\Delta V}{I} - R_1 = \frac{3.0\ \text{V}}{0.062\ \text{A}} - 24\ \Omega = 48\ \Omega - 24\ \Omega = \boxed{24\ \Omega}$
433. $\Delta V = 3.0\ \text{V}$ $R_1 = 3.3\ \Omega$ $I = 1.41\ \text{A}$	$\Delta V = IR_{eq}$ $I = \frac{\Delta V}{R_{eq}} = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2}$ $\frac{\Delta V}{R_2} = \left(I - \frac{\Delta V}{R_1}\right)$ $R_2 = \frac{\Delta V}{\left(I - \frac{\Delta V}{R_1}\right)} = \frac{3.0\ \text{V}}{\left(1.41\ \text{A} - \frac{3.0\ \text{V}}{3.3\ \Omega}\right)} = \frac{3.0\ \text{V}}{[1.41\ \text{A} - 0.91\ \text{A}]} = \boxed{6.0\ \Omega}$
434. $\Delta V = 12\ \text{V}$ $R_1 = 56\ \Omega$ $I = 3.21\ \text{A}$	$\Delta V = IR_{eq}$ $I = \frac{\Delta V}{R_{eq}} = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2}$ $\frac{\Delta V}{R_2} = \left(I - \frac{\Delta V}{R_1}\right)$ $R_2 = \frac{\Delta V}{\left(I - \frac{\Delta V}{R_1}\right)} = \frac{12\ \text{V}}{\left(3.21\ \text{A} - \frac{12\ \text{V}}{56\ \Omega}\right)} = \frac{12\ \text{V}}{[3.21\ \text{A} - 0.21\ \text{A}]} = \boxed{4.0\ \Omega}$
435. $R_1 = 56\ \Omega$ $R_2 = 82\ \Omega$ $R_3 = 24\ \Omega$ $\Delta V = 9.0\ \text{V}$	$R_{eq} = \Sigma R = R_1 + R_2 + R_3 = 56\Omega + 82\Omega + 24\Omega = 162\Omega$ $I = \frac{\Delta V}{R_{eq}} = \frac{9.0\ V}{162\ \Omega} = \boxed{56\ \text{mA}}$
436. $R_1 = 96\ \ \Omega$ $R_2 = 48\ \Omega$ $R_3 = 29\ \Omega$ $\Delta V = 115\ \text{V}$	$R_{eq} = \Sigma R = R_1 + R_2 + R_3 = 96\ \Omega + 48\ \Omega + 29\ \Omega = 173\ \Omega$ $I = \frac{\Delta V}{R_{eq}} = \frac{115\ \text{V}}{173\ \Omega} = \boxed{665\ \text{mA}}$
437. $\Delta V = 120\ \text{V}$ $R_1 = 75\ \Omega$ $R_2 = 91\ \Omega$	$I_1 = \frac{V}{R_1}$ $I_2 = \frac{V}{R_2}$ $I_1 = \frac{120\ \text{V}}{75\ \Omega} = \boxed{1.6\ \text{A}}$ $I_2 = \frac{120\ \text{V}}{91\ \Omega} = \boxed{1.3\ \text{A}}$

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438. $\Delta V = 120\text{ V}$ $R_1 = 82\ \Omega$ $R_2 = 24\ \Omega$	$I_1 = \frac{V}{R_1}$ $\qquad$ $I_2 = \frac{V}{R_2}$ $I_1 = \frac{120\text{ V}}{82\ \Omega} = \boxed{1.5\text{ A}}$ $\qquad$ $I_2 = \frac{120\text{ V}}{24\ \Omega} = \boxed{5.0\text{ A}}$
439. $R_1 = 1.5\ \Omega$ $R_2 = 6.0\ \Omega$ $R_3 = 5.0\ \Omega$ $R_4 = 4.0\ \Omega$ $R_5 = 2.0\ \Omega$ $R_6 = 5.0\ \Omega$ $R_7 = 3.0\ \Omega$	Parallel: Group (a): $\frac{1}{R_{eq.a}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{6.0\ \Omega} + \frac{1}{5.0\ \Omega} = \frac{5.0 + 6.0}{30\ \Omega}$ $R_{eq,a} = \frac{30\ \Omega}{11.0} = 2.7\ \Omega$ Group (b): $\frac{1}{R_{eq.a}} = \frac{1}{R_5} + \frac{1}{R_6} = \frac{1}{2.0\ \Omega} + \frac{1}{5.0\ \Omega} = \frac{5.0 + 2.0}{10\ \Omega}$ $R_{eq,a} = \frac{10\ \Omega}{7.0} = 1.4\ \Omega$ Series: $R_{eq} = R_1 + R_{eq,a} + R_4 + R_{eq,b} + R_7 = 1.5\ \Omega + 2.7\ \Omega + 4.0\ \Omega + 1.4\ \Omega + 3.0\ \Omega$ $R_{eq} = \boxed{12.6\ \Omega}$
440. $\Delta V_{tot} = 12.0\text{ V}$ $R_{eq} = 12.6\ \Omega$	$I_{tot} = \frac{\Delta V_{tot}}{R_{eq}} = \frac{12.0\text{ V}}{12.6\ \Omega} = \boxed{0.952\text{ A}}$
441. $I_{tot} = 0.952\text{ A}$ $R_2 = 6.0\ \Omega$ $R_3 = 5.0\ \Omega$	$\frac{1}{R_{eq.a}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{6.0\ \Omega} + \frac{1}{5.0\ \Omega} = \frac{5.0 + 6.0}{30\ \Omega}$ $R_{eq,a} = 2.7\ \Omega$ $\Delta V_2 = \Delta V_a = I_{tot}R_{eq,a} = (0.952\text{ A})(2.7\ \Omega) = \boxed{2.6\text{ V}}$
442. $\Delta V_2 = 2.6\text{ V}$ $R_2 = 6.0\ \Omega$	$I_6 = \frac{\Delta V_2}{R_2} = \frac{2.6\text{ V}}{6.0\ \Omega} = \boxed{0.43\text{ A}}$
443. $R_1 = 3.0\ \Omega$ $R_2 = 5.0\ \Omega$ $R_3 = 5.0\ \Omega$ $R_4 = 5.0\ \Omega$ $R_5 = 5.0\ \Omega$ $R_6 = 5.0\ \Omega$ $R_7 = 5.0\ \Omega$ $R_8 = 3.0\ \Omega$	Parallel: $\frac{1}{R_{eq.a}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega} = 3(0.20\ \Omega)$ $R_{eq,a} = 1.7\ \Omega = R_{eq,b}$ Series: $R_{eq} = R_1 + R_{eq,a} + R_8 + R_{eq,b} = 3.0\ \Omega + 1.7\ \Omega + 3.0\ \Omega + 1.7\ \Omega$ $R_{eq} = \boxed{9.4\ \Omega}$

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444. $\Delta V_{tot} = 15.0\ \text{V}$ $R_{eq} = 9.4\ \Omega$	$I_{tot} = \frac{\Delta V_{tot}}{R_{eq}} = \frac{15.0\ \text{V}}{9.4\ \Omega} = \boxed{1.6\ \text{A}}$
445. $I_{tot} = 1.6\ \text{A}$	$I_1 = I_{tot} = \boxed{1.6\ \text{A}}$
446. $R_1 = 3.0\ \Omega$ $R_2 = 2.0\ \Omega$ $R_3 = 3.0\ \Omega$ $R_4 = 4.0\ \Omega$ $R_5 = 8.0\ \Omega$ $R_6 = 5.0\ \Omega$ $R_7 = 2.0\ \Omega$ $R_8 = 8.0\ \Omega$ $R_9 = 4.0\ \Omega$	Parallel: $\frac{1}{R_{eq.a}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{3.0\ \Omega} + \frac{1}{2.0\ \Omega} = \frac{2.0 + 3.0}{6.0\ \Omega}$ $R_{eq,a} = \frac{6.0\ \Omega}{5.0} = 1.2\ \Omega$ $\frac{1}{R_{eq.b}} = \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{4.0\ \Omega} + \frac{1}{8.0\ \Omega} = \frac{8.0 + 4.0}{32\ \Omega}$ $R_{eq,b} = \frac{32\ \Omega}{12.0} = 2.7\ \Omega = R_{eq,c}$ Series: $R_{eq} = R_{eq,a} + R_3 + R_{eq,b} + R_6 + R_7 + R_{eq,c}$ $R_{eq} = 1.2\ \Omega + 3.0\ \Omega + 2.7\ \Omega + 5.0\ \Omega + 2.0\ \Omega + 2.7\ \Omega = \boxed{16.6\ \Omega}$
447. $\Delta V_{tot} = 24.0\ \text{V}$ $R_{eq} = 16.6\ \Omega$	$I_{tot} = \frac{\Delta V_{tot}}{R_{eq}} = \frac{24.0\ \text{V}}{16.6\ \Omega} = \boxed{1.45\ \text{A}}$
448. $I_{tot} = 1.45\ \text{A}$ $R_4 = R_9 = 4.0\ \Omega$ $R_5 = R_8 = 8.0\ \Omega$	$I_{tot} = I_4 + I_5$ $I_5 = I_{tot} - I_4$ $\Delta V_4 = \Delta V_5$ $I_4R_4 = I_5R_5$ $I_4R_4 = (I_{tot} - I_4)R_5$ $I_4(R_4 + R_5) = I_{tot}R_5$ $I_4 = I_{tot}\left(\frac{R_5}{R_4 + R_5}\right) = (1.45\ \text{A})\left(\frac{8.0\ \Omega}{4.0\ \Omega + 8.0\ \Omega}\right) = (1.45\ \text{A})\left(\frac{8.0}{12.0}\right) = \boxed{0.97\ \text{A}}$

Magnetism

449. $q = 1.60 \times 10^{-19}\ \text{C}$ $B = 0.8\ \text{T}$ $v = 3.0 \times 10^7\ \text{m/s}$	$F_{magnetic} = qvB = (1.60 \times 10^{-19}\ \text{C})(3.0 \times 10^7\ \text{m/s})(0.8\ \text{T}) = \boxed{4 \times 10^{-12}\ \text{N}}$
450. $q = 1.60 \times 10^{-19}\ \text{C}$ $v = 3.9 \times 10^6\ \text{m/s}$ $F_{magnetic} = 1.9 \times 10^{-22}\ \text{N}$	$B = \frac{F_{magnetic}}{qv} = \frac{1.9 \times 10^{-22}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(3.9 \times 10^6\ \text{m/s})} = \boxed{3.0 \times 10^{-10}\ \text{T}}$
451. $q = 1.60 \times 10^{-19}\ \text{C}$ $B = 5.0 \times 10^{-5}\ \text{T}$ $F_{magnetic} = 6.1 \times 10^{-17}\ \text{N}$	$v = \frac{F_{magnetic}}{qB} = \frac{6.1 \times 10^{-17}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(5.0 \times 10^{-5}\ \text{T})} = \boxed{7.6 \times 10^6\ \text{m/s}}$

Givens	*Solutions*
452. $I = 14$ A $\ell = 2$ m $B = 3.6 \times 10^{-4}$ T	$F_{magnetic} = BI\ell = (3.6 \times 10^{-4}\ \text{T})(14\ \text{A})(2\ \text{m}) = \boxed{1 \times 10^{-2}\ \text{N}}$
453. $\ell = 1.0$ m $F_{magnetic} = 9.1 \times 10^{-5}$ N $B = 1.3 \times 10^{-4}$ T	$I = \dfrac{F_{magnetic}}{B\ell} = \dfrac{9.1 \times 10^{-5}\ \text{N}}{(1.3 \times 10^{-4}\ \text{T})(1.0\ \text{m})} = \boxed{0.70\ \text{A}}$
454. $B = 4.6 \times 10^{-4}$ T $F_{magnetic} = 2.9 \times 10^{-3}$ N $T = 10.0$ A	$\ell = \dfrac{F_{magnetic}}{BI} = \dfrac{2.9 \times 10^{-3}\ \text{N}}{(4.6 \times 10^{-4}\ \text{T})(10.0\ \text{A})} = \boxed{0.63\ \text{m}}$
455. $\ell = 12$ m $I = 12$ A $F_{magnetic} = 7.3 \times 10^{-2}$ N	$B = \dfrac{F_{magnetic}}{I\ell} = \dfrac{7.3 \times 10^{-2}\ \text{N}}{(12\ \text{A})(12\ \text{m})} = \boxed{5.1 \times 10^{-4}\ \text{T}}$
456. $q = 1.60 \times 10^{-19}$ C $v = 7.8 \times 10^{6}$ m/s $F_{magnetic} = 3.7 \times 10^{-13}$ N	$B = \dfrac{F_{magnetic}}{qv} = \dfrac{3.7 \times 10^{-13}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(7.8 \times 10^{6}\ \text{m/s})} = \boxed{0.30\ \text{T}}$
457. $q = 1.60 \times 10^{-19}$ C $v = 2.2 \times 10^{6}$ m/s $B = 1.1 \times 10^{-2}$ T	$F_{magnetic} = qvB = (1.60 \times 10^{-19}\ \text{C})(2.2 \times 10^{6}\ \text{m/s})(1.1 \times 10^{-2}\ \text{T}) = \boxed{3.9 \times 10^{-15}\ \text{N}}$
458. $B = 1 \times 10^{-8}$ T $q = 1.60 \times 10^{-19}$ C $F_{magnetic} = 3.2 \times 10^{-22}$ N	$v = \dfrac{F_{magnetic}}{qB} = \dfrac{3.2 \times 10^{-22}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(1 \times 10^{-8}\ \text{T})} = \boxed{2 \times 10^{5}\ \text{m/s}}$
459. $\ell = 10$ m $m = 75$ kg $B = 4.8 \times 10^{-4}$ T $g = 9.81$ m/s^2	$mg = BI\ell$ $I = \dfrac{mg}{B\ell} = \dfrac{(75\ \text{kg})(9.81\ \text{m/s}^2)}{(4.8 \times 10^{-4}\ \text{T})(10\ \text{m})} = \boxed{1.5 \times 10^{5}\ \text{A}}$
460. $I = 1.5 \times 10^{3}$ A $\ell = 15$ km $= 1.4 \times 10^{4}$ m $\theta = 45°$ $B = 2.3 \times 10^{-5}$ T	$F_{magnetic} = B\cos\theta I\ell = (2.3 \times 10^{-5}\ \text{T})\cos 45°(1.5 \times 10^{3}\ \text{A})(1.5 \times 10^{4}\ \text{m})$ $F_{magnetic} = \boxed{3.7 \times 10^{2}\ \text{N}}$

Electromagnetic Induction

461. $N = 540$ turns $A = 0.016$ m^2 $\theta_i = 0°$ $\theta_f = 90.0°$ $\Delta t = 0.05$ s emf $= 3.0$ V	$B = \dfrac{\text{emf}\,\Delta t}{-NA\Delta\cos\theta} = \dfrac{\text{emf}\,\Delta t}{-NA[\cos\theta_f - \cos\theta_i]}$ $B = \dfrac{(3.0\ \text{V})(0.05\ \text{s})}{-(540)(0.016\ \text{m}^2)[\cos 90.0° - \cos 0°]}$ $B = \boxed{1.7 \times 10^{-2}\ \text{T}}$

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Givens | *Solutions*

462. $N = 550$ turns
$A = 5.0 \times 10^{-5}\ m^2$
$\Delta B = 2.5 \times 10^{-4}$ T
$\Delta t = 2.1 \times 10^{-5}$ s
$\theta = 0°$

$$emf = \frac{-NA\Delta B \cos\theta}{\Delta t}$$

$$emf = \frac{-(550)(5.0 \times 10^{-5}\ m^2)(2.5 \times 10^{-4}\ T)(\cos 0°)}{2.1 \times 10^{-5}\ s}$$

$$emf = \boxed{0.33\ V}$$

463. $N = 246$ turns
$A = 0.40\ m^2$
$\theta = 0°$
$B_i = 0.237$ T
$B_f = 0.320$ T
$\Delta t = 0.9$ s
emf = 9.1 V

$$\Delta t = \frac{-NA\Delta B\cos\theta}{emf} = \frac{-NA[B_f - B_i]\cos\theta}{emf}$$

$$\Delta t = \frac{-(246)(0.40\ m^2)[0.320\ T - 0.237\ T](\cos 0°)}{9.1\ V}$$

$$\Delta t = \boxed{0.90\ s}$$

464. $emf = 9.5$ V
$\theta_i = 0.0°$
$\theta_f = 90.0°$
$B = 1.25 \times 10^{-2}$ T
$\Delta t = 25$ ms
$A = 250\ cm^2$

$$N = \frac{emf\,\Delta t}{-A\Delta(B\cos\theta)} = \frac{emf\,\Delta t}{-AB(\cos\theta_f - \cos\theta_i)}$$

$$N = \frac{(9.5\ V)(25 \times 10^{-3}\ s)}{-(250\ cm^2)(1.25 \times 10^{-2}\ T)(\cos 90.0° - \cos 0.0°)}$$

$$N = \boxed{7.6 \times 10^2\ \text{turns}}$$

465. $\Delta V_{rms} = 320$ V
$R = 100\ \Omega$

$$\Delta V_{max} = \frac{\Delta V_{rms}}{0.707} = \frac{320\ V}{0.707} = \boxed{450\ V}$$

466. $\Delta V_{rms} = 320$ V
$R = 100\ \Omega$

$$I_{rms} = \frac{\Delta V_{rms}}{R} = \frac{320\ V}{100\ \Omega} = \boxed{3\ A}$$

467. $I_{rms} = 1.3$ A

$$I_{max} = \frac{I_{rms}}{0.707} = \frac{1.3\ A}{0.707} = \boxed{1.8\ A}$$

468. $\Delta V_2 = 6.9 \times 10^3$ V
$N_1 = 1400$ turns
$N_2 = 140$ turns

$$\Delta V_1 = \Delta V_2 \frac{N_1}{N_2} = (6.9 \times 10^3\ V)\left(\frac{1400}{140}\right) = \boxed{6.9 \times 10^4\ V}$$

469. $\Delta V_1 = 5600$ V
$N_1 = 140$ turns
$N_2 = 840$ turns

$$\Delta V_2 = \Delta V_1 \frac{N_2}{N_1} = (5600\ V)\left(\frac{840}{140}\right) = \boxed{3.4 \times 10^4\ V}$$

470. $\Delta V_1 = 1800$ V
$\Delta V_2 = 3600$ V
$N_1 = 58$ turns

$$N_2 = N_1 \frac{\Delta V_2}{\Delta V_1} = (58\ \text{turns})\left(\frac{1800\ V}{3600\ V}\right) = \boxed{29\ \text{turns}}$$

471. $\Delta V_1 = 4900$ V
$\Delta V_2 = 4.9 \times 10^4$ V
$N_2 = 480$ turns

$$N_1 = N_2 \frac{\Delta V_1}{\Delta V_2} = (480)\left(\frac{4900\ V}{4.9 \times 10^4\ V}\right) = \boxed{48\ \text{turns}}$$

Givens | *Solutions*

472. $N = 320$ turns
$\theta_i = 0.0°$
$\theta_f = 90.0°$
$B = 0.046$ T
$\Delta t = 0.25$ s
emf $= 4.0$ V

$$A = \frac{\text{emf}\,\Delta t}{-N\Delta(B\cos\theta)} = \frac{\text{emf}\,\Delta t}{-NB(\cos\theta_f - \cos\theta_i)}$$

$$A = \frac{(4.0\text{ V})(0.25\text{ s})}{-(320)(0.046\text{ T})(\cos 90.0° - \cos 0.0°)}$$

$$A = \boxed{6.8 \times 10^{-2}\text{ m}^2}$$

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473. $N = 180$ turns
$A = 5.0 \times 10^{-5}\text{ m}^2$
$\Delta B = 5.2 \times 10^{-4}$ T
$\theta = 0°$
$\Delta t = 1.9 \times 10^{-5}$ s
$R = 1.0 \times 10^2\,\Omega$

$$\text{emf} = \frac{-NA\Delta B\cos\theta}{\Delta t}$$

$$\text{emf} = \frac{-(180)(5.0 \times 10^{-5}\text{ m}^2)(5.2 \times 10^{-4}\text{ T})(\cos 0°)}{1.9 \times 10^{-5}\text{ s}}$$

$$\text{emf} = 0.25\text{ V}$$

$$I = \frac{\text{emf}}{R} = \frac{0.25\text{ V}}{1.0 \times 10^2\,\Omega} = \boxed{2.5 \times 10^{-3}\text{ A} = 25\text{ mA}}$$

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474. $I_{max} = 1.2$ A
$\Delta V_{max} = 211$ V

$$\Delta V_{rms} = 0.707\,V_{max} = 0.707(211\text{ V}) = \boxed{149\text{ V}}$$

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475. $I_{max} = 1.2$ A
$\Delta V_{max} = 211$ V

$$I_{rms} = 0.707\,I_{max} = 0.707(1.2\text{ A}) = \boxed{0.85\text{ A}}$$

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476. $V_{max} = 170$ V

$$\Delta V_{rms} = 0.707\,V_{max} = 0.707(170\text{ V}) = \boxed{120\text{ V}}$$

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477. $\Delta V_1 = 240$ V
$\Delta V_2 = 5.0$ V

$$\frac{N_1}{N_2} = \frac{\Delta V_1}{\Delta V_2} = \frac{240\text{ V}}{5.0\text{ V}} = \boxed{48{:}1}$$

Atomic Physics

478. $\lambda = 527\text{ nm} = 5.27 \times 10^{-7}$ m

$$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\text{ J•s})(3.00 \times 10^8\text{ m/s})}{5.27 \times 10^{-7}\text{ m}} = \boxed{3.77 \times 10^{-19}\text{ J}}$$

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479. $m_e = 9.109 \times 10^{-31}$ kg
$v = 2.19 \times 10^6$ m/s

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}\text{ J•s}}{(9.109 \times 10^{-31}\text{ kg})(2.19 \times 10^6\text{ m/s})} = \boxed{3.32 \times 10^{-10}\text{ m}}$$

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480. $E = 20.7$ eV

$$f = \frac{E}{h} = \frac{(20.7\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})}{6.63 \times 10^{-34}\text{ J•s}} = \boxed{5.00 \times 10^{15}\text{ Hz}}$$

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481. $E = 12.4$ MeV
$= 1.24 \times 10^7$ eV

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\text{ J•s})(3.00 \times 10^8\text{ m/s})}{(1.24 \times 10^7\text{ eV})(1.60 \times 10^{-19}\text{ J/eV})} = \boxed{1.00 \times 10^{-13}\text{ m}}$$

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482. $\lambda = 240\text{ nm} = 2.4 \times 10^{-7}$ m
$hf_t = 2.3$ eV

$$KE_{max} = \frac{hc}{\lambda} - hf_t$$

$$KE_{max} = \frac{(6.63 \times 10^{-34}\text{ J•s})(3.00 \times 10^8\text{ m/s})}{2.4 \times 10^{-7}\text{ m})(1.60 \times 10^{-19}\text{ J/eV})} - 2.3\text{ eV}$$

$$KE_{max} = 5.2\text{ eV} - 2.3\text{ eV} = \boxed{2.9\text{ eV}}$$

Givens	*Solutions*
483. $hf_t = 4.1$ eV	$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(4.1\ \text{eV})(1.60 \times 10^{-19}\ \text{eV})} = \boxed{3.0 \times 10^{-7}\ \text{m} = 300\ \text{nm}}$
484. $\lambda = 2.64 \times 10^{-14}$ m $m_p = 1.67 \times 10^{-27}$ kg	$v = \frac{\text{h}}{m\lambda} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(1.67 \times 10^{-27}\ \text{kg})(2.64 \times 10^{-14}\ \text{m})} = \boxed{1.50 \times 10^{7}\ \text{m/s}}$
485. $v = 28$ m/s $\lambda = 8.97 \times 10^{-37}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(8.97 \times 10^{-37}\ \text{m})(28\ \text{m/s})} = \boxed{26\ \text{kg}}$
486. $\lambda = 430.8$ nm $= 4.308 \times 10^{-7}$ m	$E = hf = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{4.308 \times 10^{-7}\ \text{m}} = \boxed{4.62 \times 10^{-19}\ \text{J}}$
487. $E = 1.78$ eV	$f = \frac{E}{h} = \frac{(1.78\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}} = \boxed{4.30 \times 10^{14}\ \text{Hz}}$
488. $E = 3.1 \times 10^{-6}$ eV	$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(3.1 \times 10^{-6}\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})} = \boxed{0.40\ \text{m}}$
489. $f = 6.5 \times 10^{14}$ Hz $KE_{max} = 0.20$ eV	$f_t = \frac{hf - KE_{max}}{h}$ $f_t = \frac{[(6.63 \times 10^{-34}\ \text{J•s})(6.5 \times 10^{14}\ \text{Hz}) - (0.20\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})]}{6.63 \times 10^{-34}\ \text{J•s}}$ $f_t = \boxed{6.0 \times 10^{14}\ \text{Hz}}$
490. $\lambda = 519$ nm $= 5.19 \times 10^{-7}$ m $hf_t = 2.16$ eV	$KE_{max} = \frac{hc}{\lambda} - hf_t$ $KE_{max} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(5.19 \times 10^{-7}\ \text{m})(1.60 \times 10^{-19}\ \text{J/eV})} - 2.16\ \text{eV}$ $KE_{max} = 2.40\ \text{eV} - 2.16\ \text{eV} = \boxed{0.24\ \text{eV}}$
491. $v = 5.6 \times 10^{-6}$ m/s $\lambda = 2.96 \times 10^{-8}$ m	$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(2.96 \times 10^{-8}\ \text{m})(5.6 \times 10^{-6}\ \text{m/s})} = \boxed{4.0 \times 10^{-21}\ \text{kg}}$
492. $f_t = 1.36 \times 10^{15}$ Hz	$hf_t = \frac{(6.63 \times 10^{-34}\ \text{J•s})(1.36 \times 10^{15}\ \text{Hz})}{1.60 \times 10^{-19}\ \text{J/eV}} = \boxed{5.64\ \text{eV}}$
493. $m = 7.6 \times 10^{7}$ kg $v = 35$ m/s	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}\ \text{J•s}}{(7.6 \times 10^{7}\ \text{kg})(35\ \text{m/s})} = \boxed{2.5 \times 10^{-43}\ \text{m}}$
494. $hf_t = 5.0$ eV	$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(5.0\ \text{eV})(1.60 \times 10^{-19}\ \text{eV})} = \boxed{2.5 \times 10^{-7}\ \text{m} = 250\ \text{nm}}$

Givens	Solutions
495. $f = 9.89 \times 10^{14}$ Hz $KE_{max} = 0.90$ eV	$f_t = \dfrac{hf - KE_{max}}{h}$ $f_t = \dfrac{(6.63 \times 10^{-34}\ \text{J•s})(9.89 \times 10^{14}\ \text{Hz}) - (0.90\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}{6.63 \times 10^{-34}\ \text{J•s}}$ $f_t = \boxed{7.72 \times 10^{14}\ \text{Hz}}$
496. $m_n = 1.675 \times 10^{-27}$ kg $\lambda = 5.6 \times 10^{-14}$ m	$v = \dfrac{h}{m\lambda} = \dfrac{6.63 \times 10^{-34}\ \text{J•s}}{(1.675 \times 10^{-27}\ \text{kg})(5.6 \times 10^{-14}\ \text{m})} = \boxed{7.1 \times 10^{6}\ \text{m/s}}$

Subatomic Physics

Givens	Solutions
497. Z = 19 A = 39 atomic mass of K-39 = 38.963 708 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u	$N = A - Z = 39 - 19 = 20$ $\Delta m = Z$ (atomic mass of H) + Nm_n – atomic mass of K-39 $\Delta m = 19(1.007\ 825) + 20\ (1.008\ 665\ \text{u}) – 38.963\ 708\ \text{u}$ $\Delta m = 19.148\ 675\ \text{u} + 20.173\ 300\ \text{u} - 38.963\ 708\ \text{u}$ $\Delta m = 0.358\ 267$ u $E_{bind} = (0.358\ 267\ \text{u})(931.50\ \text{MeV/u}) = \boxed{333.73\ \text{MeV}}$
498. For $^{107}_{47}$Ag: $Z = 47$ $A = 107$ atomic mass of Ag-107 = 106.905 091 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u	$N = A - Z = 107 - 47 = 60$ Δm = Z(atomic mass of H) + Nm_n – atomic mass of Ag-107 $\Delta m = 47(1.007\ 825\ \text{u}) + 60(1.008\ 665\ \text{u}) - 106.905\ 091\ \text{u}$ $\Delta m = 47.367\ 775\ \text{u} + 60.519\ 900\ \text{u} - 106.905\ 091\ \text{u}$ $\Delta m = 0.982\ 584$ u $E_{bind} = (0.982\ 584\ \text{u})(931.50\ \text{MeV/u}) = 915.28$ MeV
For $^{63}_{29}$Cu: $Z = 29$ $A = 63$ atomic mass of Cu-63 = 62.929 599 u	$N = A - Z = 63 - 29 = 34$ Δm = Z(atomic mass of H) + Nm_n – atomic mass of Cu-63 $\Delta m = 29(1.007\ 825\ \text{u}) + 34(1.008\ 665\ \text{u}) - 62.929\ 599\ \text{u}$ $\Delta m = 29.226\ 925\ \text{u} + 34.294\ 610\ \text{u} - 62.929\ 599\ \text{u}$ $\Delta m = 0.591\ 936$ u $E_{bind} = (0.591\ 936\ \text{u})(931.50\ \text{MeV/u}) = 551.39$ MeV The difference in binding energy is 915.28 MeV – 551.39 MeV = $\boxed{363.89\ \text{MeV}}$
499. $A = 58$ $Z = 28$ atomic mass of Ni-58 = 57.935 345 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u	$N = A - Z = 58 - 28 = 30$ $\Delta m = Z$(atomic mass of H) + Nm_n – atomic mass of Ni-58 $\Delta m = 28(1.007\ 825\ \text{u}) + 30(1.008\ 665\ \text{u}) - 57.935\ 345\ \text{u}$ $\Delta m = 28.219\ 100\ \text{u} + 30.259\ 950\ \text{u} - 57.935\ 345\ \text{u}$ $\Delta m = \boxed{0.543\ 705\ \text{u}}$

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Givens	Solutions
500. $^{212}_{84}Po \rightarrow ? + ^{4}_{2}He$	$A = 212 - 4 = 208$ $Z = 84 - 2 = 82$ $? = \boxed{^{208}_{82}Pb}$
501. $^{16}_{7}N \rightarrow ? + ^{0}_{-1}e + \overline{\nu}$	$A = 16 - 0 = 16$ $Z = 7 - (-1) = 8$ $? = \boxed{^{16}_{8}O}$
502. $^{147}_{62}Sm \rightarrow ^{143}_{60}Nd + ? + \overline{\nu}$	$A = 147 - 143 = 4$ $Z = 62 - 60 = 2$ $? = \boxed{^{4}_{2}He}$
503. $m_i = 3.29 \times 10^{-3}$ g $m_f = 8.22 \times 10^{-4}$ g $\Delta t = 30.0$ s	$\frac{m_f}{m_i} = \frac{8.22 \times 10^{-4} \text{ g}}{3.29 \times 10^{-3} \text{ g}} = \frac{1}{4}$ If $\frac{1}{4}$ of the sample remains after 30.0 s, then $\frac{1}{2}$ of the sample must have remained after 15.0 s, so $T_{1/2} = \boxed{15.0 \text{ s}}$.
504. $T_{1/2} = 21.6$ h $N = 6.5 \times 10^6$	$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{(21.6 \text{ h})(3600 \text{ s/h})} = 8.90 \times 10^{-6} \text{ s}^{-1}$ $\text{activity} = N\lambda = \frac{(8.9 \times 10^{-6} \text{ s}^{-1})(6.5 \times 10^6)}{3.7 \times 10^{10} \text{ s}^{-1}\text{/Ci}} = \boxed{1.5 \times 10^{-9} \text{ Ci}}$
505. $T_{1/2} = 10.64$ h	For the sample to reach $\frac{1}{2}$ its original strength, it takes 10.64 h. For the sample to reach $\frac{1}{4}$ its original strength, it takes 2(10.64 h) = 21.28 h. For the sample to reach $\frac{1}{8}$ its original strength, it takes 3(10.64 h) = $\boxed{31.92 \text{ h}}$
506. $Z = 50$ $A = 120$ atomic mass of Sn-120 = 119.902 197 atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u	$N = A - Z = 120 - 50 = 70$ $\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of Sn-120}$ $\Delta m = 50(1.007\ 825 \text{ u}) + 70(1.008\ 665 \text{ u}) - 119.902\ 197 \text{ u}$ $\Delta m = 50.391\ 25 \text{ u} + 70.606\ 55 \text{ u} - 119.902\ 197 \text{ u}$ $\Delta m = 1.095\ 60 \text{ u}$ $E_{bind} = (1.095\ 60 \text{ u})(931.50 \text{ MeV/u}) = \boxed{1020.6 \text{ MeV}}$

Givens | *Solutions*

507. For $^{12}_{6}C$:

$Z = 6$

$A = 12$

atomic mass of C-12 $= 12.000\ 000$ u

atomic mass of H $= 1.007\ 825$ u

$m_n = 1.008\ 665$ u

$N = A - Z = 12 - 6 = 6$

$\Delta m = Z$ (atomic mass of H) $+ Nm_n -$ atomic mass of C-12

$\Delta m = 6(1.007\ 825\ \text{u}) + 6(1.008\ 665\text{u}) - 12.000\ 000\ \text{u}$

$\Delta m = 6.046\ 95\ \text{u} + 6.051\ 99\ \text{u} - 12.000\ 000\ \text{u}$

$\Delta m = 0.098\ 94\ \text{u}$

$E_{bind} = (0.098\ 94\ \text{u})(931.50\ \text{MeV/u}) = 92.163\ \text{MeV}$

For $^{16}_{8}O$:

$Z = 8$

$A = 16$

atomic mass of O-16 $= 15.994\ 915$

$N = A - Z = 16 - 8 = 8$

$\Delta m = Z$ (atomic mass of H) $+ Nm_n -$ atomic mass of O-16

$\Delta m = 8(1.007\ 825\ \text{u}) + 8(1.008\ 665\text{u}) - 15.994\ 915\ \text{u}$

$\Delta m = 8.0626\ \text{u} + 8.06932\ \text{u} - 15.994\ 915\ \text{u}$

$\Delta m = 0.1370\ \text{u}$

$E_{bind} = (0.1370\ \text{u})(931.50\ \text{MeV/u}) = 127.62\ \text{MeV}$

The difference in binding energy is

$127.62\ \text{MeV} - 92.163\ \text{MeV} = \boxed{35.46\ \text{MeV}}$

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508. $A = 64$

$Z = 30$

atomic mass of Zn-64 $= 63.929\ 144$ u

atomic mass of H $= 1.007\ 825$ u

$m_n = 1.008\ 665$ u

$N = A - Z = 64 - 30 = 34$

$\Delta m = Z$(atomic mass of H) $+ Nm_n -$ atomic mass of Zn-64

$\Delta m = 30(1.007\ 825\ \text{u}) + 34(1.008\ 665\ \text{u}) - 63.929\ 144\ \text{u}$

$\Delta m = 30.234\ 750\ \text{u} + 34.294\ 610\ \text{u} - 63.929\ 144\ \text{u}$

$\Delta m = \boxed{0.600\ 216\ \text{u}}$

---

509. $? \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e + \overline{\nu}$

$A = 131 + 0 = 131$

$Z = 54 + (-1) = 53$

$? = \boxed{{}^{131}_{53}I}$

---

510. ${}^{160}_{74}W \rightarrow {}^{156}_{72}Hf + ?$

$A = 160 - 156 = 4$

$Z = 74 - 72 = 2$

$? = \boxed{{}^{4}_{2}He}$

---

511. $? \rightarrow {}^{107}_{52}Te + {}^{4}_{2}He$

$A = 107 + 4 = 111$

$Z = 52 + 2 = 54$

$? = \boxed{{}^{111}_{54}Xe}$

---

512. $m_i = 4.14 \times 10^{-4}$ g

$m_f = 2.07 \times 10^{-4}$ g

$\Delta t = 1.25$ days

$\frac{m_f}{m_i} = \frac{2.07 \times 10^{-4}\ \text{g}}{4.14 \times 10^{-4}\ \text{g}} = \frac{1}{2}$

If $\frac{1}{2}$ of the sample remains after 1.25 days, then $T_{1/2} = \boxed{1.25\ \text{days}}$

Givens	*Solutions*
513. $T_{1/2} = 462$ days	For the sample to reach $\frac{1}{2}$ its original strength, it takes 462 days. For the sample to reach $\frac{1}{4}$ its original strength, it takes 2(462 days) = $\boxed{924 \text{ days}}$
514. $T_{1/2} = 2.7$ y $N = 3.2 \times 10^9$	$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{(2.7 \text{ y})(3.156 \times 10^7 \text{ s/y})} = \boxed{8.1 \times 10^{-9} \text{ s}^{-1}}$

I

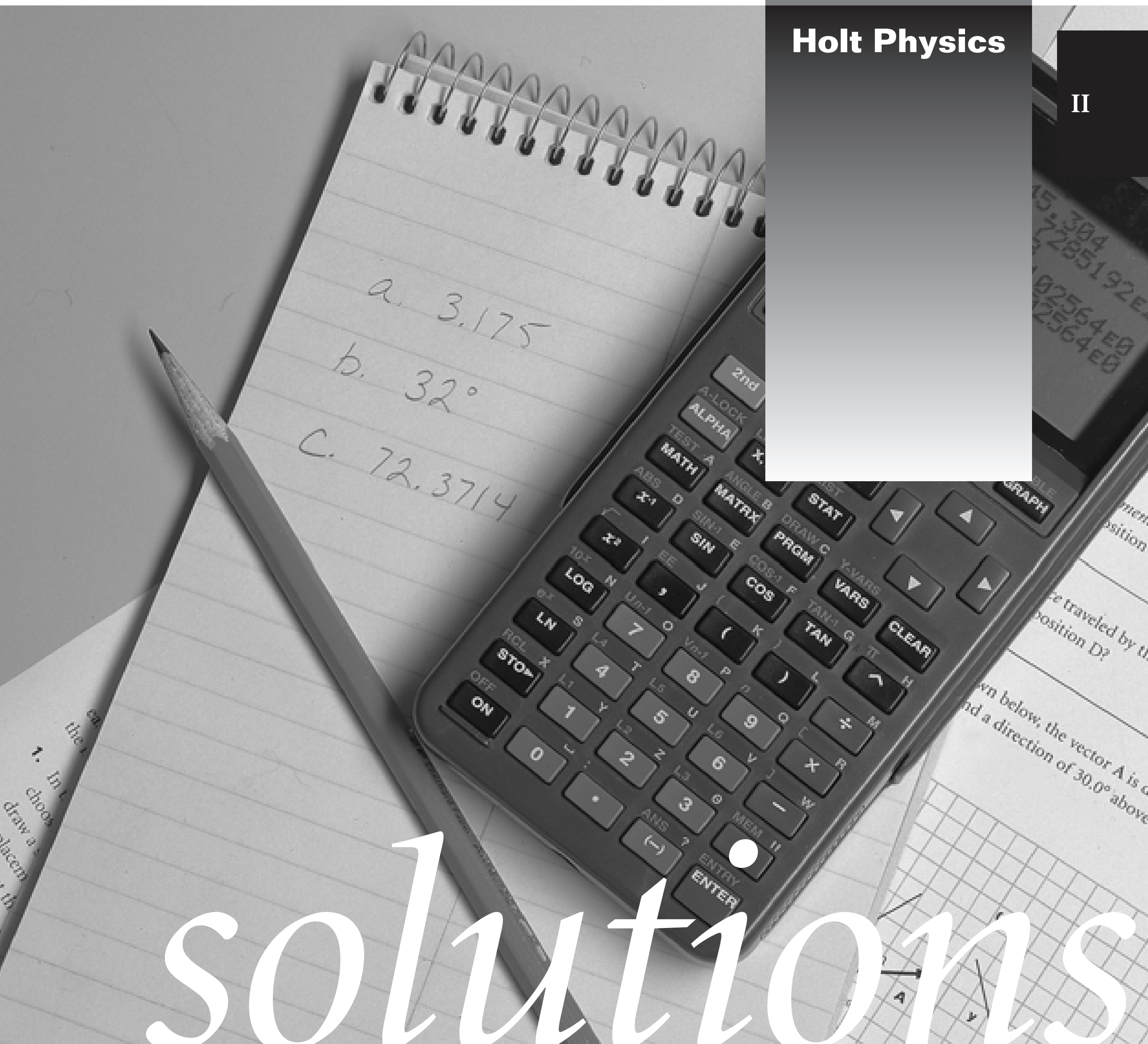
Section

II

Problem Workbook Solutions

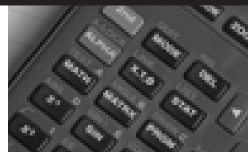
Holt Physics

II



solutions

Problem Workbook Solutions



The Science of Physics

II

Additional Practice A

Givens	*Solutions*
1. *distance* = 4.35 light years	$distance = 4.35 \cancel{\text{light years}} \times \dfrac{9.461 \times 10^{15}\ \text{m}}{1 \cancel{\text{light year}}} = 4.12 \times 10^{16}\ \text{m}$
	a. $distance = 4.12 \times 10^{16}\ \cancel{\text{m}} \times \dfrac{1\ \text{Mm}}{10^{6}\ \cancel{\text{m}}} = \boxed{4.12 \times 10^{10}\ \text{Mm}}$
	b. $distance = 4.12 \times 10^{16}\ \cancel{\text{m}} \times \dfrac{1\ \text{pm}}{10^{-12}\ \cancel{\text{m}}} = \boxed{4.12 \times 10^{28}\ \text{pm}}$
2. *energy* = 1.2×10^{44} J	**a.** $energy = 1.2 \times 10^{44}\ \cancel{\text{J}} \times \dfrac{1\ \text{kJ}}{10^{3}\ \cancel{\text{J}}} = \boxed{1.2 \times 10^{41}\ \text{kJ}}$
	b. $energy = 1.2 \times 10^{44}\ \cancel{\text{J}} \times \dfrac{1\ \text{nJ}}{10^{-9}\ \cancel{\text{J}}} = \boxed{1.2 \times 10^{53}\ \text{nJ}}$
3. $m = 1.0 \times 10^{-16}$ g	**a.** $m = 1.0 \times 10^{-16}\ \cancel{\text{g}} \times \dfrac{1\ \text{Pg}}{10^{15}\ \cancel{\text{g}}} = \boxed{1.0 \times 10^{-31}\ \text{Pg}}$
	b. $m = 1.0 \times 10^{-16}\ \cancel{\text{g}} \times \dfrac{1\ \text{fg}}{10^{-15}\ \cancel{\text{g}}} = \boxed{0.10\ \text{fg}}$
	c. $m = 1.0 \times 10^{-16}\ \cancel{\text{g}} \times \dfrac{1\ \text{ag}}{10^{-18}\ \cancel{\text{g}}} = \boxed{1.0 \times 10^{2}\ \text{ag}}$
4. *distance* = 152 100 000 km	**a.** $distance = 152\ 100\ 000\ \cancel{\text{km}} \times \dfrac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \dfrac{1\ \text{ym}}{10^{-24}\ \cancel{\text{m}}} = \boxed{1.521 \times 10^{35}\ \text{ym}}$
	b. $distance = 152\ 100\ 000\ \cancel{\text{km}} \times \dfrac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}} \times \dfrac{1\ \text{Ym}}{10^{24}\ \cancel{\text{m}}} = \boxed{1.521 \times 10^{-13}\ \text{Ym}}$
5. *energy* = 2.1×10^{15} W•h	**a.** $energy = 2.1 \times 10^{15}\ \cancel{\text{W}} \bullet \cancel{\text{h}} \times \dfrac{1\ \text{J}/\cancel{\text{s}}}{1\ \cancel{\text{W}}} \times \dfrac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}} = \boxed{7.6 \times 10^{18}\ \text{J}}$
	b. $energy = 7.6 \times 10^{18}\ \cancel{\text{J}} \times \dfrac{1\ \text{GJ}}{10^{9}\ \cancel{\text{J}}} = \boxed{7.6 \times 10^{9}\ \text{GJ}}$
6. $m = 1.90 \times 10^{5}$ kg	$m = 1.90 \times 10^{5}\ \cancel{\text{kg}} \times \dfrac{1\ \text{eV}}{1.78 \times 10^{-36}\ \cancel{\text{kg}}} = 1.07 \times 10^{41}\ \text{eV}$
	a. $m = 1.07 \times 10^{41}\ \cancel{\text{eV}} \times \dfrac{1\ \text{MeV}}{10^{6}\ \cancel{\text{eV}}} = \boxed{1.07 \times 10^{35}\ \text{MeV}}$
	b. $m = 1.07 \times 10^{41}\ \cancel{\text{eV}} \times \dfrac{1\ \text{TeV}}{10^{12}\ \cancel{\text{eV}}} = \boxed{1.07 \times 10^{29}\ \text{TeV}}$

Givens | *Solutions*

7. $m = (200)(2 \times 10^{30}\ \text{kg}) = 4 \times 10^{32}\ \text{kg}$

a. $m = 4 \times 10^{32}\ \cancel{\text{kg}} \times \dfrac{10^3\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \dfrac{10^3\text{mg}}{1\ \cancel{\text{g}}} = \boxed{4 \times 10^{38}\ \text{mg}}$

b. $m = 4 \times 10^{32}\ \cancel{\text{kg}} \times \dfrac{10^3\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \dfrac{1\ \text{Eg}}{10^{18}\ \cancel{\text{g}}} = \boxed{4 \times 10^{17}\ \text{Eg}}$

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8. $area = 166\ 241\ 700\ \text{km}^2$

$depth = 3940\ \text{m}$

$V = volume = \text{area} \times \text{depth}$

$$V = (166\ 241\ 700\ \cancel{\text{km}^2})(3940\ \text{m}) \times \left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)^2$$

$V = 6.55 \times 10^{17}\ \text{m}^3$

a. $V = 6.55 \times 10^{17}\ \cancel{\text{m}^3} \times \dfrac{10^6\ \text{cm}^3}{1\ \cancel{\text{m}^3}} = \boxed{6.55 \times 10^{23}\ \text{cm}^3}$

b. $V = 6.55 \times 10^{17}\ \cancel{\text{m}^3} \times \dfrac{10^9\ \text{mm}^3}{1\ \cancel{\text{m}^3}} = \boxed{6.55 \times 10^{26}\ \text{mm}^3}$

II

Motion In One Dimension

Additional Practice A

Givens	*Solutions*
1. $\Delta x = 443$ m $v_{avg} = 0.60$ m/s	$\Delta t = \frac{\Delta x}{v_{avg}} = \frac{443 \text{ m}}{0.60 \text{ m/s}} = \boxed{740 \text{ s} = 12 \text{ min}, 20 \text{ s}}$
2. $v_{avg} = 72$ km/h $\Delta x = 1.5$ km	$\Delta t = \frac{\Delta x}{v_{avg}} = \frac{1.5 \text{ km}}{\left(72 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)} = \boxed{75 \text{ s}}$
3. $\Delta x = 5.50 \times 10^2$ m $v_{avg} = 1.00 \times 10^2$ km/h	**a.** $\Delta t = \frac{\Delta x}{v_{avg}} = \frac{5.50 \times 10^2 \text{ m}}{\left(1.00 \times 10^2 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)} = \boxed{19.8 \text{ s}}$
$v_{avg} = 85.0$ km/h	**b.** $\Delta x = \Delta v_{avg} \Delta t$ $\Delta x = (85.0 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)(19.8 \text{ s}) = \boxed{468 \text{ m}}$
4. $\Delta x_1 = 1.5$ km $v_1 = 85$ km/h $\Delta x_1 = 0.80$ km $v_2 = 67$ km/h	**a.** $\Delta t_{tot} = \Delta t_1 + \Delta t_2 = \frac{\Delta x_1}{v_1} + \frac{\Delta x_2}{v_2}$ $\Delta t_{tot} = \frac{1.5 \text{ km}}{\left(85 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)} + \frac{0.80 \text{ km}}{\left(67 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)} = 64 \text{ s} + 43 \text{ s} = \boxed{107 \text{ s}}$ **b.** $v_{avg} = \frac{\Delta x_1 + \Delta x_2}{\Delta t_1 + \Delta t_2} = \frac{1.5 \text{ km} + 0.80 \text{ km}}{(64 \text{ s} + 43 \text{ s})\left(\frac{1 \text{ h}}{3600}\right)} = \frac{2.3 \text{ km}}{(107 \text{ s})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)} = \boxed{77 \text{ km/h}}$
5. $r = 7.1 \times 10^4$ km $\Delta t = 9$ h, 50 min	$\Delta x = 2\pi r$ $v_{avg} = \frac{\Delta x}{\Delta t} = \frac{2\pi(7.1 \times 10^7 \text{ m})}{\left[(9 \text{ h})\left(\frac{60 \text{ min}}{1 \text{ h}}\right) + 50 \text{ min}\right]\left(\frac{60 \text{ s}}{1 \text{ min}}\right)} = \frac{4.5 \times 10^8 \text{ m}}{(540 \text{ min} + 50 \text{ min})\left(\frac{60 \text{ s}}{1 \text{ min}}\right)}$ $v_{avg} = \frac{4.5 \times 10^8 \text{ m}}{(590 \text{ min})\left(\frac{60 \text{ s}}{1 \text{ min}}\right)}$ $v_{avg} = \boxed{1.3 \times 10^4 \text{ m/s}}$ Thus the average speed $= 1.3 \times 10^4$ m/s. On the other hand, the average velocity for this point is zero, because the point's displacement is zero.

II

Givens	*Solutions*
6. $\Delta x = -1.73$ km $\Delta t = 25$ s	$v_{avg} = \dfrac{\Delta x}{\Delta t} = \dfrac{-1.73 \times 10^3 \text{ m}}{25 \text{ s}} = \boxed{-69 \text{ m/s} = -250 \text{ km/h}}$
7. $v_{avg,1} = 18.0$ km/h $\Delta t_1 = 2.50$ s $\Delta t_2 = 12.0$ s	**a.** $\Delta x_1 = v_{avg,1}\Delta t_1 = (18.0 \text{ km/h})\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)(2.50\text{s}) = 12.5 \text{ m}$ $\Delta x_2 = -\Delta x_1 = -12.5$ m $v_{avg,2} = \dfrac{\Delta x_2}{\Delta t_2} = \dfrac{-12.5 \text{ m}}{12.0 \text{ s}} = \boxed{-1.04 \text{ m/s}}$ **b.** $v_{avg,tot} = \dfrac{\Delta x_1 + \Delta x_2}{\Delta t_1 + \Delta t_2} = \dfrac{12.5 \text{ m} + (-12.5 \text{ m})}{2.50 \text{ s} + 12.0 \text{ s}} = \dfrac{0.0 \text{ m}}{14.5 \text{ s}} = \boxed{0.0 \text{ m/s}}$ **c.** *total distance traveled* $= \Delta x_1 - \Delta x_2 = 12.5 \text{ m} - (-12.5 \text{ m}) = 25.0$ m *total time of travel* $= \Delta t_1 + \Delta t_2 = 2.50 \text{ s} + 12.0 \text{ s} = 14.5$ s *average speed* $= \dfrac{\text{total distance}}{\text{total time}} = \dfrac{25.0 \text{ m}}{14.5 \text{ s}} = \boxed{1.72 \text{ m/s}}$
8. $\Delta x = 2.00 \times 10^2$ km $\Delta t = 5$ h, 40 min, 37 s	**a.** $v_{avg} = \dfrac{\Delta x}{\Delta t} = \dfrac{2.00 \times 10^5 \text{ m}}{\left[(5 \text{ h})\left(\dfrac{3600 \text{ s}}{\text{h}}\right) + (40 \text{ min})\left(\dfrac{60 \text{ s}}{\text{min}}\right) + 37 \text{ s}\right]} = \dfrac{2.00 \times 10^5 \text{m}}{20\,437 \text{ s}}$ $v_{avg} = \boxed{9.79 \text{ m/s} = 35.2 \text{ km/h}}$
$v_{avg}' = (1.05)v_{avg}$ $\Delta x' = \frac{1}{2}\Delta x$	**b.** $\Delta t = \dfrac{\Delta x'}{v_{avg}'} = \dfrac{\left(\dfrac{2.00 \times 10^5 \text{ m}}{2}\right)}{(1.05)\left(9.79 \dfrac{\text{m}}{\text{s}}\right)} = 9.73 \times 10^3 \text{ s}$ $\Delta t = (9.73 \times 10^3 \text{ s})\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right) = 2.70 \text{ h}$ $(0.70 \text{ h})\left(\dfrac{60 \text{ min}}{1\text{h}}\right) = 42 \text{ min}$ $\Delta t = \boxed{2 \text{ h, 42 min}}$

II

Additional Practice B

Givens	*Solutions*
1. $v_i = 0$ km/h $= 0$ m/s $a_{avg} = 1.8$ m/s^2 $\Delta t = 1.00$ min	$v_f = a_{avg}\Delta t + v_i = (1.80 \text{ m/s}^2)(1.00 \text{ min})\left(\frac{60 \text{ s}}{1 \text{ min}}\right) + 0 \text{ m/s} = \boxed{108 \text{ m/s}}$ $v_f = 108 \text{ m/s} = (108 \text{ m/s})\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)\left(\frac{1 \text{ km}}{10^3 \text{ m}}\right) = \boxed{389 \text{ km/h}}$
2. $\Delta t = 2.0$ min $a_{avg} = 0.19$ m/s^2 $v_i = 0$ m/s	$v_f = a_{avg}\Delta t + v_i = (0.19 \text{ m/s}^2)(2.0 \text{ min})\left(\frac{60 \text{ s}}{1 \text{ min}}\right) + 0 \text{ m/s} = \boxed{23 \text{ m/s}}$
3. $\Delta t = 45.0$ s $a_{avg} = 2.29$ m/s^2 $v_i = 0$ m/s	$v_f = a_{avg}\Delta t + v_i = (2.29 \text{ m/s}^2)(45.0 \text{ s}) + 0 \text{ m/s} = \boxed{103 \text{ m/s}}$
4. $\Delta x = 29\,752$ m $\Delta t = 2.00$ h	**a.** $v_{avg} = \frac{\Delta x}{\Delta t} = \frac{29\,752 \text{ m}}{(2.00 \text{ h})\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)} = \boxed{4.13 \text{ m/s}}$
$v_i = 3.00$ m/s $v_f = 4.13$ m/s $\Delta t = 30.0$ s	**b.** $a_{avg} = \frac{\Delta v}{\Delta t} = \frac{4.13 \text{ m/s} - 3.00 \text{ m/s}}{30.0 \text{ s}} = \frac{1.13 \text{ m/s}}{30.0 \text{ s}} = \boxed{3.77 \times 10^{-2} \text{ m/s}^2}$
5. $\Delta x = (15 \text{ hops})\left(\frac{10.0 \text{ m}}{1 \text{ hop}}\right)$ $= 1.50 \times 10^2$ m $\Delta t = 60.0$ s $\Delta t_{stop} = 0.25$ s $v_f = 0$ m/s $v_i = v_{avg} = +2.50$ m/s	**a.** $v_{avg} = \frac{\Delta x}{\Delta t} = \frac{1.50 \times 10^2 \text{ m}}{60.0 \text{ s}} = \boxed{+2.50 \text{ m/s}}$ **b.** $a_{avg} = \frac{v_f - v_i}{\Delta t_{stop}} = \frac{0 \text{ m/s} - 2.50 \text{ m/s}}{0.25 \text{ s}} = \frac{-2.50 \text{ m/s}}{0.25 \text{ m/s}} = \boxed{-1.0 \times 10^1 \text{ m/s}^2}$
6. $\Delta x = 1.00 \times 10^2$ m, backward $= -1.00 \times 10^2$ m $\Delta t = 13.6$ s $\Delta t' = 2.00$ s $v_i = 0$ m/s $v_f = v_{avg}$	$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{-1.00 \times 1\,0^2 \text{ m}}{13.6 \text{ s}} = -7.35 \text{ m/s}$ $a_{avg} = \frac{v_f - v_i}{\Delta t'} = \frac{-7.35 \text{ m/s} - 0 \text{ m/s}}{2.00 \text{ s}} = \boxed{3.68 \text{ m/s}^2}$
7. $\Delta x = 150$ m $v_i = 0$ m/s $v_f = 6.0$ m/s $v_{avg} = 3.0$ m/s	**a.** $\Delta t = \frac{\Delta x}{v_{avg}} = \frac{150 \text{ m}}{3.0 \text{ m/s}} = \boxed{5.0 \times 10^1 \text{ s}}$ **b.** $a_{avg} = \frac{v_f - v_i}{\Delta t} = \frac{6.0 \text{ m/s} - 0 \text{ m/s}}{5.0 \times 10^1} = \boxed{0.12 \text{ m/s}^2}$

II

Givens	*Solutions*
8. $v_i = +245$ km/h $a_{avg} = -3.0$ m/s^2 $v_f = v_i - (0.200)\, v_i$	$v_i = \left(245 \frac{\text{km}}{\text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right) = +68.1$ m/s $v_f = (1.000 - 0.200)\, v_i = (0.800)(68.1\ \text{m/s}) = +54.5$ m/s $\Delta t = \frac{v_f - v_i}{a_{avg}} = \frac{54.5\ \text{m/s} - 68.1\ \text{m/s}}{-3.0\ \text{m/s}^2} = \frac{-13.6\ \text{m/s}}{-3.0\ \text{m/s}^2} = \boxed{4.5\ \text{s}}$
9. $\Delta x = 3.00$ km $\Delta t = 217.347$ s $a_{avg} = -1.72$ m/s^2 $v_f = 0$ m/s	$v_i = v_{avg} = \frac{\Delta x}{\Delta t} = \frac{3.00 \times 10^3\ \text{m}}{217.347\ \text{s}} = 13.8$ m/s $t_{stop} = \frac{v_f - v_i}{a_{avg}} = \frac{0\ \text{m/s} - 13.8\ \text{m/s}}{-1.72\ \text{m/s}^2} = \frac{-13.8\ \text{m/s}}{-1.72\ \text{m/s}^2} = \boxed{8.02\ \text{s}}$
10. $\Delta x = +5.00 \times 10^2$ m $\Delta t = 35.76$ s $v_i = 0$ m/s $\Delta t' = 4.00$ s $v_{max} = v_{avg} + (0.100)\, v_{avg}$	$v_f = v_{max} = (1.100)v_{avg} = (1.100)\left(\frac{\Delta x}{\Delta t}\right) = (1.100)\left(\frac{5.00 \times 10^2\ \text{m}}{35.76\ \text{s}}\right) = +15.4$ m/s $a_{avg} = \frac{\Delta v}{\Delta t'} = \frac{v_f - v_i}{\Delta t'} = \frac{15.4\ \text{m/s} - 0\ \text{m/s}}{4.00\ \text{s}} = \boxed{+3.85\ \text{m/s}^2}$

II

Additional Practice C

1. $\Delta x = 115$ m $v_i = 4.20$ m/s $v_f = 5.00$ m/s	$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(115\ \text{m})}{4.20\ \text{m/s} + 5.00\ \text{m/s}} = \frac{(2)(115\ \text{m})}{9.20\ \text{m/s}} = \boxed{25.0\ \text{s}}$
2. $\Delta x = 180.0$ km $v_i = 3.00$ km/s $v_f = 0$ km/s	$\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(180.0\ \text{km})}{3.00\ \text{km/s} + 0\ \text{km/s}} = \frac{360.0\ \text{km}}{3.00\ \text{km/s}} = \boxed{1.2 \times 10^2\ \text{s}}$
3. $v_i = 0$ km/h $v_f = 1.09 \times 10^3$ km/h $\Delta x = 20.0$ km	**a.** $\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(20.0 \times 10^3\ \text{m})}{(1.09 \times 10^3\ \text{km/h} + 0\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)}$ $\Delta t = \frac{40.0 \times 10^3\ \text{m}}{(1.09 \times 10^3\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)} = \boxed{132\ \text{s}}$
$\Delta x = 5.00$ km $v_i = 1.09 \times 10^3$ km/h $v_f = 0$ km/h	**b.** $\Delta t = \frac{2\Delta x}{v_i + v_f} = \frac{(2)(5.00 \times 10^3\ \text{m})}{(1.09 \times 10^3\ \text{km/h} + 0\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)}$ $\Delta t = \frac{10.0 \times 10^3\ \text{m}}{(1.09 \times 10^3\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)} = \boxed{33.0\ \text{s}}$

Givens	*Solutions*
4. $v_i = v_{avg} = 518$ km/h $v_f = (0.600)\ v_{avg}$ $\Delta t = 2.00$ min	$v_{avg} = \left(518\ \frac{km}{h}\right)\left(\frac{1\ h}{60\ min}\right)\left(\frac{10^3 m}{1\ km}\right) = 8.63 \times 10^3$ m/min $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}[v_{avg} + (0.600)\ v_{avg}]\Delta t = \frac{1}{2}(1.600)(8.63 \times 10^3 \text{ m/min})(2.00 \text{ min})$ $\Delta x = 13.8 \times 10^3 \text{ m} = \boxed{13.8 \text{ km}}$
5. $\Delta t = 30.0$ s $v_i = 30.0$ km/h $v_f = 42.0$ km/h	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(30.0 \text{ km/h} + 42.0 \text{ km/h})\left(\frac{1h}{3600\ s}\right)(30.0\ s)$ $\Delta x = \frac{1}{2}\left(72.0\ \frac{km}{h}\right)\left(\frac{1\ h}{3600\ s}\right)(30.0\ s)$ $\Delta x = 3.00 \times 10^{-1} \text{ km} = \boxed{3.00 \times 10^2 \text{ m}}$
6. $v_f = 96$ km/h $v_i = 0$ km/h $\Delta t = 3.07$ s	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0 \text{ km/h} + 96 \text{ km/h})\left(\frac{1h}{3600\ s}\right)\left(\frac{10^3\ m}{1\ km}\right)(3.07\ s)$ $\Delta x = \frac{1}{2}\left(96 \times 10^3\ \frac{m}{h}\right)(8.53 + \times 10^{-4}\ h) = \boxed{41\ m}$
7. $\Delta x = 290.0$ m $\Delta t = 10.0$ s $v_f = 0$ km/h $= 0$ m/s	$v_i = \frac{2\Delta x}{\Delta t} - v_f = \frac{(2)(290.0\ m)}{10.0\ s} - 0\ m/s = \boxed{58.0 \text{ m/s} = 209 \text{ km/h}}$ (Speed was in excess of 209 km/h.)
8. $\Delta x = 5.7 \times 10^3$ km $\Delta t = 86$ h $v_f = v_i + (0.10)\ v_i$	$v_f + v_i = \frac{2\Delta x}{\Delta t}$ $v_i\ (1.00 + 0.10) + v_i = \frac{2\Delta x}{\Delta t}$ $v_i = \frac{(2)(5.7 \times 10^3\ km)}{(2.10)(86\ h)} = \boxed{63 \text{ km/h}}$
9. $v_i = 2.60$ m/s $v_f = 2.20$ m/s $\Delta t = 9.00$ min	$\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(2.60 \text{ m/s} + 2.20 \text{ m/s})(9.00 \text{ min})\left(\frac{60\ s}{min}\right) = \frac{1}{2}(4.80 \text{ m/s})(5.40 \times 10^2 \text{ s})$ $\Delta x = 1.30 \times 10^3 \text{ m} = \boxed{1.30 \text{ km}}$

Additional Practice D

1. $v_i = 186$ km/h $v_f = 0$ km/h $= 0$ m/s $a = -1.5$ m/s^2	$\Delta t = \frac{v_f - v_i}{a} = \frac{0\ m/s - (186\ km/h)\left(\frac{1\ h}{3600\ s}\right)\left(\frac{10^3\ m}{1\ km}\right)}{-1.5\ m/s^2} = \frac{-51.7\ m/s}{-1.5\ m/s^2} = \boxed{34\ s}$
2. $v_i = -15.0$ m/s $v_f = 0$ m/s $a = +2.5$ m/s^2 $v_i = 0$ m/s $v_f = +15.0$ m/s $a = +2.5$ m/s	For stopping: $\Delta t_1 = \frac{v_f - v_i}{a} = \frac{0\ m/s - (-15.0\ m/s)}{2.5\ m/s^2} = \frac{15.0\ m/s}{2.5\ m/s^2} = 6.0\ s$ For moving forward: $\Delta t_2 = \frac{v_f - v_i}{a} = \frac{15.0\ m/s - 0.0\ m/s}{2.5\ m/s^2} = \frac{15.0\ m/s}{2.5\ m/s^2} = 6.0\ s$ $\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 6.0\ s + 6.0\ s = \boxed{12.0\ s}$

II

Givens | *Solutions*

3. $v_i = 24.0$ km/h

$v_f = 8.0$ km/h

$a = -0.20$ m/s^2

$$\Delta t = \frac{v_f - v_i}{a}$$

$$\Delta t = \frac{(8.0 \text{ km/h} - 24.0 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{-0.20 \text{ m/s}^2}$$

$$\Delta t = \frac{\left(-16.0 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{-0.20 \text{ m/s}^2} = \boxed{22 \text{ s}}$$

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4. $v_1 = 65.0$ km/h

$v_{i,2} = 0$ km/h

$a_2 = 4.00 \times 10^{-2}$ m/s^2

$\Delta x = 2072$ m

For cage 1:

$$\Delta x = v_1 \Delta t_1$$

$$\Delta t_1 = \frac{\Delta x}{v_1} = \frac{2072 \text{ m}}{(65.0 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)} = \boxed{115 \text{ s}}$$

For cage 2:

$$\Delta x = v_{i,2}\Delta t_2 + \tfrac{1}{2} a_2 \Delta t_2^{\,2}$$

Because $v_{i,2} = 0$ km/h,

$$\Delta t_2 = \sqrt{\frac{2\Delta x}{a_2}} = \sqrt{\frac{(2)(2072 \text{ m})}{4.00 \times 10^{-2} \text{ m/s}^2}} = \boxed{322 \text{ s}}$$

Cage 1 reaches the bottom of the shaft in nearly a third of the time required for cage 2.

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5. $\Delta x = 2.00 \times 10^2$ m

$v = 105.4$ km/h

a. $$\Delta t = \frac{\Delta x}{v} = \frac{2.00 \times 10^2 \text{ m}}{\left(105.4 \frac{\text{km}}{\text{h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)} = \boxed{6.83 \text{ s}}$$

$v_{i,car} = 0$ m/s

b. $$\Delta x = v_{i,car}\Delta t + \tfrac{1}{2} a_{car} \Delta t^2$$

$$a_{car} = \frac{2\Delta x}{\Delta t^2} = \frac{(2)(2.00 \times 10^2 \text{ m})}{(6.83 \text{ s})^2} = \boxed{8.57 \text{ m/s}^2}$$

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6. $v_i = 6.0$ m/s

$a = 1.4$ m/s^2

$\Delta t = 3.0$ s

$$\Delta x = v_i \Delta t + \tfrac{1}{2} a \Delta t^2 = (6.0 \text{ m/s})(3.0 \text{ s}) + \tfrac{1}{2}(1.4 \text{ m/s}^2)(3.0 \text{ s})^2 = 18 \text{ m} + 6.3 \text{ m} = \boxed{24 \text{ m}}$$

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7. $v_i = 3.17 \times 10^2$ km/h

$v_f = 2.00 \times 10^2$ km/h

$\Delta t = 8.0$ s

$$a = \frac{v_f - v_i}{\Delta t} = \frac{(2.00 \times 10^2 \text{ km/h} - 3.17 \times 10^2 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{8.0 \text{ s}}$$

$$a = \frac{(-117 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)}{8.0 \text{ s}} = \boxed{-4.1 \text{ m/s}^2}$$

$$\Delta x = v_i \Delta t + \tfrac{1}{2} a \Delta t^2 = (3.17 \times 10^2 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)(8.0 \text{ s}) + \tfrac{1}{2}(-4.1 \text{ m/s}^2)(8.0 \text{ s})^2$$

$$\Delta x = (7.0 \times 10^2 \text{ m}) + (-130 \text{ m}) = \boxed{+570 \text{ m}}$$

II

Givens	*Solutions*
8. $v_i = 0$ m/s $v_f = 3.06$ m/s $a = 0.800$ m/s^2 $\Delta t_2 = 5.00$ s	$\Delta t_1 = \dfrac{v_f - v_i}{a} = \dfrac{3.06\text{ m/s} - 0\text{ m/s}}{0.800\text{ m/s}^2} = 3.82$ $\Delta x_1 = v_i\Delta t_1 + \frac{1}{2}a\Delta t_1{}^2 = (0\text{ m/s})\,(3.82\text{ s}) + \frac{1}{2}(0.800\text{ m/s}^2)\,(3.82\text{ s})^2 = 5.84\text{ m}$ $\Delta x_2 = v_f\Delta t_2 = (3.06\text{ m/s})(5.00\text{ s}) = 15.3\text{ m}$ $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 5.84\text{ m} + 15.3\text{ m} = \boxed{21.1\text{ m}}$
9. $v_f = 3.50 \times 10^2$ km/h $v_i = 0$ km/h $= 0$ m/s $a = 4.00$ m/s^2	$\Delta t = \dfrac{(v_f - v_i)}{a} = \dfrac{(3.50 \times 10^2\text{ km/h} - 0\text{ km/h})\left(\dfrac{1\text{ h}}{3600\text{ s}}\right)\left(\dfrac{10^3\text{ m}}{1\text{ km}}\right)}{(4.00\text{ m/s}^2)} = \boxed{24.3\text{ s}}$ $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 = (0\text{ m/s})(24.3\text{ s}) + \frac{1}{2}(4.00\text{ m/s}^2)(24.3\text{ s})^2$ $\Delta x = 1.18 \times 10^3\text{ m} = \boxed{1.18\text{ km}}$
10. $v_i = 24.0$ m/s $a = -0.850$ m/s^2 $\Delta t = 28.0$ s	$v_f = v_i + a\Delta t = 24.0\text{ m/s} + (-0.850\text{ m/s}^2)(28.0\text{ s}) = 24.0\text{ m/s} - 23.8\text{ m/s} = \boxed{+0.2\text{ m/s}}$
11. $a = +2.67$ m/s^2 $\Delta t = 15.0$ s $\Delta x = +6.00 \times 10^2$m	$v_i\,\Delta t = \Delta x - \frac{1}{2}a\Delta t^2$ $v_i = \dfrac{\Delta x}{\Delta t} - \frac{1}{2}a\Delta t = \dfrac{6.00 \times 10^2\text{ m}}{15.0\text{ s}} - \frac{1}{2}(2.67\text{ m/s}^2)(15.0\text{ s}) = 40.0\text{ m/s} - 20.0\text{ m/s} = \boxed{+20.0\text{ m/s}}$
12. $a = 7.20$ m/s^2 $\Delta t = 25.0$ s $v_f = 3.00 \times 10^2$ ms	$v_i = v_f - a\Delta t$ $v_i = (3.00 \times 10^2\text{ m/s}) - (7.20\text{ m/s}^2)(25.0\text{ s}) = (3.00 \times 10^2\text{ m/s}) - (1.80 \times 10^2\text{ m/s})$ $v_i = \boxed{1.20 \times 10^2\text{ m/s}}$
13. $v_i = 0$ m/s $\Delta x = 1.00 \times 10^2$ m $\Delta t = 12.11$ s	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ Because $v_i = 0$ m/s, $a = \dfrac{2\Delta x}{\Delta t^2} = \dfrac{(2)(1.00 \times 10^2\text{ m})}{(12.11\text{ s})^2} = \boxed{1.36\text{ m/s}^2}$
14. $v_i = 3.00$ m/s $\Delta x = 1.00 \times 10^2$ m $\Delta t = 12.11$ s	$a = \dfrac{2(\Delta x - v_i\Delta t)}{\Delta t^2} = \dfrac{(2)[1.00 \times 10^2\text{ m} - (3.00\text{ m/s})(12.11\text{ s})]}{(12.11\text{ s})^2}$ $a = \dfrac{(2)(1.00 \times 10^2\text{ m} - 36.3\text{ m})}{(12.11\text{ s})^2}$ $a = \dfrac{(2)(64\text{ m})}{(12.11\text{ s})^2} = \boxed{0.87\text{ m/s}^2}$
15. $v_f = 30.0$ m/s $v_i = 18.0$ m/s $\Delta t = 8.0$ s	$a = \dfrac{v_f - v_i}{\Delta t} = \dfrac{30.0\text{ m/s} - 18.0\text{ m/s}}{8.0\text{ s}} = \dfrac{12.0\text{ m/s}}{8.0\text{ s}} = \boxed{1.5\text{ m/s}^2}$

II

Additional Practice E

Givens	*Solutions*
1. $v_i = 0$ km/h $v_f = 965$ km/h $a = 4.0$ m/s^2	$\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{\left[(965 \text{ km/h})^2 - (0 \text{ km/h})^2\right]\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(4.0 \text{ m/s}^2)}$ $\Delta x = \dfrac{7.19 \times 10^4 \text{m}^2/\text{s}^2}{8.0 \text{ m/s}^2} = 9.0 \times 10^3 \text{ m} = \boxed{9.0 \text{ km}}$
2. $v_i = (0.20)\, v_{max}$ $v_{max} = 2.30 \times 10^3$ km/h $v_f = 0$ km/h $a = -5.80$ m/s^2	$\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{\left[(0 \text{ km/h})^2 - (0.20)^2\,(2.30 \times 10^3 \text{ km/h})^2\right]\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(-5.80 \text{ m/s}^2)}$ $\Delta x = \dfrac{-1.63 \times 10^4 \text{m}^2/\text{s}^2}{-11.6 \text{ m/s}^2} = 1.41 \times 10^3 \text{ m} = \boxed{1.41 \text{ km}}$
3. $v_f = 9.70 \times 10^2$ km/h $v_i = (0.500) v_f$ $a = 4.8$ m/s^2	$\Delta x = \dfrac{v_f^2 - v_i^2}{2a} = \dfrac{\left[(9.70 \times 10^2 \text{ km/h})^2 - (0.50)^2\,(9.70 \times 10^2 \text{ km/h})^2\right]\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(4.8 \text{ m/s}^2)}$ $\Delta x = \dfrac{(9.41 \times 10^5 \text{ km}^2/\text{h})^2 - 2.35 \times 10^5 \text{ km}^2/\text{h}^2)\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(4.8 \text{ m/s}^2)}$ $\Delta x = \dfrac{(7.06 \times 10^5 \text{ km}^2/\text{h}^2)\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(4.8 \text{ m/s}^2)}$ $\Delta x = \dfrac{5.45 \times 10^4 \text{m}^2/\text{s}^2}{9.6 \text{ m/s}^2} = 5.7 \times 10^3 \text{ m} = \boxed{5.7 \text{ km}}$
4. $v_i = 8.0$ m/s $\Delta x = 40.0$ m $a = 2.00$ m/s^2	$v_f = \sqrt{2a\Delta x + v_i^2} = \sqrt{(2)(2.0 \text{ m/s}^2)(40.\text{m}) + (8.0 \text{ m/s})^2} = \sqrt{1.60 \times 10^2 \text{m}^2/\text{s}^2 + 64 \text{ m}^2/\text{s}^2}$ $v_f = \sqrt{224 \text{ m}^2/\text{s}^2} = \pm 15 \text{ m/s} = \boxed{15 \text{ m/s}}$
5. $\Delta x = +9.60$ km $a = -2.0$ m/s^2 $v_f = 0$ m/s	$v_i = \sqrt{v_f^2 - 2a\Delta x} = \sqrt{(0 \text{ m/s})^2 - (2)(-2.0 \text{ m/s}^2)(9.60 \times 10^3 \text{ m})}$ $v_i = \sqrt{3.84 \times 10^4 \text{m}^2/\text{s}^2} = \pm 196 \text{ m/s} = \boxed{+196 \text{ m/s}}$
6. $a = +0.35$ m/s^2 $v_i = 0$ m/s $\Delta x = 64$ m	$v_f = \sqrt{2a\Delta x + v_i^2} = \sqrt{(2)(0.35 \text{ m/s}^2)(64 \text{ m}) + (0 \text{ m/s})^2}$ $v_f = \sqrt{45 \text{ m}^2\text{s}^2} = \pm 6.7 \text{ m/s} = \boxed{+6.7 \text{ m/s}}$
7. $\Delta x = 44.8$ km $\Delta t = 60.0$ min	**a.** $v_{avg} = \dfrac{\Delta x}{\Delta t} = \dfrac{44.8 \times 10^3 \text{ m}}{(60.0 \text{ min})(60 \text{ s/min})} = \boxed{12.4 \text{ m/s}}$
$a = -2.0$ m/s^2 $\Delta x = 20.0$ m $v_i = 12.4$ m/s	**b.** $v_f = \sqrt{2a\Delta x + v_i^2} = \sqrt{(2)(-2.0 \text{ m/s}^2)(20.0 \text{ m}) + (12.4 \text{ m/s})^2}$ $v_f = \sqrt{(-80.0 \text{ m}^2/\text{s}^2) + 154 \text{ m}^2/\text{s}^2} = \sqrt{74 \text{ m}^2/\text{s}^2} = \pm 8.6 \text{ m/s} = \boxed{8.6 \text{ m/s}}$

Givens	*Solutions*
8. $\Delta x = 2.00 \times 10^2$ m $a = 1.20$ m/s^2 $v_f = 25.0$ m/s	$v_i = \sqrt{v_f^2 - 2a\Delta x} = \sqrt{(25.0 \text{ m/s})^2 - (2)(1.20 \text{ m/s}^2)(2.00 \times 10^2 \text{ m})}$ $v_i = \sqrt{625 \text{ m}^2/\text{s}^2 - 4.80 \times 10^2 \text{m}^2/\text{s}^2}$ $v_i = \sqrt{145 \text{ m}^2/\text{s}^2} = \pm 12.0 \text{ m/s} = \boxed{12.0 \text{ m/s}}$
9. $\Delta x = 4.0 \times 10^2$ m $\Delta t = 11.55$ $v_i = 0$ km/h $v_f = 2.50 \times 10^2$ km/h	$a = \dfrac{v_f^2 - v_i^2}{2\Delta x} = \dfrac{\left[(2.50 \times 10^2 \text{ km/h})^2 - (0 \text{ km/h})^2\right]\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(4.0 \times 10^2 \text{ m})}$ $a = \dfrac{4.82 \times 10^3 \text{m}^2/\text{s}^2}{8.0 \times 10^2 \text{ m}} = \boxed{6.0 \text{ m/s}^2}$
10. $v_i = 25.0$ km/h $v_f = 0$ km/h $\Delta x = 16.0$ m	$a = \dfrac{v_f^2 - v_i^2}{2\Delta x} = \dfrac{\left[(0 \text{ km/h})^2 - (25.0 \text{ km/h})^2\right]\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\dfrac{10^3 \text{ m}}{1 \text{ km}}\right)^2}{(2)(16.0 \text{ m})}$ $a = \dfrac{-4.82 \text{ m}^2/\text{s}^2}{32.0 \text{ m}} = \boxed{-1.51 \text{ m/s}^2}$

II

Additional Practice F

1. $\Delta y = -343$ m $a = -9.81$ m/s^2 $v_i = 0$ m/s	$v_f = \sqrt{2a\Delta y + v_i^2} = \sqrt{(2)(-9.81 \text{ m/s}^2)(-343 \text{ m}) + (0 \text{ m/s})^2} = \sqrt{6730 \text{ m}^2/\text{s}^2}$ $v_f = \pm 82.0 \text{ m/s} = \boxed{-82.0 \text{ m/s}}$
2. $\Delta y = +4.88$ m $v_i = +9.98$ m/s $a = -9.81$ m/s^2	$v_f = \sqrt{2a\Delta y + v_i^2} = \sqrt{(2)(-9.81 \text{ m/s}^2)(4.88 \text{ m}) + (9.98 \text{ m/s})^2} = \sqrt{-95.7 \text{ m}^2/\text{s}^2 + 99.6 \text{ m}^2/\text{s}^2}$ $v_f = \sqrt{3.90 \text{ m}^2/\text{s}^2} = \pm 1.97 \text{ m/s} = \boxed{\pm 1.97 \text{ m/s}}$
3. $\Delta y = -443 \text{ m} + 221 \text{ m}$ $= -222$ m $a = -9.81$ m/s^2 $v_i = 0$ m/s	$v_f = \sqrt{2a\Delta y - v_i^2} = \sqrt{(2)(-9.81 \text{ m/s}^2)(-222 \text{ m}) - (0 \text{ m/s})^2} = \sqrt{4360 \text{ m}^2/\text{s}^2}$ $v_f = \pm 66.0 \text{ m/s} = \boxed{-66.0 \text{ m/s}}$
4. $\Delta y = +64$ m $a = -9.81$ m/s^2 $\Delta t = 3.0$ s	$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $v_i = \dfrac{\Delta y - \frac{1}{2}a\Delta t^2}{\Delta t} = \dfrac{64 \text{ m} - \frac{1}{2}(-9.81 \text{ m/s}^2)(3.0 \text{ s})^2}{3.0 \text{ s}} = \dfrac{64 \text{ m} + 44 \text{ m}}{3.0 \text{ s}}$ $v_i = \dfrac{108 \text{ m}}{3.0 \text{ s}} = 36 \text{ m/s}$ initial speed of arrow = $\boxed{36 \text{ m/s}}$
5. $\Delta y = -111$ m $\Delta t = 3.80$ s $a = -9.81$ m/s^2	$\Delta y = v_i \Delta t + \frac{1}{2}a\Delta t^2$ $v_i = \dfrac{\Delta y - \frac{1}{2}a\Delta t^2}{\Delta t} = \dfrac{-111 \text{ m} - \frac{1}{2}(-9.81 \text{ m/s}^2)(3.80 \text{ s})^2}{3.80 \text{ s}} = \dfrac{-111 \text{ m} + 70.8 \text{ m}}{3.80 \text{ s}}$ $v_i = \dfrac{-40.2 \text{ m}}{3.80 \text{ s}} = \boxed{-10.6 \text{ m/s}}$

Givens	*Solutions*

6. $\Delta y = -228$ m
$a = -9.81$ m/s^2
$v_i = 0$ m/s

When $v_i = 0$ m/s,

$$\Delta t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{(2)(-228 \text{ m})}{-9.81 \text{ m/s}^2}} = \boxed{6.82 \text{ s}}$$

In the presence of air resistance, the sandwich would require more time to fall because the downward acceleration would be reduced.

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7. $v_i = 12.0$ m/s, upward = +12.0 m/s
$v_f = 3.0$ m/s, upward = +3.0 m/s
$a = -9.81$ m/s^2
$y_i = 1.50$ m

$$\Delta y = \frac{v_f^2 - v_i^2}{2a} = \frac{(3.0 \text{ m/s})^2 - (12.0 \text{ m/s})^2}{(2)(-9.81 \text{ m/s}^2)} = \frac{9.0 \text{ m}^3/\text{s}^2 - 144 \text{ m}^2/\text{s}^2}{(2)(-9.81 \text{ m/s}^2)}$$

$$\Delta y = \frac{-135 \text{ m}^2/\text{s}^2}{-19.6 \text{ m/s}^2} = 6.88 \text{ m}$$

height of nest from ground = h

$\Delta y = h - y_i$

$$h = \Delta y + y_i = 6.88 \text{ m} + 1.50 \text{ m} = \boxed{8.38 \text{ m}}$$

---

8. $\Delta y = +43$ m
$a = -9.81$ m/s^2
$v_f = 0$ m/s

Because it takes as long for the ice cream to fall from the top of the flagpole to the ground as it does for the ice cream to travel up to the top of the flagpole, the free-fall case will be calculated.

Thus, $v_i = 0$ m/s, $\Delta y = -43$ m, and $\Delta y = \frac{1}{2}a\Delta t^2$.

$$\Delta t = \sqrt{\frac{2\Delta y}{a}} = \sqrt{\frac{(2)(-43 \text{ m})}{-9.81 \text{ m/s}^2}} = \boxed{3.0 \text{ s}}$$

---

9. $\Delta y_{max} = +21$ cm
$a = -9.81$ m/s^2
$v_f = 0$ m/s
$\Delta y = +7.0$ cm

$$v_i = \sqrt{v_f^2 - 2a\Delta y_{max}} = \sqrt{(0 \text{ m/s})^2 - (2)(-9.81 \text{ m/s}^2)(2.1 \times 10^{-1} \text{ m})} = \sqrt{4.1 \text{ m}^2/\text{s}^2}$$

$v_i = +2.0$ m/s

For the flea to jump $+7.0$ cm $= +7.0 \times 10^{-2}$ m $= \Delta y$,

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ or $\frac{1}{2}a\Delta t^2 + v_i\Delta t - \Delta y = 0$

Solving for Δt by means of the quadratic equation,

$$\Delta t = \frac{-v_i \pm \sqrt{(v_i)^2 - 4\left(\frac{a}{2}\right)(-\Delta y)}}{2\left(\frac{a}{2}\right)}$$

$$\Delta t = \frac{-2.0 \text{ m/s} \pm \sqrt{(2.0 \text{ m/s})^2 - (2)(-9.81 \text{ m/s}^2)(-7.0 \times 10^{-2} \text{ m})}}{-9.81 \text{ m/s}^2}$$

$$\Delta t = \frac{-2.0 \text{ m/s} \pm \sqrt{4.0 \text{ m}^2/\text{s}^2 - 1.4 \text{ m}^2/\text{s}^2}}{-9.81 \text{ m/s}^2} = \frac{2.0 \text{ m/s} \pm \sqrt{2.6 \text{ m}^2/\text{s}^2}}{9.81 \text{ m/s}^2}$$

$$\Delta t = \frac{2.0 \text{ m/s} \pm 1.6 \text{ m/s}}{9.81 \text{ m/s}^2} = 0.37 \text{ s or } 0.04 \text{ s}$$

To choose the correct value for Δt, insert Δt, a, and v_i into the equation for v_f.

$v_f = a\Delta t + v_i = (-9.81 \text{ m/s}^2)(0.37 \text{ s}) + 2.0 \text{ m/s}$

$v_f = (-3.6 \text{ m/s}) + 2.0 \text{ m/s} = -1.6 \text{ m/s}$

$v_f = a\Delta t + v_i = (-9.81 \text{ m/s}^2)(0.04 \text{ s}) + 2.0 \text{ m/s}$

$v_f = (-0.4 \text{ m/s}) + 2.0 \text{ m/s} = +1.6 \text{ m/s}$

Because v_f is still directed upward, the shorter time interval is correct. Therefore,

$$\Delta t = \boxed{0.04 \text{ s}}$$

Two-Dimensional Motion and Vectors

Additional Practice A

Givens | *Solutions*

1. $\Delta t_x = 7.95$ s

$\Delta y = 161$ m

$d = 226$ m

$$d^2 = \Delta x^2 + \Delta y^2$$

$$\Delta x = \sqrt{d^2 - \Delta y^2} = \sqrt{(226\text{ m})^2 - (161\text{ m})^2} = \sqrt{5.11 \times 10^4\text{ m}^2 - 2.59 \times 10^4\text{ m}^2}$$

$$\Delta x = \sqrt{2.52 \times 10^4\text{ m}^2} = 159\text{ m}$$

$$\Delta x = \boxed{159\text{ m}}$$

$$v = \frac{\Delta x}{\Delta t_x} = \frac{159\text{ m}}{7.95\text{ s}} = \boxed{20.0\text{ m/s}}$$

---

2. $d_1 = 5.0$ km

$\theta_1 = 11.5°$

$d^2 = 1.0$ km

$\theta_2 = -90.0°$

$$\Delta x_{tot} = d_1(\cos\theta_1) + d_2(\cos\theta_2) = (5.0\text{ km})(\cos 11.5°) + (1.0\text{ km})[\cos(-90.0°)]$$

$$\Delta x_{tot} = 4.9\text{ km}$$

$$\Delta y_{tot} = d_1(\sin\theta_1) + d_2(\sin\theta_2) = (5.0\text{ km})(\sin 11.5°) + (1.0\text{ km})[\sin(-90.0°)]$$
$$= 1.0\text{ km} - 1.0\text{ km}$$

$$\Delta y_{tot} = 0.0\text{ km}$$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(4.9\text{ km})^2 + (0.0\text{ km})^2}$$

$$d = \boxed{4.9\text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{0.0\text{ km}}{4.9\text{ km}}\right) = \boxed{0.0°\text{, or due east}}$$

---

3. $\Delta x = 5$ jumps

1 jump = 8.0 m

$d = 68$ m

$$d^2 = \Delta x^2 + \Delta y^2$$

$$\Delta y = \sqrt{d^2 - \Delta x^2} = \sqrt{(68\text{ m})^2 - [(5)(8.0\text{ m})]^2} = \sqrt{4.6 \times 10^3\text{ m}^2 - 1.6 \times 10^3\text{ m}^2}$$

$$\Delta y = \sqrt{3.0 \times 10^3\text{ m}} = 55\text{ m}$$

$$\text{number of jumps northward} = \frac{55\text{ m}}{8.0\text{ m/jump}} = 6.9\text{ jumps} = \boxed{7\text{ jumps}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta x}{\Delta y}\right) = \tan^{-1}\left[\frac{(5)(8.0\text{ m})}{55\text{ m}}\right] = \boxed{36°\text{ west of north}}$$

---

4. $\Delta x = 25.2$ km

$\Delta y = 21.3$ km

$$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(25.2\text{ km})^2 + (21.3\text{ km})^2}$$

$$d = \sqrt{635\text{ km}^2 + 454\text{ km}^2} = \sqrt{1089\text{ km}^2}$$

$$d = \boxed{33.00\text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\frac{21.3\text{ km}}{25.2\text{ km}}\right)$$

$$\theta = \boxed{42.6°\text{ south of east}}$$

Givens	Solutions
5. $\Delta y = -483$ m $\Delta x = 225$ m	$\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\frac{-483}{225\text{ m}}\right) = -65.0° = \boxed{65.0° \text{ below the waters surface}}$ $d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(225\text{ m})^2 + (-483\text{ m})^2}$ $d = \sqrt{5.06 \times 10^4\text{ m}^2 + 2.33 \times 10^5\text{ m}^2} = \sqrt{2.84 \times 10^5\text{ m}^2}$ $d = \boxed{533\text{ m}}$
6. $v = 15.0$ m/s $\Delta t_x = 8.0$ s $d = 180.0$ m	$d^2 = \Delta x^2 + \Delta y^2 = (v\Delta t_x)^2 + (v\Delta t_y)^2$ $d^2 = v^2(\Delta t_x{}^2 + \Delta t_y{}^2)$ $\Delta t_y = \sqrt{\left(\frac{d}{v}\right)^2 - \Delta t_x{}^2} = \sqrt{\left(\frac{180.0\text{ m}}{15.0\text{ m/s}}\right)^2 - (8.0\text{ s})^2} = \sqrt{144\text{ s}^2 - 64\text{ s}^2} = \sqrt{8.0 \times 10^1\text{ s}^2}$ $\Delta t_y = \boxed{8.9\text{ s}}$
7. $v = 8.00$ km/h $\Delta t_x = 15.0$ min $\Delta t_y = 22.0$ min	$d = \sqrt{\Delta x^2 + \Delta y^2} = \sqrt{(v\Delta t_x)^2 + (v\Delta t_y)^2}$ $= v\sqrt{\Delta t_x{}^2 + \Delta t_y{}^2}$ $d = (8.00\text{ km/h})\left(\frac{1\text{ h}}{60\text{ min}}\right)\sqrt{(15.0\text{ min})^2 + (22.0\text{ min})^2}$ $d = (8.00\text{ km/h})\left(\frac{1\text{ h}}{60\text{ min}}\right)\sqrt{225\text{ min}^2 + 484\text{ min}^2}$ $d = \left(\frac{8.00\text{ km}}{60\text{ min}}\right)\sqrt{709\text{ min}^2} = \boxed{3.55\text{ km}}$ $\theta = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) = \tan^{-1}\left(\frac{v\Delta t_y}{v\Delta t_x}\right) = \tan^{-1}\left(\frac{\Delta t_y}{\Delta t_x}\right) = \tan^{-1}\left(\frac{22.0\text{ min}}{15.0\text{ min}}\right)$ $\theta = \boxed{55.7° \text{ north of east}}$

II

Additional Practice B

1. $d = (5)(33.0\text{ cm})$ $\Delta y = 88.0$ cm	$\theta = \sin^{-1}\left(\frac{\Delta y}{d}\right) = \sin^{-1}\left[\frac{88.0\text{ cm}}{(5)(33.0\text{ cm})}\right] = \boxed{32.2° \text{ north of west}}$ $\Delta x = d(\cos\theta) = (5)(33.0\text{ cm})(\cos 32.2°) = \boxed{1.40 \times 10^2 \text{ cm to the west}}$
2. $\theta = 60.0°$ $d = 10.0$ m	$\Delta x = d(\cos\theta) = (10.0\text{ m})(\cos 60.0°) = \boxed{5.00\text{ m}}$ $\Delta y = d(\sin\theta) = (10.0\text{ m})(\sin 60.0°) = \boxed{8.66\text{ m}}$
3. $d = 10.3$ m $\Delta y = -6.10$ m	Finding the angle between d and the x-axis yields, $\theta_1 = \sin^{-1}\left(\frac{\Delta y}{\text{d}}\right) = \sin^{-1}\left(\frac{-6.10\text{ m}}{10.3\text{ m}}\right) = -36.3°$ The angle between d and the negative y-axis is therefore, $\theta = -90.0 - (-36.3°) = -53.7°$ $\theta = \boxed{53.7° \text{ on either side of the negative } y\text{-axis}}$ $d^2 + \Delta x^2 + \Delta_y{}^2$ $\Delta x = \sqrt{d^2 - \Delta y^2} = \sqrt{(10.3\text{ m})^2 - (-6.10\text{ m})^2} = \sqrt{106\text{ m}^2 - 37.2\text{ m}^2} = \sqrt{69\text{ m}^2}$ $\Delta x = \boxed{\pm 8.3\text{ m}}$

Givens	*Solutions*
4. $d = (8)(4.5\text{ m})$ $\theta = 35°$	$\Delta x = d(\cos\theta) = (8)(4.5\text{ m})(\cos 35°) = \boxed{29\text{ m}}$ $\Delta y = d(\sin\theta) = (8)(4.5\text{ m})(\sin 35°) = \boxed{21\text{ m}}$
5. $v = 347\text{ km/h}$ $\theta = 15.0°$	$v_x = v(\cos\theta) = (347\text{ km/h})(\cos 15.0°) = \boxed{335\text{ km/h}}$ $v_y = v(\sin\theta) = (347\text{ km/h})(\sin 15.0°) = \boxed{89.8\text{ km/h}}$
6. $v = 372\text{ km/h}$ $\Delta t = 8.7\text{ s}$ $\theta = 60.0°$	$d = v\Delta t = (372\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)(10^3\text{ m/km})(8.7\text{ s}) = 9.0\times10^2\text{ m}$ $\Delta x = d(\cos\theta) = (9.0\times10^2\text{ m})(\cos 60.0°) = \boxed{450\text{ m east}}$ $\Delta y = d(\sin\theta) = (9.0\times10^2\text{ m})(\sin 60.0°) = \boxed{780\text{ m north}}$
7. $d = 14\,890\text{ km}$ $\theta = 25.0°$ $\Delta t = 18.5\text{ h}$	$v_{avg} = \frac{d}{\Delta t} = \frac{1.489\times10^4\text{ km}}{18.45\text{ h}} = \boxed{805\text{ km/h}}$ $v_x = v_{avg}(\cos\theta) = (805\text{ km/h})(\cos 25.0°) = \boxed{730\text{ km/h east}}$ $v_y = v_{avg}(\sin\theta) = (805\text{ km/h})(\sin 25.0°) = \boxed{340\text{ km/h south}}$
8. $v_i = 6.0\times10^2\text{ km/h}$ $v_f = 2.3\times10^3\text{ km/h}$ $\Delta t = 120\text{ s}$ $\theta = 35°$ with respect to horizontal	$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t}$ $a = \frac{(2.3\times10^3\text{ km/h} - 6.0\times10^2\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)(10^3\text{ m/km})}{1.2\times10^2\text{ s}}$ $a = \frac{(1.7\times10^3\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)(10^3\text{ m/km})}{1.2\times10^2\text{ s}}$ $a = 3.9\text{ m/s}^2$ $a_x = a(\cos\theta) = (3.9\text{ m/s}^2)(\cos 35°) = \boxed{3.2\text{ m/s}^2\text{ horizontally}}$ $a_y = a(\sin\theta) = (3.9\text{ m/s}^2)(\sin 35°) = \boxed{2.2\text{ m/s}^2\text{ vertically}}$

Additional Practice C

1. $\Delta x_1 = 250.0\text{ m}$ $d_2 = 125.0\text{ m}$ $\theta_2 = 120.0°$	$\Delta x_2 = d_2(\cos\theta_2) = (125.0\text{ m})(\cos 120.0°) = -62.50\text{ m}$ $\Delta y_2 = d_2(\sin\theta_2) = (125.0\text{ m})(\sin 120.0°) = 108.3\text{ m}$ $\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 250.0\text{ m} - 62.50\text{ m} = 187.5\text{ m}$ $\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 0\text{ m} + 108.3\text{ m} = 108.3\text{ m}$ $d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(187.5\text{ m})^2 + (108.3\text{ m})^2}$ $d = \sqrt{3.516\times10^4\text{ m}^2 + 1.173\times10^4\text{ m}^2} = \sqrt{4.689\times10^4\text{ m}^2}$ $d = \boxed{216.5\text{ m}}$ $\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{108.3\text{ m}}{187.5\text{ m}}\right) = \boxed{30.01°\text{ north of east}}$

II

Givens	Solutions

2. $v = 3.53 \times 10^3$ km/h

$\Delta t_1 = 20.0$ s

$\Delta t_2 = 10.0$ s

$\theta_1 = 15.0°$

$\theta_2 = 35.0°$

$$\Delta x_1 = v\Delta t_1(\cos\theta_1)$$

$$\Delta x_1 = (3.53 \times 10^3 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(10^3 \text{ m/km})(20.0 \text{ s})(\cos 15.0°) = 1.89 \times 10^4 \text{ m}$$

$$\Delta y_1 = v\Delta t_1(\sin\theta_1)$$

$$\Delta y_1 = (3.53 \times 10^3 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(10^3 \text{ m/km})(20.0 \text{ s})(\sin 15.0°) = 5.08 \times 10^3 \text{ m}$$

$$\Delta x_2 = v\Delta t_2(\cos\theta_2)$$

$$\Delta x_2 = (3.53 \times 10^3 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(10^3 \text{ m/km})(10.0 \text{ s})(\cos 35.0°) = 8.03 \times 10^3 \text{ m}$$

$$\Delta y_2 = v\Delta t_2(\sin\theta_2)$$

$$\Delta y_2 = (3.53 \times 10^3 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(10^3 \text{ m/km})(10.0 \text{ s})(\sin 35.0°) = 5.62 \times 10^3 \text{ m}$$

$$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 5.08 \times 10^3 \text{ m} + 5.62 \times 10^3 \text{ m} = \boxed{1.07 \times 10^4 \text{ m}}$$

$$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 1.89 \times 10^4 \text{ m} + 8.03 \times 10^3 \text{ m} = \boxed{2.69 \times 10^4 \text{ m}}$$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(2.69 \times 10^4 \text{ m})^2 + (1.07 \times 10^4 \text{ m})^2}$$

$$d = \sqrt{7.24 \times 10^8 \text{ m}^2 + 1.11 \times 10^8 \text{ m}^2} = \sqrt{8.35 \times 10^8 \text{ m}}$$

$$d = \boxed{2.89 \times 10^4 \text{ m}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{1.07 \times 10^4 \text{ m}}{2.69 \times 10^4 \text{ m}}\right)$$

$$\theta = \boxed{21.7° \text{ above the horizontal}}$$

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3. $\Delta x_1 + \Delta x_2 = 2.00 \times 10^2$ m

$\Delta y_1 + \Delta y_2 = 0$

$\theta_1 = 30.0°$

$\theta_2 = -45.0°$

$v = 11.6$ km/h

$$\Delta y_1 = d_1(\sin\theta_1) = -\Delta y_2 = -d_2(\sin\theta_2)$$

$$d_1 = -d_2\left(\frac{\sin\theta_2}{\sin\theta_1}\right) = -d_2\left[\frac{\sin(-45.0°)}{\sin 30.0°}\right] = 1.41d_2$$

$$\Delta x_1 = d_1(\cos\theta_1) = (1.41d_2)(\cos 30.0°) = 1.22d_2$$

$$\Delta x_2 = d_2(\cos\theta_2) = d_2[\cos(-45.0°)] = 0.707d_2$$

$$\Delta x_1 + \Delta x_2 = d_2(1.22 + 0.707) = 1.93d_2 = 2.00 \times 10^2 \text{ m}$$

$$d_2 = \boxed{104 \text{ m}}$$

$$d_1 = (1.41)d_2 = (1.41)(104 \text{ m}) = \boxed{147 \text{ m}}$$

$$v = 11.6 \text{ km/h} = (11.6 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(10^3 \text{ m/km}) = 3.22 \text{ m/s}$$

$$\Delta t_1 = \frac{d_1}{v} = \left(\frac{147 \text{ m}}{3.22 \text{ m/s}}\right) = 45.7 \text{ s}$$

$$\Delta t_2 = \frac{d_2}{v} = \left(\frac{104 \text{ m}}{3.22 \text{ m/s}}\right) = 32.3 \text{ s}$$

$$\Delta t_{tot} = \Delta t_1 + \Delta t_2 = 45.7 \text{ s} + 32.3 \text{ s} = \boxed{78.0 \text{ s}}$$

Givens | *Solutions*

4. $v = 925$ km/h

$\Delta t_1 = 1.50$ h

$\Delta t_2 = 2.00$ h

$\theta_2 = 135°$

$d_1 = v\Delta t_1 = (925 \text{ km/h})(10^3 \text{ m/km})(1.50 \text{ h}) = 1.39 \times 10^6 \text{ m}$

$d_2 = v\Delta t_2 = (925 \text{ km/h})(10^3 \text{ m/km})(2.00 \text{ h}) = 1.85 \times 10^6 \text{ m}$

$\Delta x_1 = d_1 = 1.39 \times 10^6 \text{ m}$

$\Delta y_1 = 0 \text{ m}$

$\Delta x_2 = d_2(\cos \theta_2) = (1.85 \times 10^6 \text{ m})(\cos 135°) = -1.31 \times 10^6 \text{ m}$

$\Delta y_2 = d_2(\sin \theta_2) = (1.85 \times 10^6 \text{ m})(\sin 135°) = 1.31 \times 10^6 \text{ m}$

$\Delta x_{tot} = \Delta x_1 + \Delta x_2 = 1.39 \times 10^6 \text{ m} + (-1.31 \times 10^6 \text{ m}) = 0.08 \times 10^6 \text{ m}$

$\Delta y_{tot} = \Delta y_1 + \Delta y_2 = 0 \text{ m} + 1.31 \times 10^6 \text{ m} = 1.31 \times 10^6 \text{ m}$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(0.08 \times 10^6 \text{ m})^2 + (1.31 \times 10^6 \text{ m})^2}$$

$$d = \sqrt{6 \times 10^9 \text{ m}^2 + 1.72 \times 10^{12} \text{ m}^2} = \sqrt{1.73 \times 10^{12} \text{ m}^2}$$

$$d = \boxed{1.32 \times 10^6 \text{ m} = 1.32 \times 10^3 \text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{1.31 \times 10^6 \text{ m}}{0.08 \times 10^6 \text{ m}}\right) = 86.5° = 90.0° - 3.5°$$

$$\theta = \boxed{3.5° \text{ east of north}}$$

5. $v = 57.2$ km/h

$\Delta t_1 = 2.50$ h

$\Delta t_2 = 1.50$ h

$\theta_2 = 30.0°$

$d_1 = v\Delta t_1 = (57.2 \text{ km/h})(2.50 \text{ h}) = 143 \text{ km}$

$d_2 = v\Delta t_2 = (57.2 \text{ km/h})(1.50 \text{ h}) = 85.8 \text{ km}$

$\Delta_{tot} = d_1 + d_2(\cos \theta_2) = 143 \text{ km} + (85.8 \text{ km})(\cos 30.0°) = 143 \text{ km} + 74.3 \text{ km} = 217 \text{ km}$

$\Delta y_{tot} = d_2(\sin \theta_2) = (85.8 \text{ km})(\sin 30.0°) = 42.9 \text{ km}$

$$d = \sqrt{(\Delta x_{tot})^2 + (\Delta y_{tot})^2} = \sqrt{(217 \text{ km})^2 + (42.9 \text{ km})}$$

$$d = \sqrt{4.71 \times 10^4 \text{ km}^2 + 1.84 \times 10^3 \text{ km}^2} = \sqrt{4.89 \times 10^4 \text{ km}^2}$$

$$d = \boxed{221 \text{ km}}$$

$$\theta = \tan^{-1}\left(\frac{\Delta y_{tot}}{\Delta x_{tot}}\right) = \tan^{-1}\left(\frac{42.9 \text{ km}}{217 \text{ km}}\right) = \boxed{11.2° \text{ north of east}}$$

Additional Practice D

1. $v_x = 9.37$ m/s

$\Delta y = -2.00$ m

$a_y = -g = -9.81 \text{ m/s}^2$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$\Delta x = v_x \sqrt{\frac{2\Delta y}{a_y}} = (9.37 \text{ m/s}) \sqrt{\frac{(2)(-2.00 \text{ m})}{(-9.81 \text{ m/s}^2)}} = 5.98 \text{ m}$$

$\boxed{\text{The river is 5.98 m wide.}}$

2. $\Delta x = 7.32$ km

$\Delta y = -8848$ m

$a_y = -g = -9.81 \text{ m/s}^2$

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$v_x = \sqrt{\frac{a_y}{2\Delta y}}\,\Delta x = \sqrt{\frac{(-9.81 \text{ m/s}^2)}{(2)(-8\,848 \text{ m})}}(7.32 \times 10^3 \text{ m}) = \boxed{172 \text{ m/s}}$$

No. The arrow must have a horizontal speed of 172 m/s, which is much greater than 100 m/s.

II

Givens	Solutions

3. $\Delta x = 471$ m

$v_i = 80.0$ m/s

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \frac{\Delta x}{v_x}$$

$$\Delta y = \frac{1}{2}a_y(\Delta t)^2 = \frac{a_y(\Delta x)^2}{2v_x^2} = \frac{(-9.81 \text{ m/s}^2)(471 \text{ m})^2}{(2)(80.0 \text{ m/s})^2} = -1.70 \times 10^2 \text{ m}$$

$\boxed{\text{The cliff is } 1.70 \times 10^2 \text{ m high.}}$

---

4. $v_x = 372$ km/h

$\Delta x = 40.0$ m

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \frac{\Delta x}{v_x}$$

$$\Delta y = \frac{1}{2}a_y(\Delta t)^2 = \frac{a_y(\Delta x)^2}{2v_x^2} = \frac{(-9.81 \text{ m/s}^2)(40.0 \text{ m})^2}{(2)\left[(372 \text{ km/h})\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)\right]^2}$$

$$\Delta y = -0.735 \text{ m}$$

$\boxed{\text{The ramp is 0.735 m above the ground.}}$

II

5. $\Delta x = 25$ m

$v_x = 15$ m/s

$a_y = -g = -9.81$ m/s^2

$h = 25$ m

$$\Delta t = \frac{\Delta x}{v_x}$$

$$\Delta y = \frac{1}{2}a_y(\Delta t)^2 = \frac{a_y(\Delta x)^2}{2v_x^2} = \frac{(-9.81 \text{ m/s}^2)(25 \text{ m})^2}{(2)(15 \text{ m/s})^2}$$

$$\Delta y = h - h' = -14 \text{ m}$$

$$h' = h - \Delta y = 25 \text{ m} - (-14 \text{ m})$$

$$= \boxed{39 \text{ m}}$$

---

6. $\ell = 420$ m

$\Delta y = \dfrac{-\ell}{2}$

$\Delta x = \ell$

$a_y = -g = -9.81$ m/s^2

$$\Delta t = \sqrt{\frac{2\Delta y}{a_y}} = \frac{\Delta x}{v_x}$$

$$v_x = \sqrt{\frac{a_y}{2\Delta y}}\,\Delta x = \sqrt{\frac{(-9.81 \text{ m/s}^2)}{(2)(-2\,10 \text{m})}}(420 \text{ m}) = \boxed{64 \text{ m/s}}$$

---

7. $\Delta y = -2.45$ m

$v = 12.0$ m/s

$a_y = -g = -9.81$ m/s^2

$$v_y^2 = 2a_y\Delta y$$

$$v^2 = v_x^2 + v_y^2 = v_x^2 + 2a_y\Delta y$$

$$v_x = \sqrt{v^2 - 2a_y\Delta y} = \sqrt{(12.0 \text{ m/s})^2 - (2)(-9.81 \text{ m/s}^2)(-2.45 \text{ m})}$$

$$v_x = \sqrt{144 \text{ m}^2/\text{s}^2 - 48.1 \text{ m}^2/\text{s}^2}$$

$$= \sqrt{96 \text{ m}^2/\text{s}^2}$$

$$v_x = \boxed{9.8 \text{ m/s}}$$

Givens	*Solutions*
8. $\Delta y = -1.95$ m $v_x = 3.0$ m/s $a_y = -g = -9.81$ m/s^2	$v_y{}^2 = 2a_y\,\Delta y$ $v = \sqrt{v_x{}^2 + v_y{}^2} = \sqrt{v_x{}^2 + 2a_y\Delta y}$ $v = \sqrt{(3.0\text{ m/s})^2 + (2)(-9.81\text{ m/s}^2)(-1.95\text{ m})}$ $v = \sqrt{9.0\text{ m}^2/\text{s}^2 + 38.3\text{ m}^2/\text{s}^2} = \sqrt{47.3\text{ m}^2/\text{s}^2} = \boxed{6.88\text{ m/s}}$ $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{\sqrt{2a_y\Delta y}}{v_x}\right) = \tan^{-1}\left(\frac{\sqrt{(2)(-9.81\text{ m/s}^2)(-1.95\text{ m})}}{3.0\text{ m/s}}\right)$ $\theta = \boxed{64° \text{ below the horizontal}}$

Additional Practice E

1. $\Delta x = 201.24$ m $\theta = 35.0°$ $a_y = -g = -9.81$ m/s^2	$\Delta y = v_i\,(\sin\theta)\Delta t + \frac{1}{2}a_y(\Delta t)^2 = v_i\,(\sin\theta) + \frac{1}{2}a_y\Delta t = 0$ $\Delta x = v_i(\cos\theta)\Delta t$ $\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$ $v_i(\sin\theta) = -\frac{1}{2}a_y\left[\frac{\Delta x}{v_i(\cos\theta)}\right]$ $v_i = \sqrt{\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{-(-9.81\text{ m/s}^2)(201.24\text{ m})}{(2)(\sin 35.0°)(\cos 35.0°)}}$ $v_i = \boxed{45.8\text{ m/s}}$
2. $\Delta x = 9.50 \times 10^2$ m $\theta = 45.0°$ $a_y = -g = -9.81$ m/s^2	Using the derivation shown in problem 1, $v_i = \sqrt{\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{-(-9.81\text{ m/s}^2)(9.50\times 10^2\text{ m})}{(2)(\sin 45.0°)(\cos 45.0°)}}$ $v_i = 96.5$ m/s At the top of the arrow's flight: $v = v_x = v_i(\cos\theta) = (96.5\text{ m/s})(\cos 45.0°) = \boxed{68.2\text{ m/s}}$
3. $\Delta x = 27.5$ m $\theta = 50.0°$ $a_y = -g = -9.81$ m/s^2	Using the derivation shown in problem 1, $v_i = \sqrt{\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{-(-9.81\text{ m/s}^2)(27.5\text{ m})}{(2)(\sin 50.0°)(\cos 50.0°)}}$ $v_i = \boxed{16.6\text{ m/s}}$
4. $\Delta x = 44.0$ m $\theta = 45.0°$ $a_y = -g = -9.81$ m/s^2	Using the derivation shown in problem 1, **a.** $v_i = \sqrt{\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{-(-9.81\text{ m/s}^2)(44.0\text{ m})}{(2)(\sin 45.0°)(\cos 45.0°)}}$ $v_i = \boxed{20.8\text{ m/s}}$

II

Givens	Solutions
	b. At maximum height, $v_{y,f} = 0$ m/s

$$v_{y,f}^2 = v_{y,i}^2 + 2a_y\Delta y_{max} = 0$$

$$y_{max} = \frac{-v_{y,i}^2}{2a_y} = \frac{-v_i^2(\sin\theta)^2}{2a_y} = \frac{-(20.8\text{ m/s})^2(\sin 45.0°)^2}{(2)(-9.81\text{ m/s}^2)} = 11.0\text{ m}$$

$\boxed{\text{The brick's maximum height is 11.0 m.}}$

c. $$y_{max} = \frac{-v_{y,i}^2}{2a_y} = \frac{-(20.8\text{ m/s})^2}{(2)(-9.81\text{ m/s}^2)} = 22.1\text{ m}$$

$\boxed{\text{The brick's maximum height is 22.1 m.}}$

---

5. $\Delta x = 76.5$ m

$\theta = 12.0°$

$a_y = -g = -9.81$ m/s^2

At maximum height, $v_{y,f} = 0$ m/s.

$$v_{y,f}^2 = v_{y,i}^2 + 2a_y\Delta y_{max} = 0$$

$$y_{max} = \frac{-v_{y,i}^2}{2a_y} = \frac{-v_i^2(\sin\theta)^2}{2a_y}$$

Using the derivation for v_i^2 from problem 1,

$$\Delta y_{max} = \left[\frac{-a_y\Delta x}{2(\sin\theta)(\cos\theta)}\right]\frac{-(\sin\theta)^2}{2a_y} = \frac{\Delta x(\sin\theta)}{4(\cos\theta)} = \frac{\Delta x(\tan\theta)}{4}$$

$$\Delta y_{max} = \frac{(76.5\text{ m})(\tan 12.0°)}{4} = 4.07\text{ m}$$

---

6. $v_{runner} = 5.82$ m/s

$v_{i,ball} = 2v_{runner}$

In x-direction,

$$v_{i,ball}(\cos\theta) = 2v_{runner}(\cos\theta) = v_{runner}$$

$$2(\cos\theta) = 1$$

$$\theta = \cos^{-1}\left(\tfrac{1}{2}\right) = \boxed{60°}$$

---

7. $v_i = 8.42$ m/s

$\theta = 55.2°$

$\Delta t = 1.40$ s

$a_y = -g = -9.81$ m/s^2

For first half of jump,

$$\Delta t_1 = \frac{1.40\text{ s}}{2} = 0.700\text{ s}$$

$$\Delta y = v_i(\sin\theta)\Delta t_1 + \tfrac{1}{2}a_y(\Delta t_1)^2 = (8.42\text{ m/s})(\sin 55.2°)(0.700\text{ s}) + \tfrac{1}{2}(-9.81\text{ m/s}^2)(0.700\text{ s})^2$$

$$\Delta y = 4.84\text{ m} - 2.40\text{ m} = 2.44\text{ m}$$

$\boxed{\text{The fence is 2.44 m high.}}$

$$\Delta x = v_i(\cos\theta)\Delta t$$

$$\Delta x = (8.42\text{ m/s})(\cos 55.2°)(1.40\text{ s}) = \boxed{6.73\text{ m}}$$

---

8. $v_i = 2.2$ m/s

$\theta = 21°$

$\Delta t = 0.16$ s

$a_y = -g = -9.81$ m/s^2

$$\Delta x = v_i(\cos\theta)\Delta t = (2.2\text{ m/s})(\cos 21°)(0.16\text{ s}) = \boxed{0.33\text{ m}}$$

Maximum height is reached in a time interval of $\frac{\Delta t}{2}$

$$\Delta y_{max} = v_i(\sin\theta)\left(\frac{\Delta t}{2}\right) + \tfrac{1}{2}a_y\left(\frac{\Delta t}{2}\right)^2$$

$$\Delta y_{max} = (2.2\text{ m/s})(\sin 21°)\left(\frac{0.16\text{ s}}{2}\right) + \tfrac{1}{2}(-9.81\text{ m/s}^2)\left(\frac{0.16\text{ s}}{2}\right)^2$$

$$\Delta y_{max} = 6.3\times10^{-2}\text{ m} - 3.1\times10^{-2}\text{ m} = 3.2\times10^{-2}\text{ m} = 3.2\text{ cm}$$

$\boxed{\text{The flea's maximum height is 3.2 cm.}}$

II

Additional Practice F

Givens | *Solutions*

1. $\mathbf{v_{se}}$ = 126 km/h north

$\mathbf{v_{gs}}$ = 40.0 km/h east

$$v_{ge} = \sqrt{{v_{gs}}^2 + {v_{se}}^2} = \sqrt{(40.0\text{ km/h})^2 + (126\text{ km/h})^2}$$

$$v_{ge} = \sqrt{1.60 \times 10^3\text{ km}^2/\text{h}^2 + 1.59 \times 10^4\text{ km}^2/\text{h}^2}$$

$$v_{ge} = \sqrt{1.75 \times 10^4\text{ km/h}} = \boxed{132\text{ km/h}}$$

$$\theta = \tan^{-1}\left(\frac{v_{se}}{v_{gs}}\right) = \tan^{-}1\left(\frac{126\text{ km/h}}{40.0\text{ km/h}}\right) = \boxed{72.4° \text{ north of east}}$$

---

2. $\mathbf{v_{we}} = -3.00 \times 10^2$ km/h

$\mathbf{v_{pw}} = 4.50 \times 10^2$ km/h

$\Delta x = 250$ km

$$v_{pe} = v_{pw} + v_{we} = 4.50 \times 10^2\text{ km/h} - 3.00 \times 10^2\text{ km/h} = 1.50 \times 10^2\text{ km/h}$$

$$\Delta t = \frac{\Delta x}{v_{pe}} = \frac{250\text{ km}}{1.50 \times 10^2\text{ km/h}} = \boxed{1.7\text{ h}}$$

---

3. $\mathbf{v_{tw}}$ = 9.0 m/s north

$\mathbf{v_{wb}}$ = 3.0 m/s east

$\Delta t = 1.0$ min

$$\mathbf{v_{tb}} = \mathbf{v_{tw}} + \mathbf{v_{wb}}$$

$$v_{tb} = \sqrt{{v_{tw}}^2 + {v_{wb}}^2} = \sqrt{(9.0\text{ m/s})^2 + (3.0\text{ m/s})^2} = \sqrt{81\text{ m}^2/\text{s}^2 + 9.0\text{ m}^2/\text{s}^2}$$

$$v_{tb} = \sqrt{9.0 \times 10^1\text{ m}^2/\text{s}^2}$$

$$v_{tb} = 9.5\text{ m/s}$$

$$\Delta x = v_{tb}\Delta t = (9.5\text{ m/s})(1.0\text{ min})\left(\frac{60\text{ s}}{1\text{ min}}\right) = \boxed{570\text{ m}}$$

$$\theta = \tan^{-1}\left(\frac{v_{wb}}{v_{tw}}\right) = \tan^{-1}\left(\frac{3.0\text{ m/s}}{9.0\text{ m/s}}\right) = \boxed{18° \text{ east of north}}$$

---

4. $\mathbf{v_{sw}}$ = 40.0 km/h forward

$\mathbf{v_{fw}}$ = 16.0 km/h forward

$\Delta x = 60.0$ m

$$\mathbf{v_{sf}} = \mathbf{v_{sw}} - \mathbf{v_{fw}} = 40.0\text{ km/h} - 16.0\text{ km/h} = 24.0\text{ km/h toward fish}$$

$$\Delta t = \frac{\Delta x}{v_{sf}} = \frac{60.0\text{ m}}{(24.0\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{10^3\text{ m}}{1\text{ km}}\right)} = \boxed{9.00\text{ s}}$$

---

5. $\mathbf{v_{1E}}$ = 90.0 km/h

$\mathbf{v_{2E}}$ = −90.0 km/h

$\Delta t = 40.0$ s

$$\mathbf{v_{12}} = \mathbf{v_{1E}} - \mathbf{v_{2E}}$$

$$v_{12} = 90.0\text{ km/h} - (-90.0\text{ km/h}) = 1.80 \times 10^2\text{ km/h}$$

$$\Delta x = v_{12}\Delta t = (1.80 \times 10^2\text{ km/h})\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{10^3\text{ m}}{1\text{ km}}\right)(40.0\text{ s}) = 2.00 \times 10^3\text{ m} = 2.00\text{ km}$$

$\boxed{\text{The two geese are initially 2.00 km apart}}$

---

6. $\mathbf{v_{me}}$ = 18.0 km/h forward

$\mathbf{V_{re}} = 0.333\ \mathbf{V_{me}}$
= 6.00 km/h forward

$\Delta x = 12.0$ m

$$\mathbf{v_{mr}} = \mathbf{v_{me}} - \mathbf{v_{re}}$$

$$v_{mr} = 18.0\text{ km/h} - 6.0\text{ km/h} = 12.0\text{ km/h}$$

$$\Delta t = \frac{\Delta x}{v_{mr}} = \frac{12.0\text{ m}}{(12.0\text{ km/h})}\left(\frac{3600\text{ s}}{1\text{ h}}\right)\left(\frac{1\text{ km}}{10^3\text{ m}}\right)$$

$$\Delta t = \boxed{3.60\text{ s}}$$

II

Forces and the Laws of Motion

4

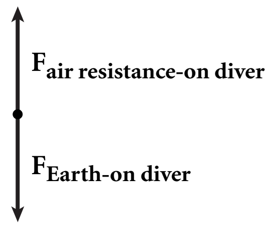
Additional Practice A

Givens | *Solutions*

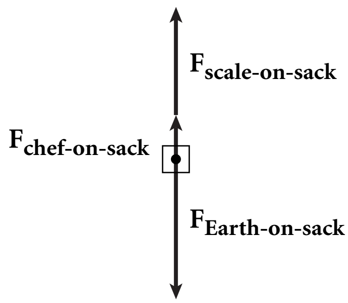
1.

a.

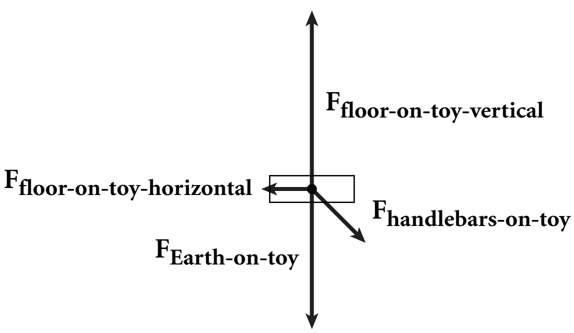
b.



2.



3.



Additional Practice B

1. $m_w = 75$ kg

$m_p = 275$ kg

$g = 9.81$ m/s^2

The normal force exerted by the platform on the weight lifter's feet is equal to and opposite of the combined weight of the weightlifter and the pumpkin.

$$F_{net} = F_n - m_w g - m_p g = 0$$

$$F_n = (m_w + m_p)g = (75 \text{ kg} + 275 \text{ kg})\ (9.81 \text{ m/s}^2)$$

$$F_n = (3.50 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2) = 3.43 \times 10^3 \text{ N}$$

$$\mathbf{F_n} = \boxed{3.43 \times 10^3 \text{ N upward against feet}}$$

Givens | *Solutions*

2. $m_b = 253$ kg

$m_w = 133$ kg

$g = 9.81$ m/s^2

$F_{net} = F_{n,1} + F_{n,2} - m_b g - m_w g = 0$

The weight of the weightlifter and barbell is distributed equally on both feet, so the normal force on the first foot ($F_{n,1}$) equals the normal force on the second foot ($F_{n,2}$).

$$2F_{n,1} = (m_b + m_w)g = 2F_{n,2}$$

$$F_{n,1} = F_{n,2} = \frac{(m_b + m_b)g}{2} = \frac{(253 \text{ kg} + 33 \text{ kg})\left(9.81 \dfrac{\text{m}}{\text{s}^2}\right)}{2}$$

$$F_{n,1} = F_{n,2} = \frac{(386 \text{ kg})(9.81 \text{ m/s}^2)}{2} = 1.89 \times 10^3 \text{ N}$$

$$\mathbf{F_{n,1}} = \mathbf{F_{n,2}} = \boxed{1.89 \times 10^3 \text{ N upward on each foot}}$$

---

3. $F_{down} = 1.70$ N

$F_{net} = 4.90$ N

$$F_{net}{}^2 = F_{forward}{}^2 + F_{down}{}^2$$

$$F_{forward} = \sqrt{F_{net}{}^2 - \text{F}_{\text{down}}{}^2} = \sqrt{(4.90 \text{ N})^2 - (1.70 \text{ N})^2}$$

$$F_{forward} = \sqrt{21.1 \text{ N}^2} = \boxed{4.59 \text{ N}}$$

II

4. $m = 3.10 \times 10^2$ kg

$g = 9.81$ m/s^2

$\theta_1 = 30.0°$

$\theta_2 = -30.0°$

$$F_{x,net} = \Sigma F_x = F_{T,1}(\sin \theta_1) + F_{T,2}(\sin \theta_2) = 0$$

$$F_{y,net} = \Sigma F_y = F_{T,1}(\cos \theta_1) + F_{T,2}(\cos \theta_2) + \text{Fg} = 0$$

$$F_{T,1}(\sin 30.0°) = -F_{T,2}[\sin(-30.0°)]$$

$$F_{T,1} = F_{T,2}$$

$$F_{T,1}(\cos \theta_1) + F_{T,1}(\cos \theta_2) = -F_g = mg$$

$$F_{T,1}(\cos 30.0°) + F_{T,1}[\cos(-30.0°)] = (3.10 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2)$$

$$F_{T,1} = \frac{(3.10 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2)}{(2)(\cos 30.0°)[\cos(-30.0°)]}$$

$$F_{T,1} = F_{T,2} = \boxed{1.76 \times 10^3 \text{ N}}$$

As the angles θ_1 and θ_2 become larger, cos θ_1 and cos θ_2 become smaller. Therefore, $F_{T,1}$ and $F_{T,2}$ must become larger in magnitude.

Givens | *Solutions*

5. $m = 155$ kg

$F_{T,1} = 2F_{T,2}$

$g = 9.81$ m/s^2

$\theta_1 = 90° - \theta_2$

$$F_{x,net} = F_{T,1}(\cos\theta_1) - F_{T,2}(\cos\theta_2) = 0$$

$$F_{y,net} = F_{T,1}(\sin\theta_1) + F_{T,2}(\sin\theta_2) - mg = 0$$

$$F_{T,1}[(\cos\theta_1) - \frac{1}{2}(\cos\theta_2)] = 0$$

$$2(\cos\theta_1) = \cos\theta_2 = \cos(90° - \theta_1) = \sin\theta_1$$

$$2 = \tan\theta_1$$

$$\theta_1 = \tan^{-1}(2) = 63°$$

$$\theta_2 = 90° - 63° = 27°$$

$$F_{T,1}(\sin\theta_1) + \frac{F_{T,1}}{2}(\sin\theta_2) = mg$$

$$F_{T,1} = \frac{mg}{(\sin\theta_1) + \frac{1}{2}(\sin\theta_2)}$$

$$F_{T,1} = \frac{(155\text{ kg})(9.81\text{ m/s}^2)}{(\sin 63°) + \frac{(\sin 27°)}{2}} = \frac{(155\text{ kg})(9.81\text{ m/s}^2)}{0.89 + 0.23} = \frac{(155\text{ kg})(9.81\text{ m})}{1.12}$$

$$F_{T,1} = \boxed{1.36 \times 1.36 \times 10^3\text{ N}}$$

$$F_{T,2} = \boxed{6.80 \times 10^2\text{ N}}$$

II

Additional Practice C

1. $v_i = 173$ km/h

$v_f = 0$ km/h

$\Delta x = 0.660$ m

$m = 70.0$ kg

$g = 9.81$ m/s^2

$$a = \frac{v_f^2 - v_i^2}{2\Delta x} = \frac{[(0\text{ km/h})^2 - (173\text{ km/h})^2](10^3\text{ m/km})^2(1\text{ h}/3600\text{ s})^2}{(2)(0.660\text{ m})}$$

$$a = -1.75 \times 10^3\text{ m/s}^2$$

$$F = ma = (70.0\text{ kg})(-1.75 \times 10^3\text{ m/s}^2) = \boxed{-1.22° \times 10^5\text{ N}}$$

$$F_g = mg = (70.0\text{ kg})(9.81\text{ m/s}^2) = \boxed{6.87 \times 10^2\text{ N}}$$

The force of deceleration is nearly 178 times as large as David Purley's weight.

2. $m = 2.232 \times 10^6$ kg

$g = 9.81$ m/s^2

$a_{net} = 0$ m/s^2

a. $F_{net} = ma_{net} = F_{up} - mg$

$$F_{up} = ma_{net} + mg = m(a_{net} + g) = (2.232 \times 10^6\text{ kg})(0\text{ m/s}^2 + 9.81\text{ m/s}^2)$$

$$F_{up} = \boxed{2.19 \times 10^7\text{ N}} = mg$$

b. $F_{down} = mg(\sin\theta)$

$$a_{net} = \frac{F_{net}}{m} = \frac{F_{up} - F_{down}}{m} = \frac{mg - mg(\sin\theta)}{m}$$

$$a_{net} = g(1 - \sin\theta) = (9.81\text{ m/s}^2)[1.00 - (\sin 30.0°)] = \frac{9.81\text{ m/s}^2}{2} = 4.90\text{ m/s}^2$$

$$\mathbf{a_{net}} = \boxed{4.90\text{ m/s}^2\text{ up the incline}}$$

3. $m = 40.00$ mg $= 4.00 \times 10^{-5}$ kg

$g = 9.807$ m/s^2

$a_{net} = (400.0)g$

$$F_{net} = F_{beetle} - F_g = ma_{net} = m(400.0)\,g$$

$$F_{beetle} = F_{net} + F_g = m(400.0 + 1)g = m(401)g$$

$$F_{beetle} = (4.000 \times 10^{-5}\text{ kg})(9.807\text{ m/s}^2)(401) = \boxed{1.573 \times 10^{-1}\text{ N}}$$

$$F_{net} = F_{beetle} - F_g = m(400.0)\,g = (4.000 \times 10^{-5}\text{ kg})(9.807\text{ m/s}^2)(400.0)$$

$$F_{net} = \boxed{1.569 \times 10^{-1}\text{ N}}$$

The effect of gravity is negligible.

Givens	Solutions
4. $m_a = 54.0$ kg	The net forces on the lifted weight is
$m_w = 157.5$ kg	$F_{w,net} = m_w a_{net} = F' - m_w g$
$a_{net} = 1.00$ m/s^2	where F' is the force exerted by the athlete on the weight.
$g = 9.81$ m/s^2	The net force on the athlete is

$F_{a,net} = F_{n,1} + F_{n,2} - F' - m_a g = 0$

where $F_{n,1}$ and $F_{n,2}$ are the normal forces exerted by the ground on each of the athlete's feet, and $-F'$ is the force exerted by the lifted weight on the athlete.

The normal force on each foot is the same, so

$F_{n,1} = F_{n,2} = F_n$ and

$F' = 2F_n - m_a g$

Using the expression for F' in the equation for $F_{w,net}$ yields the following:

$m_w a_{net} = (2F_n - m_a g) - m_a g$

$2F_n = m_w(a_{net} + g) + m_a g$

$$F_n = \frac{m_w(a_{net} + g) + m_a g}{2} = \frac{(157.5 \text{ kg})(1.00 \text{ m/s}^2 + 9.81 \text{ m/s}^2) + (54.0 \text{ kg})}{2}$$

$$F_n = \frac{(157.5 \text{ kg})(10.81 \text{ m/s}^2) + (54.0 \text{ kg})(9.81 \text{ m/s}^2)}{2}$$

$$F_n = \frac{1702 \text{ N} + 5.30 \times 10^2 \text{ N}}{2} = \frac{2232 \text{ N}}{2} = 1116 \text{ N}$$

$F_{n,1} - F_{n,2} = F_n = \boxed{1116 \text{ N upward}}$

Givens	Solutions
5. $m = 2.20 \times 10^2$ kg	$F_{net} = ma_{net} = F_{avg} - mg$
$a_{net} = 75.0$ m/s^2	$F_{avg} = m(a_{net} + g) = (2.20 \times 10^2 \text{ kg})(75.0 \text{ m/s}^2 + 9.81 \text{ m/s}^2)$
$g = 9.81$ m/s^2	$F_{avg} = (2.20 \times 10^2 \text{ kg})(84.8 \text{ m/s}^2) = 1.87 \times 10^4$ N
	$\mathbf{F_{avg}} = \boxed{1.87 \times 10^4 \text{ N upward}}$

Givens	Solutions
6. $m = 2.00 \times 10^4$ kg	$a_{net} = \dfrac{v_f - v_i}{\Delta t} = \dfrac{(1.0 \text{ m/s} - 0.0 \text{ m/s})}{2.5 \text{ s}} = 0.40 \text{ m/s}^2$
$\Delta t = 2.5$	$F_{net} = ma_{net} = F_T - mg$
$v_i = 0$ m/s	$F_T = ma_{net} + mg = m(a_{net} + g)$
$v_f = 1.0$ m/s	$F_T = (2.00 \times 10^4 \text{ kg})(0.40 \text{ m/s}^2 + 9.81 \text{ m/s}^2)$
$g = 9.81$ m/s^2	$F_T = (2.00 \times 10^4 \text{ kg})(10.21 \text{ m/s}^2) = 2.04 \times 10^5$ N
	$F_T = \boxed{2.04 \times 10^5 \text{ N}}$

Givens	Solutions
7. $m = 2.65$ kg	$F_{x,net} = F_{T,1}(\cos \theta_1) - F_{T,2}(\cos \theta_2) = 0$
$\theta_1 = \theta_2 = 45.0°$	$F_{T,1}(\cos 45.0°) = F_{T,2}(\cos 45.0°)$
$a_{net} = 2.55$ m/s^2	$F_{T,1} = F_{T,2}$
$g = 9.81$ m/s^2	$F_{y,net} = ma_{net} = F_{T,1}(\sin \theta_1) + F_{T,2}(\sin \theta_2) - mg$

$F_T = F_{T,1} = F_{T,2}$

$\theta = \theta_1 = \theta_2$

$F_T(\sin \theta) + F_T(\sin \theta) = m(a_{net} + g)$

$2F_T(\sin \theta) = m(a_{net} + g)$

Givens	Solutions
	$F_T = \frac{m(a_{net} + g)}{2\,(\sin\theta)} = \frac{(2.65\text{ kg})(2.55\text{ m/s}^2 = 9.81\text{ m/s}^2)}{(2)(\sin 45.0°)}$
	$F_T = \frac{(2.65\text{ kg})(12.36\text{ m/s}^2)}{(2)(\sin 45.0°)} = 23.2\text{ N}$
	$F_{T,1} = 23.2\text{ N}$
	$F_{T,2} = 23.2\text{ N}$
8. $m = 20.0\text{ kg}$	$a_{net} = \frac{v_f^2 - v_i^2}{2\Delta x} = \frac{(0.550\text{ m/s})^2 - (0.00\text{ m/s})^2}{(2)(1.55\text{ m})} = 9.76 \times 10^{-2}\text{ m/s}^2$
$\Delta x = 1.55\text{ m}$	$F_{net} = ma_{net} = (20.0\text{ kg})(9.76 \times 10^{-2}\text{ m/s}^2) = \boxed{1.95\text{ N}}$
$v_i = 0\text{ m/s}$	
$v_f = 0.550\text{ m/s}$	
9. $m_{max} = 70.0\text{ kg}$	$F_{max} = m_{max}g = F_T$
$m = 45.0\text{ kg}$	$F_{max} = (70.0\text{ kg})(9.81\text{ m/s}^2) = 687\text{ N}$
$g = 9.81\text{ m/s}^2$	$F_{net} = ma_{net} = F_T - mg = F_{max} - mg$
	$a_{net} = \frac{F_{max}}{m} - g = \frac{687\text{ N}}{45.0\text{ kg}} - 9.81\text{ m/s}^2 = 15.3\text{ m/s}^2 - 9.81\text{ m/s}^2 = 5.5\text{ m/s}^2$
	$\mathbf{a_{net}} = \boxed{5.5\text{ m/s}^2\text{ upward}}$
10. $m = 3.18 \times 10^5\text{ kg}$	$F_{net} = F_{applied} - F_{friction} = (81.0 \times 10^3 - 62.0 \times 10^3\text{ N})$
$F_{applied} = 81.0 \times 10^3\text{ N}$	$F_{net} = 19.0 \times 10^3\text{ N}$
$F_{friction} = 62.0 \times 10^3\text{ N}$	$a_{net} = \frac{F_{net}}{m} = \left(\frac{19.0 \times 10^3\text{ N}}{3.18 \times 10^5\text{ kg}}\right) = \boxed{5.97 \times 10^{-2}\text{ m/s}^2}$
11. $m = 3.00 \times 10^3\text{ kg}$	$F_{net} = ma_{net} = F_{applied}(\cos\theta) - F_{opposing}$
$F_{applied} = 4.00 \times 10^3\text{ N}$	$a_{net} = \frac{F_{applied}(\cos\theta) - (0.120)\,mg}{m}$
$\theta = 20.0°$	$a_{net} = \frac{(4.00 \times 10^3\text{ N})(\cos 20.0°) - (0.120)(3.00 \times 10^3\text{ kg})(9.81\text{ m/s}^2)}{3.00 \times 10^3\text{ kg}}$
$F_{opposing} = (0.120)\,mg$	$a_{net} = \frac{3.76 \times 10^3\text{ N} - 3.53 \times 10^3\text{ N}}{3.00 \times 10^3\text{ kg}} = \frac{2.3 \times 10^2\text{ N}}{3.00 \times 10^3\text{ kg}}$
$g = 9.81\text{ m/s}^2$	$a_{net} = \boxed{7.7 \times 10^{-2}\text{ m/s}^2}$
12. $m_c = 1.600 \times 10^3\text{ kg}$	For the counterweight: The tension in the cable is F_T.
$m_w = 1.200 \times 10^3\text{ kg}$	$F_{net} = F_T - m_wg = m_wa_{net}$
$v_i = 0\text{ m/s}$	For the car:
$g = 9.81\text{ m/s}^2$	$F_{net} = m_cg - F_T = m_ca_{net}$
$\Delta y = 25.0\text{ m}$	Adding the two equations yields the following:
	$m_cg - m_wg = (m_w + m_c)a_{net}$
	$a_{net} = \frac{(m_c - m_w)g}{m_c + m_w} = \frac{(1.600 \times 10^3\text{ kg} - 1.200 \times 10^3\text{ kg})(9.81\text{ m/s}^2)}{1.600 \times 10^3\text{ kg} + 1.200 \times 10^3\text{ kg}}$
	$a_{net} = \frac{(4.00 \times 10^2\text{ kg})(9.81\text{ m/s}^2)}{2.800 \times 10^3\text{ kg}} = \boxed{1.40\text{ m/s}^2}$

Givens	Solutions
	$v_f = \sqrt{2a_{net}\Delta y + v_i^2} = \sqrt{(2)(1.40\ \text{m/s}^2)(25.0\ \text{m}) + (0\ \text{m/s})^2}$
	$v_f = \boxed{8.37\ \text{m/s}}$

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13. $m = 409$ kg

$d = 6.00$ m

$\theta = 30.0°$

$g = 9.81\ \text{m/s}^2$

$F_{applied} = 2080$ N

$v_i = 0$ m/s

a. $F_{net} = F_{applied} - mg(\sin\theta) = 2080\ \text{N} - (409\ \text{kg})(9.81\ \text{m/s}^2)(\sin 30.0°)$

$F_{net} = 2080\ \text{N} - 2010\ \text{N} = 70\ \text{N}$

$\mathbf{F_{net}} = \boxed{70\ \text{N at } 30.0° \text{ above the horizontal}}$

b. $a_{net} = \frac{F_{net}}{m} = \frac{70\ \text{N}}{409\ \text{kg}} = 0.2\ \text{m/s}^2$

$\mathbf{a_{net}} = \boxed{0.2\ \text{m/s}^2 \text{ at } 30.0° \text{ above the horizontal}}$

c. $d = v_i\Delta t + \frac{1}{2}a_{net}\Delta t^2 = (0\ \text{m/s})\Delta t + \frac{1}{2}(0.2\ \text{m/s}^2)\Delta t^2$

$\Delta t = \sqrt{\frac{(2)(6.00\ \text{m})}{(0.2\ \text{m/s}^2)}} = \boxed{8\ \text{s}}$

---

14. $a_{max} = 0.25\ \text{m/s}^2$

$F_{max} = 57$ N

$F_{app} = 24$ N

a. $m = \frac{F_{max}}{a_{max}} = \frac{57\ \text{N}}{0.25\ \text{m/s}^2} = \boxed{2.3 \times 10^2\ \text{kg}}$

b. $F_{net} = F_{max} - F_{app} = 57\ \text{N} - 24\ \text{N} = 33\ \text{N}$

$a_{net} = \frac{F_{net}}{m} = \frac{33\ \text{N}}{2.3 \times 10^2\ \text{kg}} = \boxed{0.14\ \text{m/s}^2}$

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15. $m = 2.55 \times 10^3$ kg

$F_T = 7.56 \times 10^3$ N

$\theta_T = -72.3°$

$F_{buoyant} = 3.10 \times 10^4$ N

$F_{wind} = -920$ N

$g = 9.81\ \text{m/s}^2$

a. $F_{x,net} = \Sigma F_x = ma_{x,net} = F_T(\cos\theta_T) + F_{wind}$

$F_{x,net} = (7.56 \times 10^3\ \text{N})[\cos(-72.3°)] - 920\ \text{N} = 2.30 \times 10^3\ \text{N} - 920\ \text{N} = 1.38 \times 10^3\ \text{N}$

$F_{y,net} = \Sigma F_y = ma_{y,net} = F_T(\sin\theta_T) + F_{buoyant} + F_g = F_T(\sin\theta_T) + F_{buoyant} - mg$

$F_{y,net} = (7.56 \times 10^3\ \text{N})[\sin(-72.3°)] = 3.10 \times 10^4\ \text{N} - (2.55 \times 10^3\ \text{kg})(9.81\ \text{m/s}^2)$

$F_{y,net} = -7.20 \times 10^3\ \text{N} + 3.10 \times 10^4\ \text{N} - 2.50 \times 10^4 = -1.2 \times 10^3\ \text{N}$

$F_{net} = \sqrt{(F_{x,net})^2 + (F_{y,net})^2} = \sqrt{(1.38 \times 10^3\ \text{N})^2 + (-1.2 \times 10^3\ \text{N})^2}$

$F_{net} = \sqrt{1.90 \times 10^6\ \text{N}^2 + 1.4 \times 10^6\ \text{N}^2}$

$F_{net} = \sqrt{3.3 \times 10^6\ \text{N}^2} = 1.8 \times 10^3\ \text{N}$

$\theta = \tan^{-1}\left(\frac{F_{y,\,net}}{F_{x,\,net}}\right) = \tan^{-1}\left(\frac{-1.2 \times 10^3\ \text{N}}{1.38 \times 10^3\ \text{N}}\right)$

$\theta = -41°$

$\mathbf{F_{net}} = \boxed{1.8 \times 10^3\ \text{N at } 41° \text{ below the horizontal}}$

b. $a_{net} = \frac{F_{net}}{m} = \frac{1.8 \times 10^3\ \text{N}}{2.55 \times 10^3\ \text{kg}}$

$a_{net} = \boxed{0.71\ \text{m/s}^2}$

$\Delta y = -45.0$ m

$v_i = 0$ m/s

c. Because $v_i = 0$

$\Delta y = \frac{1}{2}a_{y,net}\Delta t^2$

$\Delta x = \frac{1}{2}a_{x,net}\Delta t^2$

$\Delta x = \frac{a_{x,net}}{a_{y,net}}$ $\quad \Delta y = \frac{a_{net}(\cos\theta)}{a_{net}(\sin\theta)}$ $\quad \Delta y = \frac{\Delta y}{\tan\theta}$

$\Delta x = \frac{-45.0\ \text{m}}{\tan(-41°)} = \boxed{52\ \text{m}}$

Additional Practice D

Givens | *Solutions*

1. $m = 11.0$ kg

$\mu_k = 0.39$

$g = 9.81$ m/s^2

$F_k = \mu_k F_n = \mu_k mg$

$F_k = (0.39)\ (11.0\ \text{kg})(9.81\ \text{m/s}^2) = \boxed{42.1\ \text{N}}$

---

2. $m = 2.20 \times 10^5$ kg

$\mu_s = 0.220$

$g = 9.81$ m/s^2

$F_{s,max} = \mu_s F_n = \mu_s mg$

$F_{s,max} = (0.220)(2.20 \times 10^5\ \text{kg})(9.91\ \text{m/s}^2) = \boxed{4.75 \times 10^5\ \text{N}}$

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3. $m = 25.0$ kg

$F_{applied} = 59.0$ N

$\theta = 38.0°$

$\mu_s = 0.599$

$g = 9.81$ m/s^2

$F_{s,max} = \mu_s F_m$

$F_n = mg(\cos\theta) + F_{applied}$

$F_{s,max} = \mu_s[mg(\cos\theta) = F_{applied}] = (0.599)[(25.0\ \text{kg})(9.81\ \text{m/s}^2)(\cos 38.0° + 59.0\ \text{N}]$

$F_{s,max} = (0.599)(193\ \text{N} + 59\ \text{N}) = (0.599)(252\ \text{N}) = \boxed{151\ \text{N}}$

Alternatively,

$F_{net} = mg(\sin\theta) - F_{s,max} = 0$

$F_{s,max} = mg(\sin\theta) = (25.0\ \text{kg})(9.81\ \text{m/s}^2)(\sin 38.0°) = \boxed{151\ \text{N}}$

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4. $\theta = 38.0°$

$g = 9.81$ m/s^2

$F_{net} = mg(\sin\theta) - F_k = 0$

$F_k = \mu_k F_n = \mu_k mg(\cos\theta)$

$\mu_k mg(\cos\theta) = mg(\sin\theta)$

$$\mu_k = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 38.0°$$

$\mu_k = \boxed{0.781}$

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5. $\theta = 5.2°$

$g = 9.81$ m/s^2

$F_{net} = mg(\sin\theta) - F_k = 0$

$F_k = \mu_k F_n = \mu_k mg(\cos\theta)$

$\mu_k mg(\cos\theta) = mg(\sin\theta)$

$$\mu_k = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 5.2°$$

$\mu_k = \boxed{0.091}$

II

Givens	*Solutions*
6. $m = 281.5$ kg $\theta = 30.0°$	$F_{net} = 3mg(\sin\theta) - \mu_s(3mg)(\cos\theta) - F_{applied} = 0$ $F_{applied} = mg$ $\mu_s = \frac{3mg(\sin\theta) - mg}{3mg(\cos\theta)} = \frac{3(\sin\theta) - 1.00}{3(\cos\theta)} = \frac{(3)(\sin 30.0°) - 1.00}{(3)(\cos 30.0°)}$ $\mu_s = \frac{1.50 - 1.00}{(3)(\cos 30.0°)} = \frac{0.50}{(3)(\cos 30.0°)}$ $\mu_s = \boxed{0.19}$
7. $m = 1.90 \times 10^5$ kg $\mu_s = 0.460$ $g = 9.81$ m/s^2	$F_{net} = F_{applied} - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg$ $F_{applied} = \mu_k mg = (0.460)(1.90 \times 10^5 \text{ kg})(9.81 \text{ m/s}^2)$ $F_{applied} = \boxed{8.57 \times 10^5 \text{ N}}$
8. $F_{applied} = 6.0 \times 10^3$ N $\mu_k = 0.77$ $g = 9.81$ m/s^2	$F_{net} = F_{applied} - F_k = 0$ $F_k = \mu_k F_n$ $F_n = \frac{F_{applied}}{\mu_k} = \frac{6.0 \times 10^3 \text{ N}}{0.77} = \boxed{7.8 \times 10^3 \text{ N}}$ $F_n = mg$ $m = \frac{F_n}{g} = \frac{7.8 \times 10^3 \text{ N}}{9.81 \text{ m/s}^2} = \boxed{8.0 \times 10^2 \text{ kg}}$
9. $F_{applied} = 1.13 \times 10^8$ N $\mu_s = 0.741$	$F_{net} = F_{applied} - F_{s,max} = 0$ $F_{s,max} = \mu_s F_n = \mu_s mg$ $m = \frac{F_{applied}}{\mu_s g} = \frac{1.13 \times 10^8 \text{ N}}{(0.741)(9.81 \text{ m/s}^2} = \boxed{1.55 \times 10^2 \text{ kg}}$
10. $m = 3.00 \times 10^3$ kg $\theta = 31.0°$ $g = 9.81$ m/s^2	$F_{net} = mg(\sin\theta) - F_k = 0$ $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$ $\mu_k mg(\cos\theta) = mg(\sin\theta)$ $\mu_k = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 31.0°$ $\mu_k = \boxed{0.601}$ $F_k = \mu_k mg(\cos\theta) = (0.601)(3.00 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\cos 31.0°)$ $F_k = \boxed{1.52 \times 10^4 \text{ N}}$ Alternatively, $F_k = mg(\sin\theta) = (3.00 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\sin 31.0°) = \boxed{1.52 \times 10^4 \text{ N}}$

II

Additional Practice E

Givens	*Solutions*
1. $F_{applied} = 130$ N $a_{net} = 1.00$ m/s^2 $\mu_k = 0.158$ $g = 9.81$ m/s^2	$F_{net} = ma_{net} = F_{applied} - F_k$ $F_k = \mu_k F_n = \mu_k mg$ $ma_{net} + \mu_k mg = F_{applied}$ $m(a_{net} + \mu_k g) = F_{applied}$ $m = \dfrac{F_{applied}}{a_{net} + \mu_k g} = \dfrac{130 \text{ N}}{1.00 \text{ m/s}^2 + (0.158)(9.81 \text{ m/s}^2)}$ $m = \dfrac{130 \text{ N}}{1.00 \text{ m/s}^2 + 1.55 \text{ m/s}^2} = \dfrac{130 \text{ N}}{2.55 \text{ m/s}^2} = \boxed{51 \text{ kg}}$
2. $F_{net} = -2.00 \times 10^4$ N $\theta = 10.0°$ $\mu_k = 0.797$ $g = 9.81$ m/s^2	$F_{net} = ma_{net} = mg(\sin\theta) - F_k$ $F_k = \mu_k F_n = \mu_k m_g(\cos\theta)$ $m[g(\sin\theta) - \mu_k g(\cos\theta)] = F_{net}$ $m = \dfrac{F_{net}}{g[\sin\theta - \mu_k(\cos\theta)]} = \dfrac{-2.00 \times 10^4 \text{ N}}{(9.81 \text{ m/s}^2)[(\sin 10.0°) - (0.797)(\cos 10.0°)]}$ $m = \dfrac{-2.00 \times 10^4 \text{ N}}{(9.81 \text{ m/s}^2)(0.174 - 0.785)} = \dfrac{-2.00 \times 10^4 \text{ N}}{(9.81 \text{ m/s}^2)(-0.611)}$ $m = \boxed{3.34 \times 10^3 \text{ kg}}$ $F_n = mg(\cos\theta) = (3.34 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\cos 10.0°) = \boxed{3.23 \times 10^4 \text{ N}}$
3. $F_{net} = 6.99 \times 10^3$ N $\theta = 45.0°$ $\mu_k = 0.597$	$F_{net} = ma_{net} = mg(\sin\theta) - F_k$ $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$ $m[g(\sin\theta) - \mu_k g(\cos\theta)] = F_{net}$ $m = \dfrac{F_{net}}{g[\sin\theta - \mu_k(\cos\theta)]} = \dfrac{6.99 \times 10^3 \text{ N}}{(9.81 \text{ m/s}^2)[(\sin 45.0°) - (0.597)(\cos 45.0°)]}$ $m = \dfrac{6.99 \times 10^3 \text{ N}}{(9.81 \text{ m/s}^2)(0.707 - 0.422)} = \dfrac{6.99 \times 10^3 \text{ N}}{(9.81 \text{ m/s}^2)(0.285)}$ $m = \boxed{2.50 \times 10^3 \text{ kg}}$ $F_n = mg(\cos\theta) = (2.50 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(\cos 45.0°) = \boxed{1.73 \times 10^4 \text{ N}}$
4. $m = 9.50$ kg $\theta = 30.0$ ° $F_{applied} = 80.0$ N $a_{net} = 1.64$ m/s^2 g = 9.81 m/s^2	$F_{net} = ma_{net} = F_{applied} - F_k - mg(\sin\theta)$ $F_k = \mu_k F_n = \mu_k mg(\cos\theta)$ $\mu_k mg(\cos\theta) = F_{applied} - ma_{net} - mg(\sin\theta)$ $\mu_k = \dfrac{F_{applied} - m[a_{net} + g(\sin\theta)]}{mg(\cos\theta)}$ $\mu_k = \dfrac{80.0 \text{ N} - (9.50 \text{ kg})[1.64 \text{ m/s}^2 + (9.81 \text{ m/s}^2)(\sin 30.0°)]}{(9.50 \text{ kg})(9.81 \text{ m/s}^2)(\cos 30.0°)}$

II

Givens	*Solutions*

$$\mu_k = \frac{80.0\ \text{N} - (9.50\ \text{kg})[1.64\ \text{m/s}^2 + 4.90\ \text{m/s}^2]}{(9.50\ \text{kg})(9.81\ \text{m/s}^2)(\cos 30.0°)} = \frac{80.0\ \text{N} - (9.50\ \text{kg})(6.54\ \text{m/s}^2)}{(9.50\ \text{kg})(9.81\ \text{m/s}^2)(\cos 30.0°)}$$

$$\mu_k = \frac{80.0\ \text{N} - 62.1\ \text{N}}{(9.50\ \text{kg})(9.81\ \text{m/s}^2)(\cos 30.0°)} = \frac{17.9\ \text{N}}{(9.50\ \text{kg})(9.81\ \text{m/s}^2)(\cos 30.0°)}$$

$$\mu_k = \boxed{0.222}$$

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5. $m = 1.89 \times 10^5$ kg

$F_{applied} = 7.6 \times 10^5$ N

$a_{net} = 0.11\ \text{m/s}^2$

$F_{net} = ma_{net} = F_{applied} - F_k$

$F_k = F_{applied} - ma_{net} = 7.6 \times 10^5\ \text{N} - (1.89 \times 10^5)(0.11\ \text{m/s}^2) = 7.6 \times 10^5\ \text{N} - 2.1 \times 10^4\ \text{N}$

$F_k = \boxed{7.4 \times 10^5\ \text{N}}$

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6. $\theta = 38.0°$

$\mu_k = 0.100$

$g = 9.81\ \text{m/s}^2$

$F_{net} = ma_{net} = mg(\sin\theta) - F_k$

$F_k = \mu_k F_n = \mu_k mg(\cos\theta)$

$ma_{net} = mg[\sin\theta - \mu_k(\cos\theta)]$

$a_{net} = g[\sin\theta - \mu_k(\cos\theta)] = (9.81\ \text{m/s}^2)[(\sin 38.0°) - (0.100)(\cos 38.0°)]$

$a_{net} = (9.81\ \text{m/s}^2)(0.616 - 7.88 \times 10^{-2}) = (9.81\ \text{m/s}^2)(0.537)$

$a_{net} = \boxed{5.27\ \text{m/s}^2}$

Acceleration is independent of the rider's and sled's masses. (Masses cancel.)

---

7. $\Delta t = 6.60$ s

$\theta = 34.0°$

$\mu_k = 0.198$

$g = 9.81\ \text{m/s}^2$

$v_i = 0$ m/s

$F_{net} = ma_{net} = mg(\sin\theta) - F_k$

$F_k = \mu_k F_n = \mu_k mg(\cos\theta)$

$ma_{net} = mg[\sin\theta - \mu_k(\cos\theta)]$

$a_{net} = g[\sin\theta - \mu_k(\cos\theta)] = (9.81\ \text{m/s}^2)[(\sin 34.0°) - (0.198)(\cos 34.0°)]$

$a_{net} = (9.81\ \text{m/s}^2)(0.559 - 0.164) = (9.81\ \text{m/s}^2)(0.395)$

$a_{net} = \boxed{3.87\ \text{m/s}^2}$

$v_f = v_i + a_{net}\Delta t = 0\ \text{m/s} + (3.87\ \text{m/s}^2)(6.60\ \text{s})$

$v_f = \boxed{25.5\ \text{m/s}^2 = 92.0\ \text{km/h}}$

II

Work and Energy

Additional Practice A

Givens / *Solutions*

1. $W = 1.15 \times 10^3$ J

$m = 60.0$ kg

$g = 9.81$ m/s^2

$\theta = 0°$

$$W = Fd(\cos\theta) = mgd(\cos\theta)$$

$$d = \frac{W}{mg(\cos\theta)} = \frac{1.15 \times 10^5 \text{ J}}{(60.0 \text{ kg})(9.81 \text{ m/s}^2)(\cos 0°)}$$

$$d = \boxed{195 \text{ m}}$$

---

2. $m = 1.45 \times 10^6$ kg

$g = 9.81$ m/s^2

$\theta = 0°$

$W = 1.00 \times 10^2$ MJ

$F = (2.00 \times 10^{-2})\ mg$

$$W = Fd(\cos\theta)$$

$$d = \frac{W}{F(\cos\theta)} = \frac{1.00 \times 10^8 \text{ J}}{(2.00 \times 10^{-2})(1.45 \times 10^6 \text{ kg})(9.81 \text{ m/s}^2)(\cos 0.00°)}$$

$$d = \boxed{352 \text{ m}}$$

---

3. $m = 1.7$ g

$W = 0.15$ J

$a_{net} = 1.2$ m/s^2

$\theta = 0°$

$g = 9.81$ m/s^2

$$F_{net} = ma_{net} = F - mg$$

$$F = ma_{net} + mg$$

$$W = Fd(\cos\theta) = m(a_{net} + g)d(\cos\theta)$$

$$d = \frac{W}{m(a_{net} + g)(\cos\theta)} = \frac{0.15 \text{ J}}{(1.7 \times 10^{-3} \text{ kg})(1.2 \text{ m/s}^2 + 9.81 \text{ m/s}^2)(\cos 0°)}$$

$$d = \frac{0.15 \text{ J}}{(1.7 \times 10^{-3} \text{ kg})(11.0 \text{ m/s}^2)}$$

$$d = \boxed{8.0 \text{ m}}$$

---

4. $m = 5.40 \times 10^2$ kg

$W = 5.30 \times 10^4$ J

$g = 9.81$ m/s^2

$\theta = 30.0°$

$\theta' = 0°$

$$W = Fd(\cos\theta') = Fd$$

$$F = mg(\sin\theta)$$

$$W = mg(\sin\theta)d$$

$$d = \frac{W}{mg(\sin\theta)} = \frac{5.30 \times 10^4 \text{ J}}{(5.40 \times 10^2 \text{ kg})(9.81 \text{ m/s}^3)(\sin 30.0°)}$$

$$d = \boxed{20.0 \text{ m}}$$

Givens | *Solutions*

5. $d = 5.45$ m

$W = 4.60 \times 10^4$ J

$\theta = 0°$

$$F_{net} = F_{lift} - F_g = 0$$
$$F = F_{lift} = F_g$$
$$W = Fd(\cos\theta) = F_g d(\cos\theta)$$
$$F_g = \frac{W}{d(\cos\theta)} = \frac{4.60 \times 10^4 \text{ J}}{(5.45 \text{ m})(\cos 0°)} = \boxed{8.44 \times 10^3 \text{ N}}$$

---

6. $d = 52.0$ m

$m = 40.0$ kg

$W = 2.04 \times 10^4$ J

$\theta = 0°$

$$F = \frac{W}{d(\cos\theta)} = \frac{2.04 \times 10^4 \text{ J}}{(52.0 \text{ m})(\cos 0°)} = \boxed{392 \text{ N}}$$

---

7. $d = 646$ m

$W = 2.15 \times 10^5$ J

$\theta = 0°$

$$F = \frac{W}{d(\cos\theta)} = \frac{2.15 \times 10^5 \text{ J}}{(646 \text{ m})(\cos 0°)} = \boxed{333 \text{ N}}$$

II

8. $m = 1.02 \times 10^3$ kg

$d = 18.0$ m

angle of incline $= \theta = 10.0°$

$\theta' = 0°$

$g = 9.81$ m/s^2

$\mu_k = 0.13$

$$F_{net} = F_g - F_k = mg(\sin\theta) - \mu_k mg(\cos\theta)$$
$$W_{net} = F_{net}d(\cos\theta') = mgd(\cos\theta')[(\sin\theta) - \mu_k(\cos\theta)]$$
$$W_{net} = (1.02 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(18.0 \text{ m})(\cos 0°)[(\sin 10.0°) - (0.13)(\cos 10.0°)]$$
$$W_{net} = (1.02 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(18.0 \text{ m})(0.174 - 0.128)$$
$$W_{net} = (1.02 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)(18.0 \text{ m})(0.046)$$
$$W_{net} = \boxed{8.3 \times 10^3 \text{ J}}$$

---

9. $d = 881.0$ m

$F_{applied} = 40.00$ N

$\theta = 45.00°$

$F_k = 28.00$ N

$\theta' = 0°$

$$W_{net} = F_{net}d(\cos\theta')$$
$$F_{net} = F_{applied}(\cos\theta) - F_k$$
$$W_{net} = [F_{applied}(\cos\theta) - F_k]d(\cos\theta')$$
$$W_{net} = [40.00 \text{ N}(\cos 45.00°) - 28.00° \text{ N}](881.0 \text{ m})(\cos\theta)$$
$$W_{net} = (28.28 \text{ N} - 28.00 \text{ N})(881.0 \text{ m}) = (0.28 \text{ N})(881.0 \text{ m})$$
$$W_{net} = \boxed{246.7 \text{ J}}$$

---

10. $m = 9.7 \times 10^3$ kg

$\theta = 45°$

$F = F_1 = F_2 = 1.2 \times 10^3$ N

$d = 12$ m

$$W_{net} = F_{net}d(\cos\theta) = (F_1 + F_2)d(\cos\theta) = 2Fd(\cos\theta)$$
$$W_{net} = (2)(1.2 \times 10^3 \text{ N})(12 \text{ m})(\cos 45°) = \boxed{2.0 \times 10^4 \text{ J}}$$

---

11. $m = 1.24 \times 10^3$ kg

$\mathbf{F_1} = 8.00 \times 10^3$ N east

$\mathbf{F_2} = 5.00 \times 10^3$ N 30.0° south of east

$\mathbf{d} = 20.0$ m south

Only $\mathbf{F_2}$ contributes to the work done in moving the flag south.

$$\theta = 90.0° - 30.0° = 60.0°$$
$$W_{net} = F_{net}d(\cos\theta) = F_2 d(\cos\theta) = (5.00 \times 10^3 \text{ N})(20.0 \text{ m})(\cos 60.0°)$$
$$W_{net} = \boxed{5.00 \times 10^4 \text{ J}}$$

Additional Practice B

Givens | *Solutions*

1. $\Delta x = 1.00 \times 10^2$ m

$\Delta t = 9.85$ s

$KE = 3.40 \times 10^3$ J

$$v = \frac{\Delta x}{\Delta t}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{\Delta x}{\Delta t}\right)^2$$

$$m = \frac{2KE\Delta t^2}{\Delta x^2} = \frac{(2)(3.40 \times 10^3 \text{ J})(9.85 \text{ s})^2}{(1.00 \times 10^2 \text{ m})^2} = \boxed{66.0 \text{ kg}}$$

---

2. $v = 4.00 \times 10^2$ km/h

$KE = 2.10 \times 10^7$ J

$$m = \frac{2KE}{v^2} = \frac{(2)(2.10 \times 10^7 \text{ J})}{(4.00 \times 10^2 \text{ km/h})^2 (10^3 \text{ m km})^2 (1 \text{ h}/3600 \text{ s})^2} = \boxed{3.40 \times 10^3 \text{ kg}}$$

---

3. $v = 50.3$ km/h

$KE = 6.54 \times 10^3$ J

$$m = \frac{2KE}{v^2} = \frac{(2)(6.54 \times 10^3 \text{ J})}{(50.3 \text{ km/h})^2(10^3 \text{ m/km})^2 (1 \text{ h}/3600 \text{ s})} = \boxed{67.0 \text{ kg}}$$

---

4. $v = 318$ km/h

$KE = 3.80$ MJ

$$m = \frac{2KE}{v^2} = \frac{(2)(3.80 \times 10^6 \text{ J})}{(318 \text{ km/h})^2 (10^3 \text{ m/km})^2 (1 \text{ h}/3600 \text{ s})} = \boxed{974 \text{ kg}}$$

---

5. $m = 51.0$ kg

$KE = 9.96 \times 10^4$ J

$$v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{(2)(9.96 \times 10^4 \text{ J})}{51.0 \text{ kg}}} = \boxed{62.5 \text{ m/s} = 225 \text{ km/h}}$$

---

6. $\Delta x = 93.625$ km

$\Delta t = 24.00$ h

$m = 55$ kg

a. $$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{9.3625 \times 10^4 \text{ m}}{(24.00 \text{ h})(3600 \text{ s/h})} = \boxed{1.084 \text{ m/s}}$$

b. $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(55 \text{ kg})(1.084 \text{ m/s})^2 = \boxed{32 \text{ J}}$$

---

7. $m = 3.38 \times 10^{31}$ kg

$KE = 1.10 \times 10^{42}$ J

$$v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{(2)(1.10 \times 10^{42} \text{ J})}{3.38 \times 10^{31} \text{ kg}}} = 2.55 \times 10^5 \text{ m/s} = \boxed{255 \text{ km/s}}$$

---

8. $m = 680$ kg

$v = 56.0$ km/h

a. $$KE = \frac{1}{2}mv^2 = \frac{1}{2}(680 \text{ kg})[(56.0 \text{ km/h})(10^3 \text{ m/km})(1 \text{ h}/3600 \text{ s})]^2 = \boxed{8.23 \times 10^4 \text{ J}}$$

$KE_{LB} = 3.40 \times 10^3$ J

b. $$\frac{KE_{Pb}}{KE_{LB}} = \frac{8.2 \times 10^4 \text{ J}}{3.40 \times 10^3 \text{ J}} = \boxed{\frac{24}{1}}$$

---

9. $v = 11.2$ km/s

$m = 2.3 \times 10^5$ kg

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}(2.3 \times 10^5 \text{ kg})(11.2 \times 10^3 \text{ m/s})^2 = \boxed{1.4 \times 10^{13} \text{ J}}$$

II

Additional Practice C

Givens	*Solutions*
1. $d = 227$ m	$W_{net} = \Delta KE = KE_f - KE_i = KE_f$
$m = 655$ g	$W_{net} = F_{net}d(\cos\theta)$
$g = 9.81$ m/s^2	$F_{net} = F_g - F_{resistance} = mg - (0.0220)mg = mg(1 - 0.0220)$
$F_{resistance} = (0.0220)mg$	$KE_f = mg(1 - 0.0220)d(\cos\theta) = (655 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2)(1 - 0.0220)(227\text{ m})(\cos 0°)$
$\theta = 0°$	$KE_f = (0.655\text{ kg})(9.81\text{ m/s}^2)(0.9780)(227\text{ m})$
$KE_i = 0$ J	$KE_f = \boxed{1.43 \times 10^3\text{ J}}$

2. $v_i = 12.92$ m/s	W_{net} is the work done by friction.
$W_{net} = -2830$ J	$W_{net} = \Delta KE = KE_f - KE_i = KE_f - \frac{1}{2}mv_i^2$
$m = 55.0$ kg	$KE_f = W_{net} + \frac{1}{2}mv_i^2 = -2830\text{ J} + \frac{1}{2}(55.0\text{ kg})(12.92\text{ m/s})^2 = -2830\text{ J} + 4590\text{ J}$
	$KE_f = \boxed{1.76 \times 10^3\text{ J}}$

II

3. $m = 25.0$ g	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$h_i = 553$ m	$W_{net} = F_{net}d(\cos\theta)$
$h_f = 353$ m	$F_{net} = F_g - F_r = mg - F_r$
$v_i = 0$ m/s	$d = h_i - h_f$
$v_f = 30.0$ m/s	$W_{net} = (mg - F_r)(h_i - h_f)(\cos\theta)$
$g = 9.81$ m/s^2	$mg - F_r = \dfrac{\frac{1}{2}m(v_f^2 - v_i^2)}{(h_i - h_f)(\cos\theta)}$
$\theta = 0°$	$F_r = m\left[g - \dfrac{(v_f^2 - v_i^2)}{2(h_i - h_f)(\cos\theta)}\right] = (25.0 \times 10^{-3}\text{ kg})\left[9.81\text{ m/s}^2 - \dfrac{(30.0\text{ m/s})^2 - (0\text{ m/s})^2}{(2)(553\text{ m} - 353\text{ m})(\cos 0°)}\right]$
	$F_r = (25.0 \times 10^{-3}\text{ kg})\left[9.81\text{ m/s}^2 - \dfrac{9.00 \times 10^2\text{ m}^2/\text{s}^2}{(2)(2.00 \times 10^2\text{ m})}\right]$
	$F_r = (25.0 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2 - 2.25\text{ m/s}^2) = (25.0 \times 10^{-3}\text{ kg})(7.56\text{ m/s}^2)$
	$F_r = \boxed{0.189\text{ N}}$

4. $v_i = 404$ km/h	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$W_{net} = -3.00$ MJ	$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + W_{net}$
$m = 1.00 \times 10^3$ kg	$v_f = \sqrt{v_i^2 + \dfrac{2W_{net}}{m}} = \sqrt{[(404\text{ km/h})(10^3\text{ m/km})(1\text{ h}/3600\text{ s})]^2 + \dfrac{(2)(-3.00 \times 10^6\text{ J})}{1.00 \times 10^3\text{ kg}}}$
	$v_f = \sqrt{1.26 \times 10^4\text{ m}^2/\text{s}^2 - 6.00 \times 10^3\text{ m}^2/\text{s}^2} = \sqrt{6.6 \times 10^3\text{ m}^2/\text{s}^2}$
	$v_f = \boxed{81\text{ m/s} = 290\text{ km/h}}$

5. $m = 45.0$ g	$W_{net} = \Delta KE = KE_f - KE_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$h_i = 8848.0$ m	$W_{net} = F_{net}d(\cos\theta)$
$h_f = 8806.0$ m	$F_{net} = F_g - F_r = mg - F_r$
$v_i = 0$ m/s	$d = h_i - h_f$
$v_f = 27.0$ m/s	$W_{net} = mg(h_i - h_f)(\cos\theta) - F_r(h_i - h_f)(\cos\theta)$
$g = 9.81$ m/s^2	$-F_r(h_i - h_f)(\cos\theta) = F_r(h_i - h_f)(\cos 180° + \theta) = W_r$
$\theta = 0°$	$\frac{1}{2}m(v_f^2 - v_i^2) = mg(h_i - h_f)(\cos\theta) + W_r$

Givens | *Solutions*

$$W_r = m[\tfrac{1}{2}(v_f^2 - v_i^2) - g(h_i - h_f)(\cos\theta)] = (45.0 \times 10^{-3}\ \text{kg})\Big[\tfrac{1}{2}(27.0\ \text{m/s})^2 - \tfrac{1}{2}(0\ \text{m/s})^2 - (9.81\ \text{m/s}^2)(8848.0\ \text{m} - 8806.0\ \text{m})(\cos 0°)\Big]$$

$$W_r = (45.0 \times 10^{-3}\ \text{kg})[364\ \text{m}^2/\text{s}^2 - (9.81\ \text{m/s}^2)(42.0\ \text{m})]$$

$$W_r = (45.0 \times 10^{-3}\ \text{kg})(364\ \text{m}^2/\text{s}^2 - 412\ \text{m}^2/\text{s}^2)$$

$$W_r = (45.0 \times 10^{-3}\ \text{kg})(-48\ \text{m}^2/\text{s}^2) = \boxed{-2.16\ \text{J}}$$

---

6. $v_f = 35.0$ m/s

$v_i = 25.0$ m/s

$W_{net} = 21$ kJ

$$W_{net} = \Delta KE = KE_f - KE_i = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

$$m = \frac{2W_{net}}{v_f^2 - v_i^2} = \frac{(2)(21 \times 10^3\ \text{J})}{(35.0\ \text{m/s})^2 - (25.0\ \text{m/s})^2} = \frac{42 \times 10^3\ \text{J}}{1220\ \text{m}^2/\text{s}^2 - 625\ \text{m}^2/\text{s}^2}$$

$$m = \frac{42 \times 10^3\ \text{J}}{6.0 \times 10^2\ \text{m}^2/\text{s}^2} = \boxed{7.0 \times 10^1\ \text{kg}}$$

---

7. $v_i = 104.5$ km/h

$v_f = \tfrac{1}{2}v_i$

$\mu_k = 0.120$

$g = 9.81\ \text{m/s}^2$

$\theta = 180°$

$$W_{net} = \Delta KE = KE_f - KE_i = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

$$W_{net} = W_k d(\cos\theta) = F_k d(\cos\theta) = \mu_k mgd(\cos\theta)$$

$$\tfrac{1}{2}m(v_f^2 - v_i^2) = \mu_k mgd(\cos\theta)$$

$$d = \frac{v_f^2 - v_i^2}{2\mu_k g(\cos\theta)} = \frac{[(104.5\ \text{km/h})(10^3\ \text{m/km})(1\ \text{h}/3600\ \text{s})]^2[(\tfrac{1}{2})^2 - (1)^2]}{(2)(0.120)(9.81\ \text{m/s}^2)(\cos 180°)}$$

$$d = \frac{\left(\frac{104.5}{3.600}\ \text{m/s}\right)^2\left(\frac{1}{4} - 1\right)}{-(2)(0.120)(9.81\ \text{m/s}^2)} = \frac{-(3)\left(\frac{104.5}{3.600}\ \text{m/s}\right)^2}{-(8)(0.120)(9.81\ \text{m/s}^2)}$$

$$d = \boxed{268\ \text{m}}$$

Additional Practice D

1. $h = 6.13/2\ \text{m} = 3.07$ m

$PE_g = 4.80$ kJ

$g = 9.81\ \text{m/s}^2$

$$m = \frac{PE_g}{gh} = \frac{4.80 \times 10^3\ \text{J}}{(9.81\ \text{m/s}^2)(3.07\ \text{m})} = \boxed{1.59 \times 10^2\ \text{kg}}$$

---

2. $h = 1.70$ m

$PE_g = 3.04 \times 10^3$ J

$g = 9.81\ \text{m/s}^2$

$$m = \frac{PE_g}{gh} = \frac{3.04 \times 10^3\ \text{J}}{(9.81\ \text{m/s}^2)(1.70\ \text{m})} = \boxed{182\ \text{kg}}$$

---

3. $PE_g = 1.48 \times 10^7$ J

$h = (0.100)(180\ \text{km})$

$g = 9.81\ \text{m/s}^2$

$$m = \frac{PE_g}{gh} = \frac{1.48 \times 10^7\ \text{J}}{(9.81\ \text{m/s}^2)(0.100)(180 \times 10^3\ \text{m})} = \boxed{83.8\ \text{kg}}$$

---

4. $m = 3.6 \times 10^4$ kg

$PE_g = 8.88 \times 10^8$ J

$g = 9.81\ \text{m/s}^2$

$$h = \frac{PE_g}{mg} = \frac{8.88 \times 10^8\ \text{J}}{(3.6 \times 10^4\ \text{kg})(9.81\ \text{m/s}^2)} = \boxed{2.5 \times 10^3\ \text{m} = 2.5\ \text{km}}$$

Givens	*Solutions*
5. $\frac{PE_g}{m} = 20.482\ m^2/s^2$ $g = 9.81\ m/s^2$	$\frac{PE_g}{m} = gh = 20.482\ m^2/s^2$ $h = \frac{20.482\ m^2/s^2}{g} = \frac{20.482\ m^2/s^2}{9.81\ m/s^2} = \boxed{2.09\ m}$
6. $k = 3.0 \times 10^4\ N/m$ $PE_{elastic} = 1.4 \times 10^2\ J$	$x = \pm\sqrt{\frac{2PE_{elastic}}{k}} = \pm\sqrt{\frac{(2)(1.4 \times 10^2\ J)}{3.0 \times 10^4\ N/m}} = \boxed{+9.7 \times 10^{-2}\ m = 9.7\ cm}$
7. $m = 51\ kg$ $g = 9.81\ m/s^2$ $h = 321\ m - 179\ m = 142\ m$ $k = 32\ N/m$ $x = 179\ m - 104\ m = 75\ m$	$PE_{tot} = PE_g + PE_{elastic}$ Set $PE_g = 0$ J at the river level. $PE_g = mgh = (51\ kg)(9.81\ m/s^2)(142\ m) = 7.1 \times 10^4\ J$ $PE_{elastic} = \frac{1}{2}kx^2 = \frac{1}{2}(32\ N/m)(75\ m)^2 = 9.0 \times 10^4\ J$ $PE_{tot} = (7.1 \times 10^4\ J) + (9.0 \times 10^4\ J) = \boxed{1.6 \times 10^5\ J}$
8. $h_2 = 4080\ m$ $h_1 = 1860\ m$ $m = 905\ kg$ $g = 9.81\ m/s^2$	$\Delta PE_g = PE_{g,2} - PE_{g,1} = mg(h_2 - h_1) = (905\ kg)(9.81\ m/s^2)(4080\ m - 1860\ m)$ $\Delta PE_g = (905\ kg)(9.81\ m/s^2)(2220\ m) = \boxed{1.97 \times 10^7\ J}$
9. $m = 286\ kg$ $k = 9.50 \times 10^3\ N/m$ $g = 9.81\ m/s^2$ $x = 59.0\ cm$ $h_1 = 1.70\ m$ $h_2 = h_1 - x$	**a.** $PE_{elastic} = \frac{1}{2}kx^2 = \frac{1}{2}(9.50 \times 10^3\ N/m)(0.590\ m)^2 = \boxed{1.65 \times 10^3\ J}$ **b.** $PE_{g,1} = mgh_1 = (286\ kg)(9.81\ m/s^2)(1.70\ m) = \boxed{4.77 \times 10^3\ J}$ **c.** $h_2 = 1.70\ m - 0.590\ m = 1.11\ m$ $PE_{g,2} = mgh_2 = (286\ kg)(9.81\ m/s^2)(1.11\ m) = \boxed{3.11 \times 10^3\ J}$ **d.** $\Delta PE_g = PE_{g,2} - PE_{g,1} = (3.11 \times 10^3\ J) - (4.77 \times 10^3\ J) = \boxed{-1.66 \times 10^3\ J}$ The answer in part (d) is approximately equal in magnitude to that in (a); the slight difference arises from rounding. The increase in elastic potential energy corresponds to a decrease in gravitational potential energy; hence the difference in signs for the two answers.

Givens | *Solutions*

10. $\Delta x = 9.50 \times 10^2$ m

$\theta = 45.0°$

$m = 65.0$ g

$g = 9.81$ m/s^2

a. $v_x = v_i(\cos\theta) = \dfrac{\Delta x}{\Delta t}$

$$\Delta t = \frac{\Delta x}{v_i(\cos\theta)}$$

vertical speed of the arrow for the first half of the flight $= v_i(\sin\theta) = g\left(\dfrac{\Delta t}{2}\right)$

$$v_i(\sin\theta) = \frac{g\Delta x}{2v_i(\cos\theta)}$$

$$v_i = \sqrt{\frac{g\Delta x}{2(\sin\theta)(\cos\theta)}} = \sqrt{\frac{(9.81 \text{ m/s}^2)(9.50 \times 10^2 \text{ m})}{(2)(\sin 45.0°)(\cos 45.0°)}} = 96.5 \text{ m/s}$$

$$KE_i = \tfrac{1}{2}mv_i^2 = \tfrac{1}{2}(65.0 \times 10^{-3} \text{ kg})(96.5 \text{ m/s})^2 = \boxed{303 \text{ J}}$$

$x = 55.0$ cm

b. From the conservation of energy,

$$PE_{elastic} = KE_i$$

$$\tfrac{1}{2}kx^2 = KE_i$$

$$k = \frac{2KE_i}{x^2} = \frac{(2)(303 \text{ J})}{(55.0 \times 10^{-2} \text{ m})^2} = \boxed{2.00 \times 10^3 \text{ N/m}}$$

c. $KE_i = PE_{g,max} + KE_f$

$$KE_f = \tfrac{1}{2}mv_x^2 = \tfrac{1}{2}m[(v_i(\cos\theta)]^2 = \tfrac{1}{2}(65.0 \times 10^{-3} \text{ kg})(96.5 \text{ m/s})^2(\cos 45.0°)^2 = 151 \text{ J}$$

$$PE_{g,max} = KE_i - KE_f = 303 \text{ J} - 151 \text{ J} = 152 \text{ J}$$

$$h_{max} = \frac{PE_{g,max}}{mg} = \frac{152 \text{ J}}{(65.0 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)}$$

$$h = \boxed{238 \text{ m}}$$

Additional Practice E

1. $m = 118$ kg

$h_i = 5.00$ m

$g = 9.81$ m/s^2

$v_i = 0$ m/s

$KE_f = 4.61$ kJ

$$PE_i + KE_i = PE_f + KE_f$$

$$mgh_i + \tfrac{1}{2}mv_i^2 = mgh_f + KE_f$$

$$mgh_f = mgh_i + \tfrac{1}{2}mv_i^2 - KE_f$$

$$h_f = h_i + \frac{v_i^2}{2g} - \frac{KE_f}{mg} = 5.00 \text{ m} + \frac{(0 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} - \frac{4.61 \times 10^3 \text{ J}}{(118 \text{ kg})(9.81 \text{ m/s}^2)}$$

$$h_f = 5.00 \text{ m} - 3.98 \text{ m} = \boxed{1.02 \text{ m above the ground}}$$

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2. $v_f = 42.7$ m/s

$h_f = 50.0$ m

$v_i = 0$ m

$g = 9.81$ m/s^2

$$PE_i + KE_i = PE_f + KE_f$$

$$mgh_i + \tfrac{1}{2}\mathrm{m}v_i^2 = mgh_f + \tfrac{1}{2}mv_f^2$$

$$h_i = h_f + \frac{v_f^2 - v_i^2}{2g} = 50.0 \text{ m} + \frac{(42.7 \text{ m/s})^2 - (0 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = 50.0 \text{ m} + 92.9 \text{ m}$$

$$h_i = \boxed{143 \text{ m}}$$

The mass of the nut is not needed for the calculation.

Givens | *Solutions*

3. $h_i = 3150$ m

$v_f = 60.0$ m/s

$KE_i = 0$ J

$g = 9.81$ m/s^2

$$PE_i + KE_i = PE_f + KE_f$$

$$mgh_i = mgh_f + \tfrac{1}{2}mv_f^2$$

$$h_f = h_i - \frac{v_f^2}{2g} = 3150 \text{ m} - \frac{(60.0 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = 3150 \text{ m} - 183 \text{ m}$$

$$h_f = \boxed{2970 \text{ m}}$$

---

4. $h_i = 1.20 \times 10^2$ m

$h_f = 30.0$ m

$m = 72.0$ kg

$g = 9.81$ m/s^2

$KE_i = 0$ J

$$PE_i + KE_i = PE_f + KE_f$$

$$PE_i - PE_f = KE_f$$

$$KE_f = \Delta PE = mg(h_i - h_f)$$

$$KE_f = (72.0 \text{ kg})(9.81 \text{ m/s}^2)(1.20 \times 10^2 \text{ m} - 30.0 \text{ m}) = (72.0 \text{ kg})(9.81 \text{ m/s}^2)(9.0 \times 10^1 \text{ m})$$

$$KE_f = \boxed{6.4 \times 10^4 \text{ J}}$$

$$v_f = \sqrt{\frac{2KE_f}{m}} = \sqrt{\frac{(2)(6.4 \times 10^4 \text{ J})}{72.0 \text{ kg}}}$$

$$v_f = \boxed{42 \text{ m/s}}$$

II

5. $h_f = 250.0$ m

$\Delta ME = -2.55 \times 10^5$ J

$m = 250.0$ kg

$g = 9.81$ m/s^2

$$\Delta ME = PE_f - KE_i = mgh_f - \tfrac{1}{2}mv_i^2$$

$$v_i = \sqrt{2gh_f - \frac{2\Delta ME}{m}} = \sqrt{(2)(9.81 \text{ m/s}^2)(250.0 \text{ m}) - \frac{(2)(-2.55 \times 10^5 \text{ J})}{250.0 \text{ kg}}}$$

$$v_i = \sqrt{4.90 \times 10^3 \text{ m}^2/\text{s}^2 + 2.04 \times 10^3 \text{ m}^2/\text{s}^2} = \sqrt{6.94 \times 10^3 \text{ m}^2/\text{s}^2}$$

$$v_i = 83.3 \text{ m/s} = \boxed{3.00 \times 10^2 \text{ km/h}}$$

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6. $h_i = 12.3$ km

$m = 120.0$ g

$g = 9.81$ m/s^2

$KE_i = 0$ J

$\Delta h = h_i - h_f = 3.2$ km

$$PE_i + KE_i = PE_f + KE_f$$

$$PE_i - PE_f = KE_f$$

$$KE_f = PE_i - PE_f = mgh_i - mgh_f = mg\Delta h$$

$$KE_f = mg\Delta h = (0.1200 \text{ kg})(9.81 \text{ m/s}^2)(3.2 \times 10^3 \text{ m}) = \boxed{3.8 \times 10^3 \text{ J}}$$

$$PE_f = mgh_f = mg(h_i - \Delta h) = (0.1200 \text{ kg})(9.81 \text{ m/s}^2)(12.3 \times 10^3 \text{ m} - 3.2 \times 10^3 \text{ m})$$

$$PE_f = (0.1200 \text{ kg})(9.81 \text{ m/s}^2)(9.1 \times 10^3 \text{ m}) = \boxed{1.1 \times 10^4 \text{ J}}$$

Alternatively,

$$PE_f = PE_i - KE_f = mgh_i - KE_f$$

$$PE_f = (0.1200 \text{ kg})(9.81 \text{ m/s}^2)(12.3 \times 10^3 \text{ m}) - 3.8 \times 10^3 \text{ J} = 1.45 \times 10^4 \text{ J} - 3.8 \times 10^3 \text{ J}$$

$$PE_f = \boxed{1.07 \times 10^4 \text{ J}}$$

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7. $h = 68.6$ m

$v = 35.6$ m/s

$g = 9.81$ m/s^2

$PE_f = 0$ J

$KE_i = 0$ J

$$ME_i = PE_i = mgh$$

$$ME_f = KE_f = \tfrac{1}{2}mv^2$$

$$\text{percent of energy dissipated} = \frac{(ME_i - ME_f)(100)}{ME_i} = \left(\frac{mgh - \frac{1}{2}mv^2}{mgh}\right)(100)$$

$$\text{percent of energy dissipated} = \left(\frac{gh - \frac{1}{2}v^2}{gh}\right)(100)$$

$$\text{percent of energy dissipated} = \left(\frac{(9.81 \text{ m/s}^2)(68.6 \text{ m}) - \frac{1}{2}(35.6 \text{ m/s})^2}{(9.81 \text{ m/s}^2)(68.6 \text{ m})}\right)(100)$$

$$\text{percent of energy dissipated} = \frac{(673 \text{ J} - 634 \text{ J})(100)}{673 \text{ J}} = \frac{(39 \text{ J})\ (100)}{673 \text{ J}} = \boxed{5.8 \text{ percent}}$$

Additional Practice F

Givens	*Solutions*
1. $P = 56$ MW $\Delta t = 1.0$ h	$W = P\Delta t = (56 \times 10^6 \text{ W})(1.0 \text{ h})(3600 \text{ s/h}) = \boxed{2.0 \times 10^{11} \text{ J}}$
2. $\Delta t = 62.25$ min $P = 585.0$ W	$W = P\Delta t = (585.0 \text{ W})(62.25 \text{ min})(60 \text{ s/min}) = \boxed{2.185 \times 10^6 \text{ J}}$
3. $h = 106$ m $m = 14.0$ kg $g = 9.81 \text{ m/s}^2$ $P = 3.00 \times 10^2$ W $\theta = 0°$	$W = F_g d(\cos\theta) = F_g d = mgh$ $\Delta t = \frac{W}{P} = \frac{mgh}{P} = \frac{(14.0 \text{ kg})(9.81 \text{ m/s}^2)(106 \text{ m})}{3.00 \times 10^2 \text{ W}} = \boxed{48.5 \text{ s}}$
4. $P = 2984$ W $W = 3.60 \times 10^4$ J	$\Delta t = \frac{W}{P} = \frac{3.60 \times 10^4 \text{ J}}{2984 \text{ W}} = \boxed{12.1 \text{ s}}$
5. $\Delta t = 3.0$ min $W = 54$ kJ	$P = \frac{W}{\Delta t} = \frac{54 \times 10^3 \text{ J}}{(3.0 \text{ min})(60 \text{ s/min})} = \boxed{3.0 \times 10^2 \text{ W}}$
6. $\Delta t = 16.7$ s $h = 18.4$ m $m = 72.0$ kg $g = 9.81 \text{ m/s}^2$ $\theta = 0°$	$W = F_g d(\cos\theta) = mgh$ $P = \frac{W}{\Delta t} = \frac{mgh}{\Delta t} = \frac{(72.0 \text{ kg})(9.81 \text{ m/s}^2)(18.4 \text{ m})}{16.7 \text{ s}}$ $P = \boxed{778 \text{ W}}$

II

Momentum and Collisions

Additional Practice A

Givens	Solutions
1. $v = 40.3$ km/h $p = 6.60 \times 10^2$ kg•m/s	$m = \frac{p}{v} = \frac{6.60 \times 10^2 \text{ kg•m/s}}{(40.3 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})} = \boxed{59.0 \text{ kg}}$
2. $m_h = 53$ kg $\mathbf{v} = 60.0$ m/s to the east $\mathbf{p_{tot}} = 7.20 \times 10^3$ kg•m/s to the east	$\mathbf{p_{tot}} = m_h\mathbf{v} + m_p\mathbf{v}$ $m_p = \frac{\mathbf{p_{tot}} - m_h\mathbf{v}}{\mathbf{v}} = \frac{7.20 \times 10^3 \text{ kg•m/s} - (53 \text{ kg})(60.0 \text{ m/s})}{60.0 \text{ m/s}}$ $m_p = \frac{7.20 \times 10^3 \text{ kg•m/s} - 3.2 \times 10^3 \text{ kg•m/s}}{60.0 \text{ m/s}} = \frac{4.0 \times 10^3 \text{ kg•m/s}}{60.0 \text{ m/s}} = \boxed{67 \text{ kg}}$
3. $m_1 = 1.80 \times 10^2$ kg $m_2 = 7.0 \times 10^1$ kg $\mathbf{p_{tot}} = 2.08 \times 10^4$ kg•m/s to the west $= -2.08 \times 10^4$ kg•m/s	$\mathbf{v} = \frac{\mathbf{p_{tot}}}{m_1 + m_2} = \frac{-2.08 \times 10^4 \text{ kg•m/s}}{1.80 \times 10^2 \text{ kg} + 7.0 \times 10^1 \text{ kg}} = \frac{-2.08 \times 10^4 \text{ kg•m/s}}{2.50 \times 10^2 \text{ kg}}$ $\mathbf{v} = -83.2 \text{ m/s} = \boxed{83.2 \text{ m/s to the west}}$
4. $m = 83.6$ kg $p = 6.63 \times 10^5$ kg•m/s	$v = \frac{p}{m} = \frac{6.63 \times 10^5 \text{ kg•m/s}}{83.6 \text{ kg}} = \boxed{7.93 \times 10^3 \text{ m/s} = 7.93 \text{ km/s}}$
5. $m = 6.9 \times 10^7$ kg $v = 33$ km/h	$p = mv = (6.9 \times 10^7 \text{ kg})(33 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s}) = \boxed{6.3 \times 10^8 \text{ kg•m/s}}$
6. $h = 22.13$ m $m = 2.00$ g $g = 9.81$ m/s^2	$mgh = \frac{1}{2}mv_f^2$ $v_f = \sqrt{2gh}$ $p = mv_f = m\sqrt{2gh} = (2.00 \times 10^{-3} \text{ kg})\sqrt{(2)(9.81 \text{ m/s}^2)(22.13 \text{ m})}$ $\mathbf{p} = \boxed{4.17 \times 10^{-2} \text{ kg•m/s downward}}$

Additional Practice B

Givens	Solutions
1. $m = 9.0 \times 10^4$ kg $\mathbf{v_i} = 0$ m/s $\mathbf{v_f} = 12$ cm/s upward $\mathbf{F} = 6.0 \times 10^3$ N	$\Delta t = \frac{m\mathbf{v_f} - m\mathbf{v_i}}{\mathbf{F}} = \frac{(9.0 \times 10^4 \text{ kg})(0.12 \text{ m/s}) - (9.0 \times 10^4 \text{ kg})(0 \text{ m/s})}{6.0 \times 10^3 \text{ N}}$ $\Delta t = \frac{(9.0 \times 10^4 \text{ kg})(0.12 \text{ m/s})}{6.0 \times 10^3 \text{ N}} = \boxed{1.8 \text{ s}}$

Givens	*Solutions*
2. $m = 1.00 \times 10^6$ kg $v_i = 0$ m/s $v_f = 0.20$ m/s $F = 12.5$ kN	$\Delta p = mv_f - mv_i = (1.00 \times 10^6 \text{ kg})(0.20 \text{ m/s}) - (1.00 \times 10^6 \text{ kg})(0 \text{ m/s})$ $\Delta p = \boxed{2.0 \times 10^5 \text{ kg•m/s}}$ $\Delta t = \dfrac{\Delta p}{F} = \dfrac{2.0 \times 10^5 \text{ kg•m/s}}{12.5 \times 10^3 \text{ N}} = \boxed{16 \text{ s}}$
3. $h = 12.0$ cm $\mathbf{F} = 330$ N, upward $m = 65$ kg $g = 9.81$ m/s^2	The speed of the pogo stick before and after it presses against the ground can be determined from the conservation of energy. $PE_g = KE$ $mgh = \frac{1}{2}mv^2$ $v = \pm\sqrt{2gh}$ For the pogo stick's downward motion, $v_i = -\sqrt{2gh}$ For the pogo stick's upward motion, $v_f = +\sqrt{2gh}$ $\Delta p = mv_f - mv_i = m\sqrt{2gh} - m\left(-\sqrt{2gh}\right)$ $\Delta p = 2m\sqrt{2gh}$ $\Delta t = \dfrac{\Delta p}{F} = \dfrac{2m\sqrt{2gh}}{F} = \dfrac{(2)(65 \text{ kg})\sqrt{(2)(9.81 \text{ m/s}^2)(0.120 \text{ m})}}{330 \text{ N}}$ $\Delta t = \boxed{0.60 \text{ s}}$
4. $m = 6.0 \times 10^3$ kg $\mathbf{F} = 8.0$ kN to the east $\Delta t = 8.0$ s $\mathbf{v_i} = 0$ m/s	$\mathbf{v_f} = \dfrac{\mathbf{F}\Delta t + m\mathbf{v_i}}{m} = \dfrac{(8.0 \times 10^3 \text{ N})(8.0 \text{ s}) + (6.0 \times 10^3 \text{ kg})(0 \text{ m/s})}{6.0 \times 10^3 \text{ kg}}$ $\mathbf{v_f} = \boxed{11 \text{ m/s, east}}$
5. $v_i = 125.5$ km/h $m = 2.00 \times 10^2$ kg $F = -3.60 \times 10^2$ N $\Delta t = 10.0$ s	$v_f = \dfrac{F\Delta t + mv_i}{m}$ $v_f = \dfrac{(-3.60 \times 10^2 \text{ N})(10.0 \text{ s}) + (2.00 \times 10^2 \text{ kg})(125.5 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})}{2.00 \times 10^2 \text{ kg}}$ $v_f = \dfrac{-3.60 \times 10^3 \text{ N•s} + 6.97 \times 10^3 \text{ kg•m/s}}{2.00 \times 10^2 \text{ kg}} = \dfrac{3.37 \times 10^3 \text{ kg•m/s}}{2.00 \times 10^2 \text{ kg}} = \boxed{16.8 \text{ m/s}}$ or $v_f = (16.8 \times 10^{-3} \text{ km/s})(3600 \text{ s/h}) = \boxed{60.5 \text{ km/h}}$
6. $m = 45$ kg $F = 1.6 \times 10^3$ N $\Delta t = 0.68$ s $v_i = 0$ m/s	$v_f = \dfrac{F\Delta t + mv_i}{m} = \dfrac{(1.6 \times 10^3 \text{ N})(0.68 \text{ s}) + (45 \text{ kg})(0 \text{ m/s})}{45 \text{ kg}}$ $v_f = \dfrac{(1.6 \times 10^3 \text{ N})(0.68 \text{ s})}{45 \text{ kg}} = \boxed{24 \text{ m/s}}$

II

Givens	*Solutions*
7. $m = 4.85 \times 10^5$ kg $\mathbf{v_i} = 20.0$ m/s northwest $\mathbf{v_f} = 25.0$ m/s northwest $\Delta t = 5.00$ s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(4.85 \times 10^5 \text{ kg})(25.0 \text{ m/s}) - (4.85 \times 10^5 \text{ kg})(20.0 \text{ m/s})}{5.00 \text{ s}}$ $\mathbf{F} = \dfrac{1.21 \times 10^7 \text{ kg•m/s} - 9.70 \times 10^6 \text{ kg•m/s}}{5.00 \text{ s}} = \dfrac{2.4 \times 10^6 \text{ kg•m/s}}{5.00 \text{ s}}$ $\mathbf{F} = \boxed{4.8 \times 10^5 \text{ N northwest}}$
8. $\mathbf{v_f} = 12.5$ m/s upward $m = 70.0$ kg $\Delta t = 4.00$ s $\mathbf{v_i} = 0$ m/s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(70.0 \text{ kg})(12.5 \text{ m/s}) - (70.0 \text{ kg})(0 \text{ m/s})}{4.00 \text{ s}} = 219 \text{ N}$ $\mathbf{F} = \boxed{219 \text{ N upward}}$
9. $m = 12.0$ kg $h = 40.0$ m $\Delta t = 0.250$ s $v_f = 0$ m/s $g = 9.81 \text{ m/s}^2$	From conservation of energy, $\mathbf{v_i} = -\sqrt{2gh}$ $\Delta p = m\mathbf{v_f} - m\mathbf{v_i} = m\mathbf{v_f} - m\left(-\sqrt{2gh}\right)$ $\Delta p = (12.0 \text{ kg})(0 \text{ m/s}) + (12.0 \text{ kg})\sqrt{(2)(9.81 \text{ m/s}^2)(40.0 \text{ m})} = 336 \text{ kg•m/s}$ $\mathbf{F} = \dfrac{\Delta p}{\Delta t} = \dfrac{336 \text{ kg•m/s}}{0.250 \text{ s}} = 1340 \text{ N} = \boxed{1340 \text{ N upward}}$

II

Additional Practice C

1. $\mathbf{F} = 2.85 \times 10^6$ N backward $= -2.85 \times 10^6$ N $m = 2.0 \times 10^7$ kg $\mathbf{v_i} = 3.0$ m/s forward $= +3.0$ m/s $\mathbf{v_f} = 0$ m/s $\Delta t = 21$ s	$\Delta\mathbf{p} = \mathbf{F}\Delta t = (-2.85 \times 10^6 \text{ N})(21 \text{ s})$ $\Delta\mathbf{p} = \boxed{-6.0 \times 10^7 \text{ kg•m/s forward or } 6.0 \times 10^7 \text{ kg•m/s backward}}$ $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \frac{1}{2}(3.0 \text{ m/s} + 0 \text{ m/s})(21 \text{ s}) = \boxed{32 \text{ m forward}}$
2. $m = 6.5 \times 10^4$ kg $F = -1.7 \times 10^6$ N $v_i = 1.0$ km/s $\Delta t = 30.0$ s	$\Delta p = F\Delta t = (-1.7 \times 10^6 \text{ N})(30.0 \text{ s}) = \boxed{-5.1 \times 10^7 \text{ kg•m/s}}$ $v_f = \dfrac{\Delta p + mv_i}{m} = \dfrac{-5.1 \times 10^7 \text{ kg•m/s} + (6.5 \times 10^4 \text{ kg})(1.0 \times 10^3 \text{ m/s})}{6.5 \times 10^4 \text{ kg}}$ $v_f = \dfrac{-5.1 \times 10^7 \text{ kg•m/s} + 6.5 \times 10^7 \text{ kg•m/s}}{6.5 \times 10^4 \text{ kg}} = \dfrac{1.4 \times 10^7 \text{ kg•m/s}}{6.5 \times 10^4 \text{ kg}} = 220 \text{ m/s}$ $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(1.0 \times 10^3 \text{ m/s} + 220 \text{ m/s})(30.0 \text{ s}) = \frac{1}{2}(1.2 \times 10^3 \text{ m/s})(30.0 \text{ s})$ $\Delta x = \boxed{1.8 \times 10^4 \text{ m} = 18 \text{ km}}$

Givens	*Solutions*
3. $m = 2.03 \times 10^4$ kg $\mathbf{v_i}$ = 5.00 m/s to the east = 5.00 m/s $\Delta t = 20.3$ s $F = 1.20 \times 10^3$ N to the west	$\Delta\mathbf{p} = \mathbf{F}\Delta t = (-1.20 \times 10^3 \text{ N})(20.3 \text{ s}) = \boxed{2.44 \times 10^4 \text{ kg•m/s to the west}}$ $\mathbf{v_f} = \dfrac{\Delta\mathbf{p} + m\mathbf{v_i}}{m} = \dfrac{-2.44 \times 10^4 \text{ kg•m/s} + (2.03 \times 10^4 \text{ kg})(5.00 \text{ m/s})}{2.3 \times 10^4 \text{ kg}}$ $\mathbf{v_f} = \dfrac{-2.44 \times 10^4 \text{ kg•m/s} + 1.02 \times 10^5 \text{ kg•m/s}}{2.03 \times 10^4 \text{ kg}} = \dfrac{7.58 \times 10^4 \text{ kg•m/s}}{2.03 \times 10^4 \text{ kg}}$ $\mathbf{v_f} = 3.73$ m/s $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \frac{1}{2}[5.00 \text{ m/s} + (3.73 \text{ m/s})](20.3 \text{ s}) = \frac{1}{2}(8.73 \text{ m/s})(20.3 \text{ s})$ $\Delta\mathbf{x} = 88.6 \text{ m} = \boxed{88.6 \text{ m to the east}}$
4. $m = 113$ g $\mathbf{v_i}$ = 2.00 m/s to the right $\mathbf{v_f} = 0$ m/s $\Delta t = 0.80$ s	$\mathbf{F} = \dfrac{m\mathbf{v_f} - m\mathbf{v_i}}{\Delta t} = \dfrac{(0.113 \text{ kg})(0 \text{ m/s}) - (0.113 \text{ kg})(2.00 \text{ m/s})}{0.80 \text{ s}} = \dfrac{-(0.113 \text{ kg})(2.00 \text{ m/s})}{0.80 \text{ s}}$ $\mathbf{F} = -0.28 \text{ N} = \boxed{0.28 \text{ N to the left}}$ $\Delta\mathbf{x} = \frac{1}{2}(\mathbf{v_i} + \mathbf{v_f})\Delta t = \frac{1}{2}(2.00 \text{ m/s} + 0 \text{ m/s})(0.80 \text{ s})$ $\Delta\mathbf{x} = \boxed{0.80 \text{ m to the right}}$
5. $m = 4.90 \times 10^6$ kg $v_i = 0.200$ m/s $v_f = 0$ m/s $\Delta t = 10.0$ s	$F = \dfrac{\Delta p}{\Delta t} = \dfrac{mv_f - mv_i}{\Delta t} = \dfrac{(4.90 \times 10^6 \text{ kg})(0 \text{ m/s}) - (4.90 \times 10^6 \text{ kg})(0.200 \text{ m/s})}{10.0 \text{ s}}$ $F = \dfrac{-(4.90 \times 10^6 \text{ kg})(0.200 \text{ m/s})}{10.0 \text{ s}} = -9.80 \times 10^4 \text{ N}$ $\mathbf{F} = \boxed{9.80 \times 10^4 \text{ N opposite the palace's direction of motion}}$ $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(0.200 \text{ m/s} + 0 \text{ m/s})(10.0 \text{ s})$ $\Delta x = \boxed{1.00 \text{ m}}$
6. $h = 68.6$ m $m = 1.00 \times 10^3$ kg $F = -2.24 \times 10^4$ N $g = 9.81 \text{ m/s}^2$ $v_f = 0$ m/s	From conservation of energy, $v_i = \sqrt{2gh}$ $\Delta p = mv_f - mv_i = mv_f - m\sqrt{2gh}$ $\Delta t = \dfrac{\Delta p}{F} = \dfrac{mv_f - m\sqrt{2gh}}{F} = \dfrac{(1.00 \times 10^3 \text{ kg})(0 \text{ m/s}) - (1.00 \times 10^3 \text{ kg})\sqrt{(2)(9.81. \text{ m/s}^2)(68.6 \text{ m})}}{-2.24 \times 10^4 \text{ N}}$ $\Delta t = \dfrac{-(1.00 \times 10^3 \text{ kg})\sqrt{(2)(9.81 \text{ m/s}^2)(68.6 \text{ m})}}{-2.24 \times 10^4 \text{ N}} = \boxed{1.64 \text{ s}}$ $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(\sqrt{2gh} + v_f)\Delta t$ $\Delta x = \frac{1}{2}\left(\sqrt{(2)(9.81 \text{ m/s}^2)(68.6 \text{ m})} + 0 \text{ m/s}\right)(1.64 \text{ s}) = \boxed{30.1 \text{ m}}$

II

Givens	Solutions
7. $m = 100.0$ kg $v_i = 4.5 \times 10^2$ m/s $v_f = 0$ m/s $F = -188$ N	$\Delta t = \dfrac{mv_f - mv_i}{F} = \dfrac{(100.0 \text{ kg})(0 \text{ m/s}) - (100.0 \text{ kg})(4.5 \times 10^2 \text{ m/s})}{-188 \text{ N}}$ $\Delta t = \dfrac{-(100.0 \text{ kg})(4.5 \times 10^2 \text{ m/s})}{-188 \text{ N}} = \boxed{240 \text{ s}}$ $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t = \frac{1}{2}(4.5 \times 10^2 \text{ m/s} + 0 \text{ m/s})(240 \text{ s}) = 5.4 \times 10^4 \text{ m} = 54 \text{ km}$ The tunnel is $\boxed{54 \text{ km}}$ long.

Additional Practice D

1. $m_1 = 3.3 \times 10^3$ kg $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{2,f}} = 2.5$ m/s to the right $= +2.5$ m/s $\mathbf{v_{1,f}} = 0.050$ m/s to the left $= -0.050$ m/s	Because the initial momentum is zero, the final momentum is also zero, and so $m_2 = \dfrac{-m_1\mathbf{v_{1,f}}}{\mathbf{v_{2,f}}} = \dfrac{-(3.3 \times 10^3 \text{ kg})(-0.050 \text{ m/s})}{2.5 \text{ m/s}} = \boxed{66 \text{ kg}}$
2. $m_1 = 1.25 \times 10^3$ kg $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{2,f}} = 1.40$ m/s backward $= -1.40$ m/s $\Delta t_1 = 4.0$ s $\Delta \mathbf{x_1} = 24$ cm forward $= +24$ cm	Because the initial momentum is zero, the final momentum is also zero, and so $\mathbf{v_{1,f}} = \dfrac{\Delta \mathbf{x_1}}{\Delta t_1} = \dfrac{0.24 \text{ m}}{4.0 \text{ s}} = 0.060 \text{ m/s forward}$ $m_2 = \dfrac{-m_1\mathbf{v_{1,f}}}{\mathbf{v_{2,f}}} = \dfrac{-(1.25 \times 10^3 \text{ kg})(0.060 \text{ m/s})}{-1.40 \text{ m/s}} = \boxed{54 \text{ kg}}$
3. $m_1 = 114$ kg $\mathbf{v_{2,f}} = 5.32$ m/s backward $= -5.32$ m/s $\mathbf{v_{1,f}} = 3.41$ m/s forward $= +3.41$ m/s $m_2 = 60.0$ kg	$m_1\mathbf{v_i} + m_2\mathbf{v_i} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $\mathbf{v_i} = \dfrac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}}{m_1 + m_2} = \dfrac{(114 \text{ kg})(3.41 \text{ m/s}) + (60.0 \text{ kg})(-5.32 \text{ m/s})}{114 \text{ kg} + 60.0 \text{ kg}}$ $\mathbf{v_i} = \dfrac{389 \text{ kg•m/s} - 319 \text{ kg•m/s}}{174 \text{ kg}} = \dfrac{7.0 \times 10^1 \text{ kg•m/s}}{174 \text{ kg}} = 0.40 \text{ m/s}$ $\mathbf{v_i} = \boxed{0.40 \text{ m/s forward}}$
4. $m_1 = 5.4$ kg $\mathbf{v_{1,f}} = 7.4$ m/s forward $= +7.4$ m/s $\mathbf{v_{2,f}} = 1.4$ m/s backward $= -1.4$ m/s $m_2 = 50.0$ kg	$m_1\mathbf{v_i} + m_2\mathbf{v_i} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $\mathbf{v_i} = \dfrac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}}{m_1 + m_2} = \dfrac{(5.4 \text{ kg})(7.4 \text{ m/s}) + (50.0 \text{ kg})(-1.4 \text{ m/s})}{5.4 \text{ kg} + 50.0 \text{ kg}}$ $\mathbf{v_i} = \dfrac{4.0 \times 10^1 \text{ kg•m/s} - 7.0 \times 10^1 \text{ kg•m/s}}{55.4 \text{ kg}} = \dfrac{-3.0 \times 10^1 \text{ kg•m/s}}{55.4 \text{ kg}} = -0.54 \text{ m/s}$ $\mathbf{v_i} = \boxed{0.54 \text{ m/s backward}}$

Givens	*Solutions*
5. $m_1 = 3.4 \times 10^2$ kg $\mathbf{v_{2,f}}$ = 9.0 km/h northwest = −9.0 km/h $\mathbf{v_{1,f}}$ = 28 km/h southeast = +28 km/h $m_2 = 2.6 \times 10^2$ kg	$m_1\mathbf{v_i} + m_2\mathbf{v_i} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$ $\mathbf{v_i} = \frac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}}{m_1 + m_2} = \frac{(3.4 \times 10^2 \text{ kg})(28 \text{ km/h}) + (2.6 \times 10^2 \text{ kg})(-9.0 \text{ km/h})}{3.4 \times 10^2 \text{ kg} + 2.6 \times 10^2 \text{ kg}}$ $\mathbf{v_i} = \frac{9.5 \times 10^3 \text{ kg•km/h} - 2.3 \times 10^3 \text{ kg•km/h}}{6.0 \times 10^2 \text{ kg}} = \frac{7.2 \times 10^3 \text{ kg•km/h}}{6.0 \times 10^2 \text{ kg}}$ $\mathbf{v_i} = \boxed{\text{12 km/h to the southeast}}$
6. $m_i = 3.6$ kg $m_2 = 3.0$ kg $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{2,f}}$ = 2.0 m/s to the left = −2.0 m/s	Because the initial momentum is zero, the final momentum must also equal zero. $m_i\mathbf{v_{1,f}} = -m_2\mathbf{v_{2,f}}$ $\mathbf{v_{1,f}} = \frac{-m_2\mathbf{v_{2,f}}}{m_1} = \frac{-(3.0 \text{ kg})(-2.0 \text{ m/s})}{3.6 \text{ kg}} = 1.7 \text{ m/s} = \boxed{\text{1.7 m/s to the right}}$
7. $m_1 = 449$ kg $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_{2,f}}$ = 4.0 m/s backward = −4.0 m/s $m_2 = 60.0$ kg $\Delta t = 3.0$ s	Because the initial momentum is zero, the final momentum must also equal zero. $\mathbf{v_{1,f}} = \frac{-m_2\mathbf{v_{2,f}}}{m_1} = \frac{-(60.0 \text{ kg})(-4.0 \text{ m/s})}{449 \text{ kg}} = 0.53 \text{ m/s} = 0.53 \text{ m/s forward}$ $\Delta\mathbf{x} = \mathbf{v_{1,f}}\Delta t = (0.53 \text{ m/s})(3.0 \text{ s}) = \boxed{\text{1.6 m forward}}$

Additional Practice E

1. $m_1 = 155$ kg $\mathbf{v_{1,i}}$ = 6.0 m/s forward $v_{2,i} = 0$ m/s $\mathbf{v_f}$ = 2.2 m/s forward	$m_2 = \frac{m_1\mathbf{v_{1,i}} - m_1\mathbf{v_f}}{\mathbf{v_f} - \mathbf{v_{2,i}}} = \frac{(155 \text{ kg})(6.0 \text{ m/s}) - (155 \text{ kg})(2.2 \text{ m/s})}{2.2 \text{ m/s} - 0 \text{ m/s}}$ $m_2 = \frac{930 \text{ kg•m/s} - 340 \text{ kg•m/s}}{2.2 \text{ m/s}} = \frac{590 \text{ kg•m/s}}{2.2 \text{ m/s}}$ $m_2 = \boxed{270 \text{ kg}}$
2. $v_{1,i} = 10.8$ m/s $v_{2,i} = 0$ m/s $v_f = 10.1$ m/s $m_1 = 63.0$ kg	$m_2 = \frac{m_1 v_{1,i} - m_1 v_f}{v_f - v_{2,i}} = \frac{(63.0 \text{ kg})(10.8 \text{ m/s}) - (63.0 \text{ kg})(10.1 \text{ m/s})}{10.1 \text{ m/s} - 0 \text{ m/s}}$ $m_2 = \frac{6.80 \times 10^2 \text{ kg•m/s} - 6.36 \times 10^2 \text{ kg•m/s}}{10.1 \text{ m/s}} = \frac{44 \text{ kg•m/s}}{10.1 \text{ m/s}} = \boxed{4.4 \text{ kg}}$
3. $\mathbf{v_{1,i}}$ = 4.48 m/s to the right $\mathbf{v_{2,i}} = 0$ m/s $\mathbf{v_f}$ = 4.00 m/s to the right $m_2 = 54$ kg	$m_1 = \frac{(54 \text{ kg})(4.00 \text{ m/s}) - (54 \text{ kg})(0 \text{ m/s})}{4.48 \text{ m/s} - 4.00 \text{ m/s}} = \frac{(54 \text{ kg})(4.00 \text{ m/s})}{0.48 \text{ m/s}}$ $m_1 = \boxed{450 \text{ kg}}$

Givens	*Solutions*
4. $m_1 = 28 \times 10^3$ kg $m_2 = 12 \times 10^3$ kg $\mathbf{v_{1,i}} = 0$ m/s $\mathbf{v_f} = 3.0$ m/s forward	$\mathbf{v_{2,i}} = \dfrac{(m_1 + m_2)\mathbf{v_f} - m_1\mathbf{v_{1,i}}}{m_2}$ $\mathbf{v_{2,i}} = \dfrac{(28 \times 10^3 \text{ kg} + 12 \times 10^3 \text{ kg})(3.0 \text{ m/s}) - (28 \times 10^3 \text{ kg})(0 \text{ m/s})}{12 \times 10^3 \text{ kg}}$ $\mathbf{v_{2,i}} = \dfrac{(4.0 \times 10^4 \text{ kg})(3.0 \text{ m/s})}{12 \times 10^3 \text{ kg}}$ $\mathbf{v_{2,i}} = \boxed{1.0 \times 10^1 \text{ m/s forward}}$
5. $m_1 = 227$ kg $m_2 = 267$ kg $\mathbf{v_{1,i}} = 4.00$ m/s to the left $= -4.00$ m/s $\mathbf{v_f} = 0$ m/s	$\mathbf{v_{2,i}} = \dfrac{(m_1 + m_2)\mathbf{v_f} - m_1\mathbf{v_{1,i}}}{m_2}$ $\mathbf{v_{2,i}} = \dfrac{(227 \text{ kg} + 267 \text{ kg})(0 \text{ m/s}) - (227 \text{ kg})(-4.00 \text{ m/s})}{267 \text{ kg}} = 3.40 \text{ m/s}$ $\mathbf{v_{2,i}} = \boxed{3.40 \text{ m/s to the right}}$
6. $m_1 = 9.50$ kg $\mathbf{v_{1,i}} = 24.0$ km/h to the north $m_2 = 32.0$ kg $\mathbf{v_f} = 11.0$ km/h to the north	$\mathbf{v_{2,i}} = \dfrac{(m_1 + m_2)\mathbf{v_f} - m_1\mathbf{v_1}}{m_2}$ $\mathbf{v_{2,i}} = \dfrac{(9.5 \text{ kg} + 32.0 \text{ kg})(11.0 \text{ km/h}) - (9.50 \text{ kg})(24.0 \text{ km/h})}{32.0 \text{ kg}}$ $\mathbf{v_{2,i}} = \dfrac{(41.5 \text{ kg})(11.0 \text{ km/h}) - 228 \text{ kg}\bullet\text{km/h}}{32.0 \text{ kg}} = \dfrac{456 \text{ kg}\bullet\text{km/h} - 228 \text{ kg}\bullet\text{km/h}}{32.0 \text{ kg}}$ $= \dfrac{228 \text{ kg}\bullet\text{km/h}}{32.0 \text{ kg}}$ $\mathbf{v_{2,i}} = \boxed{7.12 \text{ km/h to the north}}$
7. $m_1 = m_2$ $v_{1,i} = 89$ km/h $v_{2,i} = 69$ km/h	Because $m_1 = m_2$, $v_f = \dfrac{v_{1,i} + v_{2,i}}{2} = \dfrac{89 \text{ km/h} + 69 \text{ km/h}}{2} = \dfrac{158 \text{ km/h}}{2} = 79 \text{ km/h}$ $v_f = \boxed{79 \text{ km/h}}$
8. $m_1 = 3.0 \times 10^3$ kg $m_2 = 2.5 \times 10^2$ kg $\mathbf{v_{2,i}} = 3.0$ m/s down $= -3.0$ m/s $\mathbf{v_{1,i}} = 1.0$ m/s up $= +1.0$ m/s	$\mathbf{v_f} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \dfrac{(3.0 \times 10^3 \text{ kg})(1.0 \text{ m/s}) + (2.5 \times 10^2 \text{ kg})(-3.0 \text{ m/s})}{(3.0 \times 10^3 \text{ kg}) + (2.5 \times 10^2 \text{ kg})}$ $\mathbf{v_f} = \dfrac{3.0 \times 10^3 \text{ kg}\bullet\text{m/s} - 7.5 \times 10^2 \text{ kg}\bullet\text{m/s}}{3.2 \times 10^3 \text{ kg}} = \dfrac{2.2 \times 10^3 \text{ kg}\bullet\text{m/s}}{3.2 \times 10^3 \text{ kg}}$ $\mathbf{v_f} = 0.69 \text{ m/s} = \boxed{0.69 \text{ m/s upward}}$
9. $m_1 = (2.267 \times 10^3 \text{ kg}) + (5.00 \times 10^2 \text{ kg}) = 2.767 \times 10^3$ kg $m_2 = (1.800 \times 10^3 \text{ kg}) + (5.00 \times 10^2 \text{ kg}) = 2.300 \times 10^3$ kg $\mathbf{v_{1,i}} = 2.00$ m/s to the left $= -2.00$ m/s $\mathbf{v_{2,i}} = 1.40$ m/s to the right $= +1.40$ m/s	$\mathbf{v_f} = \dfrac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \dfrac{(2.767 \times 10^3 \text{ kg})(-2.00 \text{ m/s}) + (2.300 \times 10^3 \text{ kg})(1.40 \text{ m/s})}{2.767 \times 10^3 \text{ kg} + 2.300 \times 10^3 \text{ kg}}$ $\mathbf{v_f} = \dfrac{-5.53 \times 10^3 \text{ kg}\bullet\text{m/s} + 3220 \text{ kg}\bullet\text{m/s}}{5.067 \times 10^3 \text{ kg}} = \dfrac{-2310 \text{ kg}\bullet\text{m/s}}{5067 \text{ kg}} = -0.456 \text{ m/s}$ $\mathbf{v_f} = \boxed{0.456 \text{ m/s to the left}}$

Additional Practice F

Givens / *Solutions*

1. $m_1 = 2.0$ g

$\mathbf{v_{1,i}} = 2.0$ m/s forward $= +2.0$ m/s

$m_2 = 0.20$ g

$\mathbf{v_{2,i}} = 8.0$ m/s backward $= -8.0$ m/s forward

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2}$$

$$\mathbf{v_f} = \frac{(2.0 \times 10^{-3}\text{ kg})(2.0\text{ m/s}) + (0.20 \times 10^{-3}\text{ kg})(-8.0\text{ m/s})}{2.0 \times 10^{-3}\text{ kg} + 0.20 \times 10^{-3}\text{ kg}}$$

$$\mathbf{v_f} = \frac{4.0 \times 10^{-3}\text{ kg•m/s} - 1.6 \times 10^{-3}\text{ kg•m/s}}{2.2 \times 10^{-3}\text{ kg}}$$

$$\mathbf{v_f} = \frac{2.4 \times 10^{-3}\text{ kg•m/s}}{2.2 \times 10^{-3}\text{ kg}} = 1.1\text{ m/s forward}$$

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2$$

$$KE_i = \tfrac{1}{2}(2.0 \times 10^{-3}\text{ kg})(2.0\text{ m/s})^2 + \tfrac{1}{2}(0.20 \times 10^{-3}\text{ kg})(-8.0\text{ m/s})^2$$

$$KE_i = 4.0 \times 10^{-3}\text{ J} + 6.4 \times 10^{-3}\text{ J} = 1.04 \times 10^{-3}\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(2.0 \times 10^{-3}\text{ kg} + 0.20 \times 10^{-3}\text{ kg})(1.1\text{ m/s})^2$$

$$KE_f = \tfrac{1}{2}(2.2 \times 10^{-3}\text{ kg})(1.1\text{ m/s})^2$$

$$\Delta KE = KE_f - KE_i = 1.3 \times 10^{-3}\text{ J} - 1.04 \times 10^{-2}\text{ J} = -9.1 \times 10^{-3}\text{ J}$$

$$\text{fraction of total } KE \text{ dissipated} = \frac{\Delta KE}{KE_i} = \frac{9.1 \times 10^{-3}\text{ J}}{1.04 \times 10^{-2}\text{ J}} = \boxed{0.88}$$

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2. $m_1 = 313$ kg

$\mathbf{v_{1,i}} = 6.00$ m/s away from shore

$\mathbf{v_{2,i}} = 0$ m/s

$\mathbf{v_f} = 2.50$ m/s away from shore

$$m_2 = \frac{m_1\mathbf{v_{1,i}} - m_1\mathbf{v_f}}{\mathbf{v_f} - \mathbf{v_{2,i}}} = \frac{(313\text{ kg})(6.00\text{ m/s}) - (313\text{ kg})(2.50\text{ m/s})}{2.50\text{ m/s} - 0\text{ m/s}}$$

$$m_2 = \frac{1880\text{ kg•m/s} - 782\text{ kg•m/s}}{2.50\text{ m/s}} = \frac{1.10 \times 10^3\text{ kg•m/s}}{2.50\text{ m/s}} = 4.4 \times 10^2\text{ kg}$$

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2$$

$$KE_i = \tfrac{1}{2}(313\text{ kg})(6.00\text{ m/s})^2 + \tfrac{1}{2}(4.40 \times 10^2\text{ kg})(0\text{ m/s})^2 = 5630\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2$$

$$KE_f = \tfrac{1}{2}(313\text{ kg} + 4.40 \times 10^2\text{ kg})(2.50\text{ m/s})^2 = \tfrac{1}{2}(753\text{ kg})(2.50\text{ m/s})^2 = 2350\text{ J}$$

$$\Delta KE = KE_f - KE_i = 2350\text{ J} - 5630\text{ J} = \boxed{-3280\text{ J}}$$

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3. $m_1 = m_2 = 111$ kg

$\mathbf{v_{1,i}} = 9.00$ m/s to the right $= +9.00$ m/s

$\mathbf{v_{2,i}} = 5.00$ m/s to the left $= -5.00$ m/s

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(111\text{ kg})(9.00\text{ m/s}) + (111\text{ kg})(-5.00\text{ m/s})}{111\text{ kg} + 111\text{ kg}}$$

$$\mathbf{v_f} = \frac{999\text{ kg•m/s} - 555\text{ kg•m/s}}{222\text{ kg}} = \frac{444\text{ kg•m/s}}{222\text{ kg}} = 2.00\text{ m/s to the right}$$

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}(111\text{ kg})(9.00\text{ m/s})^2 + \tfrac{1}{2}(111\text{ kg})(-5.00\text{ m/s})^2$$

$$KE_i = 4.50 \times 10^3\text{ J} + 1.39 \times 10^3\text{ J} = 5.89 \times 10^3\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2 = \tfrac{1}{2}(111\text{ kg} + 111\text{ kg})(2.00\text{ m/s})^2 = \tfrac{1}{2}(222\text{ kg})(2.00\text{ m/s})$$

$$KE_f = 444\text{ J}$$

$$\Delta KE = KE_f - KE_i = 444\text{ J} - 5.89 \times 10^3\text{ J} = \boxed{-5450\text{ J}}$$

II

Givens | *Solutions*

4. $m_1 = m_2 = 60.0\text{ kg} + 50.0\text{ kg} = 110.0\text{ kg}$

$\mathbf{v_{1,i}} = 106.0$ km/h to the east $= +106.0$ km/h

$\mathbf{v_{2,i}} = 75.0$ km/h to the west $= -75.0$ km/h

$$\mathbf{v_f} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}}}{m_1 + m_2} = \frac{(110.0\text{ kg})(106.0\text{ km/h}) + (110.0\text{ kg})(-75.0\text{ km/h})}{110.0\text{ kg} + 110.0\text{ kg}}$$

$$\mathbf{v_f} = \frac{1.166 \times 10^4\text{ kg•km/h} - 8.25 \times 10^3\text{ kg•km/h}}{220.0\text{ kg}} = \frac{3.41 \times 10^3\text{ kg•km/h}}{220.0\text{ kg}}$$

$\mathbf{v_f} = 15.5$ km/h to the east

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2$$

$$KE_i = \tfrac{1}{2}(110.0\text{ kg})(106.0 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2 + \tfrac{1}{2}(110.0\text{ kg})(-75.0 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2$$

$$KE_i = 4.768 \times 10^4\text{ J} + 2.39 \times 10^4\text{ J} = 7.16 \times 10^4\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2$$

$$KE_f = \tfrac{1}{2}(110.0\text{ kg} + 110.0\text{ kg})(15.5 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2 = \tfrac{1}{2}(220.0\text{ kg})(15.5 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2$$

$$KE_f = 2.04 \times 10^3\text{ J}$$

$$\Delta KE = KE_f - KE_i = 2.04 \times 10^3\text{ J} - 7.16 \times 10^4\text{ J} = \boxed{-6.96 \times 10^4\text{ J}}$$

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5. $m_1 = 4.00 \times 10^5$ kg

$\mathbf{v_{1,i}} = 32.0$ km/h

$m_2 = 1.60 \times 10^5$ kg

$\mathbf{v_{2,i}} = 45.0$ km/h

$$v_f = \frac{m_1v_{1,i} + m_2v_{2,i}}{m_1 + m_2} = \frac{(4.00 \times 10^5\text{ kg})(32.0\text{ km/h}) + (1.60 \times 10^5\text{ kg})(45.0\text{ km/h})}{4.00 \times 10^5\text{ kg} + 1.60 \times 10^5\text{ kg}}$$

$$v_f = \frac{1.28 \times 10^7\text{ kg•km/h} + 7.20 \times 10^6\text{ kg•km/h}}{5.60 \times 10^5\text{ kg}} = \frac{2.00 \times 10^7\text{ kg•km/h}}{5.60 \times 10^5\text{ kg}}$$

$v_f = 35.7$ km/h

$$KE_i = \tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2$$

$$KE_i = \tfrac{1}{2}(4.00 \times 10^5\text{ kg})(32.0 \times 10^3\text{ m/h})(1\text{ h}/3600\text{ s})^2 + \tfrac{1}{2}(1.60 \times 10^5\text{ kg})(45.0 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2$$

$$KE_i = 1.58 \times 10^7\text{ J} + 1.25 \times 10^7\text{ J} = 2.83 \times 10^7\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f^2$$

$$KE_f = \tfrac{1}{2}(4.00 \times 10^5\text{ kg} + 1.60 \times 10^5\text{ kg})(35.7 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2 = \tfrac{1}{2}(5.60 \times 10^5\text{ kg})(35.7 \times 10^3\text{ m/h})^2(1\text{ h}/3600\text{ s})^2$$

$$KE_f = 2.75 \times 10^7\text{ J}$$

$$\Delta KE = KE_f - KE_i = 2.75 \times 10^7\text{ J} - 2.83 \times 10^7\text{ J} = \boxed{-8 \times 10^5\text{ J}}$$

Givens | *Solutions*

6. $m_1 = 21.3$ kg

$v_{1,i} = 0$ m/s

$m_2 = 1.80 \times 10^{-1}$ kg

$v_f = 6.00 \times 10^{-2}$ m/s

$$v_{2,i} = \frac{(m_1 + m_2)v_f - m_1 v_{1,i}}{m_2}$$

$$v_{2,i} = \frac{(21.3\text{ kg} + 1.80 \times 10^{-1}\text{ kg})(6.00 \times 10^{-2}\text{ m/s}) - (21.3\text{ kg})(0\text{ m/s})}{1.80 \times 10^{-1}\text{ kg}}$$

$$v_{2,i} = \frac{(21.5\text{ kg})(6.00 \times 10^{-2}\text{ m/s})}{1.80 \times 10^{-1}\text{ kg}} = 7.17\text{ m/s}$$

$$KE_i = \tfrac{1}{2}m_1 v_{1,i}{}^2 + \tfrac{1}{2}m_2 v_{2,i}{}^2$$

$$KE_i = \tfrac{1}{2}(21.3\text{ kg})(0\text{ m/s})^2 + \tfrac{1}{2}(1.80 \times 10^{-1}\text{ kg})(7.17\text{ m/s})^2$$

$$KE_i = 0\text{ J} + 4.63\text{ J} = 4.63\text{ J}$$

$$KE_f = \tfrac{1}{2}(m_1 + m_2)v_f{}^2$$

$$KE_f = \tfrac{1}{2}(21.3\text{ kg} + 0.180\text{ kg})(6.00 \times 10^{-2}\text{ m/s})^2 = \tfrac{1}{2}(21.5\text{ kg})(6.00 \times 10^{-2}\text{ m/s})^2$$

$$KE_f = 3.87 \times 10^{-2}\text{ J}$$

$$\Delta KE = KE_f - KE_i = 3.87 \times 10^{-2}\text{ J} - 4.63\text{ J} = \boxed{-4.59\text{ J}}$$

II

7. $m_1 = 122$ g

$m_2 = 96.0$ g

$v_{2,i} = 0$ m/s

Because $v_{2,i} = 0$ m/s, $m_1 v_{1,i} = (m_1 + m_2)v_f$

$$v_{1,i} = \frac{(m_1 + m_2)v_f}{m_1}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{\Delta KE}{KE_i} = \frac{KE_f - KE_i}{KE_i} = \frac{\frac{1}{2}(m_1 + m_2)v_f{}^2 - \frac{1}{2}m_1 v_{1,i}{}^2}{\frac{1}{2}m_1 v_{1,i}{}^2}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{(m_1 + m_2)v_f{}^2 - m_1\left[\frac{(m_1 + m_2)v_f}{m_1}\right]^2}{m_1\left[\frac{(m_1 + m_2)v_f}{m_1}\right]^2}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{m_1 v_f{}^2 + m_2 v_f{}^2 - \left[\frac{(m_1 v_f)^2 + 2m_1 m_2 v_f{}^2 + (m_2 v_f)^2}{m_1}\right]}{\frac{(m_1 v_f)^2 + 2m_1 m_2 v_f{}^2 + (m_2 v_f)^2}{m_1}}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{v_f{}^2\left(m_1 + m_2 - m_1 - 2m_2 - \frac{m_2{}^2}{m_1}\right)}{v_f{}^2\left(m_1 + 2m_2 + \frac{m_2{}^2}{m_1}\right)}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{-m_2 - \frac{m_2{}^2}{m_1}}{m_1 + 2m_2 + \frac{m_2{}^2}{m_1}} = \frac{-96.0\text{ g} - \left[\frac{(96.0\text{ g})^2}{122\text{ g}}\right]}{122\text{ g} + (2)(96.0\text{ g}) + \left[\frac{(96.0\text{ g})^2}{122\text{ g}}\right]}$$

$$\text{fraction of } KE \text{ dissipated} = \frac{-96.0\text{ g} - 75.5\text{ g}}{122\text{ g} + 192\text{ g} + 75.5\text{ g}} = \frac{-171.5\text{ g}}{3.90 \times 10^2\text{ g}} = \boxed{-0.440}$$

The fraction of kinetic energy dissipated can be determined without the initial velocity because this value cancels, as shown above. The initial velocity is needed to find the decrease in kinetic energy.

Additional Practice G

Givens	*Solutions*

1. $m_2 = 0.500\ m_1$

$v_{1,i} = 3.680 \times 10^3$ km/h

$v_{1,f} = -4.40 \times 10^2$ km/h

$v_{2,f} = 5.740 \times 10^3$ km/h

Momentum conservation

$$m_1v_{1,i} + m_2v_{2,i} = m_1v_{1,f} + m_2v_{2,f}$$

$$v_{2,i} = \frac{m_1v_{1,f} + m_2v_{2,f} - m_1v_{1,i}}{m_2} = \frac{m_1v_{1,f} + (0.500)m_1v_{2,f} - m_1v_{1,i}}{(0.500)m_1}$$

$$v_{2,i} = (2.00)v_{1,f} + v_{2,f} - (2.00)v_{1,i} = (2.00)(-4.40 \times 10^2 \text{ km/h}) + 5.740 \times 10^3 \text{ km/h} - (2.00)(3.680 \times 10^3 \text{ km/h}) = -8.80 \times 10^2 \text{ km/h} + 5.740 \times 10^3 \text{ km/h} - 7.36 \times 10^3 \text{ km/h}$$

$$v_{2,i} = \boxed{-2.50 \times 10^3 \text{ km/h}}$$

Conservation of kinetic energy (check)

$$\tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}m_2v_{2,f}^2$$

$$\tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}(0.500)m_1v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}(0.500)m_1v_{2,f}^2$$

$$v_{1,i}^2 + (0.500)v_{2,i}^2 = v_{1,f}^2 + (0.500)v_{2,f}^2$$

$$(3.680 \times 10^3 \text{ km/h})^2 + (0.500)(-2.50 \times 10^3 \text{ km/h})^2 = (-4.40 \times 10^2 \text{ km/h})^2 + (0.500)(5.740 \times 10^3 \text{ km/h})^2$$

$$1.354 \times 10^7 \text{ km}^2/\text{h}^2 + 3.12 \times 10^6 \text{ km}^2/\text{h}^2 = 1.94 \times 10^5 \text{ km}^2/\text{h}^2 + 1.647 \times 10^7 \text{ km}^2/\text{h}^2$$

$$1.666 \times 10^7 \text{ km}^2/\text{h}^2 = 1.666 \times 10^7 \text{ km}^2/\text{h}^2$$

---

2. $m_1 = 18.40$ kg

$m_2 = 56.20$ kg

$\mathbf{v_{2,i}} = 5.000$ m/s to the left $= -5.000$ m/s

$\mathbf{v_{2,f}} = 6.600 \times 10^{-2}$ m/s to the left $= -6.600 \times 10^{-2}$ m/s

$\mathbf{v_{1,f}} = 10.07$ m/s to the left $= -10.07$ m/s

Momentum conservation

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$$

$$\mathbf{v_{1,i}} = \frac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}}}{m_1}$$

$$\mathbf{v_{1,i}} = \frac{(18.40 \text{ kg})(-10.07 \text{ m/s}) + (56.20 \text{ kg})(-6.600 \times 10^{-2} \text{ m/s}) - (56.20 \text{ kg})(-5.000 \text{ m/s})}{18.40 \text{ kg}}$$

$$\mathbf{v_{1,i}} = \frac{-185.3 \text{ kg•m/s} - 3.709 \text{ kg•m/s} + 281.0 \text{ kg•m/s}}{18.40 \text{ kg}} = \frac{92.0 \text{ kg•m/s}}{18.40 \text{ kg}} = 5.00 \text{ m/s}$$

$$\mathbf{v_{1,i}} = \boxed{5.00 \text{ m/s to the right}}$$

Conservation of kinetic energy (check)

$$\tfrac{1}{2}m_1v_{1,i}^2 + \tfrac{1}{2}m_2v_{2,i}^2 = \tfrac{1}{2}m_1v_{1,f}^2 + \tfrac{1}{2}m_2v_{2,f}^2$$

$$\tfrac{1}{2}(18.40 \text{ kg})(5.00 \text{ m/s})^2 + \tfrac{1}{2}(56.20)(-5.000 \text{ m/s})^2 = \tfrac{1}{2}(18.40 \text{ kg})(-10.07 \text{ ms})^2 + \tfrac{1}{2}(56.20 \text{ kg})(-6.600 \times 10^{-2} \text{ m/s})^2$$

$$2.30 \times 10^2 \text{ J} + 702.5 \text{ J} = 932.9 \text{ J} + 0.1224 \text{ J}$$

$$932 \text{ J} = 933 \text{ J}$$

The slight difference arises from rounding.

II

Givens | *Solutions*

3. $m_1 = m_2$

$\mathbf{v_{1,i}}$ = 5.0 m/s to the right
= +5.0 m/s

$\mathbf{v_{1,f}}$ = 2.0 m/s to the left
= −2.0 m/s

$\mathbf{v_{2,f}}$ = 5.0 m/s to the right
= +5.0 m/s

Momentum conservation

$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$

$\mathbf{v_{2,i}} = \dfrac{m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}} - m_1\mathbf{v_{1,i}}}{m_2} = \mathbf{v_{1,f}} + \mathbf{v_{2,f}} - \mathbf{v_{1,i}}$

$\mathbf{v_{2,i}} = -2.0 \text{ m/s} + 5.0 \text{ m/s} - 5.0 \text{ m/s} = -2.0 \text{ m/s}$

$\mathbf{v_{2,i}} = \boxed{2.0 \text{ m/s to the left}}$

Conservation of kinetic energy (check)

$\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$v_{1,i}^2 + v_{2,i}^2 = v_{1,f}^2 + v_{2,f}^2$

$(5.0 \text{ m/s})^2 + (-2.0 \text{ m/s})^2 = (-2.0 \text{ m/s})^2 + (5.0 \text{ m/s})^2$

$25 \text{ m}^2/\text{s}^2 + 4.0 \text{ m}^2/\text{s}^2 = 4.0 \text{ m}^2/\text{s}^2 + 25 \text{ m}^2/\text{s}^2$

$29 \text{ m}^2/\text{s}^2 = 29 \text{ m}^2/\text{s}^2$

---

4. m_1 = 45.0 g

$\mathbf{v_{1,i}}$ = 273 km/h to the right
= +273 km/h

$\mathbf{v_{2,i}}$ = 0 km/h

$\mathbf{v_{1,f}}$ = 91 km/h to the left
= −91 km/h

$\mathbf{v_{2,f}}$ = 182 km/h to the right
= +182 km/h

Momentum conservation

$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$

$m_2 = \dfrac{m_1\mathbf{v_{1,f}} - m_1\mathbf{v_{1,i}}}{\mathbf{v_{2,i}} - \mathbf{v_{2,f}}} = \dfrac{(45.0 \text{ g})(-91 \text{ km/h}) - (45.0 \text{ g})(273 \text{ km/h})}{0 \text{ km/h} - 182 \text{ km/h}}$

$m_2 = \dfrac{-4.1 \times 10^3 \text{ g}\bullet\text{km/h} - 12.3 \times 10^3 \text{ g}\bullet\text{km/h}}{-182 \text{ km/h}} = \dfrac{-16.4 \times 10^3 \text{ g}\bullet\text{km/h}}{-182 \text{ km/h}}$

$m_2 = \boxed{90.1 \text{ g}}$

Conservation of kinetic energy (check)

$\frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}$

$\frac{1}{2}(45.0 \text{ g})(273 \times 10^3 \text{ m/h})^2(1 \text{ h}/3600 \text{ s})^2 + \frac{1}{2}(90.1 \text{ g})(0 \text{ m/s})^2$
$= \frac{1}{2}(45.0 \text{ g})(-91 \times 10^3 \text{ m/h})^2(1 \text{ h}/3600 \text{ s})^2 + \frac{1}{2}(90.1 \text{ g})(182 \times 10^3 \text{ m/h})^2(1 \text{ h}/3600 \text{ s})^2$

129 J + 0 J = 14 J + 115 J

129 J = 129 J

---

5. $\mathbf{v_{1,i}}$ = 185 km/h to the right
= +185 km/h

$\mathbf{v_{2,i}}$ = 0 km/h

$\mathbf{v_{i,f}}$ = 80.0 km/h to the left
= −80.0 km/h

$m_1 = 5.70 \times 10^{-2}$ kg

Momentum conservation

$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$

$\left(\dfrac{m_1}{m_2}\right)\mathbf{v_{1,i}} - \left(\dfrac{m_1}{m_2}\right)\mathbf{v_{1,f}} = \mathbf{v_{2,f}} - \mathbf{v_{2,i}}$

$\left(\dfrac{m_1}{m_2}\right)[185 \text{ km/h} - (-80.0 \text{ km/h})] = \mathbf{v_{2,f}} - 0 \text{ km/h}$

$\mathbf{v_{2,f}} = \left(\dfrac{m_1}{m_2}\right)(265 \text{ km/h})$ to the right

Conservation of kinetic energy

$KE_i = \frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 = \frac{1}{2}m_1v_{1,i}^2$

$KE_f = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$\frac{1}{2}m_1v_{1,i}^2 = \frac{1}{2}m_1v_{1,f}^2 + \frac{1}{2}m_2v_{2,f}^2$

$\left(\dfrac{m_1}{m_2}\right)(v_{1,i})^2 = \left(\dfrac{m_1}{m_2}\right)(v_{1,f})^2 + v_{2,f}^2$

$\left(\dfrac{m_1}{m_2}\right)(185 \text{ km/h})^2 = \left(\dfrac{m_1}{m_2}\right)(-80.0 \text{ km/h})^2 + v_{2,f}^2$

II

Givens | *Solutions*

$$\sqrt{\left(\frac{m_1}{m_2}\right)(3.42\times 10^4\ \text{km}^2/\text{h}^2)-\left(\frac{m_1}{m_2}\right)(6.40\times 10^3\ \text{km}^2/\text{h}^2)}=v_{2,f}$$

$$v_{2,f}=\sqrt{\left(\frac{m_1}{m_2}\right)(2.78\times 10^4\ \text{km}^2/\text{h}^2)}=\sqrt{\frac{m_1}{m_2}}\left(167\ \text{km/h}\right)$$

Equating the two results for $v_{2,f}$ yields the ratio of m_1 to m_2.

$$\left(\frac{m_1}{m_2}\right)(265\ \text{km/h})=\sqrt{\frac{m_1}{m_2}}(167\ \text{km/h})$$

$$265\ \text{km/h}=\sqrt{\frac{m_2}{m_1}}(167\ \text{km/h})$$

$$\frac{m_2}{m_1}=\left(\frac{265\ \text{km/h}}{167\ \text{km/h}}\right)^2=2.52$$

$$m_2=(2.52)\ m_1=(2.52)(5.70\times 10^{-2}\ \text{kg})$$

$$m_2=\boxed{0.144\ \text{kg}}$$

---

6. $m_1 = 4.00\times 10^5$ kg

$m_2 = 1.60\times 10^5$ kg

$\mathbf{v_{1,i}} = 32.0$ km/h to the right

$\mathbf{v_{2,i}} = 36.0$ km/h to the right

$\mathbf{v_{1,f}} = 35.5$ km/h to the right

Momentum conservation

$$m_1\mathbf{v_{1,i}}+m_2\mathbf{v_{2,i}}=m_1\mathbf{v_{1,f}}+m_2\mathbf{v_{2,f}}$$

$$\mathbf{v_{2,f}}=\frac{m_1\mathbf{v_{1,i}}+m_2\mathbf{v_{2,i}}-m_1\mathbf{v_{1,f}}}{m_2}$$

$$\mathbf{v_{2,f}}=\frac{(4.00\times 10^5\ \text{kg})(32.0\ \text{km/h})+(1.60\times 10^5\ \text{kg})(36.0\ \text{km/h})-(4.00\times 10^5\ \text{kg})(35.5\ \text{km/h})}{1.60\times 10^5\ \text{kg}}$$

$$\mathbf{v_{2,f}}=\frac{1.28\times 10^7\ \text{kg}\bullet\text{km/h}+5.76\times 10^6\ \text{kg}\bullet\text{km/h}-1.42\times 10^7\ \text{kg}\bullet\text{km/h}}{1.60\times 10^5\ \text{kg}}$$

$$\mathbf{v_{2,f}}=\frac{4.4\times 10^6\ \text{kg}\bullet\text{km/h}}{1.60\times 10^5\ \text{kg}}$$

$$\mathbf{v_{2,f}}=\boxed{28\ \text{km/h to the right}}$$

Conservation of kinetic energy (check)

$$\tfrac{1}{2}m_1v_{1,i}^{\ 2}+\tfrac{1}{2}m_2v_{2,i}^{\ 2}=\tfrac{1}{2}m_1v_{1,f}^{\ 2}+\tfrac{1}{2}m_2v_{2,f}^{\ 2}$$

$$\tfrac{1}{2}(4.00\times 10^5\ \text{kg})(32.0\times 10^3\ \text{m/h})^2(1\ \text{h}/3600\ \text{s})^2+\tfrac{1}{2}(1.60\times 10^5\ \text{kg})(36.0\times 10^3\ \text{m/h})^2(1\ \text{h}/3600\ \text{s})^2=\tfrac{1}{2}(4.00\times 10^5\ \text{kg})(35.5\times 10^3\ \text{m/h})^2(1\ \text{h}/3600\ \text{s})^2+\tfrac{1}{2}(1.60\times 10^5\ \text{kg})(28\times 10^3\ \text{m/h})^2(1\ \text{h}/3600\ \text{s})^2$$

$$1.58\times 10^7\ \text{J}+8.00\times 10^6\ \text{J}=1.94\times 10^7\ \text{J}+4.8\times 10^6\ \text{J}$$

$$2.38\times 10^7\ \text{J}=2.42\times 10^7\ \text{J}$$

The slight difference arises from rounding.

II

Givens | *Solutions*

7. $m_1 = 5.50 \times 10^5$ kg

$m_2 = 2.30 \times 10^5$ kg

$\mathbf{v_{1,i}} = 5.00$ m/s to the right $= +5.00$ m/s

$\mathbf{v_{2,i}} = 5.00$ m/s to the left $= -5.00$ m/s

$\mathbf{v_{2,f}} = 9.10$ m/s to the right $= +9.10$ m/s

Momentum conservation

$$m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} = m_1\mathbf{v_{1,f}} + m_2\mathbf{v_{2,f}}$$

$$\mathbf{v_{1,f}} = \frac{m_1\mathbf{v_{1,i}} + m_2\mathbf{v_{2,i}} - m_2\mathbf{v_{2,f}}}{m_1}$$

$$\mathbf{v_{1,f}} = \frac{(5.50 \times 10^5\ \text{kg})(5.00\ \text{m/s}) + (2.30 \times 10^5\ \text{kg})(-5.00\ \text{m/s}) - (9.10\ \text{m/s})}{5.50 \times 10^5\ \text{kg}}$$

$$\mathbf{v_{1,f}} = \frac{2.75 \times 10^6\ \text{kg•m/s} - 1.15 \times 10^6\ \text{kg•m/s} - 2.09 \times 10^6\ \text{kg•m/s}}{5.50 \times 10^5\ \text{kg}} = -0.89\ \text{m/s right}$$

$$\mathbf{v_{1,f}} = \boxed{0.89\ \text{m/s left}}$$

Conservation of kinetic energy (check)

$$\tfrac{1}{2}m_1 v_{1,i}^2 + \tfrac{1}{2}m_2 v_{2,i}^2 = \tfrac{1}{2}m_1 v_{1,f}^2 + \tfrac{1}{2}m_2 v_{2,f}^2$$

$$\tfrac{1}{2}(5.50 \times 10^5\ \text{kg})(5.00\ \text{m/s})^2 + \tfrac{1}{2}(2.30 \times 10^5\ \text{kg})(-5.00\ \text{m/s})^2 = \tfrac{1}{2}(5.50 \times 10^5\ \text{kg})(-0.89\ \text{m/s})^2 + \tfrac{1}{2}(2.30 \times 10^5\ \text{kg})(9.10 \times \text{m/s})^2$$

$$6.88 \times 10^6\ \text{J} + 2.88 \times 10^6\ \text{J} = 2.2 \times 10^5\ \text{J} + 9.52 \times 10^6\ \text{J}$$

$$9.76 \times 10^6\ \text{J} = 9.74 \times 10^6\ \text{J}$$

The slight difference arises from rounding.

II

Circular Motion and Gravitation

Additional Practice A

Givens	Solutions
1. $v_t = 0.17$ m/s $a_c = 0.29$ m/s^2	$r = \frac{v_t^2}{a_c} = \frac{(0.17 \text{ m/s})^2}{0.29 \text{ m/s}^2} = \boxed{0.10 \text{ m}}$
2. $v_t = 465$ m/s $a_c = 3.4 \times 10^{-2}$ m/s^2	$r = \frac{v_t^2}{a_c} = \frac{(465 \text{ m/s})^2}{3.4 \times 10^{-2} \text{ m/s}^2} = \boxed{6.4 \times 10^6 \text{ m}}$
3. $r = \frac{58.4 \text{ cm}}{2} = 29.2$ cm $a_c = 8.50 \times 10^{-2}$ m/s^2	$v_t = \sqrt{ra_c} = \sqrt{(29.2 \times 10^{-2} \text{ m})(8.50 \times 10^{-2} \text{ m/s}^2}$ $v_t = \boxed{0.158 \text{ m/s}}$
4. $r = \frac{12 \text{ cm}}{2} = 6.0$ cm $a_c = 0.28$ m/s^2	$v_t = \sqrt{ra_c} = \sqrt{(6.0 \times 10^{-2} \text{ m})(0.28 \text{ m/s}^2)} = \boxed{0.13 \text{ m/s}}$
5. $v_t = 7.85$ m/s $r = 20.0$ m	$a_c = \frac{v_t^2}{r} = \frac{(7.85 \text{ m/s})^2}{20.0 \text{ m}} = \boxed{3.08 \text{ m/s}^2}$
6. $\Delta t = 1.000$ h $\Delta s = 47.112$ km $r = 6.37 \times 10^3$ km	$a_c = \frac{v_t^2}{r} = \frac{\left(\frac{\Delta s}{\Delta t}\right)^2}{r} = \frac{\Delta s^2}{r\Delta t^2}$ $a_c = \frac{(47\,112 \text{ m})^2}{(6.37 \times 10^6 \text{ m})[(1.000 \text{ h})(3600 \text{ s/h})]^2} = \boxed{2.69 \times 10^{-5} \text{ m/s}^2}$

Additional Practice B

Givens	Solutions
1. $m_1 = 235$ kg $m_2 = 72$ kg $r = 25.0$ m $F_c = 1850$ N	$m_{tot} = m_1 + m_2 = 235 \text{ kg} + 72 \text{ kg} = 307 \text{ kg}$ $F_c = m_{tot}\, a_c = m_{tot} \frac{v_t^2}{r}$ $v_t = \sqrt{\frac{rF_c}{m_{tot}}} = \sqrt{\frac{(25.0 \text{ m})(1850 \text{ N})}{307 \text{ kg}}} = \boxed{12.3 \text{ m/s}}$
2. $m = 30.0$ g $r = 2.4$ m $F_T = 0.393$ N $g = 9.81$ m/s^2	$F_T = F_g + F_c = mg + m\frac{v_t^2}{r}$ $v_t = \sqrt{\frac{r(F_T - mg)}{m}} = \sqrt{\frac{(2.4 \text{ m})[0.393 \text{ N} - (30.0 \times 10^{-3} \text{ kg})(9.81 \text{ m/s}^2)]}{30.0 \times 10^{-3} \text{ kg}}}$ $v_t = \sqrt{\frac{(2.4 \text{ m})(0.393 \text{ N} - 0.294 \text{ N})}{30.0 \times 10^{-3} \text{ kg}}} = \frac{(2.4 \text{ m})(0.099 \text{ N})}{30.0 \times 10^{-3} \text{ kg}}$ $v_t = \boxed{2.8 \text{ m/s}}$

II

Givens | *Solutions*

3. $v_t = 8.1$ m/s

$r = 4.23$ m

$m_1 = 25$ g

$g = 9.81$ m/s^2

$$F_g = F_c$$

$$m_1 g = \frac{m_2 v_t^2}{r}$$

$$m_2 = \frac{m_1 g r}{v_t^2}$$

$$m_2 = \frac{(25 \times 10^{-3}\text{ kg})(9.81\text{ m/s}^2)(4.23\text{ m})}{(8.1\text{ m/s})^2} = \boxed{1.6 \times 10^{-2}\text{ kg}}$$

---

4. $v_t = 75.57$ km/h

$m = 92.0$ kg

$F_c = 12.8$ N

$$F_c = m\frac{v_t^2}{r}$$

$$r = \frac{m v_t^2}{F_c} = \frac{(92.0\text{ kg})[(75.57\text{ km/h})(10^3\text{ m/km})(1\text{ h/3600 s})]^2}{12.8\text{ N}}$$

$$r = \boxed{3.17 \times 10^3\text{ m} = 3.17\text{ km}}$$

---

5. $m = 75.0$ kg

$r = 446$ m

$v_t = 12$ m/s

$g = 9.81$ m/s^2

$$F_c = \frac{m v_t^2}{r} = \frac{(75.0\text{ kg})(12\text{ m/s})^2}{446\text{ m}} = \boxed{24\text{ N}}$$

$$F_T = F_c + mg = 24\text{ N} + (75.0\text{ kg})(9.81\text{ m/s}^2)$$

$$F_T = 24\text{ N} + 736\text{ N} = \boxed{7.60 \times 10^2\text{ N}}$$

II

Additional Practice C

1. $r = 6.3$ km

$F_g = 2.5 \times 10^{-2}$ N

$m_1 = 3.0$ kg

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

$$m_2 = \frac{F_g r^2}{G m_1} = \frac{(2.5 \times 10^{-2}\text{ N})(6.3 \times 10^3\text{ m})^2}{\left(6.673 \times 10^{-11}\dfrac{\text{N•m}^2}{\text{kg}^2}\right)(3.0\text{ kg})}$$

$$m_2 = \boxed{5.0 \times 10^{15}\text{ kg}}$$

---

2. $m_1 = 3.08 \times 10^4$ kg

$r = 1.27 \times 10^7$ m

$F_g = 2.88 \times 10^{-16}$ N

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

$$m_2 = \frac{F_g r^2}{G m_1} = \frac{(2.88 \times 10^{-16}\text{ N})(1.27 \times 10^7\text{ m})^2}{\left(6.673 \times 10^{-11}\dfrac{\text{N•m}^2}{\text{kg}^2}\right)(3.08 \times 10^4\text{ kg})}$$

$$m_2 = \boxed{2.26 \times 10^4\text{ kg}}$$

---

3. $m_1 = 5.81 \times 10^4$ kg

$r = 25.0$ m

$F_g = 5.00 \times 10^{-7}$ N

$G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$

$$m_2 = \frac{F_g r^2}{G m_1} = \frac{(5.00 \times 10^{-7}\text{ N})(25.0\text{ m})^2}{\left(6.673 \times 10^{-11}\dfrac{\text{N•m}^2}{\text{kg}^2}\right)(5.81 \times 10^4\text{ kg})}$$

$$m_2 = \boxed{80.6\text{ kg}}$$

Givens | *Solutions*

4. $m_1 = 621$ g

$m_2 = 65.0$ kg

$F_g = 1.0 \times 10^{-12}$ N

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}}$$

$$r = \sqrt{\frac{(6.673 \times 10^{-11} \text{ N•m}^2/\text{kg}^2)(0.621 \text{ kg})(65.0 \text{ kg})}{1.0 \times 10^{-12} \text{ N}}} = \boxed{52 \text{ m}}$$

---

5. $m_1 = m_2 = 1.0 \times 10^8$ kg

$F_g = 1.0 \times 10^{-3}$ N

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}}$$

$$r = \sqrt{\frac{(6.673 \times 10^{-11} \text{ N•m}^2/\text{kg}^2)(1.0 \times 10^8 \text{ kg})^2}{1.0 \times 10^{-3} \text{ N}}}$$

$$r = 2.6 \times 10^4 \text{ m} = \boxed{26 \text{ km}}$$

---

6. $m_s = 25 \times 10^9$ kg

$m_1 = m_2 = \frac{1}{2} m_s$

$r = 1.0 \times 10^3$ km

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

$$F_g = \frac{Gm_1m_2}{r^2} = \frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)\left[\frac{1}{2}(25 \times 10^9 \text{ kg})\right]^2}{(1.0 \times 10^6 \text{ m})^2} = \boxed{1.0 \times 10^{-2} \text{ N}}$$

---

7. $m_1 = 318 m_E$

$m_2 = 50.0$ kg

$V_J = 1323 V_E$

$m_E = 5.98 \times 10^{24}$ kg

$r_E = 6.37 \times 10^6$ m

$G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$

If $V_J = 1323\ V_E$, then $r_J = \sqrt[3]{1323}\, r_E$.

$$F_g = \frac{Gm_1m_2}{r_J^2} = \frac{(6.673 \times 10^{-11} \text{ N•m}^2/\text{kg}^2)(318)(5.98 \times 10^{24} \text{ kg})(50.0 \text{ kg})}{[(\sqrt[3]{1323})(6.37 \times 10^6 \text{ m})]^2}$$

$$F_g = \boxed{1.30 \times 10^3 \text{ N}}$$

Additional Practice D

1. $T = 88\,643$ s

$m = 6.42 \times 10^{23}$ kg

$r_m = 3.40 \times 10^6$ m

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}} = \sqrt[3]{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(6.42 \times 10^{23} \text{ kg})(88\,643 \text{ s})^2}{4\pi^2}}$$

$$r = 2.04 \times 10^7 \text{ m}$$

$$r_s = r - r_m = 2.04 \times 10^7 \text{ m} - 3.40 \times 10^6 \text{ m} = \boxed{1.70 \times 10^7 \text{ m}}$$

---

2. $T = 5.51 \times 10^5$ s

$m = 1.25 \times 10^{22}$ kg

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}} = \sqrt[3]{\frac{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.25 \times 10^{22} \text{ kg})(5.51 \times 10^5 \text{ s})^2}{4\pi^2}}$$

$$r = \boxed{1.86 \times 10^7 \text{ m}}$$

II

Givens	Solutions
3. $r = 4.22 \times 10^7$ m $m = 5.97 \times 10^{24}$ kg	$v_t = \sqrt{G\frac{m}{r}} = \sqrt{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(5.97 \times 10^{24}\text{ kg})}{(4.22 \times 10^7\text{ m})}} = \boxed{3.07 \times 10^3\text{ m/s}}$
4. $r = 3.84 \times 10^8$ m $m = 5.97 \times 10^{24}$ kg	$v_t = \sqrt{G\frac{m}{r}} = \sqrt{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)\frac{(5.97 \times 10^{24}\text{ kg})}{(3.84 \times 10^8\text{ m})}} = \boxed{1.02 \times 10^3\text{ m/s}}$
5. $r = 3.84 \times 10^8$ m $m = 5.97 \times 10^{24}$ kg	$T = 2\pi\sqrt{\frac{r^3}{Gm}} = 2\pi\sqrt{\frac{(3.84 \times 10^8\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24}\text{ kg})}} = 2.37 \times 10^6\text{ s} = \boxed{27.4\text{ d}}$
6. $r = 4.50 \times 10^{12}$ m $m = 1.99 \times 10^{30}$ kg	$T = 2\pi\sqrt{\frac{r^3}{Gm}} = 2\pi\sqrt{\frac{(4.50 \times 10^{12}\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(1.99 \times 10^{30}\text{ kg})}} = 5.20 \times 10^9\text{ s} = \boxed{165\text{ years}}$
7. $r = 1.19 \times 10^6$ m $T = 4.06 \times 10^5$ s	$m = 4\pi^2\frac{r^3}{GT^2} = 4\pi^2\frac{(1.19 \times 10^6\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(4.06 \times 10^5\text{ s})^2} = \boxed{6.05 \times 10^{18}\text{ kg}}$
8. $r = 2.30 \times 10^{10}$ m $T = 5.59 \times 10^5$ s $m_s = 1.99 \times 10^{30}$ kg	$m = 4\pi^2\frac{r^3}{GT^2} = 4\pi^2\frac{(2.30 \times 10^{10}\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(5.59 \times 10^5\text{ s})^2} = \boxed{2.30 \times 10^{31}\text{ kg}}$ $\frac{m}{m_s} = \frac{2.30 \times 10^{31}\text{ kg}}{1.99 \times 10^{30}\text{ kg}} = \boxed{11.6}$

II

Additional Practice E

1. $m = 3.00 \times 10^5$ kg

$\theta = 90.0° - 45.0° = 45.0°$

$\tau = 3.20 \times 10^7$ N•m

$g = 9.81$ m/s^2

$$\tau = Fd(\sin\theta) = mg\ell(\sin\theta)$$

$$\ell = \frac{\tau}{mg(\sin\theta)}$$

$$\ell = \frac{3.20 \times 10^7\text{ N•m}}{(3.00 \times 10^5\text{ kg})(9.81\text{ m/s}^2)(\sin 45.0°)}$$

$$\ell = \boxed{15.4\text{ m}}$$

Givens | *Solutions*

2. $\tau_{net} = 9.4$ kN•m

$m_1 = 80.0$ kg

$m_2 = 120.0$ kg

$g = 9.81$ m/s^2

$$\tau_{net} = \tau_1 + \tau_2 = F_1 d_1(\sin\theta_1) + F_2 d_2(\sin\theta_2)$$

$\theta_1 = \theta_2 = 90°$, so

$$\tau_{net} = F_1 d_1 + F_2 d_2 = m_1 g\left(\frac{\ell}{2}\right) + m_2 g\ell$$

$$\ell = \frac{\tau_{net}}{\frac{m_1 g}{2} + m_2 g}$$

$$\ell = \frac{9.4 \times 10^3 \text{ N•m}}{\frac{(80.0 \text{ kg})(9.81 \text{ m/s}^2)}{2} + (120.0 \text{ kg})(9.81 \text{ m/s}^2)} = \frac{9.4 \times 10^3 \text{ N•m}}{392 \text{ N} + 1.18 \times 10^3 \text{ N}}$$

$$\ell = \frac{9.4 \times 10^3 \text{ N•m}}{1.57 \times 10^3 \text{ N}} = \boxed{6.0 \text{ m}}$$

---

3. $\tau_{net} = 56.0$ N•m

$m_1 = 3.9$ kg

$m_2 = 9.1$ kg

$d_1 = 1.000$ m $-$ 0.700 m $=$ 0.300 m

$g = 9.81$ m/s^2

$$\tau_{net} = \tau_1 + \tau_2 = F_1 d_1(\sin\theta_1) + F_2 d_2(\sin\theta_2)$$

$\theta_1 = \theta_2 = 90°$, so

$$\tau_{net} = F_1 d_1 + F_2 d_2 = m_1 g d_1 + m_2 g(1.000 \text{ m} - x)$$

$$x = 1.000 \text{ m} - \frac{\tau_{net} - m_1 g d_1}{m_2 g}$$

$$x = 1.000 \text{ m} - \frac{56.0 \text{ N•m} - (3.9 \text{ kg})(9.81 \text{ m/s}^2)(0.300 \text{ m})}{(9.1 \text{ kg})(9.81 \text{ m/s}^2)}$$

$$x = \frac{56.0 \text{ N•m} - 11 \text{ N•m}}{(9.1 \text{ kg})(9.81 \text{ m/s}^2)} = \frac{45 \text{ N•m}}{(9.1 \text{ kg})(9.81 \text{ m/s}^2)} = 1.000 \text{ m} - 0.50 \text{ m}$$

$$x = \boxed{0.50 \text{ m} = 5.0 \times 10^1 \text{ cm}}$$

---

4. $\tau = -1.3 \times 10^4$ N•m

$\ell = 6.0$ m

$d = 1.0$ m

$\theta = 90.0° - 30.0° = 60.0°$

$$\tau = Fd(\sin\theta) = -F_g(\ell - d)(\sin\theta)$$

$$F_g = \frac{-\tau}{(\ell - d)(\sin\theta)} = \frac{-(-1.3 \times 10^4 \text{ N•m})}{(6.0 \text{ m} - 1.0 \text{ m})(\sin 60.0°)} = \frac{1.3 \times 10^4 \text{ N•m}}{(5.0 \text{ m})(\sin 60.0°)}$$

$$F_g = \boxed{3.0 \times 10^3 \text{ N}}$$

---

5. $R = \frac{76 \text{ m}}{2} = 38$ m

$\theta = 60.0°$

$\tau = -1.45 \times 10^6$ N•m

$$\tau = Fd(\sin\theta) = -F_g R(\sin\theta)$$

$$F_g = \frac{-\tau}{R(\sin\theta)} = \frac{-(-1.45 \times 10^6 \text{ N•m})}{(38 \text{ m})(\sin 60.0°)}$$

$$F_g = \boxed{4.4 \times 10^4 \text{ N}}$$

II

Givens | *Solutions*

6. $m_1 = 102$ kg

$m_2 = 109$ kg

$\ell = 3.00$ m

$\ell_1 = 0.80$ m

$\ell_2 = 1.80$ m

$g = 9.81$ m/s^2

$$\tau_{net} = \tau_1 + \tau_2 = F_1 d_1(\sin\theta_1) + F_2 d_2(\sin\theta_2)$$

$\theta_1 = \theta_2 = 90°$, so

$$\tau_{net} = F_1 d_1 + F_2 d_2 = m_1 g\left(\frac{\ell}{2} - \ell_1\right) + m_2 g\left(\frac{\ell}{2} - \ell_2\right)$$

$$\tau_{net} = (102\text{ kg})(9.81\text{ m/s}^2)\left(\frac{3.00\text{ m}}{2} - 0.80\text{ m}\right) + (109\text{ kg})(9.81\text{ m/s}^2)\left(\frac{3.00\text{ m}}{2} - 1.80\text{ m}\right)$$

$$\tau_{net} = (102\text{ kg})(9.81\text{ m/s}^2)(1.50\text{ m} - 0.80\text{ m}) + (109\text{ kg})(9.81\text{ m/s}^2)(1.50\text{ m} - 1.80\text{ m})$$

$$\tau_{net} = (102\text{ kg})(9.81\text{ m/s}^2)(0.70\text{ m}) + (109\text{ kg})(9.81\text{ m/s}^2)(-0.30\text{ m})$$

$$\tau_{net} = 7.0 \times 10^2\text{ N•m} - 3.2 \times 10^2\text{ N•m}$$

$$\tau_{net} = \boxed{3.8 \times 10^2\text{ N•m}}$$

---

7. $m = 5.00 \times 10^2$ kg

$d_1 = 5.00$ m

$\tau = 6.25 \times 10^5$ N•m

$g = 9.81$ m/s^2

$\theta_1 = 90.0° - 10.0° = 80.0°$

$d_2 = 4.00$ m

$\theta_2 = 90°$

a. $\tau' = Fd(\sin\theta) = mgd_1(\sin\theta_1)$

$$\tau' = (5.00 \times 10^2\text{ kg})(9.81\text{ m/s}^2)(5.00\text{ m})(\sin 80.0°)$$

$$\tau' = \boxed{2.42 \times 10^4\text{ N•m}}$$

b. $\tau_{net} = Fd_2(\sin\theta_2) - \tau' = Fd_2(\sin\theta_2) - mgd_1(\sin\theta_1)$

$$F = \frac{\tau_{net} + mgd_1(\sin\theta_1)}{d_2(\sin\theta_2)}$$

$$F = \frac{6.25 \times 10^5\text{ N•m} + 2.42 \times 10^4\text{ N•m}}{4.00\text{ m}(\sin 90°)} = \frac{6.49 \times 10^5\text{ N•m}}{4.00\text{ m}}$$

$$F = \boxed{1.62 \times 10^5\text{ N}}$$

II

Problem Workbook Solutions

Fluid Mechanics

Additional Practice A

Givens	*Solutions*
1. $m_p = 1158$ kg $V = 3.40\ \mathrm{m}^3$ $\rho = 1.00 \times 10^3\ \mathrm{kg/m^3}$ $g = 9.81\ \mathrm{m/s^2}$	$F_B = F_g$ $\rho V g = (m_p + m_r)g$ $m_r = \rho V - m_p = (1.00 \times 10^3\ \mathrm{kg/m^3})(3.40\ \mathrm{m^3}) - 1158\ \mathrm{kg} = 3.40 \times 10^3\ \mathrm{kg} - 1158\ \mathrm{kg}$ $m_r = \boxed{2.24 \times 10^3\ \mathrm{kg}}$
2. $V = 4.14 \times 10^{-2}\ \mathrm{m}^3$ apparent weight = 3.115×10^3 N $\rho_{sw} = 1.025 \times 10^3\ \mathrm{kg/m^3}$ $g = 9.81\ \mathrm{m/s^2}$	$F_B = F_g -$ apparent weight $\rho_{sw} V g = mg -$ apparent weight $m = \rho_{sw} V + \dfrac{\text{apparent weight}}{g} = (1.025 \times 10^3\ \mathrm{kg/m^3})(4.14 \times 10^{-2}\ \mathrm{m^3}) + \dfrac{3.115 \times 10^3\ \mathrm{N}}{9.81\ \mathrm{m/s^2}}$ $m = 42.4\ \mathrm{kg} + 318\ \mathrm{kg} = \boxed{3.60 \times 10^2\ \mathrm{kg}}$
3. $\ell = 3.00$ m $A = 0.500\ \mathrm{m}^2$ $\rho_{fw} = 1.000 \times 10^3\ \mathrm{kg/m^3}$ $\rho_{sw} = 1.025 \times 10^3\ \mathrm{kg/m^3}$	$F_{net,1} = F_{net,2} = 0$ $F_{B,1} - F_{g,1} = F_{B,2} - F_{g,2}$ $\rho_{fw} V g - mg = \rho_{sw} V g - (m + m_{ballast})g$ $m_{ballast} g = (\rho_{sw} - \rho_{fw}) V g$ $m_{ballast} = (\rho_{sw} - \rho_{fw}) A \ell$ $m_0 = (1.025 \times 10^3\ \mathrm{kg/m^3} - 1.000 \times 10^3\ \mathrm{kg/m^3})(0.500\ \mathrm{m^2})(3.00\ \mathrm{m})$ $m_0 = (25\ \mathrm{kg/m^3})(0.500\ \mathrm{m^2})(3.00\ \mathrm{m}) = \boxed{38\ \mathrm{kg}}$
4. $A = 3.10 \times 10^4\ \mathrm{km}^2$ $h = 0.84$ km $\rho = 1.025 \times 10^3\ \mathrm{kg/m^3}$ $g = 9.81\ \mathrm{m/s^2}$	$F_B = \rho V g = \rho A h g$ $F_B = (1.025 \times 10^3\ \mathrm{kg/m^3})(3.10 \times 10^{10}\ \mathrm{m^2})(840\ \mathrm{m})(9.81\ \mathrm{m/s^2}) = \boxed{2.6 \times 10^{17}\ \mathrm{N}}$
5. $m = 4.80 \times 10^2$ kg $g = 9.81\ \mathrm{m/s^2}$ apparent weight = 4.07×10^3 N	$F_B = F_g -$ apparent weight $= mg -$ apparent weight $F_B = (4.80 \times 10^2\ \mathrm{kg})(9.81\ \mathrm{m/s^2}) - 4.07 \times 10^3\ \mathrm{N} = 4.71 \times 10^3\ \mathrm{N} - 4.07 \times 10^3\ \mathrm{N}$ $F_B = \boxed{640\ \mathrm{N}}$

II

Givens | *Solutions*

6. $h = 167$ m

$H = 1.50$ km

$\rho_{sw} = 1.025 \times 10^3$ kg/m^3

$F_{g,i} = F_B$

$\rho_i V_i g = \rho_{sw} V_{sw} g$

$\rho_i (h + H)Ag = \rho_{sw} HAg$

$$\rho_i = \frac{\rho_{sw} H}{h + H}$$

$$\rho_i = \frac{(1.025 \times 10^3 \text{ kg/m}^3)(1.50 \times 10^3 \text{ m})}{167 \text{ m} + 1.50 \times 10^3 \text{ m}} = \frac{(1.025 \times 10^3 \text{ kg/m}^3)(1.50 \times 10^3 \text{ m})}{1670 \text{ m}} = \boxed{921 \text{ kg/m}^3}$$

---

7. $\ell = 1.70 \times 10^2$ m

$r = \frac{13.9 \text{ m}}{2} = 6.95$ m

$m_{sw} = 2.65 \times 10^7$ kg

$a = 2.00$ m/s^2

$g = 9.81$ m/s^2

$F_{net} = F_g - F_B$

$m_{sub} a = m_{sub} g - m_{sw} g$

$\rho_{sub} Va = \rho_{sub} Vg - m_{sw} g$

$\rho_{sub} (g - a) V = m_{sw} g$

$$\rho_{sub} = \frac{m_{sw} g}{(g - a)V} = \frac{m_{sw} g}{(g - a)(\pi r^2 \ell)}$$

$$\rho_{sub} = \frac{(2.65 \times 10^7 \text{ kg})(9.81 \text{ m/s}^2)}{(9.81 \text{ m/s}^2 - 2.00 \text{ m/s}^2)(\pi)(6.95 \text{ m})^2(1.70 \times 10^2 \text{ m})}$$

$$\rho_{sub} = \frac{(2.65 \times 10^7 \text{ kg})(9.81 \text{ m/s}^2)}{(9.81 \text{ m/s}^2)(\pi)(6.95 \text{ m})^2(1.70 \times 10^2 \text{ m})}$$

$$\rho_{sub} = \boxed{1.29 \times 10^3 \text{ kg/m}^3}$$

---

8. $V = 6.00$ m^3

Δ apparent weight $= 800$ N

$\rho_{water} = 1.00 \times 10^3$ kg/m^3

$g = 9.81$ m/s^2

$F_{g,1} = F_{g,2}$

$F_{B,1}$ + apparent weight in water $= F_{B,2}$ + apparent weight in PEG solution

$\rho_{water} Vg$ + apparent weight in water $-$ apparent weight in PEG solution $= \rho_{soln} Vg$

$$\rho_{soln} = \frac{\rho_{water} Vg + \Delta \text{ apparent weight}}{Vg}$$

$$\rho_{soln} = \frac{(1.00 \times 10^3 \text{ kg/m}^3)(6.00 \text{ m}^3)(9.81 \text{ m/s}^2) + 800 \text{ N}}{(6.00 \text{ m}^3)(9.81 \text{ m/s}^2)}$$

$$\rho_{soln} = \frac{5.89 \times 10^4 \text{ N} + 800 \text{ N}}{(6.00 \text{ m}^3)(9.81 \text{ m/s}^2)} = \frac{5.97 \times 10^4 \text{ N}}{(6.00 \text{ m}^3)(9.81 \text{ m/s}^2)}$$

$$\rho_{soln} = \boxed{1.01 \times 10^3 \text{ kg/m}^3}$$

Additional Practice B

1. $P = 1.01 \times 10^5$ Pa

$A = 3.3$ m^2

$F = PA\ (1.01 \times 10^5 \text{ Pa})(3.3 \text{ m}^2) = \boxed{3.3 \times 10^5 \text{ N}}$

II

Givens	*Solutions*
2. $P = 4.0 \times 10^{11}$ Pa $r = 50.0$ m	$F = PA = P(\pi r^2)$ $F = (4.0 \times 10^{11}\ \text{Pa})(\pi)(50.0\ \text{m})^2$ $F = \boxed{3.1 \times 10^{15}\ \text{N}}$
3. $m_1 = 181$ kg $m_2 = 16.0$ kg $A_1 = 1.8\ \text{m}^2$ $g = 9.81\ \text{m/s}^2$	$P_1 = P_2$ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $A_2 = \frac{F_2 A_1}{F_1} = \frac{3m_2 g A_1}{m_1 g} = \frac{3m_2 A_1}{m_1}$ $A_2 = \frac{(3)(16.0\ \text{kg})(1.8\ \text{m}^2)}{181\ \text{kg}} = \boxed{0.48\ \text{m}^2}$
4. $m = 4.0 \times 10^7$ kg $F_2 = 1.2 \times 10^4$ N $A_2 = 5.0\ \text{m}^2$ $g = 9.81\ \text{m/s}^2$	$P_1 = P_2$ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ $A_1 = \frac{A_2 F_1}{F_2} = \frac{A_2 mg}{F_2}$ $\text{A}_1 = \frac{(5.0\ \text{m}^2)(4.0 \times 10^7\ \text{kg})(9.81\ \text{m/s}^2)}{1.2 \times 10^4\ \text{N}} = \boxed{1.6 \times 10^5\ \text{m}^2}$
5. $P = 2.0 \times 10^{16}$ Pa $F = 1.02 \times 10^{31}$ N	$A = \frac{F}{P} = \frac{1.02 \times 10^{31}\ \text{N}}{2.0 \times 10^{16}\ \text{Pa}} = \boxed{5.1 \times 10^{14}\ \text{m}^2}$ $A = 4\pi r^2$ $r = \sqrt{\frac{A}{4\pi}} = \sqrt{\frac{5.1 \times 10^{14}\ \text{m}^2}{4\pi}}$ $r = \boxed{6.4 \times 10^6\ \text{m}}$
6. $F = 4.6 \times 10^6$ N $r = \frac{38\ \text{cm}}{2} = 19$ cm	$P = \frac{F}{A}$ Assuming the squid's eye is a sphere, its total surface area is $4\pi r^2$. The outer half of the eye has an area of $A = 2\pi r^2$ $\text{P} = \frac{F}{2\pi r^2} = \frac{4.6 \times 10^6\ \text{N}}{(2\pi)(0.19\ \text{m})^2} = \boxed{2.0 \times 10^7\ \text{Pa}}$
7. $A = 26.3\ \text{m}^2$ $F = 1.58 \times 10^7$ N $P_o = 1.01 \times 10^5$ Pa	$P = \frac{F}{A} = \frac{1.58 \times 10^7\ \text{N}}{26.3\ \text{m}^2} = \boxed{6.01 \times 10^5\ \text{Pa}}$ $P_{gauge} = P - P_o = 6.01 \times 10^5\ \text{Pa} - 1.01 \times 10^5\ \text{Pa} = \boxed{5.00 \times 10^5\ \text{Pa}}$

Additional Practice C

Givens	*Solutions*
1. $h = (0.800)(16.8\ \text{m})$ $P = 2.22 \times 10^5\ \text{Pa}$ $P_o = 1.01 \times 10^5\ \text{Pa}$ $g = 9.81\ \text{m/s}^2$	$P = P_o + \rho g h$ $\rho = \frac{P - P_o}{gh} = \frac{2.22 \times 10^5\ \text{Pa} - 1.01 \times 10^5\ \text{Pa}}{(9.81\ \text{m/s}^2)(0.800)(16.8\ \text{m})} = \frac{1.21 \times 10^5\ \text{Pa}}{(9.81\ \text{m/s}^2)(0.800)(16.8\ \text{m})}$ $\rho = \boxed{918\ \text{kg/m}^3}$
2. $h = -950\ \text{m}$ $P = 8.88 \times 10^4\ \text{Pa}$ $P_o = 1.01 \times 10^5\ \text{Pa}$ $g = 9.81\ \text{m/s}^2$	$P = P_o + \rho g h$ $\rho = \frac{P - P_o}{\frac{gh}{1}} = \frac{8.88 \times 10^4\ \text{Pa} - 1.01 \times 10^5\ \text{Pa}}{(9.81\ \text{m/s}^2)(-950\ \text{m})} = \frac{-1.2 \times 10^4\ \text{Pa}}{(9.81\ \text{m/s}^2)(-950\ \text{m})}$ $\rho = \boxed{1.3\ \text{kg/m}^3}$
3. $P = 13.6P_0$ $P_0 = 1.01 \times 10^5\ \text{Pa}$ $\rho = 1.025 \times 10^3\ \text{kg/m}^3$ $g = 9.81\ \text{m/s}^2$	$P = P_0 + \rho g h$ $h = \frac{13.6P_0 - P_0}{\rho g} = \frac{12.6P_0}{\rho g}$ $h = \frac{(12.6)(1.01 \times 10^5\ \text{Pa})}{(1.025 \times 10^3\ \text{kg/m}^3)(9.81\ \text{m/s}^2)} = \boxed{127\ \text{m}}$
4. $P = 4.90 \times 10^6\ \text{Pa}$ $P_0 = 1.01 \times 10^5\ \text{Pa}$ $\rho = 1.025 \times 10^3\ \text{kg/m}^3$ $g = 9.81\ \text{m/s}^2$	$P = P_0 + \rho g h$ $h = \frac{P - P_0}{\rho g} = \frac{4.90 \times 10^6\ \text{Pa} - 1.01 \times 10^5\ \text{Pa}}{(1.025 \times 10^3\ \text{kg/m}^3)(9.81\ \text{m/s}^2)}$ $h = \frac{4.80 \times 10^6\ \text{Pa}}{(1.025 \times 10^3\ \text{kg/m}^3)(9.81\ \text{m/s}^2)} = \boxed{477\ \text{m}}$
5. $h = 245\ \text{m}$ $P_o = 1.01 \times 10^5\ \text{Pa}$ $\rho = 1.025 \times 10^3\ \text{kg/m}^3$ $g = 9.81\ \text{m/s}^2$	$P = P_o + \rho g h$ $P = 1.01 \times 10^5\ \text{Pa} + (1.025 \times 10^3\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(245\ \text{m})$ $P = 1.01 \times 10^5\ \text{Pa} + 2.46 \times 10^6\ \text{Pa}$ $P = \boxed{2.56 \times 10^6\ \text{Pa}}$
6. $h = 10\,916\ \text{m}$ $P_0 = 1.01 \times 10^5\ \text{Pa}$ $\rho = 1.025 \times 10^3\ \text{kg/m}^3$ $g = 9.81\ \text{m/s}^2$	$P = P_0 + \rho g h = 1.01 \times 10^5\ \text{Pa} + (1.025 \times 10^3\ \text{kg/m}^3)(9.81\ \text{m/s}^2)(10\,916\ \text{m})$ $P = 1.01 \times 10^5\ \text{Pa} + 1.10 \times 10^8\ \text{Pa} = \boxed{1.10 \times 10^8\ \text{Pa}}$

II

Heat

Additional Practice A

Givens / *Solutions*

1. $T_C = 14°C$

$T = T_C + 273.15$

$T = (14 + 273.15)$ K

$T = \boxed{287 \text{ K}}$

$T_F = \frac{9}{5}T_C + 32.0$

$T_F = \left[\frac{9}{5}(14) + 32.0\right]°F = (25 + 32.0)°F$

$T_F = \boxed{57°F}$

2. $T_F = (4.00 \times 10^2)°F$

$T_C = \frac{5}{9}(T_F - 32.0)$

$T_C = \frac{5}{9}[(4.00 \times 10^2) - 32.0]°C = \frac{5}{9}(368)°C$

$T_C = \boxed{204°C}$

$T = T_C + 273.15$

$T = (204 + 273.15)$ K

$T = \boxed{477 \text{ K}}$

3. $T_{C,1} = 117°C$

$T_{C,2} = -163°C$

$\Delta T_C = T_{C,1} - T_{C,2} = 117°C - (-163°C)$

$\Delta T_C = (2.80 \times 10^2)°C$

$\Delta T_F = \frac{9}{5}\Delta T_C$

$\Delta T_F = \frac{9}{5}(2.80 \times 10^2)°F$

$\Delta T_F = \boxed{504°F}$

4. $T_F = 860.0°F$

$T_C = \frac{5}{9}(T_F - 32.0)$

$T_C = \frac{5}{9}(860.0 - 32.0)°C = \frac{5}{9}(828.0)°C$

$T_C = \boxed{460.0°C}$

Givens | *Solutions*

5. $\Delta T_F = 49.0°F$

$T_{C,2} = 7.00°C$

$T_F = \frac{9}{5}T_C + 32.0$

$T_{F,2} = \left[\frac{9}{5}(7.00) + 32.0\right]°F = (12.6 + 32.0)°F$

$T_{F,2} = \boxed{44.6°F}$

$T_{F,1} = T_{F,2} - \Delta T_F = 44.6°F - 49.0°F$

$T_{F,1} = \boxed{-4.4°F}$

$T_{C,1} = \frac{5}{9}(T_{F,1} - 32.0)$

$T_{C,1} = \frac{5}{9}(-4.4 - 32.0)°C = \frac{5}{9}(-36.4)°C$

$T_{C,1} = \boxed{-20.2°C}$

6. $\Delta T_C = 56°C$

$T_{C,2} = -49°C$

$T_{C,1} = T_{C,2} + \Delta T_C$

$T_{C,1} = -49°C + 56°C$

$T_{C,1} = 7°C$

$T_1 = T_{C,1} + 273.15$

$T_1 = (7 + 273.15)$ K

$T_1 = \boxed{2.80 \times 10^2 \text{ K}}$

$T_2 = T_{C,2} + 273.15$

$T_2 = (-49 + 273.15)$ K

$T_2 = \boxed{2.24 \times 10^2 \text{ K}}$

7. $T_F = 116$ °F

$T = T_C + 273.15 = \frac{5}{9}(T_F - 32.0) + 273.15$

$T = \left[\frac{5}{9}(116 - 32.0) + 273.15\right] \text{K} = \left[\frac{5}{9}(84) + 273.15\right] \text{K} = (47 + 273.15) \text{ K}$

$T = \boxed{3.20 \times 10^2 \text{ K}}$

Additional Practice B

1. $m_H = 3.05 \times 10^5$ kg

$v_i = 120.0$ km/h

$v_f = 90.0$ km/h

$\Delta T = 10.0°C$

$k = \frac{\Delta U}{m_w \Delta T} = \frac{4186 \text{ J}}{(1.00 \text{ kg})(1.00°C)}$

$\Delta PE + \Delta KE + \Delta U = 0 \qquad \Delta PE = 0$

$\Delta KE = \frac{1}{2}m_H v_f^2 - \frac{1}{2}m_H v_i^2 = \frac{m_H}{2}(v_f^2 - v_i^2)$

$\Delta U = -\Delta KE = \frac{m_H}{2}(v_i^2 - v_f^2)$

$$m_w = \left(\frac{m_w \Delta T}{\Delta U}\right)\left(\frac{\Delta U}{\Delta T}\right) = \left(\frac{1}{k}\right)\left(\frac{\Delta U}{\Delta T}\right) = \frac{m_H}{2k\Delta T}(v_i^2 - v_f^2)$$

$$m_w = \frac{3.05 \times 10^5 \text{ kg}}{\left(\frac{(2)(4186 \text{ J})(10.0°C)}{(1.00 \text{ kg})(1.00°C)}\right)}\left[\left(\frac{120.0 \text{ km}}{\text{h}}\right)^2 - \left(\frac{90.0 \text{ km}}{\text{h}}\right)^2\right]\left[\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)\right]^2$$

$m_w = (3.64 \text{ kg•s}^2/\text{m}^2)(1110 \text{ m}^2/\text{s}^2 - 625 \text{ m}^2/\text{s}^2)$

$m_w = (3.64 \text{ kg•s}^2/\text{m}^2)(480 \text{ m}^2/\text{s}^2)$

$m_w = \boxed{1.7 \times 10^3 \text{ kg}}$

II

Givens	*Solutions*
2. $h = 228$ m	$\Delta PE = -mgh$

2. Givens: $h = 228$ m; $T_i = 0.0°C$; $g = 9.81$ m/s^2; fraction of ME_f converted to $U = 0.500$; $k = (\Delta U/m) =$ energy needed to melt ice $= 3.33 \times 10^5$ J/1.00 kg

$\Delta PE = -mgh$

When the ice lands, its kinetic energy is tranferred to the internal energy of the ground and the ice. Therefore, $\Delta KE = 0$ J.

$\Delta U = (0.500)(ME_f) = -(0.500)(\Delta PE) = (0.500)(mgh)$

$$\frac{\Delta U}{m} = (0.500)(gh)$$

$$f = \frac{\Delta U}{km} = \frac{(0.500)(gh)}{k}$$

$$f = \frac{(0.500)(9.81 \text{ m/s}^2)(228 \text{ m})}{(3.33 \times 10^5 \text{ J/1.00 kg})}$$

$$f = \boxed{3.36 \times 10^{-3}}$$

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3. Givens: $v_i = 2.333 \times 10^3$ km/h; $h = 4.000 \times 10^3$ m; $g = 9.81$ m/s^2; fraction of ME converted to $U = 0.0100$; $k = \dfrac{\Delta U}{m\Delta T} = \dfrac{(355 \text{ J})}{(1.00 \text{ kg})(1.00°\text{C})}$

$(0.0100)(\Delta PE + \Delta KE) + \Delta U = 0$

$\Delta PE = PE_f - PE_i = 0 - mgh = -mgh$

$\Delta KE = KE_f - KE_i = 0 - \frac{1}{2}mv_i^2 = -\frac{1}{2}mv_i^2$

$$\Delta U = -(0.0100)(\Delta PE + \Delta KE) = -(0.0100)(m)\left(-gh - \tfrac{1}{2}v^2\right) = (0.0100)(m)\left(gh + \tfrac{1}{2}v^2\right)$$

$$\Delta T = \frac{\left(\dfrac{\Delta U}{m}\right)}{k} = \frac{(0.0100)\left(gh + \frac{1}{2}v^2\right)}{\dfrac{355 \text{ J}}{(1.00 \text{ kg})(1.00°\text{C})}}$$

$$\Delta T = \frac{(0.0100)\left[(9.81 \text{ m/s}^2)(4.000 \times 10^3 \text{ m}) + \left(\frac{1}{2}\right)\left(\dfrac{2.333 \times 10^6 \text{ m/h}}{3600 \text{ s/h}}\right)^2\right]}{355 \text{ m}^2/\text{s}^2 \bullet °\text{C}}$$

$$\Delta T = \frac{(0.0100)[(3.92 \times 10^4 \text{ m}^2/\text{s}^2) + (2.100 \times 10^5 \text{ m}^2/\text{s}^2)]}{355 \text{ m}^2/\text{s}^2 \bullet °\text{C}}$$

$$\Delta T = \boxed{7.02°\text{C}}$$

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4. Givens: $h = 8848$ m; $g = 9.81$ m/s^2; fraction of ME_f converted to $U = 0.200$; $T_i = -18.0°C$; $\dfrac{\Delta T}{\Delta U/m} = \dfrac{1.00°\text{C}}{448 \text{ J/kg}}$

$\Delta PE = -mgh$

$ME_f = -\Delta PE$

When the hook lands, its kinetic energy is transferred to the internal energy of the hook and the ground. Therefore, $\Delta KE = 0$ J.

$\Delta U = (0.200)(ME_f) = (-0.200)(\Delta PE) = (0.200)(mgh)$

$\Delta U/m = (0.200)(gh)$

$$\Delta T = \left(\frac{\Delta T}{\Delta U/m}\right)\left(\frac{\Delta U}{m}\right) = \left(\frac{1.00°\text{C}}{448 \text{ J/kg}}\right)[(0.200)(gh)]$$

$$\Delta T = \left(\frac{1.00°\text{C}}{448 \text{ J/kg}}\right)(0.200)(9.81 \text{ m/s}^2)(8848 \text{ m}) = 38.7°\text{C}$$

$T_f = T_i + \Delta T = -18.0°C + 38.7°C$

$$T_f = \boxed{20.7°\text{C}}$$

II

Givens	Solutions
5. $h_i = 629$ m $g = 9.81$ m/s^2 $v_f = 42$ m/s fraction of ME converted to $U = 0.050$ $m = 3.00$ g	Because $h_f = 0$ m, $PE_f = 0$ J. Further, $v_i = 0$ m/s, so $KE_i = 0$ J. $\Delta U = -(0.050)(\Delta ME) = -(0.050)(\Delta PE + \Delta KE)$ $\Delta PE = PE_f - PE_i = 0\text{ J} - PE_i = -mgh$ $\Delta KE = KE_f - KE_i = KE_f - 0\text{ J} = \frac{1}{2}mv_f^2$ $\Delta U = (0.050)(-\Delta PE - \Delta KE) = (0.050)(mgh - \frac{1}{2}mv_f^2) = (0.050)(m)(gh - \frac{1}{2}v_f^2)$ $\Delta U = (0.050)(3.00 \times 10^{-3}\text{ kg})[(9.81\text{ m/s}^2)(629\text{ m}) - (0.5)(42\text{ m/s})^2]$ $\Delta U = (0.050)(3.00 \times 10^{-3}\text{ kg})(6170\text{ m}^2/\text{s}^2 - 880\text{ m}^2/\text{s}^2)$ $\Delta U = (0.050)(3.00 \times 10^{-3}\text{ kg})(5290\text{ m}^2/\text{s}^2)$ $\Delta U = \boxed{0.79\text{ J}}$
6. $h = 2.49$ m $g = 9.81$ m/s^2 $m = 312$ kg $v = 0.50$ m/s fraction of ME converted to $U = 0.500$	$(0.500)(\Delta PE + \Delta KE) + \Delta U = 0$ $\Delta PE = PE_f - PE_i = 0 - mgh = -mgh$ $\Delta KE = KE_f - KE_i = 0 - \frac{1}{2}mv^2 = \frac{-mv^2}{2}$ $\Delta U = -(0.500)(\Delta PE + \Delta KE) = -(0.500)\left(-mgh - \frac{mv^2}{2}\right) = (0.500)\left(mgh + \frac{mv^2}{2}\right)$ $\Delta U = (0.500)[(312\text{ kg})(9.81\text{ m/s}^2)(2.49\text{ m}) + (0.5)(312\text{ kg})(0.50\text{ m/s})^2]$ $\Delta U = (0.500)[(7.62 \times 10^3\text{ J}) + 39\text{ J}]$ $\Delta U = \boxed{3.83 \times 10^3\text{ J}}$
7. $\Delta T = 0.230$°C $g = 9.81$ m/s^2 fraction of ME_f converted to $U = 0.100$ $\frac{\Delta U/m}{\Delta T} = \frac{4186\text{ J/kg}}{1.00°\text{C}}$	$\frac{\Delta U}{m} = \Delta T\left(\frac{\Delta U/m}{\Delta T}\right) = \frac{(0.100)(ME_f)}{m} = \frac{(0.100)(\Delta PE)}{m} = (0.100)(gh)$ Because the kinetic energy at the bottom of the falls is converted to the internal energy of the water and the ground, $\Delta KE = 0$ J. $h = \frac{\Delta T\left(\frac{\Delta U/m}{\Delta T}\right)}{(0.100)(g)}$ $h = \left(\frac{0.230°\text{C}}{(0.100)(9.81\text{ m/s}^2)}\right)\left(\frac{4186\text{ J/kg}}{1.00°\text{C}}\right)$ $h = \boxed{981\text{ m}}$

II

Additional Practice C

Givens	Solutions
1. $Q = (2.8 \times 10^9\ \text{W})(1.2\ \text{s})$ $c_{p,c} = 387\ \text{J/kg•°C}$ $T_c = 26.0°\text{C}$ $T_f = 21.0°\text{C}$	$Q = -m_c c_{p,c}(T_f - T_c) = m_c c_{p,c}(T_c - T_f)$ $m_c = \dfrac{Q}{c_{p,c}(T_c - T_f)}$ $m_c = \dfrac{(2.8 \times 10^9\ \text{W})(1.2\ \text{s})}{(387\ \text{J/kg•°C})(26.0°\text{C} - 21.0°\text{C})}$ $m_c = \dfrac{(2.8 \times 10^9\ \text{W})(1.2\ \text{s})}{(387\ \text{J/kg•°C})(5.0°\text{C})} = \boxed{1.7 \times 10^6\ \text{kg}}$
2. $m_w = 143 \times 10^3\ \text{kg}$ $T_w = 20.0°\text{C}$ T_x = temperature of burning wood = 280.0°C $T_f = 100.0°\text{C}$ $c_{p,x}$ = specific heat capacity of wood = $1.700 \times 10^3\ \text{J/kg•°C}$ $c_{p,w} = 4186\ \text{J/kg•°C}$	$-c_{p,x} m_x (T_f - T_x) = c_{p,w} m_w (T_f - T_w)$ $m_x = \dfrac{c_{p,w} m_w (T_f - T_w)}{c_{p,x}(T_x - T_f)}$ $m_x = \dfrac{(4186\ \text{J/kg•°C})(143 \times 10^3\ \text{kg})(100.0°\text{C} - 20.0°\text{C})}{(1.700 \times 10^3\ \text{J/kg•°C})(280.0°\text{C} - 100.0°\text{C})}$ $m_x = \dfrac{(4186\ \text{J/kg•°C})(143 \times 10^3\ \text{kg})(80.0°\text{C})}{(1.700 \times 10^3\ \text{J/kg•°C})(180.0°\text{C})}$ $m_x = \boxed{1.56 \times 10^5\ \text{kg}}$
3. $\Delta U = Q = (0.0100)(1.450\ \text{GW})(1.00\ \text{year})$ $c_{p,x}$ = specific heat capacity of iron = 448 J/kg•°C m_x = mass of steel = $25.1 \times 10^9\ \text{kg}$	$Q = c_{p,x} m_x \Delta T$ $\Delta T = \dfrac{Q}{c_{p,x} m_x}$ $\Delta T = \dfrac{(0.0100)(1.450 \times 10^9\ \text{W})(1.00\ \text{year})}{(448\ \text{J/kg•°C})(25.1 \times 10^9\ \text{kg})}\left(\dfrac{365.25\ \text{days}}{1\ \text{year}}\right)\left(\dfrac{24\ \text{h}}{1\ \text{day}}\right)\left(\dfrac{3600\ \text{s}}{1\ \text{h}}\right)$ $\Delta T = \boxed{40.7°\text{C}}$
4. $m_l = 2.25 \times 10^3\ \text{kg}$ $T_{l,i} = 28.0°\text{C}$ $c_{p,l} = c_{p,w} = 4186\ \text{J/kg•°C}$ $m_i = 9.00 \times 10^2\ \text{kg}$ $T_{i,i} = -18.0°\text{C}$ $c_{p,i} = 2090\ \text{J/kg•°C}$ $T_{i,f} = 0.0°\text{C}$	$-m_l c_{p,l}(T_{l,f} - T_{l,i}) = m_i c_{p,i}(T_{i,f} - T_{i,i})$ $T_{l,f} = T_{l,i} - \left(\dfrac{m_i}{m_l}\right)\left(\dfrac{c_{p,i}}{c_{p,l}}\right)(T_{i,f} - T_{i,i})$ $T_{l,f} = (28.0°\text{C}) - \left(\dfrac{9.00 \times 10^2\ \text{kg}}{2.25 \times 10^3\ \text{kg}}\right)\left(\dfrac{2090\ \text{J/kg•°C}}{4186\ \text{J/kg•°C}}\right)[(0.0°\text{C}) - (-18.0°\text{C})]$ $T_{l,f} = 28.0°\text{C} - 3.59°\text{C} = \boxed{24.4°\text{C}}$
5. $m_w = 1.33 \times 10^{19}\ \text{kg}$ $T_w = 4.000°\text{C}$ $c_{p,w} = 4186\ \text{J/kg•°C}$ $P = 1.33 \times 10^{10}\ \text{W}$ $\Delta t = 1.000 \times 10^3\ \text{years}$	$P\Delta t = Q = m_w c_{p,w}(T_f - T_w)$ $T_f = \left(\dfrac{P\Delta t}{m_w c_{p,w}}\right) + T_w$ $T_f = \dfrac{(1.33 \times 10^{10}\ \text{W})(1.000 \times 10^3\ \text{years})\left(\dfrac{365.25\ \text{day}}{1\ \text{year}}\right)\left(\dfrac{24\ \text{h}}{1\ \text{day}}\right)\left(\dfrac{3600\ \text{s}}{1\ \text{h}}\right)}{(1.33 \times 10^{19}\ \text{kg})(4186\ \text{J/kg•°C})} + 4.000°\text{C}$ $T_f = (7.54 \times 10^{-3})°\text{C} + 4.000°\text{C}$ $T_f = \boxed{4.008°\text{C}}$

II

Givens	*Solutions*

6. $T_i = 18.0°C$

$T_f = 32.0°C$

$Q = 20.8$ kJ

$m_x = 0.355$ kg

$$Q = m_x c_{p,x} \Delta T$$

$$c_{p,x} = \frac{Q}{m_x \Delta T} = \frac{Q}{m_x(T_f - T_i)}$$

$$c_{p,x} = \frac{20.8 \times 10^3 \text{ J}}{(0.355 \text{ kg})(32.0°\text{C} - 18.0°\text{C})}$$

$$c_{p,x} = \boxed{4190 \text{ J/kg}\bullet°\text{C}}$$

---

7. $T_m = -62.0°C$

$T_w = 38.0°C$

$m_m = 180$ g

$m_w = 0.500$ kg

$T_f = 36.9°C$

$c_{p,w} = 4186$ J/kg•°C

$$m_m c_{p,m}(T_f - T_m) = -m_w c_{p,w}(T_f - T_w)$$

$$c_{p,m} = \left(\frac{m_w}{m_m}\right)(c_{p,w})\left(\frac{T_w - T_f}{T_f - T_m}\right)$$

$$c_{p,m} = \left(\frac{0.500 \text{ kg}}{0.18 \text{ kg}}\right)(4186 \text{ J/kg}\bullet°\text{C})\left(\frac{(38.0°\text{C}) - (36.9°\text{C})}{(36.9°\text{C}) - (-62.0°\text{C})}\right)$$

$$c_{p,m} = \boxed{1.3 \times 10^2 \text{ J/kg}\bullet°\text{C}}$$

The metal could be gold ($c_p = 129$ J/kg•°C) or lead ($c_p = 128$ J/kg•°C).

II

Additional Practice D

1. $m_{w,S} = 1.20 \times 10^{16}$ kg

$m_{w,E} = 4.8 \times 10^{14}$ kg

$T_E = 0.0°C$

$T_S = 100.0°C$

$c_{p,w} = 4186$ J/kg•°C

L_f of ice $= 3.33 \times 10^5$ J/kg

Q_S = energy transferred by heat from Lake Superior $= c_{p,w} m_{w,S}(T_S - T_f)$

Q_E = energy transferred by heat to Lake Erie $= m_{w,E} L_f + m_{w,E} c_{p,w}(T_f - T_E)$

From the conservation of energy,

$$Q_S = Q_E$$

$$c_{p,w} m_{w,S}(T_S - T_f) = m_{w,E} L_f + m_{w,E} c_{p,w}(T_f - T_E)$$

$$(m_{w,E} c_{p,w} + c_{p,w} m_{w,S}) T_f = c_{p,w} m_{w,S} T_S + m_{w,E} c_{p,w} T_E - m_{w,E} L_f$$

$$T_f = \frac{c_{p,w}(m_{w,S} T_S + m_{w,E} T_E) - m_{w,E} L_f}{c_{p,w}(m_{w,E} + m_{w,S})}, \text{ where } T_E = 0.0°\text{C}$$

$$T_f = \frac{c_{p,w} m_{w,S} T_S - m_{w,E} L_f}{c_{p,w}(m_{w,E} + m_{w,S})}$$

$$T_f = \frac{(4186 \text{ J/kg}\bullet°\text{C})(1.20 \times 10^{16} \text{ kg})(100.0°\text{C}) - (4.8 \times 10^{14} \text{ kg})(3.33 \times 10^5 \text{ J/kg})}{(4186 \text{ J/kg}\bullet°\text{C})[(4.8 \times 10^{14} \text{ kg}) + (1.20 \times 10^{16} \text{ kg})]}$$

$$T_f = \frac{(5.02 \times 10^{21} \text{ J}) - (1.6 \times 10^{20} \text{ J})}{(4186 \text{ J/kg}\bullet°\text{C})(1.25 \times 10^{16} \text{ kg})}$$

$$T_f = \boxed{92.9°\text{C}}$$

---

2. $T_f = -235°C$

$T_{freezing} = 0.0°$

$m_w = 0.500$ kg

$c_{p,w} = 4186$ J/kg•°C

$c_{p,ice} = c_{p,i} = 2090$ J/kg•°C

L_f of ice $= 3.33 \times 10^5$ J/kg

$Q_{tot} = 471$ kJ

$$Q_{tot} = c_{p,w} m_w (T_i - 0.0°) + L_f m_w + m_w c_{p,i}(0.0° - T_f) = c_{p,w} m_w T_i + L_f m_w - c_{p,i} m_w T_f$$

$$T_i = \frac{Q_{tot} - L_f m_w + c_{p,i} m_w T_f}{c_{p,w} m_w}$$

$$T_i = \frac{(4.71 \times 10^5 \text{ J}) - (3.33 \times 10^5 \text{ J/kg})(0.500 \text{ kg}) + (-235°\text{C})(2090 \text{ J/kg}\bullet°\text{C})(0.500 \text{ kg})}{(4186 \text{ J/kg}\bullet°\text{C})(0.500 \text{ kg})}$$

$$T_i = \frac{(4.71 \times 10^5 \text{ J}) - (1.66 \times 10^5 \text{ J}) - (2.46 \times 10^5 \text{ J})}{2093 \text{ J/°C}}$$

$$T_i = \boxed{28°\text{C}}$$

Givens	*Solutions*
3. $T_i = 0.0°C$ $m_i = 4.90 \times 10^6$ kg L_f of ice $= 3.33 \times 10^5$ J/kg $T_s = 100.0°C$ L_v of steam $= 2.26 \times 10^6$ J/kg	$m_s L_v = m_i L_f$ $m_s = \frac{m_i L_f}{L_v}$ $m_s = \frac{(4.90 \times 10^6 \text{ kg})(3.33 \times 10^5 \text{ J/kg})}{2.26 \times 10^6 \text{ J/kg}}$ $m_s = \boxed{7.22 \times 10^5 \text{ kg}}$
4. $m_s = 1.804 \times 10^6$ kg L_f of silver $= L_{f,s} =$ 8.82×10^4 J/kg L_f of ice $= L_{f,i} =$ 3.33×10^5 J/kg	$m_s L_{f,s} = m_i L_{f,i}$ $m_i = \frac{m_s L_{f,s}}{L_{f,i}}$ $m_i = \frac{(1.804 \times 10^6 \text{ kg})(8.82 \times 10^4 \text{ J/kg})}{3.33 \times 10^5 \text{ J/kg}}$ $m_i = \boxed{4.78 \times 10^5 \text{ kg}}$
5. $m_g = 12.4414$ kg $T_{g,i} = 5.0°C$ $Q = 2.50$ MJ $c_{p,g} = 129$ J/kg•°C $T_{g,f} = 1063°C$	$Q = m_g c_{p,g}(T_{g,f} - T_{g,i}) + m_g L_f$ $L_f = \frac{Q - m_g c_{p,g}(T_{g,f} - T_{g,i})}{m_g}$ $L_f = \frac{(2.50 \times 10^6 \text{ J}) - (12.4414 \text{ kg})(129 \text{ J/kg•°C})(1063°C - 5.0°C)}{12.4414 \text{ kg}}$ $L_f = \frac{(2.50 \times 10^6 \text{ J}) - (1.70 \times 10^6 \text{ J})}{12.4414 \text{ kg}}$ $L_f = \boxed{6.4 \times 10^4 \text{ J/kg}}$
6. $V_p = 7.20 \text{ m}^3$ $V_c = (0.800)(V_p)$ $\rho_c = 8.92 \times 10^3 \text{ kg/m}^3$ $L_f = 1.34 \times 10^5$ J/kg	**a.** $m_c = \rho_c V_c$ $m_c = (8.92 \times 10^3 \text{ kg/m}^3)(0.800)(7.20 \text{ m}^3)$ $m_c = \boxed{5.14 \times 10^4 \text{ kg}}$ **b.** fraction of melted coins $= \frac{Q}{m_c L_f} = \frac{15}{100}$ $Q = \frac{15}{100} m_c L_f = \frac{15(5.14 \times 10^4 \text{ kg})(1.34 \times 10^5 \text{ J/kg})}{100}$ $Q = \boxed{1.03 \times 10^9 \text{ J}}$

II

Givens

7. $m_w = 3.5 \times 10^{19}$ kg

$T_i = 10.0°C$

$T_f = 100.0°C$

$c_{p,w} = 4186$ J/kg•°C

L_v of water $= 2.26 \times 10^6$ J/kg

$P = 4.0 \times 10^{26}$ J/s

Solutions

a. $Q = m_w c_{p,w}(T_f - T_i) + m_w L_v$

$$Q = (3.5 \times 10^{19}\ \text{kg})(4186\ \text{J/kg•°C})(100.0°\text{C} - 10.0°\text{C}) + (3.5 \times 10^{19}\ \text{kg})(2.26 \times 10^6\ \text{J/kg})$$

$$Q = 1.3 \times 10^{25} + 7.9 \times 10^{25}\ \text{J} = \boxed{9.2 \times 10^{25}\ \text{J}}$$

b. $Q = P\Delta t$

$$\Delta t = \frac{Q}{P} = \frac{9.2 \times 10^{25}\ \text{J}}{4.0 \times 10^{26}\ \text{J/s}} = \boxed{0.23\ \text{s}}$$

II

Thermodynamics

Additional Practice A

Givens / *Solutions*

1. $P = 5.1$ kPa

$W = 3.6 \times 10^3$ J

$V_i = 0.0$ m^3

$W = P\Delta V$

$$\Delta V = \frac{W}{P} = \frac{3.6 \times 10^3 \text{ J}}{5.1 \times 10^3 \text{ Pa}} = 7.1 \times 10^{-1} \text{ m}^3$$

$$V = V_i + \Delta V = 0.0 \text{ m}^3 + 7.1 \times 10^{-1} \text{ m}^3 = \boxed{7.1 \times 10^{-1} \text{ m}^3}$$

2. $m = 207$ kg

$g = 9.81$ m/s^2

$h = 3.65$ m

$P = 1.8 \times 10^6$ Pa

$W = mgh = -P\Delta V$

$$\Delta V = \frac{mgh}{-P}$$

$$\Delta V = \frac{(207 \text{ kg})(9.81 \text{ m/s}^2)(3.65 \text{ m})}{-(1.8 \times 10^6 \text{ Pa})} = \boxed{-4.1 \times 10^{-3} \text{ m}^3}$$

3. $r_f = 1.22$ m

$r_i = 0.0$ m

$W = 642$ kJ

$W = P\Delta V$

$$P = \frac{W}{\Delta V}$$

$$\Delta V = \tfrac{4}{3}\pi(r_f^{\,3} - r_i^{\,3})$$

$$P = \frac{W}{\frac{4}{3}\pi(r_f^{\,3} - r_i^{\,3})} = \frac{642 \times 10^3 \text{ J}}{\frac{4}{3}\pi\left[(1.22 \text{ m})^3 - (0.0 \text{ m})^3\right]} = \boxed{8.44 \times 10^4 \text{ Pa}}$$

4. $r_f = 7.0 \times 10^5$ km

$= 7.0 \times 10^8$ m

$r_i = 0.0$ m

$W = 3.6 \times 10^{34}$ J

$W = P\Delta V$

$$V = \tfrac{4}{3}\pi r^3$$

$$\Delta V = V_f - V_i = \tfrac{4}{3}\pi(r_f^{\,3} - r_i^{\,3})$$

$$W = (P)(\tfrac{4}{3}\pi)(r_f^{\,3} - r_i^{\,3})$$

$$P = \frac{W}{(\frac{4}{3}\pi)(r_f^{\,3} - r_i^{\,3})}$$

$$P = \frac{(3.6 \times 10^{34} \text{ J})}{(\frac{4}{3}\pi)[(7.0 \times 10^8 \text{ m})^3 - (0.0 \text{ m})^3]} = \boxed{2.5 \times 10^7 \text{ Pa}}$$

5. $P = 87$ kPa

$\Delta V = -25.0 \times 10^{-3}$ m^3

$W = P\Delta V$

$$W = (87 \times 10^3 \text{ Pa})(-25.0 \times 10^{-3} \text{ m}^3) = \boxed{-2.2 \times 10^3 \text{ J}}$$

Givens | *Solutions*

6. $r_f = 29.2$ cm

$r_i = 0.0$ m

$P = 25.0$ kPa

$m = 160.0$ g

$W = P\Delta V$

$\Delta V = \frac{4}{3}\pi(r_f^{\,3} - r_i^{\,3})$

$W = \frac{1}{2}mv^2$

$\frac{1}{2}mv^2 = (P)\left(\frac{4}{3}\pi\right)(r_f^{\,3} - r_i^{\,3})$

$v = \sqrt{\frac{8\pi P}{3m}(r_f^{\,3} - r_i^{\,3})}$

$v = \sqrt{\frac{(8\pi)(25.0 \times 10^3 \text{ Pa})}{(3)(160.0 \times 10^{-3} \text{ kg})}\left[(29.2 \times 10^{-2} \text{ m})^3 - (0.0 \text{ m})^3\right]}$

$v = \boxed{181 \text{ m/s}}$

Additional Practice B

1. $m = 227$ kg

$h = 8.45$ m

$g = 9.81$ m/s^2

$U_i = 42.0$ kJ

$Q = 4.00$ kJ

$\Delta U = U_f - U_i = Q - W$

$W = mgh$

$U_f = U_i + Q - W = U_i + Q - mgh$

$U_f = (42.0 \times 10^3 \text{ J}) + (4.00 \times 10^3 \text{ J}) - (227 \text{ kg})(9.81 \text{ m/s}^2)(8.45 \text{ m})$

$U_f = (42.0 \times 10^3 \text{ J}) + (4.00 \times 10^3 \text{ J}) - (18.8 \times 10^3 \text{ J})$

$U_f = \boxed{27.2 \times 10^3 \text{ J} = 27.2 \text{ kJ}}$

II

2. $m = 4.80 \times 10^2$ kg

$Q = 0$ J

$v = 2.00 \times 10^2$ m/s

a. Assume that all work is transformed to the kinetic energy of the cannonball.

$W = \frac{1}{2}mv^2$

$W = \frac{1}{2}(4.80 \times 10^2 \text{ kg})(2.00 \times 10^2 \text{ m/s})^2$

$W = \boxed{9.60 \times 10^6 \text{ J} = 9.60 \text{ MJ}}$

$U_f = 12.0$ MJ

b. $\Delta U = Q - W = -W$

$U_f - U_i = -W$

$U_i = U_f + W$

$U_i = (12.0 \times 10^6 \text{ J}) + (9.60 \times 10^6 \text{ J})$

$U_i = \boxed{21.6 \times 10^6 \text{ J} = 21.6 \text{ MJ}}$

3. $m = 4.00 \times 10^4$ kg

$c_p = 4186$ J/kg•°C

$\Delta T = -20.0$°C

a. $Q = mc_p\Delta T$

$Q = (4.00 \times 10^4 \text{ kg})(4186 \text{ J/kg•°C})(-20.0\text{°C})$

$Q = \boxed{-3.35 \times 10^9 \text{ J}}$

$W = 1.64 \times 10^9$ J

b. Q of gas $= -Q$ of jelly $= -(-3.35 \times 10^9 \text{ J}) = 3.35 \times 10^9$ J

$\Delta U = Q - W$

$\Delta U = (3.35 \times 10^9 \text{ J}) - (1.64 \times 10^9 \text{ J})$

$\Delta U = \boxed{1.71 \times 10^9 \text{ J}}$

Givens	*Solutions*

4. $m = 1.64 \times 10^{15}$ kg
$h = 75.0$ m
$g = 9.81$ m/s^2
$T_i = 6.0°C$
$T_f = 100.0°C$
$c_{p,w} = 4186$ J/kg•°C
L_v of water $= 2.26 \times 10^6$ J/kg
$\Delta U = (-0.900)(U_i)$

$W = mgh = (1.64 \times 10^{15}\ \text{kg})(9.81\ \text{m/s}^2)(75.0\ \text{m})$

$W = 1.21 \times 10^{18}$ J

$Q = -mc_{p,w}(T_f - T_i) - mL_v = -m[c_{p,w}(T_f - T_i) + L_v]$

$T_f - T_i = 100.0°C - 6.0°C = 94.0°C$

$Q = -(1.64 \times 10^{15}\ \text{kg})[(4186\ \text{J/kg•°C})(94.0°C) + (2.26 \times 10^6\ \text{J/kg})]$

$Q = -4.35 \times 10^{21}$ J

$\Delta U = U_f - U_i = (-0.900)(U_i) = Q - W$

$U_f = (1 - 0.900)U_i = (0.100)(U_i)$

$$-\Delta U = U_i - U_f = \frac{U_f}{0.100} - U_f = (0.900)\left(\frac{U_f}{0.100}\right) = W - Q$$

$$U_f = \left(\frac{0.100}{0.900}\right)(W - Q)$$

$$U_f = \left(\frac{0.100}{0.900}\right)[(1.21 \times 10^{18}\ \text{J}) - (-4.35 \times 10^{21}\ \text{J})]$$

$$U_f = \boxed{4.83 \times 10^{20}\ \text{J}}$$

(Note: Nearly all of the energy is used to increase the temperature of the water and to vaporize the water.)

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5. $m = 5.00 \times 10^3$ kg
$v = 40.0$ km/h
$U_i = 2.50 \times 10^5$ J
$U_f = 2U_i$

$W = \frac{1}{2}mv^2$

$\Delta U = U_f - U_i = Q - W$

$U_f = 2U_i$

$\Delta U = 2U_i - U_i = U_i$

$Q = \Delta U + W = U_i + \frac{1}{2}mv^2$

$$Q = (2.50 \times 10^5\ \text{J}) + \tfrac{1}{2}(5.00 \times 10^3\ \text{kg})\left[\left(\frac{40.0\ \text{km}}{\text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\text{m}}{1\ \text{km}}\right)\right]^2$$

$Q = (2.50 \times 10^5\ \text{J}) + (3.09 \times 10^5\ \text{J})$

$$Q = \boxed{5.59 \times 10^5\ \text{J}}$$

---

6. $P = \dfrac{Q}{\Delta t} = 5.9 \times 10^9$ J/s
$\Delta t = 1.0$ s
$\Delta U = 2.6 \times 10^9$ J

$\Delta U = Q - W = P\Delta t - W$

$W = P\Delta t - \Delta U$

$W = (5.9 \times 10^9\ \text{J/s})(1.0\ \text{s}) - (2.6 \times 10^9\ \text{J})$

$$W = \boxed{3.3 \times 10^9\ \text{J}}$$

II

Givens | *Solutions*

7. $h = 1.00 \times 10^2$ m

$v = 141$ km/h

$U_i = 40.0$ MJ

$m = 76.0$ kg

a. $\Delta U = Q - W$

All energy is transferred by heat, so $W = \boxed{0 \text{ J}}$

b. $\Delta U = Q = \frac{1}{2}mv^2$

$$\left(\frac{\Delta U}{U_i} \times 100\right) = \left(\frac{mv^2}{2U_i}\right)(100)$$

$$\left(\frac{\Delta U}{U_i} \times 100\right) = \frac{(76.0 \text{ kg})\left(\frac{141 \text{ km}}{\text{h}}\right)^2\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)^2\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)^2(100)}{(2)(40.0 \times 10^6 \text{ J})}$$

$$\left(\frac{\Delta U}{U_i} \times 100\right) = \boxed{0.146 \text{ percent}}$$

Additional Practice C

1. $eff = 8$ percent $= 0.080$

$Q_h = 2.50$ kJ

$$eff = \frac{Q_h - Q_c}{Q_h} = 1 - \frac{Q_c}{Q_h}$$

$$-Q_c = Q_h(eff - 1)$$

$$Q_c = Q_h(1 - eff)$$

$$Q_c = (2.50 \text{ kJ})(1 - 0.08) = (2.50 \text{ kJ})(0.92)$$

$$Q_c = \boxed{2.3 \text{ kJ}}$$

$$W = Q_h - Q_c$$

$$W = 2.50 \text{ kJ} - 2.3 \text{ kJ}$$

$$W = \boxed{0.2 \text{ kJ}}$$

---

2. $P_{net} = 1.5$ MW

$eff = 16$ percent $= 0.16$

$Q_h = 2.0 \times 10^9$ J

$$eff = \frac{W_{net}}{Q_h} = \frac{P_{net}\Delta t}{Q_h}$$

$$\Delta t = \frac{(eff)(Q_h)}{P_{net}}$$

$$\Delta t = \frac{(0.16)(2.0 \times 10^9 \text{ J})}{1.5 \times 10^6 \text{ W}}$$

$$\Delta t = \boxed{2.1 \times 10^2 \text{ s}}$$

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3. $P_{net} = 19$ kW

$eff = 6.0$ percent $= 0.060$

$\Delta t = 1.00$ h

$$W_{net} = P_{net}\Delta t$$

$$eff = \frac{W_{net}}{Q_h}$$

$$Q_h = \frac{W_{net}}{eff} = \frac{P_{net}\Delta t}{eff}$$

$$Q_h = \frac{(19 \text{ kW})(1.00 \text{ h})\left(\frac{3.6 \times 10^3 \text{ s}}{1 \text{ h}}\right)}{(0.060)}$$

$$Q_h = \boxed{1.1 \times 10^6 \text{ kJ} = 1.1 \times 10^9 \text{ J}}$$

Givens | *Solutions*

4. $P_{net} = 370$ W

$\Delta t = 1.00$ min $= 60.0$ s

$eff = 0.19$

$$eff = \frac{W_{net}}{Q_h} = \frac{P_{net}\Delta t}{Q_h}$$

$$Q_h = \frac{P_{net}\Delta t}{eff}$$

$$Q_h = \frac{(370\text{ W})(60.0\text{ s})}{0.19}$$

$$Q_h = 1.2 \times 10^5\text{ J} = \boxed{120\text{ kJ}}$$

5. $W_{net} = 2.6$ MJ

$Qh/m = 32.6\ \frac{\text{MJ}}{\text{kg}}$

$m = 0.80$ kg

$$eff = \frac{W_{net}}{Q_h} = \frac{W_{net}}{\left(\frac{Q_h}{m}\right)(m)}$$

$$eff = \frac{2.6\text{ MJ}}{\left(32.6\ \frac{\text{MJ}}{\text{kg}}\right)(0.80\text{ kg})}$$

$$eff = \boxed{0.10 = 10\text{ percent}}$$

6. $m = 3.00 \times 10^4$ kg

$g = 9.81$ m/s^2

$h = 1.60 \times 10^2$ m

$Q_c = 3.60 \times 10^8$ J

$$W_{net} = mgh = Q_h - Q_c$$

$$Q_h = W_{net} + Q_c$$

$$eff = \frac{W_{net}}{Q_h} = \frac{W_{net}}{W_{net} + Q_c} = \frac{mgh}{mgh + Q_c}$$

$$eff = \frac{(3.00 \times 10^4\text{ kg})(9.81\text{ m/s}^2)(1.60 \times 10^2\text{ m})}{(3.00 \times 10^4\text{ kg})(9.81\text{ m/s}^2)(1.60 \times 10^2\text{ m}) + 3.60 \times 10^8\text{ J}}$$

$$eff = \boxed{0.12}$$

II

Vibrations and Waves

Additional Practice A

Givens | *Solutions*

1. $m = 0.019$ kg

$g = 9.81$ m/s^2

$k = 83$ N/m

$$k = \frac{F}{x} = \frac{mg}{x}$$

$$x = \frac{(0.019\text{ kg})(9.81\text{ m/s}^2)}{83\text{ N/m}}$$

$$x = \boxed{2.25 \times 10^{-3}\text{ m}}$$

---

2. $m = 187$ kg

$k = 1.53 \times 10^4$ N/m

$g = 9.81$ m/s^2

$$k = \frac{F}{x} = \frac{mg}{x}$$

$$x = \frac{(187\text{ kg})(9.81\text{ m/s}^2)}{1.53 \times 10^4\text{ N/m}} = \boxed{0.120\text{ m}}$$

---

3. $m_1 = 389$ kg

$x_2 = 1.2 \times 10^{-3}$ m

$m_2 = 1.5$ kg

$$\frac{F_1}{x_1} = \frac{F_2}{x_2}$$

$$x_1 = \frac{F_1 x_2}{F_2} = \frac{m_1 g x_2}{m_2 g}$$

$$x_1 = \frac{(389\text{ kg})(1.2 \times 10^{-3}\text{ m})}{(1.5\text{ kg})} = \boxed{0.31\text{ m}}$$

---

4. $m = 18.6$ kg

$x = 3.7$ m

$g = 9.81$ m/s^2

$$k = \frac{F}{x} = \frac{mg}{x} = \frac{(18.6\text{ kg})(9.81\text{ m/s}^2)}{(3.7\text{ m})}$$

$$k = \boxed{49\text{ N/m}}$$

---

5. $h = 533$ m

$x_1 = \frac{1}{3}h$

$m = 70.0$ kg

$x_2 = \frac{2}{3}h$

$g = 9.81$ m/s^2

$$k = \frac{F}{x} = \frac{mg}{(x_2 - x_1)} = \frac{3mg}{h}$$

$$k = \frac{3(70.0\text{ kg})(9.81\text{ m/s}^2)}{(533\text{ m})} = \boxed{3.87\text{ N/m}}$$

---

6. $k = 2.00 \times 10^2$ N/m

$x = 0.158$ m

$g = 9.81$ m/s^2

a. $F = kx = (2.00 \times 10^2\text{ N/m})(0.158\text{ m}) = \boxed{31.6\text{ N}}$

b. $$m = \frac{F}{g} = \frac{kx}{g}$$

$$m = \frac{(2.00 \times 10^2\text{ N/m})(0.158\text{ m})}{(9.81\text{ m/s}^2)}$$

$$m = \boxed{3.22\text{ kg}}$$

Givens | *Solutions*

7. $h = 1.02 \times 10^4$ m

$L = 4.20 \times 10^3$ m

$k = 3.20 \times 10^{-2}$ N/m

$F = kx = k(h - L)$

$F = (3.20 \times 10^{-2}\text{ N/m})(6.0 \times 10^3\text{ m}) = \boxed{190\text{ N}}$

8. $h = 348$ m

$L = 2.00 \times 10^2$ m

$k = 25.0$ N/m

$g = 9.81\text{ m/s}^2$

$F = kx = k(h - L) = mg$

$$m = \frac{(25.0\text{ N/m})(148\text{ m})}{(9.81\text{ m/s}^2)} = \boxed{377\text{ kg}}$$

Additional Practice B

1. $L = 6.7$ m

$a_g = g = 9.81\text{ m/s}^2$

$$T = 2\pi\sqrt{\frac{L}{a_g}} = 2\pi\sqrt{\frac{(6.7\text{ m})}{(9.81\text{ m/s}^2)}} = \boxed{5.2\text{ s}}$$

2. $L = 0.150$ m

$a_g = g = 9.81\text{ m/s}^2$

$$T = 2\pi\sqrt{\frac{L}{a_g}} = 2\pi\sqrt{\frac{(0.150\text{ m})}{(9.81\text{ m/s}^2)}} = \boxed{0.777\text{ s}}$$

3. $x = 0.88$ m

$a_g = g = 9.81\text{ m/s}^2$

$$T = 2\pi\sqrt{\frac{4x}{a_g}} = 2\pi\sqrt{\frac{4(0.88\text{ m})}{(9.81\text{ m/s}^2)}}$$

$T = \boxed{3.8\text{ s}}$

4. $f = 6.4 \times 10^{-2}$ Hz

$a_g = g = 9.81\text{ m/s}^2$

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{L}{a_g}}$$

$$L = \frac{a_g}{4\pi^2 f^2} = \frac{(9.81\text{ m/s}^2)}{4\pi^2(6.4 \times 10^{-2}\text{ Hz})^2}$$

$L = \boxed{61\text{ m}}$

5. $t = 3.6 \times 10^3$ s

$N = 48$ oscillations

$a_g = g = 9.81\text{ m/s}^2$

$$T = 2\pi\sqrt{\frac{L}{a_g}} = \frac{t}{N}$$

$$L = \frac{\left(\frac{t}{N}\right)^2 a_g}{4\pi^2} = \frac{(3.6 \times 10^3\text{ s})^2(9.81\text{ m/s}^2)}{4\pi^2\,(48)^2}$$

$L = \boxed{1.4 \times 10^3\text{ m}}$

6. $L = 1.00$ m

$T = 10.5$ s

$$a_g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2(1.00\text{ m})}{(10.5\text{ s})^2} = \boxed{0.358\text{ m/s}^2}$$

II

Additional Practice C

Givens	*Solutions*
1. $f_1 = 90.0$ Hz $k = 2.50 \times 10^2$ N/m	$T = 2\pi\sqrt{\dfrac{m}{k}} = \dfrac{1}{3.00 \times 10^{-2} f_1}$ $m = \dfrac{k}{4\pi^2(3.00 \times 10^{-2})^2 f_1^2} = \dfrac{(2.50 \times 10^2 \text{ N/m})}{4\pi^2(3.00 \times 10^{-2})^2(90.0 \text{ Hz})^2}$ $m = \boxed{0.869 \text{ kg}}$
2. $m_1 = 3.5 \times 10^6$ kg $f = 0.71$ Hz $k = 1.0 \times 10^6$ N/m	$T = \dfrac{1}{f} = 2\pi\sqrt{\dfrac{m_1 + m_2}{k}}$ $m_2 = \dfrac{k}{4\pi^2 f^2} - m_1$ $m_2 = \dfrac{(1.0 \times 10^6 \text{ N/m})}{4\pi^2(0.71 \text{ Hz})^2} - 3.5 \times 10^4 \text{ kg} = \boxed{1.5 \times 10^4 \text{ kg}}$
3. $m = 20.0$ kg $f = \dfrac{42.7}{60 \text{ s}} = 0.712$ Hz	$k = \dfrac{4\pi^2 m}{T^2} = 4\pi^2 m f^2$ $k = 4\pi^2 (20.0 \text{ kg})(0.712 \text{ Hz})^2$ $k = \boxed{4.00 \times 10^2 \text{ N/m}}$
4. $m = 2.00 \times 10^5$ kg $T = 1.6$ s	$T = 2\pi\sqrt{\dfrac{m}{k}}$ $k = \dfrac{4\pi^2 m}{T^2} = \dfrac{4\pi^2 (2.00 \times 10^5 \text{ kg})}{(1.6 \text{ s})^2} = \boxed{3.1 \times 10^6 \text{ N/m}}$
5. $m = 2662$ kg $x = 0.200$ m $g = 9.81 \text{ m/s}^2$	$T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{mx}{mg}}$ $T = 2\pi\sqrt{\dfrac{(0.200 \text{ m})}{(9.81 \text{ m/s}^2)}} = \boxed{0.897 \text{ s}}$
6. $m = 10.2$ kg $k = 2.60 \times 10^2$ N/m	$T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{(10.2 \text{ kg})}{(2.60 \times 10^2 \text{ N/m})}} = \boxed{1.24 \text{ s}}$

Additional Practice D

1. $f = 2.50 \times 10^2$ Hz $v = 1530$ m/s	$\lambda = \dfrac{v}{f} = \dfrac{1530 \text{ m/s}}{2.50 \times 10^2 \text{ Hz}} = \boxed{6.12 \text{ m}}$

II

Givens	*Solutions*
2. $f = 123$ Hz $v = 334$ m/s	$\lambda = \frac{v}{f} = \frac{(334 \text{ m/s})}{(123 \text{ Hz})} = \boxed{2.72 \text{ m}}$
3. $\lambda = 2.0 \times 10^{-2}$ m $v = 334$ m/s	$f = \frac{v}{\lambda} = \frac{(334 \text{ m/s})}{(2.0 \times 10^{-2} \text{ m})} = \boxed{1.7 \times 10^4 \text{ Hz}}$
4. $\lambda = 2.54$ m $v = 334$ m/s	$f = \frac{v}{\lambda} = \frac{(334 \text{ m/s})}{(2.54 \text{ m})} = \boxed{131 \text{ Hz}}$
5. $f = 73.4$ Hz $\lambda = 4.50$ m	$v = f\lambda = (73.4 \text{ Hz})(4.50 \text{ m}) = \boxed{3.30 \times 10^2 \text{ m/s}}$
6. $f = 2.80 \times 10^5$ Hz $\lambda = 5.10 \times 10^{-3}$ m $\Delta x = 3.00 \times 10^3$ m	$v = f\lambda = (2.80 \times 10^5 \text{ Hz})(5.10 \times 10^{-3} \text{ m})$ $v = \boxed{1.43 \times 10^3 \text{ m/s}}$ $\Delta t = \frac{\Delta x}{v} = \frac{(3.00 \times 10^3 \text{ m})}{(1.43 \times 10^3 \text{ m/s})}$ $\Delta t = \boxed{2.10 \text{ s}}$

II

Sound

Additional Practice A

Givens	*Solutions*
1. $Intensity = 3.0 \times 10^{-3}\ \text{W/m}^2$ $r = 4.0\ \text{m}$	$Intensity = \dfrac{P}{4\pi r^2}$ $P = 4\pi r^2(Intensity) = 4\pi(4.0\ \text{m})^2(3.0 \times 10^{-3}\ \text{W/m}^2)$ $P = \boxed{0.60\ \text{W}}$
2. $r = 8.0 \times 10^3\ \text{m}$ $Intensity = 1.0 \times 10^{-12}\ \text{W/m}^2$	$Intensity = \dfrac{P}{4\pi r^2}$ $P = 4\pi r^2(Intensity)$ $P = 4\pi(8.0 \times 10^3\ \text{m})^2(1.0 \times 10^{-12}\ \text{W/m}^2) = \boxed{8.0 \times 10^{-4}\ \text{W}}$
3. $Intensity = 1.0 \times 10^{-12}\ \text{W/m}^2$ $P = 2.0 \times 10^{-6}\ \text{W}$	$Intensity = \dfrac{P}{4\pi r^2}$ $r = \sqrt{\dfrac{P}{4\pi(Intensity)}}$ $r = \sqrt{\dfrac{2.0 \times 10^{-6}\ \text{W}}{4\pi(1.0 \times 10^{-12}\ \text{W/m}^2)}} = \boxed{4.0 \times 10^2\ \text{m}}$
4. $Intensity = 1.1 \times 10^{-13}\ \text{W/m}^2$ $P = 3.0 \times 10^{-4}\ \text{W}$	$r^2 = \dfrac{P}{4\pi\ Intensity}$ $r = \sqrt{\dfrac{P}{4\pi\ Intensity}} = \sqrt{\dfrac{(3.0 \times 10^{-4}\ \text{W})}{4\pi(1.1 \times 10^{-13}\ \text{W/m}^2)}} = \boxed{1.5 \times 10^4\ \text{m}}$
5. $P = 1.0 \times 10^{-4}\ \text{W}$ $r = 2.5\ \text{m}$	$Intensity = \dfrac{P}{4\pi r^2}$ $Intensity = \dfrac{(1.0 \times 10^{-4}\ \text{W})}{4\pi(2.5\ \text{m})^2} = \boxed{1.3 \times 10^{-6}\ \text{W/m}^2}$
6. $Intensity = 2.5 \times 10^{-6}\ \text{W/m}^2$ $r = 2.5\ \text{m}$	$P = 4\pi r^2(Intensity)$ $P = 4\pi(2.5\ \text{m})^2(2.5 \times 10^{-6}\ \text{W/m}^2)$ $P = \boxed{2.0 \times 10^{-4}\ \text{W}}$

Additional Practice B

Givens	Solutions
1. $f_{15} = 26.7$ Hz $v = 334$ m/s $n = 15$	$L = \frac{15v}{4f_{15}} = \frac{15(334 \text{ m/s})}{4(26.7 \text{ Hz})}$ $L = \boxed{46.9 \text{ m}}$
2. $\lambda = 3.47$ m $v_s = 5.00 \times 10^2$ m/s $n = 3$ $v_a = 334$ m/s	$L = \frac{\lambda v_s n}{2v_a} = \frac{(3.47 \text{ m})(5.00 \times 10^2 \text{ m/s})(3)}{2(334 \text{ m/s})}$ $L = \boxed{7.79 \text{ m}}$
3. $n = 19$ $L = 86$ m $v = 334$ m/s	$f_{19} = \frac{nv}{2L} = \frac{19(334 \text{ m/s})}{2(86 \text{ m})}$ $f_{19} = \boxed{37 \text{ Hz}}$
4. $L = 3.50 \times 10^2$ m $f_{75} = 35.5$ Hz $n = 75$	$f_{75} = \frac{75\,v}{2L}$ $v = \frac{2Lf_{75}}{75} = \frac{2(3.50 \times 10^2 \text{ m})(35.5 \text{ Hz})}{75}$ $v = \boxed{331 \text{ m/s}}$
5. $L = 4.7 \times 10^{-3}$ m $\lambda = 3.76 \times 10^{-3}$ m	$\lambda_n = \frac{4L}{n}$ $n = \frac{4L}{\lambda_n} = \frac{4(4.7 \times 10^{-3} \text{ m})}{(3.76 \times 10^{-3} \text{ m})} = \boxed{5}$

II

Light and Reflection

Additional Practice A

Givens	*Solutions*
1. $f = 9.00 \times 10^8$ Hz $d = 60.0$ m $c = 3.00 \times 10^8$ m/s	$c = f\lambda$ $\frac{d}{\lambda} = \frac{d}{\left(\frac{c}{f}\right)} = \frac{df}{c}$ $\frac{d}{\lambda} = \frac{(60.0\ \text{m})(9.00 \times 10^8\ \text{Hz})}{(3.00 \times 10^8\ \text{m/s})}$ $\frac{d}{\lambda} = \boxed{1.80 \times 10^2\ \text{wavelengths}}$
2. $f = 5.20 \times 10^{14}$ Hz $d = 2.00 \times 10^{-4}$ m $c = 3.00 \times 10^8$ m/s	$c = f\lambda$ $\frac{d}{\lambda} = \frac{d}{\left(\frac{c}{f}\right)} = \frac{df}{c}$ $\frac{d}{\lambda} = \frac{(2.00 \times 10^{-4}\ \text{m})(5.20 \times 10^{14}\ \text{Hz})}{(3.00 \times 10^8\ \text{m/s})}$ $\frac{d}{\lambda} = \boxed{347\ \text{wavelengths}}$
3. $f = 2.40 \times 10^{10}$ Hz $c = 3.00 \times 10^8$ m/s	$c = f\lambda$ $\lambda = \frac{c}{f}$ $\lambda = \frac{(3.00 \times 10^8\ \text{m/s})}{(2.40 \times 10^{10}\ \text{Hz})}$ $\lambda = \boxed{1.25 \times 10^{-2}\ \text{m} = 1.25\ \text{cm}}$
4. $\lambda = 1.2 \times 10^{-6}$ m $c = 3.00 \times 10^8$ m/s	$c = f\lambda$ $f = \frac{c}{\lambda}$ $f = \frac{(3.00 \times 10^8\ \text{m/s})}{(1.2 \times 10^{-6}\ \text{m})}$ $f = \boxed{2.5 \times 10^{14}\ \text{Hz} = 250\ \text{TH}}$

II

Givens | *Solutions*

5. $\lambda_1 = 2.0 \times 10^{-3}$ m

$\lambda_2 = 5.0 \times 10^{-3}$ m

$c = 3.00 \times 10^8$ m/s

$c = f\lambda$

$$f_1 = \frac{c}{\lambda_1} = \frac{(3.00 \times 10^8 \text{ m/s})}{(2.0 \times 10^{-3} \text{ m})}$$

$f_1 = 1.5 \times 10^{11}\text{ Hz} = 15 \times 10^{10}\text{ Hz}$

$$f_2 = \frac{c}{\lambda_2} = \frac{(3.00 \times 10^8 \text{ m/s})}{(5.0 \times 10^{-3} \text{ m})}$$

$f_2 = 6.0 \times 10^{10}$ Hz

$\boxed{6.0 \times 10^{10}\text{ Hz} < f < 15 \times 10^{10}\text{ Hz}}$

---

6. $f = 10.0$ Hz

$c = 3.00 \times 10^8$ m/s

$c = f\lambda$

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{(3.00 \times 10^8 \text{ m/s})}{(10.0 \text{ Hz})}$$

$\lambda = \boxed{3.00 \times 10^7\text{ m} = 3.00 \times 10^4\text{ km}}$

II

Additional Practice B

1. $p = 3.70 \times 10^5$ m

$f = 2.50 \times 10^5$ m

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{1}{(2.50 \times 10^5 \text{ m})} - \frac{1}{(3.70 \times 10^5 \text{ m})} = \frac{(4.00 \times 10^{-6})}{1 \text{ m}} - \frac{(2.70 \times 10^{-6})}{1 \text{ m}}$$

$$q = \left(\frac{1.30 \times 10^{-6}}{1 \text{ m}}\right)^{-1} = 7.69 \times 10^5 \text{ m} = \boxed{769 \text{ km}}$$

$$M = -\frac{q}{p} = \frac{-7.69 \times 10^5 \text{ m}}{3.70 \times 10^5 \text{ m}}$$

$M = \boxed{-2.08}$

---

2. $h = 8.00 \times 10^{-5}$ m

$f = 2.50 \times 10^{-2}$ m

$q = -5.9 \times 10^{-1}$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q}$$

$$\frac{1}{p} = \frac{1}{(2.50 \times 10^{-2} \text{ m})} - \frac{1}{(-5.9 \times 10^{-1} \text{ m})} = \frac{40.0}{1 \text{ m}} - \frac{1.69}{1 \text{ m}} = \frac{41.7}{1 \text{ m}}$$

$p = \boxed{2.40 \times 10^{-2}\text{ m}}$

$$M = \frac{h'}{h} = -\frac{q}{p} = -\frac{(-5.9 \times 10^{-1} \text{ m})}{(2.40 \times 10^{-2} \text{ m})} = \boxed{24.6}$$

Givens | *Solutions*

3. $h' = -28.0$ m

$h = 7.00$ m

$f = 30.0$ m

Image is real, so $q > 0$ and $h' < 0$.

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} + \frac{1}{\left(\frac{-ph'}{h}\right)} = \frac{1}{f}$$

$$\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$$

$$p = f\left(1 - \frac{h}{h'}\right)$$

$$p = (30.0 \text{ m})\left(1 + \frac{7.00 \text{ m}}{28.0 \text{ m}}\right)$$

$$p = \boxed{37.5 \text{ m}}$$

---

4. $h' = 67.4$ m

$h = 1.69$ m

$R = 12.0$ m

$(h' > 0, q < 0)$

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{p} + \frac{1}{\left(\frac{-ph'}{h}\right)} = \frac{2}{R}$$

$$\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{2}{R}$$

$$p = \left(\frac{R}{2}\right)\left(1 - \frac{h}{h'}\right)$$

$$p = \frac{(12.0 \text{ m})}{2}\left(1 - \frac{1.69 \text{ m}}{67.4 \text{ m}}\right) = (6.00 \text{ m})(0.975)$$

$$p = \boxed{5.85 \text{ m}}$$

$\boxed{\text{Image is virtual and therefore upright.}}$

II

Givens	*Solutions*
5. $h = 32$ m $f = 120$ m $p = 180$ m	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$ $\frac{1}{q} = \frac{1}{(120 \text{ m})} - \frac{1}{(180 \text{ m})} = \frac{0.0083}{1 \text{ m}} - \frac{0.0056}{1 \text{ m}} = \frac{0.0027}{1 \text{ m}}$ $q = \boxed{3.7 \times 10^2 \text{ m}}$ $M = \frac{h'}{h} = -\frac{q}{p}$ $h' = -\frac{qh}{p}$ $h' = \frac{-(370 \text{ m})(32 \text{ m})}{(180 \text{ m})}$ $h' = \boxed{-66 \text{ m}}$ The image is inverted ($h' < 1$) and real ($q > 0$)
6. $h = 0.500$ m $R = 0.500$ m $p = 1.000$ m	$\frac{1}{q} = \frac{2}{R} - \frac{1}{p}$ $\frac{1}{q} = \frac{2}{(0.500 \text{ m})} - \frac{1}{(1.000 \text{ m})} = \frac{4.00}{1 \text{ m}} - \frac{1.000}{1 \text{ m}} = \frac{3.00}{1 \text{ m}}$ $q = \boxed{0.333 \text{ m} = 333 \text{ mm}}$ $M = -\frac{q}{p} = \frac{h'}{h}$ $h' = -\frac{qh}{p} = \frac{-(0.333 \text{ m})(0.500 \text{ m})}{(1.000 \text{ m})}$ $h' = \boxed{-0.166 \text{ m} = -166 \text{ mm}}$ The image is real ($q > 0$).

II

Givens | *Solutions*

7. $p = 1.00 \times 10^5$ m

$h = 1.00$ m

$h' = -4.00 \times 10^{-6}$ m

($h' < 0$ because image is inverted)

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$R = \frac{2}{\left(\frac{1}{p} - \frac{h}{ph'}\right)} = \frac{2p}{\left(1 - \frac{h}{h'}\right)}$$

$$R = \frac{2(1.00 \times 10^5 \text{ m})}{\left[1 + \frac{(1.00 \text{ m})}{(4.00 \times 10^{-6} \text{ m})}\right]} = \frac{(2.00 \times 10^5 \text{ m})}{(1 + 2.50 \times 10^5)}$$

$$R = \boxed{0.800 \text{ m} = 80.0 \text{ cm}}$$

---

8. $h = 10.0$ m

$p = 18.0$ m

$h' = -24.0$ m

Image is real, so $q > 0$, and h' must be negative.

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{h'p}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$R = \frac{2}{\left(\frac{1}{p} - \frac{h}{ph'}\right)} = \frac{2p}{\left(1 - \frac{h}{h'}\right)}$$

$$R = \frac{2(18.0 \text{ m})}{\left(1 + \frac{10.0 \text{ m}}{24.0 \text{ m}}\right)} = \frac{36.0 \text{ m}}{(1 + 0.417)} = \frac{(36.0 \text{ m})}{(1.417)}$$

$$R = \boxed{25.4 \text{ m}}$$

II

Additional Practice C

Givens | *Solutions*

1. $R = -6.40 \times 10^6$ m

$p = 3.84 \times 10^8$ m

$h = 3.475 \times 10^6$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{2}{(-6.40 \times 10^6 \text{ m})} - \frac{1}{(3.84 \times 10^8 \text{ m})} = -\frac{(3.13 \times 10^{-7})}{1 \text{ m}} - \frac{(2.60 \times 10^{-9})}{1 \text{ m}}$$

$$q = -\left(\frac{3.16 \times 10^{-7}}{1 \text{ m}}\right)^{-1} = -3.16 \times 10^6 \text{ m} = -3.16 \times 10^3 \text{ km}$$

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$h' = -\frac{qh}{p}$$

$$h' = \frac{-(-3.16 \times 10^6 \text{ m})(3.475 \times 10^6 \text{ m})}{(3.84 \times 10^8 \text{ m})}$$

$$h' = \boxed{2.86 \times 10^4 \text{ m} = 28.6 \text{ km}}$$

2. $p = 553$ m

$R = -1.20 \times 10^2$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{2}{(-1.20 \times 10^2 \text{ m})} - \frac{1}{(553 \text{ m})} = -\frac{0.0167}{1 \text{ m}} - \frac{0.00181}{1 \text{ m}} = -\frac{0.0185}{1 \text{ m}}$$

$$q = -54.1 \text{ m}$$

$$M = -\frac{q}{p} = \frac{-(-54.1 \text{ m})}{(553 \text{ m})}$$

$$M = \boxed{9.78 \times 10^{-2}}$$

3. $R = -35.0 \times 10^3$ m

$p = 1.00 \times 10^5$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{q} = \frac{2}{R} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{2}{(-35.0 \times 10^3 \text{ m})} - \frac{1}{(1.00 \times 10^5 \text{ m})} = -\frac{(5.71 \times 10^{-5})}{1 \text{ m}} - \frac{(1.00 \times 10^{-5})}{1 \text{ m}}$$

$$q = -\left(\frac{6.71 \times 10^{-5}}{1 \text{ m}}\right)^{-1} = \boxed{-1.49 \times 10^4 \text{ m} = -14.9 \text{ km}}$$

Givens | *Solutions*

4. $h = 1.4 \times 10^6$ m

$h' = 11.0$ m

$R = -5.50$ m

$$M = \frac{h'}{h}$$

$$M = \frac{11.0 \text{ m}}{(1.4 \times 10^6 \text{ m})}$$

$$M = \boxed{7.9 \times 10^{-6}}$$

$$\boxed{\text{Scale is } 7.9 \times 10^{-6}\text{:}1}$$

$$q = -pM$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{p}\left(1 - \frac{1}{M}\right) = \frac{2}{R}$$

$$p = \frac{R}{2}\left(1 - \frac{1}{M}\right)$$

$$p = \left(\frac{-5.50 \text{ m}}{2}\right)\left(\frac{1 - 1}{7.9 \times 10^{-6}}\right)$$

$$p = \boxed{3.5 \times 10^5 \text{ m} = 3.5 \times 10^2 \text{ km}}$$

---

5. scale factor = 1:1400

$f = -20.0 \times 10^{-3}$ m

$M = \frac{1}{1400}$

$$M = -\frac{q}{p}$$

$$q = -Mp$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p}\left(1 - \frac{1}{M}\right) = \frac{1}{f}$$

$$p = f\left(1 - \frac{1}{M}\right)$$

$$p = (-20.0 \times 10^{-3} \text{ m})(1 - 1400)$$

$$p = \boxed{28 \text{ m}}$$

II

Givens | *Solutions*

6. $h = 1.38$ m

$p = 6.00$ m

$h' = 9.00 \times 10^{-3}$ m

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$

$$\frac{1}{p} - \frac{h}{ph'} = \frac{2}{R}$$

$$R = \frac{2p}{\left(1 - \frac{h}{h'}\right)}$$

$$R = \frac{2(6.00\text{ m})}{\left(1 - \frac{1.38\text{ m}}{9.00 \times 10^{-3}\text{ m}}\right)} = \frac{12.0\text{ m}}{(1 - 153)}$$

$$R = \boxed{-7.89 \times 10^{-2}\text{ m} = -7.89\text{ cm}}$$

---

7. $h' = 4.78 \times 10^{-3}$ m

$h = 12.8 \times 10^{-2}$ m

$f = -64.0 \times 10^{-2}$ m

$$M = -\frac{q}{p} = \frac{h'}{h}$$

$$p = -\frac{qh}{h'}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{\left(\frac{-qh}{h'}\right)} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q}\left(\frac{-h'}{h} + 1\right) = \frac{1}{f}$$

$$q = f\left(1 - \frac{h'}{h}\right)$$

$$q = (-64.0 \times 10^{-2}\text{ m})\left(1 - \frac{4.78 \times 10^{-3}\text{ m}}{12.8 \times 10^{-2}\text{ m}}\right) = (-64.0 \times 10^{-2}\text{ m})(0.963)$$

$$q = \boxed{-61.6 \times 10^{-2}\text{ m} = -61.6\text{ cm}}$$

II

Givens | *Solutions*

8. $h = 0.280$ m

$h' = 2.00 \times 10^{-3}$ m

$q = -50.0 \times 10^{-2}$ m

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$p = -\frac{qh}{h'}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{\left(\frac{-qh}{h'}\right)} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q}\left(\frac{-h'}{h} + 1\right) = \frac{1}{f}$$

$$f = \frac{q}{\left(1 - \frac{h'}{h}\right)}$$

$$f = \frac{(-50.0 \times 10^{-2}\ \text{m})}{\left[1 - \frac{(2.00 \times 10^{-3}\ \text{m})}{(0.280\ \text{m})}\right]} = \frac{(-50.0 \times 10^{-2}\ \text{m})}{(0.993)}$$

$$f = \boxed{-50.4 \times 10^{-2}\ \text{m} = -50.4\ \text{cm}}$$

II

Refraction

Additional Practice A

Givens	Solutions
1. $\theta_i = 72°$ $\theta_r = 34°$ $n_i = 1.00$	$n_r = n_i \dfrac{\sin\theta_i}{\sin\theta_r} = (1.00)\dfrac{(\sin 72°)}{(\sin 34°)} = \boxed{1.7}$
2. $\theta_i = 47.9°$ $\theta_r = 29.0°$ $n_i = 1.00$	$n_r = n_i \dfrac{\sin\theta_i}{\sin\theta_r} = (1.00)\dfrac{(\sin 47.9°)}{(\sin 29.0°)} = \boxed{1.53}$
3. $\theta_r = 17°$ $n_i = 1.5$ $n_r = 1.33$	glass to water: $\theta_i = \sin^{-1}\left[\dfrac{n_r}{n_i}(\sin\theta_r)\right] = \sin^{-1}\left[\dfrac{1.33}{1.5}(\sin 17°)\right] = \boxed{15°}$
$\theta_r = 15°$ $n_r = 1.5$ $n_i = 1.00$	air to glass: $\theta_i = \sin^{-1}\left[\dfrac{n_r}{n_i}(\sin\theta_r)\right] = \sin^{-1}\left[\dfrac{1.5}{1.00}(\sin 15°)\right] = \boxed{23°}$
4. $\theta_i = 55.0°$ $\theta_r = 53.8°$ $n_r = 1.33$	$n_i = n_r \dfrac{(\sin\theta_r)}{(\sin\theta_i)} = 1.33\dfrac{(\sin 53.8°)}{(\sin 55.0°)} = \boxed{1.31}$
5. $\theta_i = 48°$ $n_i = 1.00$ $n_r = 1.5$	air to glass 1: $\theta_r = \sin^{-1}\left[\dfrac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\dfrac{1.00}{1.5}(\sin 48°)\right] = \boxed{3.0 \times 10^{1}\,°}$
$\theta_i = 3.0 \times 10^{1}\,°$ $n_i = 1.5$ $n_r = 1.6$	glass 1 to glass 2: $\theta_r = \sin^{-1}\left[\dfrac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\dfrac{1.5}{1.6}(\sin 3.0°)\right] = \boxed{28°}$
$\theta_i = 28°$ $n_i = 1.6$ $n_r = 1.7$	glass 2 to glass 3: $\theta_r = \sin^{-1}\left[\dfrac{n_i}{n_r}(\sin\theta_i)\right] = \sin^{-1}\left[\dfrac{1.6}{1.7}(\sin 28°)\right] = \boxed{26°}$

II

Additional Practice B

Givens | *Solutions*

1. $f = 8.45$ m

$q = -25$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q}$$

$$\frac{1}{p} = \frac{1}{(8.45\ \text{m})} - \frac{1}{(-25)} = \frac{0.118}{1\ \text{m}} + \frac{0.040}{1\ \text{m}} = \frac{0.158}{1\ \text{m}}$$

$$p = 6.3\ \text{m}$$

$$M = -\frac{q}{p} = \frac{-(-25\ \text{m})}{6.3\ \text{m}}$$

$$M = \boxed{4.0}$$

2. $h' = 1.50$ m

$q = -6.00$ m

$f = -8.58$ m

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-8.58\ \text{m}} - \frac{1}{-6.00\ \text{m}}$$

$$\frac{1}{p} = \frac{-0.117}{1\ \text{m}} + \frac{0.167}{1\ \text{m}} = \frac{0.050}{1\ \text{m}}$$

$$p = \boxed{20.0\ \text{m}}$$

$$h = \frac{-h'p}{q} = -\frac{(1.50\ \text{m})(20.0\ \text{m})}{(-6.00\ \text{m})} = \boxed{5.00\ \text{m}}$$

3. $h = 7.60 \times 10^{-2}$ m

$h' = 4.00 \times 10^{-2}$ m

$f = -14.0 \times 10^{-2}$ m

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} + \frac{1}{\left(\frac{-ph'}{h}\right)} = \frac{-1}{f}$$

$$\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$$

$$p = f\left(1 - \frac{h}{h'}\right)$$

$$p = (-14.0 \times 10^{-2}\ \text{m})\left(1 - \frac{7.60 \times 10^{-2}\ \text{m}}{4.00 \times 10^{-2}\ \text{m}}\right) = (-14.0 \times 10^{-2}\ \text{m})(0.90)$$

$$p = \boxed{1.30 \times 10^{-1}\ \text{m} = 13.0\ \text{cm}}$$

$$q = -\frac{ph'}{h} = -\frac{(1.3 \times 10^{-1}\ \text{m})(4.00 \times 10^{-2}\ \text{m})}{(7.60 \times 10^{-2}\ \text{m})}$$

$$q = \boxed{-6.84 \times 10^{-2}\ \text{m} = -6.84\ \text{cm}}$$

II

Givens	*Solutions*
4. $h = 28.0$ m $h' = 3.50$ m $f = -10.0$ m	$M = \frac{h'}{h} = -\frac{q}{p}$ $q = -\frac{h'p}{h}$ $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\frac{1}{p} + \frac{1}{\left(\frac{-h'p}{h}\right)} = \frac{1}{f}$ $\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$ $p = f\left(1 - \frac{h}{h'}\right)$ $p = (-10.0 \text{ m})\left(1 - \frac{28.0 \text{ m}}{3.50 \text{ m}}\right)$ $p = \boxed{70.0 \text{ m}}$
5. $h' = 1.40$ cm $q = -19.0$ cm $f = 20.0$ cm	$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-20.0 \text{ cm}} - \frac{1}{-19.0 \text{ cm}}$ $\frac{1}{p} = \frac{-0.0500}{1 \text{ cm}} + \frac{0.0526}{1 \text{ cm}} = \frac{2.60 \times 10^3}{1 \text{ cm}}$ $p = 385 \text{ cm} = \boxed{3.85 \text{ m}}$ $h = -\frac{ph'}{q} = -\frac{(385 \text{ cm})(1.40 \text{ cm})}{(-19.0 \text{ cm})} = \boxed{28.4 \text{ cm}}$
6. $h = 1.3 \times 10^{-3}$ m $h' = 5.2 \times 10^{-3}$ m $f = 6.0 \times 10^{-2}$ m	$M = \frac{h'}{h} = -\frac{q}{p}$ $q = -\frac{ph'}{h}$ $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\frac{1}{p} + \frac{1}{\left(-\frac{ph'}{h}\right)} = \frac{1}{f}$ $\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$ $p = f\left(1 - \frac{h}{h'}\right)$ $p = (6.0 \times 10^{-2} \text{ m})\left[1 - \frac{(1.3 \times 10^{-3} \text{ m})}{(5.2 \times 10^{-3} \text{ m})}\right]$ $p = \boxed{4.5 \times 10^{-2} \text{ m} = 4.5 \text{ cm}}$ $q = -\frac{ph'}{h} = \frac{-(4.5 \times 10^{-2} \text{ m})(5.2 \times 10^{-3} \text{ m})}{(1.3 \times 10^{-3} \text{ m})}$ $q = \boxed{-0.18 \text{ m} = -18 \text{ cm}}$

II

Givens | *Solutions*

7. $f = 26.7 \times 10^{-2}$ m

$p = 3.00$ m

Image is real, so $h' < 0$.

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{1}{(26.7 \times 10^{-2}\ \text{m})} - \frac{1}{(3.00\ \text{m})} = \frac{3.75}{1\ \text{m}} - \frac{0333}{1\ \text{m}} = \frac{3.42}{1\ \text{m}}$$

$$q = \boxed{0.292\ \text{m} = 29.2\ \text{cm}}$$

$$M = -\frac{q}{p}$$

$$M = -\frac{(0.292\ \text{m})}{(3.00\ \text{m})}$$

$$M = \boxed{-9.73 \times 10^{-2}}$$

---

8. $h' = 2.25$ m

$p = 12.0$ m

$f = -5.68$ m

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-5.68\ \text{m}} - \frac{1}{12.0\ \text{m}}$$

$$\frac{1}{q} = \frac{-0.176}{1\ \text{m}} - \frac{0.083}{1\ \text{m}} = \frac{-0.259}{1\ \text{m}}$$

$$q = \boxed{-3.86\ \text{m}}$$

$$h = -\frac{h'p}{q} = -\frac{(2.25\ \text{m})(12.0\ \text{m})}{-3.86\ \text{m}} = \boxed{6.99\ \text{m}}$$

---

9. $h = 0.108$ m

$p = 4h = 0.432$ m

$f = -0.216$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{1}{(-0.216\ \text{m})} - \frac{1}{(0.432\ \text{m})} = -\frac{4.63}{1\ \text{m}} - \frac{2.31}{1\ \text{m}} = -\frac{6.94}{1\ \text{m}}$$

$$q = \boxed{-0.144\ \text{m} = -144\ \text{mm}}$$

$$\frac{h'}{h} = -\frac{q}{p}$$

$$h' = -\frac{qh}{p}$$

$$h' = \frac{-(-0.144\ \text{m})(0.108\ \text{m})}{(0.432\ \text{m})}$$

$$h' = \boxed{0.0360\ \text{m} = 36.0\ \text{mm}}$$

Givens	*Solutions*

10. $p = 117 \times 10^{-3}$ m

$M = 2.4$

$$M = -\frac{q}{p}$$

$$q = -pM = -(117 \times 10^{-3}\text{ m})(2.4)$$

$$q = -0.28\text{ m}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{(117 \times 10^{-3}\text{ m})} - \frac{1}{(0.28\text{ m})} = \frac{8.55}{1\text{ m}} - \frac{3.6}{1\text{ m}} = \frac{5.0}{1\text{ m}}$$

$$f = \boxed{0.20\text{ m} = 2.0 \times 10^{2}\text{ mm}}$$

---

11. Image is real, and therefore inverted.

$\frac{h'}{h} = M = -64$

$q = 12$ m

$$p = -\frac{q}{M}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$-\frac{M}{q} + \frac{1}{q} = \frac{1}{f}$$

$$f = \frac{q}{(1 - M)}$$

$$f = \frac{(12\text{ m})}{[1 - (-64)]}$$

$$f = \boxed{0.18\text{ m} = 18\text{ cm}} \quad \boxed{\text{Image is inverted}}$$

---

12. $h' = -0.55$ m

$h = 2.72$ m

$p = 5.0$ m

$$-\frac{q}{p} = \frac{h'}{h}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{p} - \frac{h}{ph'}$$

$$\frac{1}{f} = \frac{1}{p}\left(1 - \frac{h}{h'}\right)$$

$$f = \frac{p}{\left(1 - \frac{h}{h'}\right)}$$

$$f = \frac{5.0\text{ m}}{\left[1 - \frac{(2.72\text{ m})}{(-0.55\text{ m})}\right]} = \frac{5.0\text{ m}}{5.9}$$

$$f = \boxed{0.85\text{ m}}$$

II

Givens	Solutions
13. $p = 12.0 \times 10^{-2}$ m $M = 3.0$	$M = -\frac{q}{p}$ $q = -Mp$ $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\frac{1}{p} - \frac{1}{Mp} = \frac{1}{f}$ $\frac{1}{p}\left(1 - \frac{1}{M}\right) = \frac{1}{f}$ $f = \frac{p}{\left(1 - \frac{1}{M}\right)}$ $f = \frac{(12.0 \times 10^{-2}\text{ m})}{\left(1 - \frac{1}{3.0}\right)}$ $f = \boxed{1.8 \times 10^{-1}\text{ m} = 18\text{ cm}}$
14. $h = 7.60 \times 10^{-2}$ m $p = 16.0 \times 10^{-2}$ m $f = -12.0 \times 10^{-2}$ m	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $M = -\frac{q}{p} = \frac{h'}{h}$ $q = -\frac{ph'}{h}$ $\frac{1}{p} + \frac{1}{\left(\frac{-ph'}{h}\right)} = \frac{1}{f}$ $\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$ $1 - \frac{h}{h'} = \frac{p}{f}$ $\frac{h}{h'} = 1 - \frac{p}{f}$ $h' = \frac{h}{\left(1 - \frac{p}{f}\right)}$ $h' = \frac{(7.60 \times 10^{-2}\text{ m})}{\left[1 - \frac{(16.0 \times 10^{-2}\text{ m})}{(-12.0 \times 10^{-2}\text{ m})}\right]} = \frac{(7.60 \times 10^{-2}\text{ m})}{(2.33)}$ $h' = \boxed{3.26 \times 10^{-2}\text{ m} = 3.26\text{ cm}}$

Givens | *Solutions*

15. $h = 48$ m

$f = 1.1 \times 10^{-1}$ m

$p = 120$ m

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$\frac{1}{q} = \frac{1}{(1.1 \times 10^{-1}\ \text{m})} - \frac{1}{(120\ \text{m})} = \frac{9.1}{1\ \text{m}} - \frac{(8.3 \times 10^{-3})}{1\ \text{m}} = \frac{9.1}{1\ \text{m}}$$

$$q = 1.1 \times 10^{-1}\text{m}$$

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$h' = -\frac{qh}{p}$$

$$h' = \frac{-(1.1 \times 10^{-1}\text{m})(48\ \text{m})}{(120\ \text{m})}$$

$$h' = \boxed{4.4 \times 10^{-2}\ \text{m} = -\ 4.4\ \text{cm}}$$

---

16. $f = -0.80$ m

$h' = 0.50 \times 10^{-3}$ m

$h = 0.280$ m

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$q = -\frac{ph'}{h}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} + \frac{1}{\left(\frac{-ph'}{h}\right)} = \frac{1}{f}$$

$$\frac{1}{p}\left(1 - \frac{h}{h'}\right) = \frac{1}{f}$$

$$p = f\left(1 - \frac{h}{h'}\right)$$

$$p = (-\ 0.80\ \text{m})\left[1 - \frac{(0.280\ \text{m})}{(0.50 \times 10^{-3}\ \text{m})}\right]$$

$$p = \boxed{4.5 \times 10^{2}\ \text{m}}$$

$$q = -\frac{ph'}{h} = \frac{-(4.5 \times 10^{2}\ \text{m})(0.50 \times 10^{-3}\ \text{m})}{(0.280\ \text{m})}$$

$$q = \boxed{-0.80\ \text{m}}$$

Additional Practice C

1. $\theta_c = 46°$

$n_i = 1.5$

$$n_r = n_i \sin\theta_c = (1.5)(\sin 46°) = \boxed{1.1}$$

II

Givens	*Solutions*
2. $n_i = 1.00$ $\theta_i = 75.0°$ $\theta_r = 23.3°$	$n_r = n_i \dfrac{(\sin \theta_i)}{(\sin \theta_r)} = (1.00)\dfrac{(\sin 75.0°)}{(\sin 23.3°)} = 2.44$
$n_i = 2.44$ $n_r = 1.00$	$\theta_c = \sin = -1\left[\dfrac{n_r}{n_i}\right]$ $\theta_c = \sin^{-1}\left[\dfrac{1.00}{2.44}\right] = \boxed{24.2°}$
3. $\theta_c = 42.1°$ $n_r = 1.00$	$n_i = \dfrac{n_r}{\sin \theta_c} = \dfrac{1.00}{\sin 42.1°} = \boxed{1.49}$
4. $n_i = 1.56$ $n_r = 1.333$	$\sin \theta_c = \dfrac{n_r}{n_i}$ $\theta_c = \sin^{-1}\left[\dfrac{n_r}{n_i}\right] = \sin^{-1}\left[\dfrac{1.333}{1.56}\right] = \boxed{58.7°}$
5. $n_i = 1.52$ $h = 0.025$ mm $n_r = 1.00$	$\theta_c = \sin^{-1}\left[\dfrac{n_r}{n_i}\right] = \sin^{-1}\left[\dfrac{1.00}{1.52}\right] = \boxed{41.1°}$ $\Delta x = h(\tan \theta_c)$ where $\tan \theta_c = \dfrac{n_r}{n_i}$ $\Delta x = h\left(\dfrac{n_r}{n_i}\right) = (0.025\text{ mm})\left(\dfrac{1.00}{1.52}\right) = 0.0160\text{ mm}$ $d = 2\Delta x = 2(0.0160\text{ mm}) = \boxed{0.0320\text{ mm}}$

Interference and Diffraction

Additional Practice A

Givens | *Solutions*

1. $d = 1.20 \times 10^{-6}$ m

$\lambda = 156.1 \times 10^{-9}$ m

$m = 5$; constructive interference

For constructive interference,

$$d \sin \theta = m\lambda$$

$$\sin \theta = \frac{m\lambda}{d}$$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$$

$$\theta = \sin^{-1}\left[\frac{(5)(156.1 \times 10^{-9}\ \text{m})}{(1.20 \times 10^{-6}\ \text{m})}\right]$$

$$\theta = \boxed{40.6°}$$

---

2. $d = 6.00 \times 10^{-6}$ m

$\lambda = 6.33 \times 10^{-7}$ m

$m = 0$; destructive interference

For destructive interference,

$$d \sin \theta = \left(m + \tfrac{1}{2}\right)\lambda$$

$$\sin \theta = \frac{\left(m + \tfrac{1}{2}\right)\lambda}{d}$$

$$\theta = \sin^{-1}\left[\frac{\left(m + \tfrac{1}{2}\right)\lambda}{d}\right]$$

$$\theta = \sin^{-1}\left[\frac{\left(0 + \tfrac{1}{2}\right)(6.33 \times 10^{-7}\ \text{m})}{(6.00 \times 10^{-6}\ \text{m}}\right]$$

$$\theta = \boxed{3.02°}$$

---

3. $d = 0.80 \times 10^{-3}$ m

$m = 3$; destructive interference

$\theta = 1.6°$

For destructive interference,

$$d \sin \theta = \left(m + \tfrac{1}{2}\right)\lambda$$

$$\lambda = \frac{d \sin \theta}{\left(m + \tfrac{1}{2}\right)}$$

$$\lambda = \frac{(0.80 \times 10^{-3}\ \text{m})(\sin 1.6°)}{\left(3 + \tfrac{1}{2}\right)}$$

$$\lambda = \boxed{6.4 \times 10^{-6}\ \text{m} = 6.4\ \mu\text{m}}$$

Givens	*Solutions*
4. $d = 15.0 \times 10^{-6}$ m $m = 2$; constructive interference $\theta = 19.5°$	For constructive interference, $d \sin \theta = m\lambda$ $\lambda = \frac{d \sin \theta}{m}$ $\lambda = \frac{(15.0 \times 10^{-6}\ \text{m})[\sin(19.5°)]}{2}$ $\lambda = \boxed{2.50 \times 10^{-6}\ \text{m} = 2.50\ \mu\text{m}}$
5. $\lambda = 443 \times 10^{-9}$ m $m = 4$; destructive interference $\theta = 2.27°$	For destructive interference, $d \sin \theta = \left(m + \frac{1}{2}\right)\lambda$ $d = \frac{\left(m + \frac{1}{2}\right)\lambda}{\sin \theta}$ $d = \frac{\left(4 + \frac{1}{2}\right)(443 \times 10^{-9}\ \text{m})}{(\sin 2.27°)}$ $d = \boxed{5.03 \times 10^{-5}\ \text{m}}$
6. $f = 60.0 \times 10^{3}$ Hz $c = 3.00 \times 10^{8}$ m/s $m = 4$; constructive interference $\theta = 52.0°$	For constructive interference, $d \sin \theta = m\lambda = \frac{mc}{f}$ $d = \frac{mc}{f \sin \theta}$ $d = \frac{(4)(3.00 \times 10^{8}\ \text{m/s})}{(60.0 \times 10^{3}\ \text{Hz})(\sin 52.0°)}$ $d = \boxed{2.54 \times 10^{4}\ \text{m} = 25.4\ \text{km}}$
7. $f = 137 \times 10^{6}$ Hz $c = 3.00 \times 10^{8}$ m/s $m = 2$; constructive interference $\theta = 60.0°$	For constructive interference, $d \sin \theta = m\lambda = \frac{mc}{f}$ $d = \frac{mc}{f \sin \theta}$ $d = \frac{(2)(3.00 \times 10^{8}\ \text{m/s})}{(137 \times 10^{6}\ \text{Hz})(\sin 60.0°)}$ $d = \boxed{5.06\ \text{m}}$ $m_{max} = \frac{d(\sin 90.0°)}{\lambda} = \frac{d}{\lambda} = \frac{df}{c}$ $m_{max} = \frac{(5.06\ \text{m})(137 \times 10^{6}\ \text{Hz})}{(3.00 \times 10^{8}\ \text{m/s})} = 2.31$ $\boxed{\text{The second-order maximum } (m = 2) \text{ is the highest observable with this apparatus.}}$

II

Additional Practice B

Givens	*Solutions*
1. $d = \dfrac{1}{1.00 \times 10^2 \text{ lines/m}}$ $m = 1$ $\theta = 30.0°$ $c = 3.00 \times 10^8$ m/s	$d(\sin\theta) = m\lambda$ $\lambda = \dfrac{d(\sin\theta)}{m}$ $\lambda = \dfrac{[\sin(30.0°)]}{(1.00 \times 10^2 \text{ lines/m})(1)}$ $\lambda = \boxed{5.00 \times 10^{-3} \text{ m} = 5.00 \text{ mm}}$ $f = \dfrac{c}{\lambda} = \dfrac{(3.00 \times 10^8 \text{ m/s})}{(5.00 \times 10^{-3} \text{ m})}$ $f = \boxed{6.00 \times 10^{10} \text{ Hz} = 60.0 \text{ Ghz}}$
2. $d = 2.0 \times 10^{-8}$ m $m = 3$ $\theta = 12°$	$d(\sin\theta) = m\lambda$ $\lambda = \dfrac{d(\sin\theta)}{m}$ $\lambda = \dfrac{(2.0 \times 10^{-8} \text{ m})[\sin(12°)]}{3}$ $\lambda = \boxed{1.4 \times 10^{-9} \text{ m} = 1.4 \text{ nm}}$
3. $\lambda = 714 \times 10^{-9}$ m $m = 3$ $\theta = 12.0°$	$d(\sin\theta) = m\lambda$ $d = \dfrac{m\lambda}{(\sin\theta)}$ $d = \dfrac{(3)(714 \times 10^{-9} \text{ m})}{[\sin(12.0°)]}$ $d = \boxed{1.03 \times 10^{-5} \text{ m between lines}}$ or $\boxed{9.71 \times 10^4 \text{ lines/m}}$
4. $\lambda = 40.0 \times 10^{-9}$ m $d = 150.0 \times 10^{-9}$ m $m = 2$	$d(\sin\theta) = m\lambda$ $\theta = \sin^{-1}\left(\dfrac{m\lambda}{d}\right)$ $\theta = \sin^{-1}\left[\dfrac{2(40.0 \times 10^{-9} \text{ m})}{(150.0 \times 10^{-9} \text{ m})}\right]$ $\theta = \boxed{32.2°}$

II

Givens | *Solutions*

5. $f = 1.612 \times 10^9$ Hz

$c = 3.00 \times 10^8$ m/s

$d = 45.0 \times 10^{-2}$ m

$m = 1$

$$d(\sin\theta) = m\lambda = \frac{mc}{f}$$

$$\theta = \sin^{-1}\left(\frac{mc}{df}\right)$$

$$\theta = \sin^{-1}\left[\frac{(1)(3.00 \times 10^8 \text{ m/s})}{(45.0 \times 10^{-2} \text{ m})(1.612 \times 10^9 \text{ Hz})}\right]$$

$$\theta = \boxed{24.4^\circ}$$

---

6. $\lambda = 2.2 \times 10^{-6}$ m

$d = \dfrac{1}{6.4 \times 10^4 \text{ lines/m}}$

$\theta = 34.0^\circ$

$$d(\sin\theta) = m\lambda$$

$$m = \frac{d(\sin\theta)}{\lambda}$$

$$m = \frac{[\sin(34.0^\circ)]}{(6.4 \times 10^4 \text{ lines/m})(2.2 \times 10^{-6} \text{ m})} = 4.0$$

$$m = \boxed{4.0}$$

II

7. $d = \dfrac{1}{25 \times 10^4 \text{ lines/m}}$

$\lambda = 7.5 \times 10^{-7}$ m

$\theta = 48.6^\circ$

$$d(\sin\theta) = m\lambda$$

$$m = \frac{d(\sin\theta)}{\lambda}$$

$$m = \frac{[\sin(48.6^\circ)]}{(25 \times 10^4 \text{ lines/m})(7.5 \times 10^{-7} \text{ m})} = 4.0$$

$$m = \boxed{4.0}$$

Electric Forces and Fields

Additional Practice A

Givens	Solutions

1. $q_1 = 0.085$ C

$r = 2.00 \times 10^3$ m

$F_{electric} = 8.64 \times 10^{-8}$ N

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F_{electric} = k_C \frac{q_1 q_2}{r^2}$$

$$q_2 = \frac{F_{electric} r^2}{k_C q_1}$$

$$q_2 = \frac{(8.64 \times 10^{-8}\ \text{N})(2.00 \times 10^3\ \text{m})^2}{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(0.085\ \text{C})} = \boxed{4.5 \times 10^{-10}\ \text{C}}$$

2. $q_1 = q$

$q_2 = 3q$

$F_{electric} = 2.4 \times 10^{-6}$ N

$r = 3.39$ m

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F = k_C \frac{q_1 q_2}{r^2} = k_C \frac{3q^2}{r^2}$$

$$q = \sqrt{\frac{Fr^2}{3k_C}} = \sqrt{\frac{(2.4 \times 10^{-6}\ \text{N})(3.39\ \text{m})^2}{(3)(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)}}$$

$$q = \boxed{3.2 \times 10^{-8}\ \text{C}}$$

3. $F_{electric} = 1.0$ N

$r = 2.4 \times 10^{22}$ m

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F = k_C \frac{N^2 (q_e)^2}{r^2}$$

$$q_e = \sqrt{\frac{Fr^2}{k_C}} = r\sqrt{\frac{F}{k_C}}$$

$$q_e = (2.4 \times 10^{22}\ \text{m})\left(\sqrt{\frac{1.0\ \text{N}}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}\right)$$

$$q_e = \boxed{2.5 \times 10^{17}\ \text{C}}$$

4. $r = 1034$ m

$q_1 = 2.0 \times 10^{-9}$ C

$q_2 = -2.8 \times 10^{-9}$ C

$k_C = 8.99 \times 10^9$ N•m²/C²

$r_2 = 2r$

$$F_{electric} = k_C \frac{q_1 q_2}{r^2} = \frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(2.0 \times 10^{-9}\ \text{C})(2.8 \times 10^{-9}\ \text{C})}{(1034\ \text{m})^2}$$

$$F_{electric} = \boxed{4.7 \times 10^{-14}\ \text{N}}$$

$$r_2 = 2r = (2)(1034\ \text{m}) = 2068\ \text{m}$$

$$q = \sqrt{\frac{F_{electric} r_2^2}{k_C}} = \sqrt{\frac{(4.7 \times 10^{-14}\ \text{N})(2068\ \text{m})^2}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$$

$$q = \boxed{4.7 \times 10^{-9}\ \text{C}}$$

5. $q_1 = 1.0 \times 10^5$ C

$q_2 = -1.0 \times 10^5$ C

$r = 7.0 \times 10^{11}$ m

$k_C = 8.99 \times 10^9$ N•m²/C²

$$F = k_C \frac{q_1 q_2}{r^2}$$

$$F = (8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)\left(\frac{(1.0 \times 10^5\ \text{C})^2}{(7.0 \times 10^{11}\ \text{m})^2}\right)$$

$$F = \boxed{1.8 \times 10^{-4}\ \text{N}}$$

II

Givens	*Solutions*

6. $N = 2\,000\,744$

$q_p = 1.60 \times 10^{-19}$ C

$r = 1.00 \times 10^3$ m

$k_C = 8.99 \times 10^9$ N•m²/C² → $k_C = 8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2}$

$$q = \frac{Nq_p}{2} = \frac{(2\,000\,744)(1.60 \times 10^{-19}\ \mathrm{C})}{2} = \boxed{1.60 \times 10^{-13}\ \mathrm{C}}$$

$$F_{electric} = k_C \frac{q^2}{r^2}$$

$$F_{electric} = (8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})\left(\frac{(1.60 \times 10^{-13}\ \mathrm{C})^2}{(1.00 \times 10^3\ \mathrm{m})^2}\right)$$

$$F_{electric} = \boxed{2.30 \times 10^{-22}\ \mathrm{N}}$$

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7. $N_1 = 4.00 \times 10^3$

$N_2 = 3.20 \times 10^5$

$q = 1.60 \times 10^{-19}$ C

$r = 1.00 \times 10^3$ m

$k_C = 8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2}$

$$F_{electric} = \frac{k_C q_1 q_2}{r^2} = \frac{k_C N_1 N_2 q^2}{r^2}$$

$$F_{electric} = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(4.00 \times 10^3)(3.20 \times 10^5)(1.60 \times 10^{-19}\ \mathrm{C})^2}{(1.00 \times 10^3\ \mathrm{m})^2}$$

$$F_{electric} = \boxed{2.95 \times 10^{-25}\ \mathrm{N}}$$

$$F_{electric} = k_C \frac{N_2^2 q^2}{r^2} = \frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(3.20 \times 10^5)^2(1.60 \times 10^{-19}\ \mathrm{C})^2}{(1.00 \times 10^3\ \mathrm{m})^2}$$

$$F_{electric} = \boxed{2.36 \times 10^{-23}\ \mathrm{N}}$$

---

8. $F_{electric} = 2.0 \times 10^{-28}$ N

$N = 111$

$q_p = 1.60 \times 10^{-19}$ C

$k_C = 8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2}$

$$F_{electric} = k_C \frac{q^2}{r^2} = k_C \frac{N^2 q_p^2}{r^2}$$

$$r = \sqrt{\frac{k_C N^2 q_p^2}{F_{electric}}} = \sqrt{\frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(111)^2(1.60 \times 10^{-19}\ \mathrm{C})^2}{2.0 \times 10^{-28}\ \mathrm{N}}}$$

$$r = \boxed{1.2 \times 10^2\ \mathrm{m}}$$

---

9. $q = 1.00$ C

$F_{electric} = 4.48\ \mathrm{m} \times 10^4$ N

$k_C = 8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2}$

$$r = \sqrt{k_C \frac{q^2}{F_{electric}}} = \sqrt{\frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(1.0\ \mathrm{C})^2}{4.48 \times 10^4\ \mathrm{N}}} = \boxed{448\ \mathrm{m}}$$

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10. $F_{electric} = 1.18 \times 10^{-11}$ N

$q_1 = 5.00 \times 10^{-9}$ C

$q_2 = -2.50 \times 10^{-9}$ C

$k_C = 8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2}$

$$F_{electric} = k_C \frac{q_1 q_2}{r^2}$$

$$r = \sqrt{\frac{k_C q^2}{F_{electric}}} = \sqrt{\frac{(8.99 \times 10^9\ \mathrm{N{\bullet}m^2/C^2})(5.00 \times 10^{-9}\ \mathrm{C})(2.50 \times 10^{-9}\ \mathrm{C})}{1.18 \times 10^{-11}\ \mathrm{N}}}$$

$$r = \boxed{97.6\ \mathrm{m}}$$

$$L = r \cos\theta = (97.6\ \mathrm{m})\cos 45° = \boxed{69.0\ \mathrm{m}}$$

Additional Practice B

Givens	*Solutions*
1. $q_1 = 2.80 \times 10^{-3}$ C $q_2 = -6.40 \times 10^{-3}$ C $q_3 = 4.80 \times 10^{-2}$ C $r_{1,3} = 9740$ m $r_{1,2} = 892$ m $k_C = 8.99 \times 10^9$ N•m^2/C^2	$F = k_C \dfrac{q_1 q_2}{r^2}$ $F_{1,2} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.80 \times 10^{-3}\text{ C})(6.40 \times 10^{-3}\text{ C})}{(892\text{ m})^2} = 2.02 \times 10^{-1}$ N $F_{1,3} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.80 \times 10^{-3}\text{ C})(4.80 \times 10^{-2}\text{ C})}{(9740\text{ m})^2} = 1.27 \times 10^{-2}$ N $F_{1,tot} = F_{1,2} + F_{1,3} = -(2.02 \times 10^{-1}\text{ N}) + (1.27 \times 10^{-2}\text{ N}) = -0.189$ N $\mathbf{F_{1,tot}} = \boxed{0.189\text{ N downward}}$
2. $q_1 = 2.0 \times 10^{-9}$ C $q_2 = 3.0 \times 10^{-9}$ C $q_3 = 4.0 \times 10^{-9}$ C $q_4 = 5.5 \times 10^{-9}$ C $r_{1,2} = 5.00 \times 10^2$ m $r_{1,3} = 1.00 \times 10^3$ m $r_{1,4} = 1.747 \times 10^3$ m $k_C = 8.99 \times 10^9$ N•m^2/C^2	$F = k_C \dfrac{q_1 q_2}{r^2}$ $F_{1,2} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.0 \times 10^{-9}\text{ C})(3.0 \times 10^{-9}\text{ C})}{(5.00 \times 10^2\text{ m})^2} = 2.2 \times 10^{-13}$ N $F_{1,3} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.0 \times 10^{-9}\text{ C})(4.0 \times 10^{-9}\text{ C})}{(1.00 \times 10^3\text{ m})^2} = 7.2 \times 10^{-14}$ N $F_{1,4} = \dfrac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.0 \times 10^{-9}\text{ C})(5.5 \times 10^{-9}\text{ C})}{(1.747 \times 10^3\text{ m})^2} = 3.2 \times 10^{-14}$ N $F_{1,tot} = F_{1,2} + F_{1,3} + F_{1,4} = (2.2 \times 10^{-13}\text{ N}) + (7.2 \times 10^{-14}\text{ N}) + (3.2 \times 10^{-14}\text{ N})$ $\mathbf{F_{1,tot}} = \boxed{3.2 \times 10^{-13}\text{ N down the rope}}$
3. $w = 7.00 \times 10^{-2}$ m $L = 2.48 \times 10^{-1}$ m $q = 1.0 \times 10^{-9}$ C $k_C = 8.99 \times 10^9$ N•m^2/C^2	$F = k_C \dfrac{q_1 q_2}{r^2}$ $F_x = F_1 + F_2(\cos\theta) = F_1 + F_2\left(\dfrac{L}{\sqrt{w^2 + L^2}}\right)$ $F_x = k_C q^2 \left(\dfrac{1}{L^2} + \dfrac{L}{(w^2 + L^2)^{3/2}}\right)$ $F_x = k_C q^2 \left(\dfrac{1}{(2.48 \times 10^{-1}\text{ m})^2} + \dfrac{2.48 \times 10^{-1}\text{ m}}{[(7.00 \times 10^{-2}\text{ m})^2 + (2.48 \times 10^{-1}\text{ m})^2]^{3/2}}\right)$ $F_x = (8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.0 \times 10^{-9}\text{ C})^2(30.8/\text{m}^2) = 2.8 \times 10^{-7}$ N $F_y = F_3 + F_2(\sin\theta) = F_3 + F_2\left(\dfrac{w}{\sqrt{w^2 + L^2}}\right)$ $F_y = k_C q^2 \left(\dfrac{1}{w^2} + \dfrac{w}{(w^2 + L^2)^{3/2}}\right)$ $F_y = k_C q^2 \left(\dfrac{1}{(7.00 \times 10^{-2}\text{ m})^2} + \dfrac{7.00 \times 10^{-2}\text{ m}}{[(7.00 \times 10^{-2}\text{ m})^2 + (2.48 \times 10^{-1}\text{ m})^2]^{3/2}}\right)$ $F_y = (8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.0 \times 10^{-9}\text{ C})^2(2.00 \times 10^2/\text{m}^2) = 1.8 \times 10^{-6}$ N $F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(2.8 \times 10^{-7}\text{ N})^2 + (1.8 \times 10^{-6}\text{ N})^2}$ $F_{net} = 1.8 \times 10^{-6}$ N $\theta' = \tan^{-1}\left(\dfrac{F_y}{F_x}\right) = \tan^{-1}\left(\dfrac{1.8 \times 10^{-6}\text{ N}}{2.8 \times 10^{-7}\text{ N}}\right) = 81°$ $\mathbf{F_{net}} = \boxed{1.8 \times 10^{-6}\text{ N, 81° above the positive } x\text{-axis}}$

II

Givens | *Solutions*

4. $L = 10.7\ \text{m}$

$w = 8.7\ \text{m}$

$q_1 = -1.2 \times 10^{-8}\ \text{C}$

$q_2 = 5.6 \times 10^{-9}\ \text{C}$

$q_3 = 2.8 \times 10^{-9}\ \text{C}$

$q_4 = 8.4 \times 10^{-9}\ \text{C}$

$k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$

$$F = k_C \frac{q_1 q_2}{r^2}$$

$$F_x = F_4 + F_3(\cos\theta)$$

$$F_y = F_2 + F_3(\sin\theta)$$

$$F_x = k_C q_1 \left(\frac{q_4}{L^2} + \frac{q_3 L}{(L^2 + w^2)^{3/2}}\right)$$

$$F_x = (8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(1.2 \times 10^{-8}\ \text{C})\left(\frac{(8.4 \times 10^{-9}\ \text{C})}{(10.7\ \text{m})^2} + \frac{(2.8 \times 10^{-9}\ \text{C})(10.7\ \text{m})}{[(10.7\ \text{m})^2 + (8.7\ \text{m})^2]^{3/2}}\right)$$

$$F_x = 9.1 \times 10^{-9}\ \text{N}$$

$$F_y = k_C q_1 \left(\frac{q_2}{w^2} + \frac{q_3 w}{(L^2 + w^2)^{3/2}}\right)$$

$$F_y = (8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(1.2 \times 10^{-8}\ \text{C})\left(\frac{(5.6 \times 10^{-9}\ \text{C})}{(8.7\ \text{m})^2} + \frac{(2.8 \times 10^{-9}\ \text{C})(8.7\ \text{m})}{[(10.7\ \text{m})^2 + (8.7\ \text{m})^2]^{3/2}}\right)$$

$$F_y = 9.0 \times 10^{-9}\ \text{N}$$

$$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(9.1 \times 10^{-9}\ \text{N})^2 + (9.0 \times 10^{-9}\ \text{N})^2} = 1.28 \times 10^{-8}\ \text{N}$$

$$\theta' = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{9.0 \times 10^{-9}\ \text{N}}{9.1 \times 10^{-9}\ \text{N})}\right) = 45°$$

$$\mathbf{F_{net}} = \boxed{1.28 \times 10^{-8}\ \text{N, 45° above the positive } x\text{-axis}}$$

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5. $d = 1.2 \times 10^3\ \text{m}$

$q_1 = 1.6 \times 10^{-2}\ \text{C}$

$q_2 = 2.4 \times 10^{-3}\ \text{C}$

$q_3 = -3.2 \times 10^{-3}\ \text{C}$

$q_4 = -4.0 \times 10^{-3}\ \text{C}$

$k_C = 8.99 \times 10^9\ \text{N•m}^2/\text{C}^2$

$$\Delta x = \Delta y = \frac{d}{\sqrt{2}} = \frac{1.2 \times 10^3\ \text{m}}{\sqrt{2}} = 8.5 \times 10^2\ \text{m}$$

$$F = \frac{k_C q_1 q_2}{r^2}$$

$$F_x = -F_2 + F_3(\cos 45°) = k_C q_1\left(-\frac{q_2}{\Delta x^2} + \frac{q_3(\cos 45°)}{d^2}\right)$$

$$F_x = (8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(1.6 \times 10^{-2}\ \text{C})\left(-\frac{2.4 \times 10^{-3}\ \text{C}}{(8.5 \times 10^2\ \text{m})^2} + \frac{(3.2 \times 10^{-3}\ \text{C})(\cos 45°)}{(1.2 \times 10^3\ \text{m})^2}\right)$$

$$F_x = -0.24\ \text{N}$$

$$F_y = -F_4 - F_3(\sin 45°) = k_C q_1\left(\frac{q_4}{\Delta y^2} + \frac{q_3(\sin 45°)}{d^2}\right)$$

$$F_y = -(8.99 \times 10^9\ \text{N•m}^2/\text{C}^2)(1.60 \times 10^{-2}\ \text{C})\left(\frac{4.0 \times 10^{-3}\ \text{C}}{(8.5 \times 10^2\ \text{m})^2} + \frac{(3.2 \times 10^{-3}\ \text{C})(\sin 45°)}{(1.2 \times 10^3\ \text{m})^2}\right)$$

$$F_y = -1.0\ \text{N}$$

$$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(0.24\ \text{N})^2 + (1.0\ \text{N})^2} = 1.0\ \text{N}$$

$$\theta' = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{(1.0\ \text{N})}{(0.24\ \text{N})}\right) = 77°$$

$$\mathbf{F_{net}} = \boxed{1.0\ \text{N, 77° below the negative } x\text{-axis}}$$

II

Givens | *Solutions*

6. $d = \dfrac{228.930 \times 10^3\ \text{m}}{3} = 7.631 \times 10^4\ \text{m}$

$q_1 = 8.8 \times 10^{-9}$ C

$q_2 = -2.4 \times 10^{-9}$ C

$q_3 = 4.0 \times 10^{-9}$ C

$k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$

$\theta = 60.0°$

$$F = \frac{k_C q_1 q_2}{r^2}$$

$$F_x = F_2 - F_3(\cos 60.0°)$$

$$F_y = F_3(\sin 60.0°)$$

$$F_x = k_C q_1\left(\frac{q_2}{d^2} - \frac{q_3(\cos 60.0°)}{d^2}\right)$$

$$F_x = (8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(8.8 \times 10^{-9}\ \text{C})\left(\frac{2.4 \times 10^{-9}\ \text{C}}{(7.631 \times 10^4\ \text{m})^2} - \frac{(4.0 \times 10^{-9}\ \text{C})(\cos 60.0°)}{(7.631 \times 10^4\ \text{m})^2}\right)$$

$$F_x = 5.5 \times 10^{-18}\ \text{N}$$

$$F_y = -\frac{k_C q_1 q_3(\sin 60.0°)}{r^2}$$

$$F_y = -\frac{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(8.8 \times 10^{-9}\ \text{C})(4.0 \times 10^{-9}\ \text{C})(\sin 60.0°)}{(7.631 \times 10^4\ \text{m})^2}$$

$$F_y = -4.7 \times 10^{-17}\ \text{N}$$

$$F_{net} = \sqrt{F_x{}^2 + F_y{}^2} = \sqrt{(5.5 \times 10^{-18}\ \text{N})^2 + (4.7 \times 10^{-17}\ \text{N})^2} = 4.7 \times 10^{-17}\ \text{N}$$

$$\theta' = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{4.7 \times 10^{-17}\ \text{N}}{5.5 \times 10^{-18}\ \text{N}}\right) = 83°$$

$$\mathbf{F_{net}} = \boxed{4.7 \times 10^{-18}\ \text{N, 83° below the positive } x\text{-axis}}$$

II

Additional Practice C

1. $q_1 = 2.5 \times 10^{-9}$ C

$q_3 = 1.0 \times 10^{-9}$ C

$r_{2,1} = 5.33$ m

$r_{3,1} = 1.90$ m

$$r_{3,2} = r_{2,1} - r_{3,1} = 5.33\ \text{m} - 1.90\ \text{m} = 3.43\ \text{m}$$

$$F_{3,1} = F_{3,2} = k_C\left(\frac{q_3 q_1}{(r_{3,1})^2}\right) = k_C\left(\frac{q_3 q_2}{(r_{3,2})^2}\right)$$

$$q_2 = q_1\left(\frac{r_{3,2}}{r_{3,1}}\right)^2$$

$$q_2 = (2.50 \times 10^{-9}\ \text{C})\left(\frac{3.43\ \text{m}}{1.90\ \text{m}}\right)^2 = \boxed{8.15 \times 10^{-9}\ \text{C}}$$

2. $q_1 = 7.5 \times 10^{-2}$ C

$q_3 = 1.0 \times 10^{-4}$ C

$r_{2,1} = 6.00 \times 10^2$ km

$r_{3,1} = 24$ km

$$r_{3,2} = r_{2,1} - r_{3,1} = 6.00 \times 10^2\ \text{km} - 24\ \text{km} = 576\ \text{km}$$

$$F_{3,1} = F_{3,2} = k_C\left(\frac{q_3 q_1}{(r_{3,1})^2}\right) = k_C\left(\frac{q_3 q_2}{(r_{3,2})^2}\right)$$

$$q_2 = q_1 = \left(\frac{r_{3,2}}{r_{3,1}}\right)^2$$

$$q_2 = (7.5 \times 10^{-2}\ \text{C})\left(\frac{576\ \text{km}}{24\ \text{km}}\right)^2 = \boxed{43\ \text{C}}$$

Givens	*Solutions*
3. $m_E = 6.0 \times 10^{24}$ kg $m_m = 7.3 \times 10^{22}$ kg $G = 6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2$ $k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$	$F_g = F_{electric}$ $\frac{Gm_Em_m}{r^2} = \frac{k_Cq^2}{r^2}$ $q = \sqrt{\frac{Gm_Em_m}{k_C}} = \sqrt{\frac{(6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2)(6.0 \times 10^{24}\ \text{kg})(7.3 \times 10^{22}\ \text{kg})}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$ $q = \boxed{5.7 \times 10^{13}\ \text{C}}$
4. $m = 17.23$ kg $r = 0.800$ m $F_{net} = 167.6$ N $g = 9.81\ \text{m/s}^2$ $k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$	$F_{net} = F_g - F_{electric}$ $F_{net} = mg - \frac{k_Cq^2}{r^2}$ $q = \sqrt{\frac{r^2(mg - F_{net})}{k_C}}$ $q = \sqrt{\frac{(0.800\ \text{m})^2[(17.23\ \text{kg})(9.81\ \text{m/s}^2) - (167.6\ \text{N})]}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$ $q = \boxed{1.0 \times 10^{-5}\ \text{C}}$
5. $m_1 = 9.00$ kg $m_2 = 8.00$ kg $r = 1.00$ m $k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$ $g = 9.81\ \text{m/s}^2$	$F_{g,1} = F_{g,2} + F_{electric}$ $g(m_1 - m_2) = \frac{k_Cq^2}{r^2}$ $q = \sqrt{\frac{gr^2(m_1 - m_2)}{k_C}} = \sqrt{\frac{(9.81\ \text{m/s}^2)(1.00\ \text{m})^2(9.00\ \text{kg} - 8.00\ \text{kg})}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2}}$ $q = \boxed{3.30 \times 10^{-5}\ \text{C}}$
6. $m = 9.2 \times 10^4$ kg $l_1 = 1.00$ m $g = 9.81\ \text{m/s}^2$ $l_2 = 8.00$ m $r = 2.5$ m $k_C = 8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2$	$\tau_1 = \tau_2$ $mgl_1 = \frac{k_Cq^2l_2}{r^2}$ $q = \sqrt{\frac{r^2mgl_1}{k_Cl_2}}$ $q = \sqrt{\frac{(2.5\ \text{m})^2(9.2 \times 10^4\ \text{kg})(9.81\ \text{m/s}^2)(1.00\ \text{m})}{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)(8.00\ \text{m})}} = \boxed{8.9 \times 10^{-3}\ \text{C}}$
7. $q_1 = 2.0$ C $q_2 = 6.0$ C $q_3 = 4.0$ C $L = 2.5 \times 10^9$ m	$F_{net} = 0 = F_1 + F_2$ $k_C\frac{q_1q_3}{x^2} = \frac{k_Cq_2q_3}{(L-x)^2}$ $\frac{q_1}{x^2} = \frac{q_2}{(L-x)^2}$ $(L - x)\sqrt{q_1} = x\sqrt{q_2}$ $\frac{L}{x} - \frac{x}{x} = \sqrt{\frac{q_2}{q_1}}$ $\frac{L}{x} = \sqrt{\frac{q_2}{q_1}} + 1$ $x = \frac{L}{\sqrt{\frac{q_2}{q_1}} + 1} = \frac{2.5 \times 10^9\ \text{m}}{\sqrt{\frac{6.0\ \text{C}}{2.0\ \text{C}}} + 1} = \boxed{9.3 \times 10^8\ \text{m}}$

II

Givens	*Solutions*
8. $q_1 = 55 \times 10^{-6}$ C $q_2 = 137 \times 10^{-6}$ C $q_3 = 14 \times 10^{-6}$ C $L = 87$ m	$F_{net} = 0 = F_1 + F_2$ $k_C \frac{q_1 q_3}{x^2} = \frac{k_C q_2 q_3}{(L-x)^2}$ $\frac{q_1}{x^2} = \frac{q_2}{(L-x)^2}$ $(L-x)\sqrt{q_1} = x\sqrt{q_2}$ $\frac{L}{x} - \frac{x}{x} = \sqrt{\frac{q_2}{q_1}}$ $\frac{L}{x} = \sqrt{\frac{q_2}{q_1}} + 1$ $x = \frac{L}{\sqrt{\frac{q_2}{q_1}} + 1} = \frac{87 \text{ m}}{\sqrt{\frac{137 \times 10^{-6} \text{ C}}{55 \times 10^{-6} \text{ C}}} + 1} = \boxed{34 \text{ m}}$
9. $F = 1.00 \times 10^8$ N $q_1 = 1.80 \times 10^4$ C $q_2 = 6.25 \times 10^4$ C $k_C = 8.99 \times 10^9$ N•m^2/C^2	$F = \frac{k_C q_1 q_2}{r^2}$ $r = \sqrt{\frac{k_C q_1 q_2}{F}}$ $r = \sqrt{\frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.80 \times 10^4 \text{ C})(6.25 \times 10^4 \text{ C})}{1.00 \times 10^8 \text{ N}}}$ $r = \boxed{3.18 \times 10^5 \text{ m}}$
10. $m = 5.00$ kg $q = 4.00 \times 10^{-2}$ C $k_C = 8.99 \times 10^9$ N•m^2/C^2 $g = 9.81$ m/s^2	$F_g = F_{electric}$ $mg = \frac{k_C q^2}{h^2}$ $h = \frac{k_C q^2}{mg}$ $h = \sqrt{\frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(4.00 \times 10^{-2} \text{ C})^2}{(5.00 \text{ kg})(9.81 \text{ m/s}^2)}} = \boxed{542 \text{ m}}$
11. $m = 1.0 \times 10^{-19}$ kg $r = 1.0$ m $q = 1.60 \times 10^{-19}$ C $k_C = 8.99 \times 10^9$ N•m^2/C^2	$F_{res} = F_{electric} = \frac{k_C q^2}{r^2}$ $F_{res} = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(1.60 \times 10^{-19} \text{ C})^2}{(1.0 \text{ m})^2}$ $F_{res} = \boxed{2.3 \times 10^{-28} \text{ N}}$
12. $m = 5.0 \times 10^{-6}$ kg $q = 2.0 \times 10^{-15}$ C $r = 1.00$ m $k_C = 8.99 \times 10^9$ N•m^2/C^2 $G = 6.673 \times 10^{-11}$ N•m^2/kg^2	$F_{net} = F_{electric} + F_g$ $F_{electric} = \frac{k_C q^2}{r^2} = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.0 \times 10^{-15} \text{ C})^2}{(1.00 \text{ m})^2}$ $F_g = \frac{Gm^2}{r^2} = \frac{(6.673 \times 10^{-11} \text{ N•m}^2/\text{kg}^2)(5.0 \times 10^{-6} \text{ kg})^2}{(1.00 \text{ m})^2}$ $F_{net} = 3.6 \times 10^{-20} \text{ N} + 1.7 \times 10^{-21} \text{ N} = \boxed{3.8 \times 10^{-20} \text{ N}}$

Givens | *Solutions*

13. $m = 2.00 \times 10^{-2}$ kg

$q_1 = 2.0 \times 10^{-6}$ C

$q_2 = -8.0 \times 10^{-6}$ C

$r = 1.7$ m

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$g = 9.81$ m/s^2

$$F_{electric} = F_{friction}$$

$$\frac{k_C q_1 q_2}{r^2} = \mu_k mg$$

$$\mu_k = \frac{k_C q_1 q_2}{mgr^2}$$

$$\mu_k = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(2.0 \times 10^{-6}\text{ C})(8.0 \times 10^{-6}\text{ C})}{(2.00 \times 10^{-2}\text{ kg})(9.81\text{ m/s}^2)(1.7\text{ m})^2} = \boxed{0.25}$$

Additional Practice D

1. $r = 3.72$ m

$E = 0.145$ N/C

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$\theta = 60.0°$

$$E = \frac{k_C q}{r^2}$$

$$E_x = \left(\frac{k_C q}{r^2}\right)(\cos 60.0°) - \left(\frac{k_C q}{r^2}\right)(\cos 60.0°) = 0 \text{ N/C}$$

Because $E_x = 0$ N/C, the electric field points directly upward.

$$E_y = \frac{2k_C q(\sin 60.0°)}{r^2}$$

$$q = \frac{E_y r^2}{2k_C(\sin 60.0°)} = \frac{(0.145\text{ N/C})(3.72\text{ m})^2}{(2)(8.99 \times 10^9\text{ N•m}^2/\text{C}^2)(\sin 60.0°)} = \boxed{1.29 \times 10^{-10}\text{ C}}$$

2. $\Delta y = 190$ m

$q_1 = 1.2 \times 10^{-8}$ C

$\Delta x = 120$ m

$E_x = 1.60 \times 10^{-2}$ N/C

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$$E = \frac{k_C q}{r^2}$$

$$E_x = E_1 + E_2(\cos\theta) = \frac{k_C q_1}{\Delta x^2} + \frac{k_C q_2(\Delta x)}{(\Delta x^2 + \Delta y^2)\sqrt{\Delta x^2 + \Delta y^2}}$$

$$q_2 = \left(E_x - \frac{k_C q_1}{\Delta x^2}\right)\left(\frac{(\Delta x^2 + \Delta y^2)^{3/2}}{k_C \Delta x}\right)$$

$$E_x - \frac{k_C q_1}{\Delta x^2} = \left(1.60 \times 10^{-2}\text{ N/C} - \frac{(8.99 \times 10^9\text{ N•m}^2/\text{C}^2)(1.2 \times 10^{-8}\text{ C})}{(120\text{ m})^2}\right)$$

$$= 8.5 \times 10^{-3}\text{ N/C}$$

$$\frac{(\Delta x^2 + \Delta y^2)^{3/2}}{k_C \Delta x} = \left(\frac{[(120\text{ m})^2 + (190\text{ m})^2]^{3/2}}{(8.99 \times 10^9\text{ N•m}^2/\text{C}^2)(120\text{ m})}\right)$$

$$= 1.0 \times 10^{-5}\text{ C}^2/\text{N}$$

$$q_2 = (8.5 \times 10^{-3}\text{ N/C})(1.0 \times 10^{-5}\text{ C}^2/\text{N}) = \boxed{8.5 \times 10^{-8}\text{ C}}$$

3. $q_1 = 1.80 \times 10^{-5}$ C

$q_2 = -1.20 \times 10^{-5}$ C

$\mathbf{E_{net}} = 22.3$ N/C toward q_2

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$$\mathbf{E_{net}} = \frac{k_C}{r^2}(q_1 + q_2) \qquad r^2 = \frac{k_C}{\mathbf{E_{net}}}(q_1 + q_2)$$

$$r = \sqrt{\frac{k_C(q_1 + q_2)}{\mathbf{E_{net}}}}$$

$$r = \sqrt{\frac{(8.99 \times 10^9\text{ N•m}^2/\text{C}^2)[(1.80 \times 10^{-5}\text{ C}) + (1.20 \times 10^{-5}\text{ C})]}{22.3\text{ N/C toward } q_2}}$$

$$r = \boxed{1.10 \times 10^2\text{ m}}$$

Givens	Solutions
4. $d = 86.5$ m $q_1 = 4.8 \times 10^{-9}$ C $q_2 = 1.6 \times 10^{-8}$ C	$E_{net} = E_1 + E_2 = 0$ $E_1 = E_2$ $\frac{q_1}{x^2} = \frac{q_2}{(d-x)^2}$ $(d-x)\sqrt{q_1} = x\sqrt{q_2}$ $x\left(\sqrt{q_1} + \sqrt{q_2}\right) = d\sqrt{q_1}$ $x = \frac{d\sqrt{q_1}}{\left(\sqrt{q_1} + \sqrt{q_2}\right)} = \frac{(86.5\text{ m})\sqrt{4.8 \times 10^{-9}\text{ C}}}{\sqrt{(4.8 \times 10^{-9}\text{ C})} + \sqrt{(1.6 \times 10^{-8}\text{ C})}}$ $x = \boxed{3.0 \times 10^1\text{ m}}$
5. $q = 3.6 \times 10^{-6}$ C $L = 960$ m $w = 750$ m $k_C = 8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2$	$E = \frac{k_C q}{r^2}$ $E_y = E_1 + E_2(\sin\theta) = \frac{k_C q}{w^2} + \frac{k_C q w}{\sqrt{w^2 + L^2}(w^2 + L^2)}$ $E_y = k_C q\left(\frac{1}{w^2} + \frac{w}{(w^2 + L^2)^{3/2}}\right)$ $E_y = (8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(3.6 \times 10^{-6}\text{ C})\left[\frac{1}{(750\text{ m})^2} + \frac{750\text{ m}}{[(750\text{ m})^2 + (960\text{ m})^2]^{3/2}}\right]$ $E_y = 7.1 \times 10^{-2}$ N/C $E_x = E_3 + E_2(\cos\theta) = \frac{k_C q}{L^2} + \frac{k_C q L}{\sqrt{w^2 + L^2}(w^2 + L^2)}$ $E_x = k_C q\left(\frac{1}{L^2} + \frac{L}{(w^2 + L^2)^{3/2}}\right)$ $E_x = (8.99 \times 10^9\text{ N}\bullet\text{m}^2/\text{C}^2)(3.6 \times 10^{-6}\text{ C})\left[\frac{1}{(960\text{ m})^2} + \frac{960\text{ m}}{[(750\text{ m})^2 + (960\text{ m})^2]^{3/2}}\right]$ $E_x = 5.2 \times 10^{-2}$ N/C $E_{net} = \sqrt{E_y{}^2 + E_x{}^2} = \sqrt{(7.1 \times 10^{-2}\text{ N/C})^2 + (5.2 \times 10^{-2}\text{ N/C})^2} = 8.8 \times 10^{-2}$ N/C $\theta' = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{7.1 \times 10^{-2}\text{ N/C}}{5.2 \times 10^{-2}\text{ N/C}}\right) = 54°$ $\mathbf{E_{net}} = \boxed{8.8 \times 10^{-2}\text{ N/C, 54° above the horizontal}}$

Givens

6. $w = 218$ m

$h = 50.0$ m

$q = 6.4 \times 10^{-9}$ C

$k_C = 8.99 \times 10^9$ N•m^2/C^2

$q_1 = q_2 = q$

$q_3 = 3q$

$q_4 = 2q$

Solutions

$$r = \frac{\sqrt{h^2 + w^2}}{2} = \frac{\sqrt{(50.0 \text{ m})^2 + (218 \text{ m})^2}}{2} = 112 \text{ m}$$

$$\theta = \tan^{-1}\left(\frac{h}{w}\right) = \tan^{-1}\left(\frac{50.0 \text{ m}}{218 \text{ m}}\right) = 12.9°$$

The electric fields of charges on opposite corners of the rectangle cancel to give $2q$ on the lower left corner and q on the lower right corner.

$$E = \frac{k_C q}{r^2}$$

$$E_x = \left(\frac{k_C 2q}{r^2} - \frac{k_C q}{r^2}\right)(\cos\theta) = \frac{k_C q(\cos\theta)}{r^2}$$

$$E_x = \frac{(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(6.4 \times 10^{-9} \text{ C})(\cos 12.9°)}{(112 \text{ m})^2} = 4.5 \times 10^{-3} \text{ N/C}$$

$$E_y = \left(\frac{k_C 2q}{r^2} + \frac{k_C q}{r^2}\right)(\sin\theta) = \frac{3k_C q(\sin\theta)}{r^2}$$

$$E_y = \frac{(3)(8.99 \times 10^9 \text{ N•m}^2/\text{C}^2)(6.4 \times 10^{-9} \text{ C})(\sin 12.9°)}{(112 \text{ m})^2} = 3.1 \times 10^{-3} \text{ N/C}$$

$$E_{net} = \sqrt{E_x{}^2 + E_y{}^2} = \sqrt{(4.5 \times 10^{-3} \text{ N/C})^2 + (3.1 \times 10^{-3} \text{ N/C})^2}$$

$$E_{net} = 5.5 \times 10^{-3} \text{ N/C}$$

$$\theta' = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{3.1 \times 10^{-3} \text{ N/C}}{4.5 \times 10^{-3} \text{ N/C}}\right) = 35°$$

$\mathbf{E_{net}}$ = $\boxed{5.5 \times 10^{-3} \text{ N/C, 35° above the positive } x\text{-axis}}$

II

Electrical Energy and Current

Additional Practice A

Givens	*Solutions*
1. $r = 4.8 \times 10^{-4}$ m $q = 2.9 \times 10^{-9}$ C	$\Delta V = k_C \dfrac{q}{r} = (8.99 \times 10^9\ \mathrm{N \bullet m^2/C^2})\left(\dfrac{2.9 \times 10^{-9}\ \mathrm{C}}{2.8 \times 10^{-4}\ \mathrm{m}}\right) = \boxed{5.4 \times 10^4\ \mathrm{V}}$
2. $q = -1.6 \times 10^{-19}$ C $\Delta PE_{electric} = 3.3 \times 10^{-15}$ J $d = 3.5$ cm	$\Delta PE_{electric} = -qEd$ Rearrange to solve for E. $E = \dfrac{\Delta PE_{electric}}{-qd} = \dfrac{3.3 \times 10^{-15}\ \mathrm{J}}{-(-1.6 \times 10^{-19}\ \mathrm{C})(0.035\ \mathrm{m})} = \boxed{5.9 \times 10^5\ \dfrac{\mathrm{N}}{\mathrm{C}}}$
3. $\Delta PE_{electric} = 3.1 \times 10^{-12}$ J $d = 4.7$ cm $\Delta V = -73$ V	**a.** $\Delta V = -Ed$ Rearrange to solve for E. $E = -\dfrac{\Delta V}{d} = \dfrac{-73\ \mathrm{V}}{4.7 \times 10^{-2}\ \mathrm{m}} = \boxed{1.6 \times 10^3\ \dfrac{\mathrm{N}}{\mathrm{C}}}$
$\Delta PE_{electric} = 3.1 \times 10^{-12}$ J $d = 4.7$ cm $\Delta V = -73$ V	**b.** $\Delta V = \dfrac{\Delta PE_{electric}}{q}$ Rearrange to solve for q. $q = \dfrac{\Delta PE_{electric}}{\Delta V} = \dfrac{3.1 \times 10^{-12}\ \mathrm{J}}{-73\mathrm{V}} = \boxed{-4.2 \times 10^{-14}\ \mathrm{C}}$
4. $d = 9.35$ m $\Delta PE_{electric} = 3.17 \times 10^{-10}$ J $E = 1.25 \times 10^5$ N/C	**a.** $\Delta PE_{electric} = -qEd$ Rearrange to solve for q. $q = -\dfrac{\Delta PE_{electric}}{Ed} = -\dfrac{3.17 \times 10^{-10}\ \mathrm{J}}{(1.25 \times 10^5\ \mathrm{N/C})(9.35\ \mathrm{m})}$ $q = \boxed{-2.71 \times 10^{-16}\ \mathrm{C}}$
$d = 9.35$ m $\Delta PE_{electric} = 3.17 \times 10^{-10}$ J $E = 1.25 \times 10^5$ N/C	**b.** $\Delta PE_{electric} = -qEd$ Rearrange to solve for q. $q = -\dfrac{\Delta PE_{electric}}{Ed} = -\dfrac{3.17 \times 10^{-10}\ \mathrm{J}}{(1.25 \times 10^5\ \mathrm{N/C})(9.35\ \mathrm{m})}$ $q = -2.71 \times 10^{-16}$ C $\Delta V = \dfrac{\Delta PE_{electric}}{q} = \dfrac{3.17 \times 10^{-10}\ \mathrm{J}}{-2.71 \times 10^{-16}\ \mathrm{C}} = \boxed{-1.17 \times 10^6\ \mathrm{V}}$

II

Givens	Solutions
5. $E = 1.5 \times 10^2$ N/C $d = 439$ m $\Delta PE_{electric} = -3.7 \times 10^{-8}$ J	**a.** $q = -\frac{\Delta PE_{electric}}{Ed} = -\frac{-3.7 \times 10^{-8}\text{ J}}{(1.5 \times 10^2\text{ N/C})(439\text{ m})}$ $q = \boxed{5.6 \times 10^{-13}\text{ C}}$
$E = 1.5 \times 10^2$ N/C $d = 439$ m $\Delta PE_{electric} = -3.7 \times 10^{-8}$ J	**b.** $\Delta V = -Ed = -(1.5 \times 10^2\text{ N/C})(439\text{ m})$ $\Delta V = \boxed{-6.6 \times 10^4\text{ V}}$
$E = 1.5 \times 10^2$ N/C $d = 439$ m $\Delta PE_{electric} = -3.7 \times 10^{-8}$ J	**c.** Use the value for q found in part a. $V = \frac{\Delta PE_{electric}}{q} = \frac{-3.7 \times 10^{-8}\text{ J}}{5.6 \times 10^{-13}\text{ C}} = \boxed{-6.6 \times 10^4\text{ V}}$
6. $E = 6.5 \times 10^2$ N/C $d = 0.077$ cm	$\Delta V = -Ed = -(6.5 \times 10^2\text{ N/C})(7.7 \times 10^{-4}\text{ m}) = -5.0 \times 10^{-1}\text{ V}$ The absolute value gives the magnitude of the potential difference. $\left\|-5.0 \times 10^{-1}\text{ V}\right\| = \boxed{5.0 \times 10^{-1}\text{ V}}$
7. $q = 1.6 \times 10^{-19}$ C $E = 383$ N/C $d = 3.75$ m	**a.** $\Delta V = -Ed = -(383\text{ N/C})(3.75\text{ m}) = -1.44 \times 10^3\text{ V}$ $\left\|-1.44 \times 10^3\text{ V}\right\| = \boxed{1.44 \times 10^3\text{ V}}$
$q = 1.6 \times 10^{-19}$ C $E = 383$ N/C $d = 3.75$ m	**b.** $\Delta V = -Ed = -(383\text{ N/C})(3.75\text{ m}) = -1.44 \times 10^3\text{ V}$ $\Delta V = \frac{\Delta PE_{electric}}{q}$ Rearrange to solve for $\Delta PE_{electric}$. $\Delta PE_{electric} = \Delta Vq = (-1.44 \times 10^3\text{ V}) \times (1.6 \times 10^{-19}\text{ C})$ $\Delta PE_{electric} = \boxed{-2.3 \times 10^{-16}\text{ J}}$
8. $q = -4.8 \times 10^{-19}$ C $d = -0.63$ cm $E = 279$ V/m	**a.** $\text{V} = \frac{\text{N•m}}{\text{C}}$; Rearrange to get $\frac{\text{V}}{\text{m}} = \frac{\text{N}}{\text{C}}$ 279 V/m = 279 N/C $\Delta PE_{electric} = -qEd = (-4.8 \times 10^{-19}\text{ C})(279\text{ N/C})(-6.3 \times 10^{-3}\text{ m})$ $\Delta PE_{electric} = \boxed{-8.4 \times 10^{-19}\text{ J}}$
$q = -4.8 \times 10^{-19}$ C $d = -0.63$ cm $E = 279$ V/m	**b.** $\text{V} = \frac{\text{N•m}}{\text{C}}$; Rearrange to get $\frac{\text{V}}{\text{m}} = \frac{\text{N}}{\text{C}}$ 279 V/m = 279 N/C $\Delta PE_{electric} = -qEd = (-4.8 \times 10^{-19}\text{ C})(279\text{ N/C})(-6.3 \times 10^{-3}\text{ m})$ $\Delta PE_{electric} = -8.4 \times 10^{-19}$ J Find the electric potential associated with a charged particle. $V = \frac{PE_{electric}}{q} = \frac{-8.4 \times 10^{-19}\text{ J}}{-4.8 \times 10^{-19}\text{ C}} = \boxed{1.8\text{ V}}$

II

Additional Practice B

Givens	*Solutions*
1. $\Delta V = 3.00 \times 10^2$ V $PE_{electric} = 17.1$ kJ	$PE_{electric} = \frac{1}{2}C(\Delta V)^2$ $C = \frac{2PE_{electric}}{(\Delta V)^2}$ $C = \frac{2(17.1 \times 10^3\ \text{J})}{(3.00 \times 10^2\ \text{V})^2}$ $C = \boxed{3.80 \times 10^{-1}\ \text{F}}$
2. $PE_{electric} = 1450$ J $\Delta V = 1.0 \times 10^4$ V	$PE_{electric} = \frac{1}{2}C(\Delta V)^2$ $C = \frac{2PE_{electric}}{(\Delta V)^2}$ $C = \frac{2(1450\ \text{J})}{(1.0 \times 10^4\ \text{V})^2}$ $C = \boxed{2.9 \times 10^{-5}\ \text{F}}$
3. $E_{max} = 3.0 \times 10^6$ V/m $d = 0.2 \times 10^{-3}$ m $A = 6.7 \times 10^3\ \text{m}^2$ $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$	$\Delta V_{max} = E_{max}d$ $\Delta V_{max} = \frac{Q_{max}}{C} = \frac{Q_{max}}{\left(\frac{\varepsilon_0 A}{d}\right)}$ $E_{max}d = \frac{Q_{max}}{\left(\frac{\varepsilon_0 A}{d}\right)}$ $Q_{max} = E_{max}\varepsilon_0 A$ $Q_{max} = (3.0 \times 10^6\ \text{V/m})(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(6.7 \times 10^3\ \text{m}^2)$ $Q_{max} = \boxed{0.18\ \text{C}}$
4. $r = 3.1$ m $d = 1.0 \times 10^{-3}$ m $E_{max} = 3.0 \times 10^6$ V/m $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$	$Q_{max} = C\Delta V_{max} = CE_{max}d$ $C = \frac{\varepsilon_0 A}{d}$ $Q_{max} = \varepsilon_0 AE_{max} = \varepsilon_0 \pi r^2 E_{max}$ $Q_{max} = (8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(\pi)(3.1\ \text{m})^2(3.0 \times 10^6\ \text{V/m})$ $Q_{max} = \boxed{8.0 \times 10^{-4}\ \text{C} = 0.80\ \text{mC}}$
5. $P = 5.0 \times 10^{15}$ W $\Delta t = 1.0 \times 10^{-12}$ s $C = 0.22$ F	$PE_{electric} = \frac{1}{2}C(\Delta V)^2$ $PE_{electric} = P\Delta t$ $P\Delta t = \frac{1}{2}C(\Delta V)^2$ $\Delta V = \sqrt{\frac{2P\Delta t}{C}}$ $\Delta V = \sqrt{\frac{2(5.0 \times 10^{15}\ \text{W})(1.0 \times 10^{-12}\ \text{s})}{(0.22\ \text{F})}}$ $\Delta V = \boxed{210\ \text{V}}$

II

Givens | *Solutions*

6. $A = 2.32 \times 10^5\ \text{m}^2$

$d = 1.5 \times 10^{-2}\ \text{m}$

$Q = 0.64 \times 10^{-3}\ \text{C}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$

$$PE_{electric} = \frac{1}{2}\frac{Q^2}{C}$$

$$C = \frac{\varepsilon_0 A}{d}$$

$$PE_{electric} = \frac{1}{2}\frac{Q^2 d}{\varepsilon_0 A}$$

$$PE_{electric} = \frac{1}{2}\frac{(0.64 \times 10^{-3}\ \text{C})^2(1.5 \times 10^{-2}\ \text{m})}{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(2.32 \times 10^5\ \text{m}^2)}$$

$$PE_{electric} = \boxed{1.5 \times 10^{-3}\ \text{J}}$$

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7. $r = 18.0\ \text{m}$

$\Delta V = 575\ \text{V}$

$PE_{electric} = 3.31\ \text{J}$

$$PE_{electric} = \tfrac{1}{2}C(\Delta V)^2$$

$$C = \frac{2\ PE_{electric}}{(\Delta V)^2} = \frac{2(3.31\ \text{J})}{(575\ \text{V})^2}$$

$$C = \boxed{2.00 \times 10^{-5}\ \text{F}}$$

$$d = \frac{\varepsilon_0 A}{C} = \frac{\varepsilon_0 \pi r^2}{C}$$

$$d = \frac{(8.85 \times 10^{-12}\ \text{C2/N}\bullet\text{m2})(\pi)(18.0\ \text{m})^2}{(2.00 \times 10^{-5}\ \text{F})}$$

$$d = 4.5 \times 10^{-4}\ \text{m} = \boxed{0.45\ \text{mm}}$$

---

8. $d_i = 5.00 \times 10^{-3}\ \text{m}$

$d_f = 0.30 \times 10^{-3}\ \text{m}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$

$A = 1.20 \times 10^{-4}\ \text{m}^2$

$$\Delta C = C_f - C_i = \frac{\varepsilon_0 A}{d_f} - \frac{\varepsilon_0 A}{d_i}$$

$$\Delta C = \varepsilon_0 A\left(\frac{1}{d_f} - \frac{1}{d_i}\right)$$

$$\Delta C = \left(8.85 \times 10^{-12}\frac{\text{C}^2}{\text{N}\bullet\text{m}^2}\right)(1.20 \times 10^{-4}\ \text{m}^2)\left(\frac{1}{0.30 \times 10^{-3}\ \text{m}} - \frac{1}{5.00 \times 10^{-3}\ \text{m}}\right)$$

$$\Delta C = \boxed{3.3 \times 10^{-12}\ \text{F} = -3.3\ \text{pF}}$$

---

9. $A = 98 \times 10^6\ \text{m}^2$

$C = 0.20\ \text{F}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$

$$C = \frac{\varepsilon_0 A}{d}$$

$$d = \frac{\varepsilon_0 A}{C}$$

$$d = \frac{(8.85 \times 10^{-12}\text{C}^2/\text{N}\bullet\text{m}^2)(98 \times 10^6\ \text{m}^2)}{(0.20\ \text{F})}$$

$$d = \boxed{4.3 \times 10^{-3}\ \text{m} = 4.3\ \text{mm}}$$

Givens | *Solutions*

10. $A = 7.0\ \text{m} \times 12.0\ \text{m}$

$d = 1.0 \times 10^{-3}\ \text{m}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$

$PE_{electric} = 1.0\ \text{J}$

a. $C = \dfrac{\varepsilon_0 A}{d}$

$$C = \frac{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(7.0\ \text{m})(12.0\ \text{m})}{(1.0 \times 10^{-3}\ \text{m})}$$

$$C = \boxed{7.4 \times 10^{-7}\ \text{F} = 0.74\ \mu\text{F}}$$

b. $PE_{electric} = \frac{1}{2}C(\Delta V)^2$

$$\Delta V = \sqrt{\frac{2PE_{electric}}{C}}$$

$$\Delta V = \sqrt{\frac{2(1.0\ \text{J})}{(7.4 \times 10^{-7}\ \text{F})}}$$

$$\Delta V = \boxed{1.6 \times 10^3\ \text{V} = 1.6\ \text{kV}}$$

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11. $A = 44\ \text{m}^2$

$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2$

$Q = 2.5 \times 10^{-6}\ \text{C}$

$\Delta V = 30.0\ \text{V}$

a. $C = \dfrac{Q}{\Delta V}$

$$C = \frac{(2.5 \times 10^{-6}\ \text{C})}{(30.0\ \text{V})}$$

$$C = \boxed{8.3 \times 10^{-8}\ \text{F} = 83\ \text{nF}}$$

b. $C = \dfrac{\varepsilon_0 A}{d}$

$$d = \frac{\varepsilon_0 A}{C}$$

$$d = \frac{(8.85 \times 10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)(44\ \text{m}^2)}{(8.3 \times 10^{-8}\ \text{F})}$$

$$d = \boxed{4.7 \times 10^{-3}\ \text{m}}$$

c. $PE_{electric} = \frac{1}{2}Q\Delta V$

$$PE_{electric} = \tfrac{1}{2}(2.5 \times 10^{-6}\ \text{C})(30.0\ \text{V})$$

$$PE_{electric} = \boxed{3.8 \times 10^{-5}\ \text{J}}$$

II

Additional Practice C

1. $I = 3.00 \times 10^2\ \text{A}$

$\Delta t = 2.4\ \text{min}$

$\Delta Q = I\Delta t$

$$\Delta Q = (3.00 \times 10^2\ \text{A})(2.4\ \text{min})\left(\frac{60\ \text{s}}{1\ \text{min}}\right)$$

$$\Delta Q = \boxed{4.3 \times 10^4\ \text{C}}$$

Givens	*Solutions*
2. $\Delta t = 7$ min, 29 s $I = 0.22$ A	$\Delta Q = I\Delta t$ $\Delta Q = (0.22\ \text{A})\left[(7\ \text{min})\left(\frac{60\ \text{s}}{1\ \text{min}}\right) + 29\ \text{s}\right] = (0.22\ \text{A})(449\ \text{s})$ $\Delta Q = \boxed{99\ \text{C}}$
3. $\Delta t = 3.3 \times 10^{-6}$ s $I = 0.88$ A $q = e = 1.60 \times 10^{-19} \frac{\text{C}}{\text{electron}}$	$\Delta Q = I\Delta t = nq$ $n = \frac{I\Delta t}{q}$ $n = \frac{(0.88\ \text{A})(3.3 \times 10^{-6}\ \text{s})}{(1.60 \times 10^{-19}\ \text{C/electron})}$ $n = \boxed{1.8 \times 10^{13}\ \text{electrons}}$
4. $\Delta t = 3.00$ h $\Delta Q = 1.51 \times 10^4$ C	$I = \frac{\Delta Q}{\Delta t}$ $I = \frac{(1.51 \times 10^4\ \text{C})}{(3.00\ \text{h})\left(\frac{3.60 \times 10^3\ \text{s}}{1\ \text{h}}\right)}$ $I = \boxed{1.40\ \text{A}}$
5. $\Delta Q = 1.8 \times 10^5$ C $\Delta t = 6.0$ min	$I = \frac{\Delta Q}{\Delta t}$ $I = \frac{(1.8 \times 10^5\ \text{C})}{(6.0\ \text{min})\left(\frac{60\ \text{s}}{1\ \text{min}}\right)}$ $I = \boxed{5.0 \times 10^2\ \text{A}}$
6. $I = 13.6$ A $Q = 4.40 \times 10^5$ C	$\Delta t = \frac{\Delta Q}{I}$ $\Delta t = \frac{(4.40 \times 10^5\ \text{C})}{(13.6\ \text{A})}$ $\Delta t = \boxed{3.24 \times 10^4\ \text{s} = 9.00\ \text{h}}$

Additional Practice D

1. $\Delta V = 440$ V $I = 0.80$ A	$R = \frac{\Delta V}{I}$ $R = \frac{(440\ \text{V})}{(0.80\ \text{A})}$ $R = \boxed{5.5 \times 10^2\ \Omega}$

II

Givens	*Solutions*
2. $\Delta V = 9.60$ V $I = 1.50$ A	$R = \frac{\Delta V}{I}$ $R = \frac{(9.60\ \text{V})}{(1.50\ \text{A})}$ $R = \boxed{6.40\ \Omega}$
3. $\Delta V = 312$ V $\Delta Q = 2.8 \times 10^5$ C $\Delta t = 1.00$ h	$I = \frac{\Delta Q}{\Delta t}$ $R = \frac{\Delta V}{I} = \frac{\Delta V}{\left(\frac{\Delta Q}{\Delta t}\right)} = \frac{\Delta V \Delta t}{\Delta Q}$ $R = \frac{(312\ \text{V})(1.00\ \text{h})\left(\frac{3.60 \times 10^3\ \text{s}}{1\ \text{h}}\right)}{(2.8 \times 10^5\ \text{C})}$ $R = \boxed{4.0\ \Omega}$
4. $I = 3.8$ A $R = 0.64\ \Omega$	$\Delta V = IR$ $\Delta V = (3.8\ \text{A})(0.64\ \Omega)$ $\Delta V = \boxed{2.4\ \text{V}}$
5. $R = 0.30\ \Omega$ $I = 2.4 \times 10^3$ A	$\Delta V = IR = (2.4 \times 10^3\ \text{A})(0.30\ \Omega) = \boxed{7.2 \times 10^2\ \text{V}}$
6. $\Delta V = 3.0$ V $R = 16\ \Omega$	$I = \frac{\Delta V}{R}$ $I = \frac{(3.0\ \text{V})}{(16\ \Omega)}$ $I = \boxed{0.19\ \text{A}}$
7. $\Delta V = 6.00 \times 10^2$ V $R = 4.4\ \Omega$	$I = \frac{\Delta V}{R} = \frac{(6.00 \times 10^2\ \text{V})}{(4.4\ \Omega)} = \boxed{1.4 \times 10^2\ \text{A}}$

Additional Practice E

1. $P = 12 \times 10^3$ W $R = 2.5 \times 10^2\ \Omega$	$P = I^2R$ $I = \sqrt{\frac{P}{R}}$ $I = \sqrt{\frac{(12 \times 10^3\ \text{W})}{(2.5 \times 10^2\ \Omega)}}$ $I = \boxed{6.9\ \text{A}}$

II

Givens | *Solutions*

2. $P = 33.6 \times 10^3$ W

$\Delta V = 4.40 \times 10^2$ V

$P = I\Delta V$

$I = \frac{P}{\Delta V}$

$I = \frac{(33.6 \times 10^3 \text{ W})}{(4.40 \times 10^2 \text{ V})}$

$I = \boxed{76.4 \text{ A}}$

---

3. $P = 850$ W

$V = 12.0$ V

$P = I\Delta V$

$I = \frac{P}{\Delta V}$

$I = \frac{850 \text{ W}}{12.0 \text{ V}}$

$I = \boxed{70.8 \text{ A}}$

II

4. $P = \left(\frac{4.2 \times 10^{10} \text{ J}}{1.1 \times 10^3 \text{ h}}\right)$

$R = 40.0\ \Omega$

$P = \frac{(\Delta V)^2}{R}$

$\Delta V = \sqrt{PR}$

$\Delta V = \sqrt{\left(\frac{4.2 \times 10^{10} \text{ J}}{1.1 \times 10^3 \text{ h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)(40.0\ \Omega)}$

$\Delta V = \boxed{6.5 \times 10^2\ V}$

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5. $P = 6.0 \times 10^{13}$ W

$\Delta V = 8.0 \times 10^6$ V

$P = \frac{(\Delta V)^2}{R}$

$R = \frac{(\Delta V)^2}{P}$

$R = \frac{(8.0 \times 10^6 \text{ V})^2}{(6.0 \times 10^{13} \text{ W})}$

$R = \boxed{1.1\ \Omega}$

---

6. $I = 6.40 \times 10^3$ A

$\Delta V = 4.70 \times 10^3$ V

$P = I\Delta V$

$P = (6.40 \times 10^3 \text{ A})(4.70 \times 10^3 \text{ V})$

$P = \boxed{3.01 \times 10^7 \text{ W} = 30.1 \text{ MW}}$

Additional Practice F

Givens | *Solutions*

1. $q_1 = -12.0 \times 10^{-9}$ C

$q_2 = -68.0 \times 10^{-9}$ C

$V = -25.3$ V

$r_1 = 16.0$ m

$r_2 = d - r_1$

$k_C = 8.99 \times 10^9 \dfrac{\text{N}\bullet\text{m}^2}{\text{C}^2}$

$$V = k_C\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right] = k_C\left[\frac{q_1}{r_1} + \frac{q_2}{(d - r_1)}\right]$$

$$\frac{V}{k_C} - \frac{q_1}{r_1} + \frac{q_2}{(d - r_1)}$$

$$d = \frac{q_2}{\left[\dfrac{V}{k_C} - \dfrac{q_1}{r_1}\right]} + r_1$$

$$d = \frac{-68.0 \times 10^{-9}\ \text{C}}{\left[\dfrac{-25.3\ \text{V}}{8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2} - \dfrac{(-12.0 \times 10^{-9}\ \text{C})}{16.0\ \text{m}}\right]} + 16.0\ \text{m}$$

$$d = 33.0\ \text{m} + 16.0\ \text{m} = \boxed{49.0\ \text{m}}$$

---

2. $q_1 = 18.0 \times 10^{-9}$ C

$q_2 = 92.0 \times 10^{-9}$ C

$V = 53.3$ V

$r_1 = d - r_2$

$d = 97.5$ m

$k_C = 8.99 \times 10^9 \dfrac{\text{N}\bullet\text{m}^2}{\text{C}^2}$

$$V = k_C \sum \frac{q}{r} = k_C\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V = k_C\left(\frac{q_1}{d - r_2} + \frac{q_2}{r_2}\right)$$

$$\left(\frac{V}{k_C}\right) = \frac{(q_1 r_2 + q_2 d - q_2 r_2)}{(d - r_2)(r_2)}$$

$$-\left(\frac{V}{k_C}\right) r_2{}^2 + \left(\frac{V}{k_C}\right) d r_2 = (q_1 - q_2) r_2 + q_2 d$$

$$\left(\frac{V}{k_C}\right) r_2{}^2 + \left(q_1 - q_2 - \frac{Vd}{k_C}\right) r_2 + q_2 d = 0$$

Solve using the quadratic formula:

$$r_2 = \frac{-\left(q_1 - q_2 - \dfrac{Vd}{k_C}\right) \pm \sqrt{\left(q_1 - q_2 - \dfrac{Vd}{k_C}\right)^2 - \left(\dfrac{4Vq_2 d}{k_C}\right)}}{\left(\dfrac{2V}{k_C}\right)}$$

$$\left(q_1 - q_2 - \frac{Vd}{k_C}\right) = 18.0 \times 10^{-9}\ \text{C} - 92.0 \times 10^{-9}\ \text{C} - \left[\frac{(53.3\ \text{V})(97.5\ \text{m})}{\left(8.99 \times 10^9 \dfrac{\text{N}\bullet\text{m}^2}{\text{C}^2}\right)}\right]$$

$$\left(q_1 - q_2 - \frac{Vd}{k_C}\right) = -652 \times 10^{-9}\ \text{C}$$

$$\frac{4Vq_2 d}{k_C} = \frac{4(53.3\ \text{V})(92.0 \times 10^{-9}\ \text{C})(97.5\ \text{m})}{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)} = 2.13 \times 10^{-13}\ \text{C}^2$$

$$\frac{2V}{k_C} = \frac{2(53.3\ \text{V})}{(8.99 \times 10^9\ \text{N}\bullet\text{m}^2/\text{C}^2)} = 11.9 \times 10^{-9}\ \frac{\text{C}}{\text{m}}$$

$$r_2 = \frac{-(-652 \times 10^{-9}\ \text{C}) \pm \sqrt{(-652 \times 10^{-9}\ \text{C})^2 - (2.13 \times 10^{-13}\ \text{C}^2)}}{(11.9 \times 10^{-9}\ \text{C/m})}$$

$$r_2 = \frac{652 \pm 460}{11.9}\ \text{m}$$

II

Givens | *Solutions*

Of the two roots, the one that yields the correct answer is

$$r_2 = \frac{(652 - 460)}{11.9}\,\text{m}$$

$$r_2 = \boxed{16.1\ \text{m}}$$

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3. $V = 1.0 \times 10^6\ \text{V}$

$r = 12 \times 10^{-2}\ \text{m}$

$k_C = 8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}$

$$V = k_C\frac{q}{r}$$

$$q = \frac{Vr}{k_C}$$

$$q = \frac{(1.0 \times 10^6\ \text{V})(12 \times 10^{-2}\ \text{m})}{\left(8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}\right)}$$

$$q = \boxed{1.3 \times 10^{-5}\ \text{C}}$$

II

4. $M_E = 5.98 \times 10^{24}\ \text{kg}$

$G = 6.673 \times 10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$

$k_C = 8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}$

$m = 1.0\ \text{kg}$

$q = 1.0\ \text{C}$

$$mV_{gravity} = qV_{electric}$$

$$\frac{mM_EG}{r} = \frac{qQ_Ek_C}{r}$$

$$Q_E = \frac{mM_EG}{qk_C}$$

$$Q_E = \frac{(1.0\ \text{kg})(5.98 \times 10^{24}\ \text{kg})\left(6.673 \times 10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)}{(1.0\ \text{C})\left(8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}\right)}$$

$$Q_E = \boxed{4.44 \times 10^4\ \text{C}}$$

---

5. $m_{sun} = 1.97 \times 10^{30}\ \text{kg}$

m_H = mass of hydrogen atom = $1.67 \times 10^{-27}\ \text{kg}$

q_1 = charge of proton = $+1.60 \times 10^{-19}\ \text{C}$

q_2 = charge of electron = $-1.60 \times 10^{-19}\ \text{C}$

$r_1 = 1.1 \times 10^{11}\ \text{m}$

$r_2 = 1.5 \times 10^{11}\ \text{m} - 1.1 \times 10^{11}\ \text{m} = 4.0 \times 10^{10}\ \text{m}$

$k_C = 8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}$

a. Q_+ = charge of proton cloud = (number of protons)$q_1 = \frac{m_{sun}q_1}{m_H}$

$$Q_+ = \frac{(1.97 \times 10^{30}\ \text{kg})(1.60 \times 10^{-19}\ \text{C})}{(1.67 \times 10^{-27}\ \text{kg})}$$

$$Q_+ = \boxed{1.89 \times 10^{38}\ \text{C}}$$

Q_- = charge of electron cloud = $\frac{m_{sun}q_2}{m_H}$

$$Q_- = \boxed{-1.89 \times 10^{38}\ \text{C}}$$

b. $V = k_C\sum\frac{q}{r} = k_C\left(\frac{Q_+}{r_1} + \frac{Q_-}{r_2}\right)$

$$V = \left(8.99 \times 10^9\ \frac{\text{N}\bullet\text{m}^2}{\text{C}^2}\right)\left(\frac{1.89 \times 10^{38}\ \text{C}}{1.1 \times 10^{11}\ \text{m}} - \frac{1.89 \times 10^{38}\ \text{C}}{4.0 \times 10^{10}\ \text{m}}\right)$$

$$V = \boxed{-2.7 \times 10^{37}\ \text{V}}$$

Givens | *Solutions*

6. $r = r_1 = r_2 = r_3 = r_4 = \sqrt{\left(\frac{x}{2}\right)^2 + \left(\frac{y}{2}\right)^2}$

$x = 292$ m

$y = 276$ m

$q = 64 \times 10^{-9}$ C

$q_1 = 1.0q$

$q_2 = -3.0q$

$q_3 = 2.5q$

$q_4 = 4.0q$

$k_C = 8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}$

$$V = k_C \sum \frac{q}{r} = k_C \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \frac{q_4}{r_4} \right)$$

$$V = \frac{k_C q(1.0 - 3.0 + 2.5 + 4.0)}{\sqrt{\left(\frac{x}{2}\right)^2 + \left(\frac{y}{2}\right)^2}}$$

$$V = \frac{\left(8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}\right)(64 \times 10^{-9}\ \text{C})(4.5)}{\sqrt{\left(\frac{292\ \text{m}}{2}\right)^2 + \left(\frac{276\ \text{m}}{2}\right)^2}}$$

$$V = \boxed{13\ \text{V}}$$

---

7. $q_1 = q_2 = q_3 = q$
$= 7.2 \times 10^{-2}$ C

$\ell = 1.6 \times 10^7$ m

$r_1 = r_2 = \frac{\ell}{2}$

$r_3 = \sqrt{\ell^2 - \left(\frac{\ell}{2}\right)^2}$

$k_C = 8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}$

$$V = k_C \sum \frac{q}{r} = k_C \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} \right)$$

$$V = k_C \left(\frac{q}{\left(\frac{\ell}{2}\right)} + \frac{q}{\left(\frac{\ell}{2}\right)} + \frac{q}{\sqrt{\ell^2 - \left(\frac{\ell}{2}\right)^2}} \right) = \frac{k_C q}{\ell} \left(2 + 2 + \frac{1}{\sqrt{1 - \left(\frac{1}{2}\right)^2}} \right)$$

$$V = \frac{\left(8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}\right)(0.072\ \text{C})}{(1.6 \times 10^7\ \text{m})} \left(4 + \frac{1}{\sqrt{\frac{3}{4}}} \right)$$

$$V = \boxed{2.1 \times 10^2\ \text{V}}$$

---

8. $q_1 = q_2 = q_3 = q$
$= 25.0 \times 10^{-9}$ C

$r_1 = r_2 = \ell$

$r_3 = \sqrt{\ell^2 + \ell^2}$

$\ell = 184$ m

$k_C = 8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}$

$$V = k_C \sum \frac{q}{r} = k_C \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} \right)$$

$$V = k_C q \left(\frac{1}{\ell} + \frac{1}{\ell} + \frac{1}{\sqrt{\ell^2 + \ell^2}} \right) = \frac{k_C q}{\ell} \left(1 + 1 + \frac{1}{\sqrt{2}} \right)$$

$$V = \frac{\left(8.99 \times 10^9 \frac{\text{N} \bullet \text{m}^2}{\text{C}^2}\right)(25.0 \times 10^{-9}\ \text{C})}{(184\ \text{m})}(2.707)$$

$$V = \boxed{3.31\ \text{V}}$$

II

Additional Practice G

Givens	*Solutions*
1. $P = 8.8 \times 10^6$ kW total cost = $\$1.0 \times 10^6$ cost of energy = \$0.081/kW•h	total cost of electricity = $P\Delta t$(cost of energy) $\Delta t = \dfrac{\text{total cost of electricity}}{P(\text{cost of energy})}$ $\Delta t = \dfrac{\$1.0 \times 10^6}{(8.8 \times 10^6 \text{ kW})(\$0.081/\text{kW•h})}$ $\Delta t = \boxed{1.4 \text{ h}}$
2. $P = 104$ kW cost of energy = \$0.120/kW•h purchase power = \$18 000	energy that can be purchased = $\dfrac{\text{purchase power}}{\text{cost of energy}} = P\Delta t$ $\Delta t = \dfrac{\text{purchase power}}{(\text{cost of energy})(P)}$ $\Delta t = \dfrac{\$18\ 000}{(\$0.120/\text{kW•h})(104 \text{ kW})}$ $\Delta t = \boxed{1.4 \times 10^3 \text{ h} = 6.0 \times 10^1 \text{ days}}$
3. $\Delta t = 1.0 \times 10^4$ h cost of energy = \$0.086/kW•h total cost = \$23	total cost of electricity = $P\Delta t$(cost of energy) $P = \dfrac{\text{total cost of electricity}}{\Delta t(\text{cost of energy})}$ $P = \dfrac{\$23}{(1.0 \times 10^4 \text{ h})(\$0.086 \text{ kW•h})}$ $P = \boxed{2.7 \times 10^{-2} \text{ kW}}$
4. $\Delta V = 110$ V $R = 80.0\ \Omega$ (for maximum power) $\Delta t = 24$ h cost of energy = \$0.086/kW•h	$P = \dfrac{(\Delta V)^2}{R}$ total cost of electricity = $P\Delta t$(cost of energy) total cost = $\dfrac{(\Delta V)^2(\Delta t)}{R}$(cost of energy) total cost = $\dfrac{(110 \text{ V})^2(24 \text{ h})}{(80.0\ \Omega)}\left(\dfrac{\$0.086}{1 \text{ kW•h}}\right)\left(\dfrac{1 \text{ kW}}{1000 \text{ W}}\right)$ total cost = $\boxed{\$0.31}$
5. 15.5 percent of solar energy converted to electricity cost of energy = \$0.080/kW•h purchase power = \$1000.00	$(0.155)E_{solar} = \dfrac{\text{purchase power}}{\text{cost of energy}}$ $E_{solar} = \dfrac{(\$1000.00)}{(0.155)(\$0.080/\text{kW•h})}$ $E_{solar} = \boxed{8.1 \times 10^4 \text{ kW•h} = 2.9 \times 10^{11} \text{ J}}$

II

Circuits and Circuit Elements

Additional Practice A

Givens	*Solutions*
1. $R = 160\ \text{k}\Omega$ $R_1 = 2.0R$ $R_2 = 3.0R$ $R_3 = 7.5R$	$R_{eq} = R_1 + R_2 + R_3 = 2.0R + 3.0R + 7.5R = 12.5R$ $R_{eq} = (12.5)(160\ \text{k}\Omega) = \boxed{2.0 \times 10^3\ \text{k}\Omega}$
2. $R = 5.0 \times 10^8\ \Omega$ $R_1 = \frac{1}{3}R$ $R_2 = \frac{2}{7}R$ $R_3 = \frac{1}{5}R$	$R_{eq} = R_1 + R_2 + R_3 = \frac{1}{3}R + \frac{2}{7}R + \frac{1}{5}R$ $R_{eq} = \frac{35 + 30 + 21}{105}R = \frac{86}{105}R = \frac{86}{105}(5.0 \times 10^8\ \Omega) = \boxed{4.1 \times 10^8\ \Omega}$
3. $R_1 = 16\ \text{k}\Omega$ $R_2 = 22\ \text{k}\Omega$ $R_3 = 32\ \text{k}\Omega$ $R_{eq} = 82\ \text{k}\Omega$	$R_4 = R_{eq} - R_1 - R_2 - R_3 = 82\ \text{k}\Omega - 16\ \text{k}\Omega - 22\ \text{k}\Omega - 32\ \text{k}\Omega = \boxed{12\ \text{k}\Omega}$
4. $R_1 = 3.0\ \text{k}\Omega$ $R_2 = 4.0\ \text{k}\Omega$ $R_3 = 5.0\ \text{k}\Omega$ $P = (0.0100)(3.2\ \text{MW}) = 0.032\ \text{MW}$	$R_{eq} = R_1 + R_2 + R_3 = 3.0\ \text{k}\Omega + 4.0\ \text{k}\Omega + 5.0\ \text{k}\Omega = 12.0\ \text{k}\Omega$ $P = \frac{(\Delta V)^2}{R}$ $\Delta V = \sqrt{PR_{eq}} = \sqrt{(3.2 \times 10^4\ \text{W})(1.20 \times 10^4\ \Omega)} = \boxed{2.0 \times 10^4\ \text{V}}$
5. $R_1 = 4.5\ \Omega$ $R_2 = 4.0\ \Omega$ $R_3 = 16.0\ \Omega$	$R_{12} = R_1 + R_2 = 4.5\ \Omega + 4.0\ \Omega = \boxed{8.5\ \Omega}$ $R_{13} = R_1 + R_3 = 4.5\ \Omega + 16.0\ \Omega = \boxed{20.5\ \Omega}$ $R_{23} = R_2 + R_3 = 4.0\ \Omega + 16.0\ \Omega = \boxed{20.0\ \Omega}$
6. $R_1 = 2.20 \times 10^2\ \Omega$ $\Delta V_i = 1.20 \times 10^2\ \text{V}$ $\Delta V_f = 138\ \text{V}$	Because the current is unchanged, the following relationship can be written. $\frac{V_i}{R_1} = \frac{V_f}{R_1 + R_2}$ $R_2 = \frac{V_f R_1 - V_i R_1}{V_i} = \frac{(138\ \text{V})(220\ \Omega) - (120\ \text{V})(220\ \Omega)}{120\ \text{V}}$ $R_2 = \frac{30\ 400\ \text{V}\bullet\Omega - 26\ 400\ \text{V}\bullet\Omega}{120\ \text{V}} = \frac{4000\ \text{V}\bullet\Omega}{120\ \text{V}} = \boxed{33\ \Omega}$

II

Givens	*Solutions*
7. $R_1 = 3.6 \times 10^{-5}\ \Omega$ $R_2 = 8.4 \times 10^{-6}\ \Omega$ $I = 280$ A	$R_{eq} = R_1 + R_2 = 3.6 \times 10^{-5}\ \Omega + 8.4 \times 10^{-6}\ \Omega = 4.4 \times 10^{-5}\ \Omega$ $P = I^2 R_{eq} = (280\ \text{A})^2(4.4 \times 10^{-5}\ \Omega) = \boxed{3.4\ \text{W}}$

Additional Practice B

1. $R_1 = 1.8\ \Omega$

$R_2 = 5.0\ \Omega$

$R_3 = 32\ \Omega$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{1.8\ \Omega} + \frac{1}{5.0\ \Omega} + \frac{1}{32\ \Omega}\right)^{-1}$$

$$R_{eq} = \left(0.55\ \frac{1}{\Omega} + 0.20\ \frac{1}{\Omega} + 0.031\ \frac{1}{\Omega}\right)^{-1} = \left(0.78\ \frac{1}{\Omega}\right)^{-1} = \boxed{1.3\ \Omega}$$

2. $R = 450\ \Omega$

$R_1 = R$

$R_2 = 2.0R$

$R_3 = 0.50R$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{450\ \Omega} + \frac{1}{900\ \Omega} + \frac{1}{220\ \Omega}\right)^{-1}$$

$$R_{eq} = \left(0.0022\ \frac{1}{\Omega} + 0.0011\ \frac{1}{\Omega} + 0.0045\ \frac{1}{\Omega}\right)^{-1} = \left(0.0078\ \frac{1}{\Omega}\right)^{-1} = \boxed{1.3 \times 10^2\ \Omega}$$

3. $R_1 = 2.48 \times 10^{-2}\ \Omega$

$R_{eq} = 6.00 \times 10^{-3}\ \Omega$

$$R_2 = \left(\frac{1}{R_{eq}} - \frac{2}{R_1}\right)^{-1} = \left(\frac{1}{6.00 \times 10^{-3}\ \Omega} - \frac{2}{2.48 \times 10^{-2}\ \Omega}\right)^{-1}$$

$$R_2 = \left(167\ \frac{1}{\Omega} - 80.6\ \frac{1}{\Omega}\right)^{-1} = \left(86\ \frac{1}{\Omega}\right)^{-1} = \boxed{0.012\ \Omega}$$

4. $R_1 = R$

$R_2 = 3R$

$R_3 = 7R$

$R_4 = 11R$

$R_{eq} = 6.38 \times 10^{-2}\ \Omega$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{R} + \frac{1}{3R} + \frac{1}{7R} + \frac{1}{11R}\right)^{-1}$$

$$R_{eq} = \left(\frac{231 + 77 + 33 + 21}{231R}\right)^{-1} = \left(\frac{362}{231R}\right)^{-1} = \left(\frac{1.57}{R}\right)^{-1}$$

$$R = 1.57R_{eq} = 1.57(6.38 \times 10^{-2}\ \Omega) = \boxed{0.100\ \Omega}$$

5. ratio $= 1.22 \times 10^{-2}\ \Omega$/m

$\ell = 1813$ km

$R_1 = \frac{1}{2}R$

$R_2 = \frac{1}{4}R$

$R_3 = \frac{1}{5}R$

$R_4 = \frac{1}{20}R$

a. $R = (\text{ratio})(\ell) = (1.22 \times 10^{-2}\ \Omega/\text{m})(1.813 \times 10^6\ \text{m}) = \boxed{2.21 \times 10^4\ \Omega}$

b. $$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{2}{R} + \frac{4}{R} + \frac{5}{R} + \frac{20}{R}\right)^{-1}$$

$$R_{eq} = \left(\frac{31}{R}\right)^{-1} = \left(\frac{31}{1.00 \times 10^{10}\ \Omega}\right)^{-1} = \boxed{3.23 \times 10^8\ \Omega}$$

6. $\Delta V = 14.4$ V

$P = 225$ W

$$P = \frac{(\Delta V)^2}{R}$$

$$R = \frac{(\Delta V)^2}{P} = \frac{(14.4\ \text{V})^2}{225\ \text{W}} = \boxed{0.922\ \Omega}$$

$$R_{eq} = \left(\frac{4}{R}\right)^{-1} = \frac{R}{4} = \frac{0.922\ \Omega}{4} = 0.230\ \Omega$$

$$I = \frac{\Delta V}{R_{eq}} = \frac{14.4\ \text{V}}{0.230\ \Omega} = \boxed{62.6\ \text{A}}$$

II

Givens	Solutions
7. $L = 3.22 \times 10^5$ km $\ell = 1.00 \times 10^3$ km ratio $= 1.0 \times 10^{-2}\ \Omega/\mathrm{m}$ $\Delta V = 1.50$ V	$R_{eq} = \mathrm{N}\left(\frac{1}{\mathrm{R}}\right)$ where $\mathrm{N} = \frac{L}{\ell}$ and $R = (\text{ratio})\ell$ $R_{eq} = \left[\frac{L}{(\text{ratio})\ell^2}\right]^{-1} = \left[\frac{3.22 \times 10^8\ \mathrm{m}}{(1.0 \times 10^{-2}\ \Omega/\mathrm{m})(1.00 \times 10^6\ \mathrm{m})^2}\right]^{-1} = 31\ \Omega$ $I = \frac{\Delta V}{R_{eq}} = \frac{1.50\ \mathrm{V}}{31\ \Omega} = \boxed{0.048\ \mathrm{A}}$

Additional Practice C

Givens	Solutions
1. $R_1 = 6.60 \times 10^2\ \Omega$ $R_2 = 2.40 \times 10^2\ \Omega$ $R_3 = 2.00 \times 10^2\ \Omega$ $R_4 = 2.00 \times 10^2\ \Omega$	$R_{12} = R_1 + R_2 = 660\ \Omega + 240\ \Omega = 900\ \Omega$ $R_{123} = \left(\frac{1}{R_{12}} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{900\ \Omega} + \frac{1}{200\ \Omega}\right)^{-1}$ $R_{123} = \left(0.00111\ \frac{1}{\Omega} + 0.00500\ \frac{1}{\Omega}\right)^{-1} = \left(0.00611\ \frac{1}{\Omega}\right)^{-1} = 164\ \Omega$ $R_{eq} = R_{123} + R_4 = 164\ \Omega + 200\ \Omega = \boxed{364\ \Omega}$
2. $\Delta V = 24$ V $R_1 = 2.0\ \Omega$ $R_2 = 4.0\ \Omega$ $R_3 = 6.0\ \Omega$ $R_4 = 3.0\ \Omega$	$R_{12} = R_1 + R_2 = 2.0\ \Omega + 4.0\ \Omega = 6.0\ \Omega$ $R_{34} = \left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{3.0\ \Omega}\right)^{-1}$ $R_{34} = \left(0.17\ \frac{1}{\Omega} + 0.33\ \frac{1}{\Omega}\right)^{-1} = \left(0.50\ \frac{1}{\Omega}\right)^{-1} = 2.0\ \Omega$ $R_{eq} = \left(\frac{1}{R_{12}} + \frac{1}{R_{34}}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{2.0\ \Omega}\right)^{-1}$ $R_{eq} = \left(0.17\ \frac{1}{\Omega} + 0.50\ \frac{1}{\Omega}\right)^{-1} = \left(0.67\ \frac{1}{\Omega}\right)^{-1} = 1.5\ \Omega$ $I = \frac{\Delta V}{R_{eq}} = \frac{24\ \mathrm{V}}{1.5\ \mathrm{V}} = \boxed{16\ \mathrm{A}}$
3. $R_1 = 2.5\ \Omega$ $R_2 = 3.5\ \Omega$ $R_3 = 3.0\ \Omega$ $R_4 = 4.0\ \Omega$ $R_5 = 1.0\ \Omega$ $\Delta V = 12$ V	$R_{12} = R_1 + R_2 = 2.5\ \Omega + 3.5\ \Omega = 6.0\ \Omega$ $R_{123} = \left(\frac{1}{R_{12}} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{6.0\ \Omega} + \frac{1}{3.0\ \Omega}\right)^{-1}$ $R_{123} = \left(0.17\ \frac{1}{\Omega} + 0.33\ \frac{1}{\Omega}\right)^{-1} = \left(0.50\ \frac{1}{\Omega}\right)^{-1} = 2.0\ \Omega$ $R_{45} = \left(\frac{1}{R_4} + \frac{1}{R_5}\right)^{-1} = \left(\frac{1}{4.0\ \Omega} + \frac{1}{1.0\ \Omega}\right)^{-1}$ $R_{45} = \left(0.25\ \frac{1}{\Omega} + 1.0\ \frac{1}{\Omega}\right)^{-1} = \left(1.2\ \frac{1}{\Omega}\right)^{-1} = 0.83\ \Omega$ $R_{eq} = R_{123} + R_{45} = 2.0\ \Omega + 0.83\ \Omega = \boxed{2.8\ \Omega}$ $I = \frac{\Delta V}{R} = \frac{12\ \mathrm{V}}{2.8\ \Omega} = \boxed{4.3\ \mathrm{A}}$

Givens | *Solutions*

4. $\Delta V = 1.00 \times 10^3$ V

$R_1 = 1.5\ \Omega$

$R_2 = 3.0\ \Omega$

$R_3 = 1.0\ \Omega$

$$R_{12} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{1.5\ \Omega} + \frac{1}{3.0\ \Omega}\right)^{-1}$$

$$R_{12} = \left(0.67\ \frac{1}{\Omega} + 0.33\ \frac{1}{\Omega}\right)^{-1} = \left(1.00\ \frac{1}{\Omega}\right)^{-1} = 1.00\ \Omega$$

$$R_{eq} = R_{12} + R_3 = 1.00\ \Omega + 1.0\ \Omega = \boxed{2.0\ \Omega}$$

$$P = \frac{(\Delta V)^2}{R_{eq}} = \frac{(1.00 \times 10^3\ \text{V})^2}{2.0\ \Omega} = \boxed{5.0 \times 10^5\ \text{W}}$$

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5. $\Delta V = 2.00 \times 10^3$ V

$I = 1.0 \times 10^{-8}$ A

$R_1 = r$

$R_2 = 3r$

$R_3 = 2r$

$R_4 = 4r$

$$R_{eq} = \frac{\Delta V}{I} = \frac{2.00 \times 10^3\ \text{V}}{1.0 \times 10^{-8}\ \text{A}} = \boxed{2.0 \times 10^{11}\ \Omega}$$

$$R_{12} = R_1 + R_2 = r + 3r = 4r$$

$$R_{34} = R_3 + R_4 = 2r + 4r = 6r$$

$$R_{eq} = \left(\frac{1}{R_{12}} + \frac{1}{R_{34}}\right)^{-1} = \left(\frac{1}{4r} + \frac{1}{6r}\right)^{-1}$$

$$R_{eq} = \left(\frac{3+2}{12r}\right)^{-1} = \left(\frac{5}{12r}\right)^{-1} = \frac{12}{5}r$$

$$r = \frac{5}{12}R_{eq} = \frac{5}{12}(2.0 \times 10^{11}\ \Omega) = \boxed{8.3 \times 10^{10}\ \Omega}$$

---

6. $P = 6.0 \times 10^5$ W

$\Delta V = 220$ V

$$R = \frac{(\Delta V)^2}{P} = \frac{(220\ \text{V})^2}{6.0 \times 10^5\ \text{W}} = \boxed{8.1 \times 10^{-2}\ \Omega}$$

$$R_{12} = R_{45} = 2R = 2(0.081\ \Omega) = 0.16\ \Omega$$

$$R_{12345} = \left(\frac{1}{R_{12}} + \frac{1}{R_3} + \frac{1}{R_{45}}\right)^{-1} = \left(\frac{1}{0.16\ \Omega} + \frac{1}{0.081\ \Omega} + \frac{1}{0.16\ \Omega}\right)^{-1}$$

$$R_{12345} = \left(6.2\ \frac{1}{\Omega} + 12\ \frac{1}{\Omega} + 6.2\ \frac{1}{\Omega}\right)^{-1} = \left(24\ \frac{1}{\Omega}\right)^{-1} = 0.042\ \Omega$$

$$R_{eq} = R_{12345} + R_6 = 0.042\ \Omega + 0.081\ \Omega = 0.123\ \Omega$$

$$P = \frac{(\Delta V)^2}{R_{eq}} = \frac{(220\ \text{V})^2}{0.123\ \Omega} = \boxed{3.9 \times 10^5\ \text{W}}$$

Additional Practice D

1. $R = 8.1 \times 10^{-2}\ \Omega$

$R_{eq} = 0.123\ \Omega$

$\Delta V = 220$ V

$R_{12} = R_{45} = 0.16\ \Omega$

$R_{12345} = 0.042\ \Omega$

a. $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{220\ \text{V}}{0.123\ \Omega} = 1800$ A

$$\Delta V_{12345} = IR_{12345} = (1800\ \text{A})(0.042\ \Omega) = 76\ \text{V}$$

$$\Delta V_3 = \Delta V_{12345} = \boxed{76\ \text{V}}$$

$$I_3 = \frac{\Delta V_3}{R_3} = \frac{76\ \text{V}}{8.1 \times 10^{-2}\ \Omega} = \boxed{9.4 \times 10^2\ \text{A}}$$

Givens | *Solutions*

b. $\Delta V_{12} = \Delta V_{12345} = 76\text{ V}$

$$I_{12} = \frac{\Delta V_{12}}{R_{12}} = \frac{76\text{ V}}{0.16\ \Omega} = 4.8 \times 10^2\text{ A}$$

$I_2 = I_{12} = \boxed{4.8 \times 10^2\text{ A}}$

$\Delta V_2 = I_2 R_2 = (4.8 \times 10^2\text{ A})(8.1 \times 10^{-2}\ \Omega) = \boxed{39\text{ V}}$

c. Same as part b:

$I_4 = \boxed{4.8 \times 10^2\text{ A}}$

$\Delta V_4 = \boxed{39\text{ V}}$

---

2. $\Delta V = 12\text{ V}$

$R_1 = 2.5\ \Omega$

$R_3 = 3.0\ \Omega$

$R_4 = 4.0\ \Omega$

$R_5 = 1.0\ \Omega$

$R_{12} = 6.0\ \Omega$

$R_{123} = 2.0\ \Omega$

$R_{45} = 0.83\ \Omega$

$R_{eq} = 2.8\ \Omega$

$I = 4.3\text{ A}$

a. $\Delta V_{45} = IR_{45} = (4.3\text{ A})(0.83\ \Omega) = 3.6\text{ V}$

$\Delta V_5 = \Delta V_{45} = \boxed{3.6\text{ V}}$

$$I_5 = \frac{\Delta V_5}{R_5} = \frac{3.6\text{ V}}{1.0\ \Omega} = \boxed{3.1\text{ A}}$$

b. $\Delta V_{123} = IR_{123} = (4.3\text{ A})(2.0\ \Omega) = 8.6\text{ V}$

$\Delta V_{12} = \Delta V_{123} = 8.6\text{ V}$

$$I_1 = I_{12} = \frac{\Delta V_{12}}{R_{12}} = \frac{8.6\text{ V}}{6.0\ \Omega} = \boxed{1.4\text{ A}}$$

$\Delta V_1 = I_1 R_1 = (1.4\text{ A})(2.5\ \Omega) = \boxed{3.5\text{ V}}$

c. $I_{45} = I = 4.3\text{ A}$

$\Delta V_{45} = I_{45} R_{45} = (4.3\text{ A})(0.83\ \Omega) = 3.6\text{ V}$

$V_4 = \Delta V_{45} = \boxed{3.6\text{ V}}$

$$I_4 = \frac{\Delta V_4}{R_4} = \frac{3.6\text{ V}}{4.0\ \Omega} = \boxed{0.90\text{ V}}$$

d. $\Delta V_3 = \Delta V_{123} = \boxed{8.6\text{ V}}$

$$I_3 = \frac{\Delta V_3}{R_3} = \frac{8.6\text{ V}}{3.0\ \Omega} = \boxed{2.9\text{ A}}$$

II

Givens | *Solutions*

3. $R_1 = 15\ \Omega$

$R_2 = 3.0\ \Omega$

$R_3 = 2.0\ \Omega$

$R_4 = 5.0\ \Omega$

$R_5 = 7.0\ \Omega$

$R_6 = 3.0\ \Omega$

$R_7 = 3.0 \times 10^1\ \Omega$

$\Delta V = 2.00 \times 10^3\ \text{V}$

$$R_{23} = R_2 + R_3 = 3.0\ \Omega + 2.0\ \Omega = 5.0\ \Omega$$

$$R_{234} = \left(\frac{1}{R_{23}} + \frac{1}{R_4}\right)^{-1} = \left(\frac{1}{5.0\ \Omega} + \frac{1}{5.0\ \Omega}\right)^{-1}$$

$$R_{234} = \left(0.40\frac{1}{\Omega}\right)^{-1} = 2.5\ \Omega$$

$$R_{56} = R_5 + R_6 = 7.0\ \Omega + 3.0\ \Omega = 10.0\ \Omega$$

$$R_{567} = \left(\frac{1}{R_{56}} + \frac{1}{R_7}\right)^{-1} = \left(\frac{1}{10.0\ \Omega} + \frac{1}{30\ \Omega}\right)^{-1}$$

$$R_{567} = \left(0.100\ \frac{1}{\Omega} + 0.033\ \frac{1}{\Omega}\right)^{-1} = \left(0.133\ \frac{1}{\Omega}\right)^{-1} = 7.52\ \Omega$$

$$R_{eq} = R_1 + R_{234} + R_{567} = 15\ \Omega + 2.5\ \Omega + 7.52\ \Omega = 25\ \Omega$$

a. $I = \dfrac{\Delta V}{R_{eq}} = \dfrac{2.00 \times 10^3\ \text{V}}{25\ \Omega} = 80\ \text{A}$

$\Delta V_{234} = IR_{234} = (80\ \text{A})(2.5\ \Omega) = 2.0 \times 10^2\ \text{V}$

$\Delta V_4 = \Delta V_{234} = \boxed{2.0 \times 10^2\ \text{V}}$

$I_4 = \dfrac{\Delta V_4}{R_4} = \dfrac{200\ \text{V}}{5.0\ \Omega} = \boxed{4.0 \times 10^1\ \text{A}}$

b. $\Delta V_{23} = \Delta V_{234} = 200\ \text{V}$

$I_{23} = \dfrac{\Delta V_{23}}{R_{23}} = \dfrac{200\ \text{V}}{5.0\ \Omega} = 40\ \text{A}$

$I_3 = I_{23} = \boxed{4.0 \times 10^1\ \text{A}}$

$\Delta V_3 = I_3R_3 = (40\ \text{A})(2.0\ \Omega) = \boxed{8.0 \times 10^1\ \text{V}}$

c. $I_{567} = I = 80\ \text{A}$

$V_{567} = I_{567}R_{567} = (80\ \text{A})(7.52\ \Omega) = 600\ \text{V}$

$\Delta V_{56} = \Delta V_{567} = 600\ \text{V}$

$I_{56} = \dfrac{\Delta V_{56}}{R_{56}} = \dfrac{600\ \text{V}}{10.0\ \Omega} = 60\ \text{A}$

$I_5 = I_{56} = \boxed{6.0 \times 10^1\ \text{A}}$

$\Delta V_5 = I_5R_5 = (60\ \text{A})(7.0\ \Omega) = \boxed{4.2 \times 10^2\ \text{V}}$

d. $\Delta V_7 = \Delta V_{567} = \boxed{6.0 \times 10^2\ \text{V}}$

$I_7 = \dfrac{\Delta V_7}{R_7} = \dfrac{600\ \text{V}}{30\ \Omega} = \boxed{2.0 \times 10^1\ \text{A}}$

II

Magnetism

Additional Practice A

Givens / *Solutions*

1. $B = 45\ \text{T}$

$v = 7.5 \times 10^6\ \text{m/s}$

$q = e = 1.60 \times 10^{-19}\ \text{C}$

$m_e = 9.109 \times 10^{-31}\ \text{kg}$

$$F_{magnetic} = qvB$$

$$F_{magnetic} = (1.60 \times 10^{-19}\ \text{C})(7.5 \times 10^6\ \text{m/s})(45\ \text{T})$$

$$F_{magnetic} = \boxed{5.4 \times 10^{-11}\ \text{N}}$$

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2. $q = 12 \times 10^{-9}\ \text{C}$

$v = 450\ \text{km/h}$

$B = 2.4\ \text{T}$

$$F_{magnetic} = qvB$$

$$F_{magnetic} = (12 \times 10^{-9}\ \text{C})(450\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)(2.4\ \text{T})$$

$$F_{magnetic} = \boxed{3.6 \times 10^{-6}\ \text{N}}$$

---

3. $v = 350\ \text{km/h}$

$q = 3.6 \times 10^{-8}\ \text{C}$

$B = 7.0 \times 10^{-5}\ \text{T}$

$\theta = 30.0°$

$$F_{magnetic} = qvB = q[v\,(\sin\theta)]B$$

$$F_{magnetic} = (3.6 \times 10^{-8}\ \text{C})(350\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)(\sin 30.0°)(7.0 \times 10^{-5}\ \text{T})$$

$$F_{magnetic} = \boxed{1.2 \times 10^{-10}\ \text{N}}$$

---

4. $v = 2.60 \times 10^2\ \text{km/h}$

$F_{magnetic} = 3.0 \times 10^{-17}\ \text{N}$

$q = 1.60 \times 10^{-19}\ \text{C}$

$$F_{magnetic} = qvB$$

$$B = \frac{F_{magnetic}}{qv}$$

$$B = \frac{(3.0 \times 10^{-17}\ \text{N})}{(1.60 \times 10^{-19}\ \text{C})(2.60 \times 10^2\ \text{km/h})\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)}$$

$$B = \boxed{2.6\ \text{T}}$$

Givens	Solutions
5. $q = 1.60 \times 10^{-19}$ C $v = 60.0$ km/h $F_{magnetic} = 2.0 \times 10^{-22}$ N	$F_{magnetic} = qvB$ $B = \dfrac{F_{magnetic}}{qv}$ $B = \dfrac{(2.0 \times 10^{-22}\ \text{N})}{(1.60 \times 10^{-19}\ \text{C})(60.0\ \text{km/h})\left(\dfrac{1\ \text{h}}{3600\ \text{s}}\right)\left(\dfrac{10^3\ \text{m}}{1\ \text{km}}\right)}$ $B = \boxed{7.5 \times 10^{-5}\ \text{T}}$
6. $q = 88 \times 10^{-9}$ C $B = 0.32$ T $F_{magnetic} = 1.25 \times 10^{-6}$ N	$F_{magnetic} = qvB$ $v = \dfrac{F_{magnetic}}{qB}$ $v = \dfrac{(1.25 \times 10^{-6}\ \text{N})}{(88 \times 10^{-9}\ \text{C})(0.32\ \text{T})}$ $v = \boxed{44\ \text{m/s} = 160\ \text{km/h}}$
7. $q = 1.60 \times 10^{-19}$ C $B = 6.4$ T $F_{magnetic} = 2.76 \times 10^{-16}$ N	**a.** $F_{magnetic} = qvB$ $v = \dfrac{F_{magnetic}}{qB}$ $v = \dfrac{(2.76 \times 10^{-16}\ \text{N})}{(1.60 \times 10^{-19}\ \text{C})(6.4\ \text{T})}$ $v = \boxed{2.7 \times 10^2\ \text{m/s} = 9.7 \times 10^2\ \text{km/h}}$
$\Delta x = 4.0 \times 10^3$ m $v_i = 0$ m/s $v_f = 270$ m/s	**b.** $\Delta x = \dfrac{(v_f + v_i)}{2}\Delta t$ $\Delta t = \dfrac{2\Delta x}{(v_f + v_i)}$ $\Delta t = \dfrac{2(4.0 \times 10^3\ \text{m})}{(270\ \text{m/s} + 0\ \text{m/s})}$ $\Delta t = \boxed{3.0 \times 10^1\ \text{s}}$
8. $B = 0.600$ T $q = 1.60 \times 10^{-19}$ C $v = 2.00 \times 10^5$ m/s	**a.** $F_{magnetic} = qvB$ $F_{magnetic} = (1.60 \times 10^{-19}\ \text{C})(2.00 \times 10^5\ \text{m/s})(0.600\ \text{T})$ $F_{magnetic} = \boxed{1.92 \times 10^{-14}\ \text{N}}$
$m_1 = 9.98 \times 10^{-27}$ kg $m_2 = 11.6 \times 10^{-27}$ kg	**b.** $F_{c,1} = \dfrac{m_1 v^2}{r_1} = F_{magnetic}$ $F_{c,2} = \dfrac{m_2 v^2}{r_2} = F_{magnetic}$ $r_1 = \dfrac{m_1 v^2}{F_{magnetic}}$ $r_2 = \dfrac{m_2 v^2}{F_{magnetic}}$

II

Givens	*Solutions*

$$r_1 = \frac{(9.98 \times 10^{-27}\ \text{kg})(2.00 \times 10^5\ \text{m/s})^2}{(1.92 \times 10^{-14}\ \text{N})}$$

$$r_1 = 2.08 \times 10^{-2}\ \text{m}$$

$$r_2 = \frac{(11.6 \times 10^{-27}\ \text{kg})(2.00 \times 10^5\ \text{m/s})^2}{(1.92 \times 10^{-14}\ \text{N})}$$

$$r_2 = 2.42 \times 10^{-2}\ \text{m}$$

$$r_2 - r_1 = \boxed{3.40 \times 10^{-3}\ \text{m} = 3.4\ \text{mm}}$$

Additional Practice B

1. $B = 22.5\ \text{T}$

$\ell = 12 \times 10^{-2}\ \text{m}$

$I = 8.4 \times 10^{-2}\ \text{A}$

$$F_{magnetic} = BI\ell$$

$$F_{magnetic} = (22.5\ \text{T})(8.4 \times 10^{-2}\ \text{A})(12 \times 10^{-2}\ \text{m})$$

$$F_{magnetic} = \boxed{0.23\ \text{N}}$$

2. $\ell = 1066\ \text{m}$

$F_{magnetic} = 6.3 \times 10^{-2}\ \text{N}$

$I = 0.80\ \text{A}$

$$F_{magnetic} = BI\ell$$

$$B = \frac{F_{magnetic}}{I\ell}$$

$$B = \frac{(6.3 \times 10^{-2}\ \text{N})}{(0.80\ \text{A})(1066\ \text{m})}$$

$$B = \boxed{7.4 \times 10^{-5}\ \text{T}}$$

3. $\ell = 5376\ \text{m}$

$F_{magnetic} = 3.1\ \text{N}$

$I = 12\ \text{A}$

$\theta = 38°$

$$F_{magnetic} = BI\ell = [B(\sin\theta)]I\ell$$

$$B = \frac{F_{magnetic}}{I\ell(\sin\theta)}$$

$$B = \frac{(3.1\ \text{N})}{(12\ \text{A})(5376\ \text{m})(\sin 38.0°)}$$

$$B = \boxed{7.8 \times 10^{-5}\ \text{T}}$$

4. $\ell = 21.0 \times 10^3\ \text{m}$

$B = 6.40 \times 10^{-7}\ \text{T}$

$F_{magnetic} = 1.80 \times 10^{-2}\ \text{N}$

$$F_{magnetic} = BI\ell$$

$$I = \frac{F_{magnetic}}{B\ell}$$

$$I = \frac{(1.80 \times 10^{-2}\ \text{N})}{(6.40 \times 10^{-7}\ \text{T})(21.0 \times 10^3\ \text{m})}$$

$$I = \boxed{1.34\ \text{A}}$$

Givens	*Solutions*
5. $B = 2.5 \times 10^{-4}$ T $\ell = 4.5 \times 10^{-2}$ m $F_{magnetic} = 3.6 \times 10^{-7}$ N	$F_{magnetic} = BI\ell$ $I = \frac{F_{magnetic}}{B\ell}$ $I = \frac{(3.6 \times 10^{-7}\ \text{N})}{(2.5 \times 10^{-4}\ \text{T})(4.5 \times 10^{-2}\ \text{m})}$ $I = \boxed{3.2 \times 10^{-2}\ \text{A}}$
6. $F_{magnetic} = 5.0 \times 10^{5}$ N $B = 3.8$ T $I = 2.00 \times 10^{2}$ A	$F_{magnetic} = BI\ell$ $\ell = \frac{F_{magnetic}}{BI}$ $\ell = \frac{(5.0 \times 10^{5}\ \text{N})}{(3.8\ \text{T})(2.00 \times 10^{2}\ \text{A})}$ $\ell = \boxed{6.6 \times 10^{2}\ \text{m}}$
7. $F_{magnetic} = 16.1$ N $B = 6.4 \times 10^{-5}$ T $I = 2.8$ A	$F_{magnetic} = BI\ell$ $\ell = \frac{F_{magnetic}}{BI}$ $\ell = \frac{(16.1\ \text{N})}{(6.4 \times 10^{-5}\ \text{T})(2.8\ \text{A})}$ $\ell = \boxed{9.0 \times 10^{4}\ \text{m}}$
8. $B = 0.040$ T $I = 0.10$ A $\theta = 45°$ $\ell = 55$ cm $= 0.55$ m	$F_{magnetic} = BI\ell = [B(\sin\theta)]I\ell$ $F_{magnetic} = (0.040\ \text{T})(\sin 45°)(0.10\ \text{A})(0.55\ \text{m})$ $F_{magnetic} = \boxed{1.6 \times 10^{-3}\ \text{N}}$
9. $B = 38$ T $\ell = 2.0$ m $m = 75$ kg $g = 9.81$ m/s^2	$F_{magnetic} = BI\ell$ $F_g = mg$ $F_{magnetic} = F_g$ $BI\ell = mg$ $I = \frac{mg}{B\ell}$ $I = \frac{(75\ \text{kg})(9.81\ \text{m/s}^2)}{(38\ \text{T})(2.0\ \text{m})}$ $I = \boxed{9.7\ \text{A}}$

II

Givens	*Solutions*
10. $\ell = 478 \times 10^3$ m $F_{magnetic} = 0.40$ N $B = 7.50 \times 10^{-5}$ T	$F_{magnetic} = BI\ell$ $I = \dfrac{F_{magnetic}}{B\ell}$ $I = \dfrac{(0.40 \text{ N})}{(7.50 \times 10^{-5} \text{ T})(478 \times 10^3 \text{ m})}$ $I = \boxed{1.1 \times 10^{-2} \text{ A}}$

II

Problem Workbook Solutions

Electromagnetic Induction

Additional Practice A

Givens	*Solutions*
1. $A_i = 6.04 \times 10^5\ \text{m}^2$ $A_f = \frac{1}{2}(6.04 \times 10^5\ \text{m}^2)$ $B = 6.0 \times 10^{-5}\ \text{T}$ $\text{emf} = 0.80\ \text{V}$ $N = 1$ turn $\theta = 0.0°$	$\text{emf} = -N\dfrac{\Delta\Phi_M}{\Delta t} = \dfrac{-N\Delta[AB\cos\theta]}{\Delta t}$ $\Delta t = \dfrac{-NB\cos\theta}{\text{emf}}\Delta A$ $\Delta t = \dfrac{-NB\cos\theta}{\text{emf}}(A_f - A_i)$ $\Delta t = \dfrac{-(1)(6.0 \times 10^{-5}\ \text{T})(\cos 0.0°)}{(0.80\ \text{V})}(6.04 \times 10^5\ \text{m}^2)\left(\frac{1}{2} - 1\right)$ $\Delta t = \boxed{23\ \text{s}}$
2. $r = \dfrac{100.0\ \text{m}}{2} = 50.0\ \text{m}$ $B_i = 0.800\ \text{T}$ $B_f = 0.000\ \text{T}$ $\theta = 0.00°$ $\text{emf} = 46.7\ \text{V}$ $N = 1$ turn	$\text{emf} = -N\dfrac{\Delta\Phi_M}{\Delta t} = \dfrac{-N\Delta[AB\cos\theta]}{\Delta t}$ $\Delta t = -NA\cos\theta\dfrac{\Delta B}{\text{emf}} = \dfrac{-N(\pi r^2)(\cos\theta)(B_f - B_i)}{\text{emf}}$ $\Delta t = \dfrac{-(1)(\pi)(50.0\ \text{m})^2(\cos 0.0°)(0.000\ \text{T} - 0.800\ \text{T})}{(46.7\ \text{V})}$ $\Delta t = \boxed{135\ \text{s}}$
3. $\text{emf} = 32.0 \times 10^6\ \text{V}$ $B_i = 1.00 \times 10^3\ \text{T}$ $B_f = 0.00\ \text{T}$ $A = 4.00 \times 10^{-2}\ \text{m}^2$ $N = 50$ turns $\theta = 0.00°$	$\text{emf} = -N\dfrac{\Delta\Phi_M}{\Delta t} = \dfrac{-N\Delta[AB\cos\theta]}{\Delta t}$ $\Delta t = -NA\cos\theta\dfrac{\Delta B}{\text{emf}} = \dfrac{-NA\cos\theta(B_f - B_i)}{\text{emf}}$ $\Delta t = \dfrac{-(50)(4.00 \times 10^{-2}\ \text{m}^2)(\cos 0.00°)[(0.00\ \text{T}) - (1.00 \times 10^3\ \text{T})]}{(32.0 \times 10^6\ \text{V})}$ $\Delta t = \boxed{6.3 \times 10^{-5}\ \text{s}}$
4. $A_f = 3.2 \times 10^4\ \text{m}^2$ $A_i = 0.0\ \text{m}^2$ $\Delta t = 20.0\ \text{min}$ $B = 4.0 \times 10^{-2}\ \text{T}$ $N = 300$ turns $\theta = 0.0°$	$\text{emf} = -N\dfrac{\Delta\Phi_M}{\Delta t} = \dfrac{-N\Delta[AB\cos\theta]}{\Delta t} = -NB\cos\theta\dfrac{\Delta A}{\Delta t} = \dfrac{-NB\cos\theta}{\Delta t}(A_f - A_i)$ $\text{emf} = \dfrac{-(300)(4.0 \times 10^{-2}\ \text{T})(\cos 0.0°)}{(20.0\ \text{min})\left(\dfrac{60\ \text{s}}{1\ \text{min}}\right)}[(3.2 \times 10^4\ \text{m}^2) - (0.0\ \text{m}^2)]$ $\text{emf} = \boxed{-3.2 \times 10^2\ \text{V}}$

II

Givens | *Solutions*

5. $B_i = 8.0 \times 10^{-15}$ T

$B_f = 10\ B_i = 8.0 \times 10^{-14}$ T

$\Delta t = 3.0 \times 10^{-2}$ s

$A = 1.00$ m^2

emf $= -1.92 \times 10^{-11}$ V

$\theta = 0.0°$

$$\text{emf} = -N\frac{\Delta\Phi_M}{\Delta t} = \frac{-N\Delta[AB\cos\theta]}{\Delta t}$$

$$N = \frac{-(\text{emf})(\Delta t)}{A\cos\theta\,\Delta B} = \frac{-(\text{emf})(\Delta t)}{A\cos\theta(B_f - B_i)}$$

$$N = \frac{-(-1.92\times10^{-11}\text{ V})(3.0\times10^{-2}\text{ s})}{(1.00\text{ m}^2)(\cos 0.0°)[(8.0\times10^{-14}\text{ T}) - (8.0\times10^{-15}\text{ T})]}$$

$$N = \boxed{8\text{ turns}}$$

6. $B_i = 0.50$ T

$B_f = 0.00$ T

$N = 880$ turns

$\Delta t = 12$ s

emf $= 147$ V

$\theta = 0.0°$

$$\text{emf} = -N\frac{\Phi_M}{\Delta t} = \frac{-N\Delta[AB\cos\theta]}{\Delta t} = -NA\cos\theta\frac{\Delta B}{\Delta t}$$

$$A = \frac{-(\text{emf})(\Delta t)}{N\cos\theta\,\Delta B} = \frac{-(\text{emf})(\Delta t)}{N\cos\theta\,(B_f - B_i)}$$

$$A = \frac{-(147\text{ V})(12\text{ s})}{(880)(\cos 0.0°)(0.00\text{ T} - 0.50\text{ T})}$$

$$A = \boxed{4.0\text{ m}^2}$$

II

Additional Practice B

1. $\Delta V_{rms} = 120$ V

$R = 6.0 \times 10^{-2}\ \Omega$

$\frac{1}{\sqrt{2}} = 0.707$

a. $$I_{rms} = \frac{\Delta V_{rms}}{R}$$

$$I_{rms} = \frac{(120\text{ V})}{(6.0\times10^{-2}\ \Omega)}$$

$$I_{rms} = \boxed{2.0\times10^3\text{ A}}$$

b. $$I_{max} = (I_{rms})\sqrt{2}$$

$$I_{max} = \frac{(2.0\times10^3\text{ A})}{(0.707)}$$

$$I_{max} = \boxed{2.8\times10^3\text{ A}}$$

c. $$P = (I_{rms})(\Delta V_{rms})$$

$$P = (2.0\times10^3\text{ A})(120\text{ V})$$

$$P = \boxed{2.4\times10^5\text{ W}}$$

Givens / *Solutions*

2. Givens: $P = 10.0(\text{Acoustic power})$

Acoustic power $= 30.8 \times 10^3$ W

$\Delta V_{rms} = 120.0$ V

$\frac{1}{\sqrt{2}} = 0.707$

Solutions:

$$P = \Delta V_{rms} I_{rms}$$

$$I_{rms} = \frac{P}{\Delta V_{rms}}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$\frac{I_{max}}{\sqrt{2}} = \frac{P}{\Delta V_{rms}}$$

$$I_{max} = \frac{P\sqrt{2}}{\Delta V_{rms}}$$

$$I_{max} = \frac{(10.0)(30.8 \times 10^3 \text{ W})}{(120.0 \text{ V})(0.707)}$$

$$I_{max} = \boxed{3.63 \times 10^3 \text{ A}}$$

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3. Givens: $P = 1.325 \times 10^8$ W

$\Delta V_{rms} = 5.4 \times 10^4$ V

$\frac{1}{\sqrt{2}} = 0.707$

Solutions:

$$P = \Delta V_{rms} I_{rms} = (I_{rms})^2 R = \frac{(\Delta V_{rms})^2}{R}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$I_{max} = \sqrt{2}\, I_{rms} = \frac{\sqrt{2}\, P}{\Delta V_{rms}}$$

$$I_{max} = \frac{1.325 \times 10^8 \text{ W}}{(5.4 \times 10^4 \text{ V})(0.707)}$$

$$I_{max} = \boxed{3.5 \times 10^3 \text{ A}}$$

$$R = \frac{(\Delta V_{rms})^2}{P}$$

$$R = \frac{(5.4 \times 10^4 \text{ V})^2}{(1.325 \times 10^8 \text{ W})}$$

$$R = \boxed{22\ \Omega}$$

---

4. Givens: $\Delta V_{rms} = 1.024 \times 10^6$ V

$I_{rms} = 2.9 \times 10^{-2}$ A

$\frac{1}{\sqrt{2}} = 0.707$

Solutions:

$$\Delta V_{max} = \Delta V_{rms}\sqrt{2}$$

$$\Delta V_{max} = \frac{(1.024 \times 10^6 \text{ V})}{(0.707)}$$

$$\Delta V_{max} = \boxed{1.45 \times 10^6 \text{ V} = 1.45 \text{ MV}}$$

$$I_{max} = I_{rms}\sqrt{2}$$

$$I_{max} = \frac{(2.9 \times 10^{-2} \text{ A})}{(0.707)}$$

$$I_{max} = \boxed{4.1 \times 10^{-2} \text{ A}}$$

Givens / *Solutions*

5. $\Delta V_{max} = 320\text{ V}$

$I_{max} = 0.80\text{ A}$

$\frac{1}{\sqrt{2}} = 0.707$

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$$

$$\Delta V_{rms} = (320\text{ V})(0.707)$$

$$\Delta V_{rms} = \boxed{2.3 \times 10^2\text{ V}}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$I_{rms} = (0.80\text{ A})(0.707)$$

$$I_{rms} = \boxed{0.57\text{ A}}$$

$$R = \frac{\Delta V_{max}}{I_{max}} = \frac{\Delta V_{rms}}{I_{rms}}$$

$$R = \frac{(320\text{ V})}{(0.80\text{A})} = \frac{(230\text{ V})}{(0.57\text{A})}$$

$$R = \boxed{4.0 \times 10^2\ \Omega}$$

II

6. $I_{max} = 75\text{ A}$

$R = 480\ \Omega$

$\frac{1}{\sqrt{2}} = 0.707$

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$$

$$\Delta V_{max} = (I_{max})(R)$$

$$\Delta V_{rms} = \frac{I_{max}R}{\sqrt{2}}$$

$$\Delta V_{rms} = (75\text{ A})(480\ \Omega)(0.707)$$

$$\Delta V_{rms} = \boxed{2.5 \times 10^4\text{ V} = 25\text{ kV}}$$

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7. $P_{tot} = 6.2 \times 10^7\text{ W}$

$P_{tot} = 24\text{ P}$

$R = 1.2 \times 10^5\ \Omega$

$\frac{1}{\sqrt{2}} = 0.707$

$$P = (I_{rms})^2 R = \frac{P_{tot}}{24}$$

$$P = \frac{6.2 \times 10^7\text{ W}}{24}$$

$$P = \boxed{2.6 \times 10^6\text{ W} = 2.6\text{ MW}}$$

$$I_{rms} = \sqrt{\frac{P}{R}}$$

$$I_{rms} = \sqrt{\frac{(2.6 \times 10^6\text{ W})}{(1.2 \times 10^5\ \Omega)}}$$

$$I_{rms} = \boxed{4.7\text{ A}}$$

$$I_{max} = \sqrt{2}\, I_{rms}$$

$$I_{max} = \frac{4.7\text{ A}}{0.707}$$

$$I_{max} = \boxed{6.6\text{ A}}$$

Additional Practice C

Givens	*Solutions*
1. $N_1 = 5600$ turns $N_2 = 240$ turns $\Delta V_2 = 4.1 \times 10^2$ V	$\Delta V_1 = \Delta V_2\left(\frac{N_1}{N_2}\right)$ $\Delta V_1 = (4.1 \times 10^3\ \text{V}) = \left(\frac{5600}{240}\right)$ $\Delta V_1 = \boxed{9.6 \times 10^4\ \text{V} = 96\ \text{kV}}$
2. $N_1 = 74$ turns $N_2 = 403$ turns $\Delta V_2 = 650$ V	$\Delta V_1 = \Delta V_2\left(\frac{N_1}{N_2}\right)$ $\Delta V_1 = (650\ \text{V})\left(\frac{74}{403}\right)$ $\Delta V_1 = \boxed{120\ \text{V}}$
3. $\Delta V_1 = 2.0 \times 10^{-2}$ V $N_1 = 400$ turns $N_2 = 3600$ turns	$\Delta V_2 = \Delta V_1\left(\frac{N_2}{N_1}\right)$ $\Delta V_2 = (2.0 \times 10^{-2}\ \text{V})\left(\frac{3600}{400}\right)$ $\Delta V_2 = \boxed{0.18\ \text{V}}$
$\Delta V_2 = 2.0 \times 10^{-2}$ V	$\Delta V_1 = \Delta V_2\left(\frac{N_1}{N_2}\right)$ $\Delta V_1 = (2.0 \times 10^{-2}\ \text{V})\left(\frac{400}{3600}\right)$ $\Delta V_1 = \boxed{2.2 \times 10^{-3}\ \text{V}}$
4. $\Delta V_1 = 765 \times 10^3$ V $\Delta V_2 = 540 \times 10^3$ V $N_1 = 2.8 \times 10^3$ turns	$\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$ $N_2 = \left(\frac{\Delta V_2}{\Delta V_1}\right)N_1$ $N_2 = \left(\frac{540 \times 10^3\ \text{V}}{765 \times 10^3\ \text{V}}\right)(2.8 \times 10^3)$ $N_2 = \boxed{2.0 \times 10^3\ \text{turns}}$

II

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5. $\Delta V_1 = 230 \times 10^3$ V

$\Delta V_2 = 345 \times 10^3$ V

$N_1 = 1.2 \times 10^4$ turns

$$\frac{N_2}{N_1} = \frac{\Delta V_2}{\Delta V_1}$$

$$N_2 = N_1\left(\frac{\Delta V_2}{\Delta V_1}\right)$$

$$N_2 = (1.2 \times 10^4)\left(\frac{345 \times 10^3\ \text{V}}{230 \times 10^3\ \text{V}}\right)$$

$$N_2 = \boxed{1.8 \times 10^4\ \text{turns}}$$

---

6. $P = 20.0$ W

$\Delta V_1 = 120$ V

a. $P = (\Delta V_1)(I_1)$

$$I_1 = \frac{P}{\Delta V_1} = \frac{(20.0\ \text{W})}{(120\ \text{V})}$$

$$I_1 = \boxed{0.17\ \text{A}}$$

II

$\frac{N_1}{N_2} = 0.36$

b. $$\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$$

$$\Delta V_2 = \left(\frac{N_2}{N_1}\right)\Delta V_1$$

$$\Delta V_2 = \left(\frac{1}{0.36}\right)(120\ \text{V})$$

$$\Delta V_2 = \boxed{3.3 \times 10^2\ \text{V}}$$

---

7. $\Delta V_1 = 120$ V

$\Delta V_2 = 220$ V

$I_2 = 30.0$ A

$N_2 = 660$ turns

$$P_1 = P_2$$

$$\Delta V_1 I_1 = \Delta V_2 I_2$$

$$I_1 = \left(\frac{\Delta V_2}{\Delta V_1}\right) I_2$$

$$I_1 = \left(\frac{220\ \text{V}}{120\ \text{V}}\right)(30.0\ \text{A})$$

$$I_1 = \boxed{55\ \text{A}}$$

$$\frac{N_2}{N_1} = \frac{\Delta V_2}{\Delta V_1}$$

$$N_1 = N_2\left(\frac{\Delta V_1}{\Delta V_2}\right)$$

$$N_1 = (660)\left(\frac{120\ \text{V}}{220\ \text{V}}\right)$$

$$N_1 = \boxed{360\ \text{turns}}$$

Atomic Physics

Additional Practice A

Givens | *Solutions*

1. $E = 1.29 \times 10^{-15}$ J

$C = 3.00 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{1.29 \times 10^{-15}\ \text{J}}$$

$$\lambda = 1.54 \times 10^{-10}\ \text{m} = \boxed{0.154\ \text{nm}}$$

---

2. $E = 6.6 \times 10^{-19}$ J

$C = 3.00 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{6.6 \times 10^{-19}\ \text{J}}$$

$$\lambda = \boxed{3.0 \times 10^{-7}\ \text{m}}$$

---

3. $E = 5.92 \times 10^{-6}$ eV

$C = 3.00 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$$\lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^{8}\ \text{m/s})}{(5.92 \times 10^{-6}\ \text{eV})(1.60 \times 10^{-19}\ \text{J/eV})}$$

$$\lambda = \boxed{0.210\ \text{m}}$$

---

4. $E = 2.18 \times 10^{-23}$ J

$h = 6.63 \times 10^{-34}$ J•s

$$E = hf$$

$$f = \frac{E}{h}$$

$$f = \frac{2.18 \times 10^{-23}\ \text{J}}{6.63 \times 10^{-34}\ \text{J•s}}$$

$$f = \boxed{3.29 \times 10^{10}\ \text{Hz}}$$

---

5. $E = 1.85 \times 10^{-23}$ J

$h = 6.63 \times 10^{-34}$ J•s

$$f = \frac{E}{h} = \frac{1.85 \times 10^{-23}\ \text{J}}{6.63 \times 10^{-34}\ \text{J/s}} = \boxed{2.79 \times 10^{10}\ \text{Hz}}$$

---

6. $f = 9\ 192\ 631\ 770\ \text{s}^{-1}$

$h = 6.626\ 0755 \times 10^{-34}$ J•s

$1\ \text{eV} = 1.602\ 117\ 33 \times 10^{-19}$ J

$$E = hf$$

$$E = \frac{(6.626\ 0755 \times 10^{-34}\ \text{J•s})(9\ 192\ 631\ 770\ \text{s}^{-1})}{1.602\ 117\ 33 \times 10^{-19}\ \text{J/eV}}$$

$$E = \boxed{3.801\ 9108 \times 10^{-5}\ \text{eV}}$$

---

7. $\lambda = 92\ \text{cm} = 92 \times 10^{-2}$ m

$c = 3.00 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$h = 4.14 \times 10^{-15}$ eV•s

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.00 \times 10^{8}\ \text{m/s}}{92 \times 10^{-2}\ \text{m}}$$

$$f = \boxed{3.3 \times 10^{8}\ \text{Hz} = 330\ \text{MHz}}$$

$$E = hf$$

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$E = (6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.3 \times 10^{8}\ \text{Hz})$

$E = \boxed{2.2 \times 10^{-25}\ \text{J}}$

$E = (4.14 \times 10^{-15}\ \text{eV}\bullet\text{s})(3.3 \times 10^{8}\ \text{Hz})$

$E = \boxed{1.4 \times 10^{-6}\ \text{eV}}$

---

8. $v = 1.80 \times 10^{-17}$ m/s

$\Delta t = 1.00$ year

$\lambda = \Delta x$

$c = 3.00 \times 10^{8}$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$\Delta x = v\Delta t$

$$\Delta x = (1.80 \times 10^{-17}\ \text{m/s})(1.00\ \text{year})\left(\frac{365.25\ \text{days}}{1\ \text{year}}\right)\left(\frac{24\ \text{h}}{1\ \text{day}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)$$

$\Delta x = \boxed{5.68 \times 10^{-10}\ \text{m}}$

$$E = hf = \frac{hc}{\lambda} = \frac{hc}{\Delta x}$$

$$E = \frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{5.68 \times 10^{-10}\ \text{m}}$$

$E = \boxed{3.50 \times 10^{-16}\ \text{J}}$

II

Additional Practice B

1. $hf_t = 4.5$ eV

$KE_{max} = 3.8$ eV

$h = 4.14 \times 10^{-15}$ eV•s

$$f = \frac{[KE_{max} + hf_t]}{h} = \frac{[3.8\ \text{eV} + 4.5\ \text{eV}]}{4.14 \times 10^{-15}\ \text{eV}\bullet\text{s}} = \boxed{2.0 \times 10^{15}\ \text{Hz}}$$

---

2. $hf_t = 4.3$ eV

$KE_{max} = 3.2$ eV

$h = 4.14 \times 10^{-15}$ eV•s

$KE_{max} = hf - hf_t$

$$f = \frac{KE_{max} + hf_t}{h}$$

$$f = \frac{3.2\ \text{eV} + 4.3\ \text{eV}}{4.14 \times 10^{-15}\ \text{eV}\bullet\text{s}}$$

$f = \boxed{1.8 \times 10^{15}\ \text{Hz}}$

---

3. $hf_{t,Cs} = 2.14$ eV

$hf_{t,Se} = 5.9$ eV

$h = 4.14 \times 10^{-15}$ eV•s

$c = 3.00 \times 10^{8}$ m/s

$KE_{max} = 0.0$ eV for both cases

a. $KE_{max} = hf - hf_t = 0.0\ \text{eV} = \dfrac{hc}{\lambda} - hf_t$

$$\lambda = \frac{hc}{hf_t}$$

$$\lambda_{Cs} = \frac{hc}{hf_{t,Cs}} = \frac{(4.14 \times 10^{-15}\ \text{eV}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{2.14\ \text{eV}}$$

$\lambda_{Cs} = \boxed{5.80 \times 10^{-7}\ \text{m} = 5.80 \times 10^{2}\ \text{nm}}$

b. $$\lambda_{Se} = \frac{hc}{hf_{t,Se}} = \frac{(4.14 \times 10^{-15}\ \text{eV}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{5.9\ \text{eV}}$$

$\lambda_{Se} = \boxed{2.1 \times 10^{-7}\ \text{m} = 2.1 \times 10^{2}\ \text{nm}}$

Givens	Solutions
4. $\lambda = 2.00 \times 10^2$ nm = 2.00×10^{-7} m	$KE_{max} = \frac{1}{2}m_e v^2 = hf - hf_t$
$v = 6.50 \times 10^5$ m/s	$\frac{1}{2}m_e v^2 = \frac{hc}{\lambda} - hf_t$
$m_e = 9.109 \times 10^{-31}$ kg	$hf_t = \frac{hc}{\lambda} - \frac{1}{2}m_e v^2$
$c = 3.00 \times 10^8$ m/s	$hf_t = \frac{(4.14 \times 10^{-15}\ \text{eV•s})(3.00 \times 10^8\ \text{m/s})}{2.00 \times 10^{-7}\ \text{m}} - \frac{(0.5)(9.109 \times 10^{-31}\ \text{kg})(6.50 \times 10^5\ \text{m/s})^2}{1.60 \times 10^{-19}\ \text{J/eV}}$
$h = 4.14 \times 10^{-15}$ eV•s	$hf_t = 6.21\ \text{eV} - 1.20\ \text{eV}$
	$hf_t = \boxed{5.01\ \text{eV}}$
	$f_t = \frac{5.01\ \text{eV}}{4.14 \times 10^{-15}\ \text{eV•s}} = \boxed{1.21 \times 10^{15}\ \text{Hz}}$
5. $f = 2.2 \times 10^{15}$ Hz	$KE_{max} = hf - hf_t$
$KE_{max} = 4.4$ eV	$hf_t = hf - KE_{max}$
$h = 4.14 \times 10^{-15}$ eV•s	$hf_t = (4.14 \times 10^{-15}\ \text{eV•s})(2.2 \times 10^{15}\ \text{Hz}) - 4.4\ \text{eV}$
	$hf_t = 9.1\ \text{eV} - 4.4\ \text{eV} = \boxed{4.7\ \text{eV}}$
	$f_t = \frac{4.7\ \text{eV}}{4.14 \times 10^{-15}\ \text{eV•s}} = \boxed{1.1 \times 10^{15}\ \text{Hz}}$
6. $\lambda = 2.00 \times 10^2$ nm = 2.00×10^{-7} m	$KE_{max} = hf - hf_t$
$KE_{max} = 0.46$ eV	$hf_t = hf - KE_{max} = \frac{hc}{\lambda} - KE_{max}$
$h = 4.14 \times 10^{-15}$ eV•s	$hf_t = \frac{(4.14 \times 10^{-15}\ \text{eV•s})(3.00 \times 10^8\ \text{m/s})}{2.00 \times 10^{-7}\ \text{m}} - 0.46\ \text{eV}$
$c = 3.00 \times 10^8$ m/s	$hf_t = 6.21\ \text{eV} - 0.46\ \text{eV}$
	$hf_t = \boxed{5.8\ \text{eV}}$
	$f_t = \frac{5.8\ \text{eV}}{4.14 \times 10^{-15}\ \text{eV•s}} = \boxed{1.4 \times 10^{15}\ \text{Hz}}$
7. $\lambda = 589$ nm = 589×10^{-9} m	$KE_{max} = hf - hf_t = \frac{hc}{\lambda} - hf_t$
$hf_t = 2.3$ eV	$KE_{max} = \frac{(4.14 \times 10^{-15}\ \text{eV•s})(3.00 \times 10^8\ \text{m/s})}{589 \times 10^{-9}\ \text{m}} - 2.3\ \text{eV}$
$c = 3.00 \times 10^8$ m/s	$KE_{max} = 2.11\ \text{eV} - 2.3\ \text{eV}$
$h = 4.14 \times 10^{-15}$ eV•s	$KE_{max} = \boxed{-0.2\ \text{eV}}$
	No. The photons in the light produced by sodium vapor need 0.2 eV more energy to liberate photoelectrons from the solid sodium.

II

Givens	*Solutions*
8. $hf_t = 2.3$ eV $\lambda = 410$ nm $= 4.1 \times 10^{-7}$ m $h = 4.14 \times 10^{-15}$ eV•s $c = 3.00 \times 10^8$ m/s	$KE_{max} = \frac{hc}{\lambda} - hf_t$ $KE = \frac{(4.14 \times 10^{-15}\ \text{eV•s})(3.00 \times 10^8\ \text{m/s})}{4.1 \times 10^{-7}\ \text{m}} - 2.3\ \text{eV}$ $KE = 3.03\ \text{eV} - 2.3\ \text{eV} = \boxed{0.7\ \text{eV}}$
9. $hf_{t,Zn} = 4.3$ eV $hf_{t,Pb} = 4.1$ eV $KE_{max,Zn} = 0.0$ eV $m_e = 9.109 \times 10^{-31}$ kg	$KE_{max} = hf - hf_t$ $KE_{max,Pb} = hf - hf_{t,Pb} = (KE_{max,Zn} + hf_{t,Zn}) - hf_{t,Pb}$ $KE_{max,Pb} = \frac{1}{2}m_e v^2$ $\frac{1}{2}m_e v^2 = (KE_{max,Zn} + hf_{t,Zn}) - hf_{t,Pb}$ $v = \sqrt{\frac{2(KE_{max,Zn} + hf_{t,Zn} - hf_{t,Pb})}{m_e}}$ $v = \sqrt{\left(\frac{(2)(0.0\ \text{eV} + 4.3\ \text{eV} - 4.1\ \text{eV})}{9.109 \times 10^{-31}\ \text{kg}}\right)\left(\frac{1.60 \times 10^{-19}\ \text{J}}{1\ \text{eV}}\right)}$ $v = \sqrt{\left(\frac{(2)(0.2\ \text{eV})}{9.109 \times 10^{-31}\ \text{kg}}\right)\left(\frac{1.60 \times 10^{-19}\ \text{J}}{1\ \text{eV}}\right)} = \boxed{3 \times 10^5\ \text{m/s}}$

II

Additional Practice C

1. $\lambda = 671.9$ nm $E_{final} = E_1 = 0$ eV	$E = E_{initial} - E_{final} = E_{initial} - E_1$ $E = \frac{hc}{\lambda}$ $E_{initial} = \left(\frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^8\ \text{m/s})}{671.9\ \text{nm}}\right)\left(\frac{10^9\ \text{nm}}{1\ \text{m}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right) + 0\ \text{eV}$ $E_{initial} = 1.85\ \text{eV} + 0\ \text{eV} = \boxed{1.85\ \text{eV}}$ The photon is produced by the transition of the electron from the E_2 energy level to E_1.
2. $E_{initial} = E_4 = 5.24$ eV $E_{final} = E_1 = 0$ eV	$E = E_{initial} - E_{final} = E_4 - E_1$ $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{hc}{E_4 - E_1}$ $\lambda = \left(\frac{(6.63 \times 10^{-34}\ \text{J•s})(3.00 \times 10^8\ \text{m/s})}{5.24\ \text{eV} - 0\ \text{eV}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right)$ $\lambda = \boxed{2.37 \times 10^{-7}\ \text{m} = 237\ \text{nm}}$

Givens | *Solutions*

3. $E_{initial} = E_3 = 4.69$ eV

$E_{final} = E_1 = 0$ eV

$E = E_{initial} - E_{final} = E_3 - E_1$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{hc}{E_3 - E_1}$$

$$\lambda = \left(\frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{4.69\ \text{eV} - 0\ \text{eV}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right)$$

$$\lambda = \boxed{2.65 \times 10^{-7}\ \text{m} = 265\ \text{nm}}$$

---

4. $E_{initial} = E_2 = 3.15$ eV

$E_{final} = E_1 = 0$ eV

$E = E_{initial} - E_{final} = E_2 - E_1$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{hc}{E_2 - E_1}$$

$$\lambda = \left(\frac{(6.63 \times 10^{-34}\ \text{J}\bullet\text{s})(3.00 \times 10^{8}\ \text{m/s})}{3.15\ \text{eV} - 0\ \text{eV}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \text{J}}\right)$$

$$\lambda = \boxed{3.95 \times 10^{-7}\ \text{m} = 395\ \text{nm}}$$

II

Additional Practice D

1. $v = 3.2$ m/s

$\lambda = 3.0 \times 10^{-32}$ m

$h = 6.63 \times 10^{-34}$ J•s

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{(3.0 \times 10^{-32}\ \text{m})(3.2\ \text{m/s})} = \boxed{6.9 \times 10^{-3}\ \text{kg}}$$

2. $\lambda = 6.4 \times 10^{-11}$ m

$v = 64$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$$mv = \frac{h}{\lambda}$$

$$m = \frac{h}{\lambda v}$$

$$m = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{(6.4 \times 10^{-11}\ \text{m})(64\ \text{m/s})}$$

$$m = \boxed{1.6 \times 10^{-25}\ \text{kg}}$$

---

3. $q = (2)(1.60 \times 10^{-19}\ \text{C}) = 3.20 \times 10^{-19}$ C

$\Delta V = 240$ V

$h = 6.63 \times 10^{-34}$ J•s

$\lambda = 4.4 \times 10^{-13}$ m

$$KE = q\Delta V = \tfrac{1}{2}mv^2$$

$$m = \frac{2q\Delta V}{V^2}$$

$$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{(4.4 \times 10^{-13}\ \text{m})(1.5 \times 10^{-26}\ \text{kg})} = 1.0 \times 10^{5}\ \text{m/s}$$

$$m = \frac{2(3.20 \times 10^{-19}\ \text{C})(240\ \text{V})}{(1.0 \times 10^{5}\ \text{m/s})^2}$$

$$m = \boxed{1.5 \times 10^{-26}\ \text{kg}}$$

Givens | *Solutions*

4. $\lambda = 2.5 \text{ nm} = 2.5 \times 10^{-9}$ m

$m_n = 1.675 \times 10^{-27}$ kg

$h = 6.63 \times 10^{-34}$ J•s

$$mv = \frac{h}{\lambda}$$

$$v = \frac{h}{\lambda m_n}$$

$$v = \frac{6.63 \times 10^{-34} \text{ J•s}}{(2.5 \times 10^{-9} \text{ m})(1.675 \times 10^{-27} \text{ kg})}$$

$$v = \boxed{1.6 \times 10^{2} \text{ m/s}}$$

5. $m = 7.65 \times 10^{-70}$ kg

$\lambda = 5.0 \times 10^{32}$ m

$h = 6.63 \times 10^{-34}$ J•s

$$mv = \frac{h}{\lambda}$$

$$v = \frac{h}{\lambda m}$$

$$v = \frac{6.63 \times 10^{-34} \text{ J•s}}{(5.0 \times 10^{32} \text{ m})(7.65 \times 10^{-70} \text{ kg})}$$

$$v = \boxed{1.7 \times 10^{3} \text{ m/s}}$$

6. $m = 1.6 \text{ g} = 1.6 \times 10^{-3}$ kg

$v = 3.8$ m/s

$h = 6.63 \times 10^{-34}$ J•s

$$mv = \frac{h}{\lambda}$$

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.63 \times 10^{-34} \text{ J•s}}{(1.6 \times 10^{-3} \text{ kg})(3.8 \text{ m/s})}$$

$$\lambda = \boxed{1.1 \times 10^{-31} \text{ m}}$$

7. $\Delta x = 42\,195$ m

$\Delta t = 3 \text{ h } 47 \text{ min} = 227$ min

$m = 0.080$ kg

$h = 6.63 \times 10^{-34}$ J•s

$$v = \frac{\Delta x}{\Delta t} = \frac{42\,195 \text{ m}}{(227 \text{ min})\left(\frac{60 \text{ s}}{1 \text{ min}}\right)} = \boxed{3.10 \text{ m/s}}$$

$$\frac{h}{\lambda} = mv$$

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{6.63 \times 10^{-34} \text{ J•s}}{(0.080 \text{ kg})(3.10 \text{ m/s})}$$

$$\lambda = \boxed{2.7 \times 10^{-33} \text{ m}}$$

II

Subatomic Physics

Additional Practice A

Givens	*Solutions*
1. $E = 610\ \text{TW}\bullet\text{h}$	**a.** $\Delta m = \dfrac{E}{c^2} = \dfrac{(610 \times 10^9\ \text{kW}\bullet\text{h})(3.6 \times 10^6\ \text{J/kW}\bullet\text{h})}{(3.00 \times 10^8\ \text{m/s})^2}$ $\Delta m = \boxed{24\ \text{kg}}$
atomic mass of ${}^2_1\text{H} =$ 2.014 102 u	**b.** $n = \dfrac{\Delta m}{\text{atomic mass of } {}^2_1\text{H}} = \dfrac{24\ \text{kg}}{(1.66 \times 10^{-27}\ \text{kg/u})(2.014\ 102\ \text{u})}$ $n = \boxed{7.2 \times 10^{27}\ {}^2_1\text{H nuclei}}$
atomic mass of ${}^{56}_{26}\text{Fe} =$ 55.934 940 u	**c.** $n = \dfrac{\Delta m}{\text{atomic mass of } {}^{56}_{26}\text{Fe}} = \dfrac{24\ \text{kg}}{(1.66 \times 10^{-27}\ \text{kg/u})(55.934\ 940\ \text{u})}$ $n = \boxed{2.6 \times 10^{26}\ {}^{56}_{26}\text{Fe nuclei}}$
atomic mass of ${}^{226}_{88}\text{Ra} =$ 226.025 402 u	**d.** $n = \dfrac{\Delta m}{\text{atomic mass of } {}^{226}_{88}\text{Ra}} = \dfrac{24\ \text{kg}}{(1.66 \times 10^{-27}\ \text{kg/u})(226.025\ 402\ \text{u})}$ $n = \boxed{6.4 \times 10^{25}\ {}^{226}_{88}\text{Ra nuclei}}$

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2. Givens:

$m = 4.1 \times 10^7$ kg

$h = 10.0$ cm

$Z = 26$

$N = 56 - 26 = 30$

$m_H = 1.007\ 825$ u

$m_n = 1.008\ 665$ u

atomic mass of ${}^{56}_{26}\text{Fe} =$ 55.934 940 u

Solutions:

a. $E = mgh = (4.1 \times 10^7\ \text{kg})(9.81\ \text{m/s}^2)(0.100\ \text{m})$

$E = \boxed{4.0 \times 10^7\ \text{J}}$

b. $E_{tot} = \dfrac{(4.0 \times 10^7\ \text{J})(1 \times 10^{-6}\ \text{MeV/eV})}{(1.60 \times 10^{-19}\ \text{J/eV})} = 2.5 \times 10^{20}\ \text{MeV}$

$$\Delta m_{tot} = \frac{2.5 \times 10^{20}\ \text{MeV}}{931.49\ \text{MeV/u}} = 2.7 \times 10^{17}\ \text{u}$$

$$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } {}^{56}_{26}\text{Fe}$$

$$\Delta m = 26(1.007\ 825\ \text{u}) + 30(1.008\ 665\ \text{u}) - 55.934\ 940\ \text{u}$$

$$\Delta m = 0.528\ 460\ \text{u}$$

$$E_{bind} = (0.528\ 460\ \text{u})\left(931.49\ \frac{\text{MeV}}{\text{u}}\right)$$

$$E_{bind} = 492.26\ \text{MeV}$$

$$n = \frac{E_{tot}}{E_{bind}} = \frac{2.5 \times 10^{20}\ \text{MeV}}{492.26\ \text{MeV}} = 5.1 \times 10^{17}\ \text{reactions}$$

$$m_{tot} = (5.1 \times 10^{17})(55.934\ 940\ \text{u})\left(1.66 \times 10^{-27}\ \frac{\text{kg}}{\text{u}}\right) = \boxed{4.7 \times 10^{-8}\ \text{kg}}$$

II

Givens	*Solutions*
3. $E = 2.0 \times 10^3$ TW•h = 2.0×10^{15} W•h atomic mass of $^{235}_{92}$U = 235.043 924 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u $Z = 92$ $N = 235 - 92 = 143$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } ^{235}_{92}\text{U}$ $\Delta m = 92(1.007\ 825\ \text{u}) + 143(1.008\ 665\ \text{u}) - 235.043\ 924\ \text{u} = 1.915\ 071\ \text{u}$ $E_{bind} = (1.915\ 071\ \text{u})\left(931.49\ \frac{\text{MeV}}{\text{u}}\right) = 1.7839 \times 10^3\ \text{MeV} = 1.7839 \times 10^9\ \text{eV}$ $E_{bind} = (1.7839 \times 10^9\ \text{eV})\left(1.60 \times 10^{-19}\ \frac{\text{J}}{\text{eV}}\right) = 2.85 \times 10^{-10}\ \text{J}$ $E = (2.0 \times 10^{15}\ \text{W•h})\left(\frac{3.60 \times 10^3\ \text{s}}{\text{h}}\right) = 7.2 \times 10^{18}\ \text{J}$ $n = \frac{E}{E_{bind}} = \frac{7.2 \times 10^{18}\ \text{J}}{2.85 \times 10^{-10}\ \text{J}} = 2.5 \times 10^{28}$ reactions $m_{tot} = (2.5 \times 10^{28})(235.043\ 924\ \text{u})\left(1.66 \times 10^{-27}\ \frac{\text{kg}}{\text{u}}\right) = \boxed{9.8 \times 10^3\ \text{kg}}$
4. $E = 2.1 \times 10^{19}$ J atomic mass of $^{12}_{6}$C = 12.000 000 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u $Z = 6$ $N = 12 - 6 = 6$	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } ^{12}_{6}\text{C}$ $\Delta m = 6(1.007\ 825\ \text{u}) + 6(1.008\ 665\ \text{u}) - 12.000\ 000\ \text{u}$ $\Delta m = 9.8940 \times 10^{-2}$ u $E_{bind} = (9.8940 \times 10^{-2}\ \text{u})\left(931.49\ \frac{\text{MeV}}{\text{u}}\right) = 92.162\ \text{MeV}$ $E_{bind} = (92.162 \times 10^6\ \text{eV})\left(1.60 \times 10^{-19}\ \frac{\text{J}}{\text{eV}}\right) = 1.47 \times 10^{-11}\ \text{J}$ $n = \frac{E}{E_{bind}} = \frac{2.1 \times 10^{19}\ \text{J}}{1.47 \times 10^{-11}\ \text{J}} = 1.4 \times 10^{30}$ reactions $m_{tot} = (1.4 \times 10^{30})(12.000\ 000\ \text{u})\left(1.66 \times 10^{-27}\ \frac{\text{kg}}{\text{u}}\right) = \boxed{2.8 \times 10^4\ \text{kg}}$
5. $P_{tot} = 3.9 \times 10^{26}$ J/s $Z = 2$ $N = 4 - 2 = 2$ atomic mass of $^{4}_{2}$He = 4.002 602 u atomic mass of H = 1.007 825 u m_n =1.008 665 u	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } ^{4}_{2}\text{He}$ $\Delta m = (2)(1.007\ 825\ \text{u}) + (2)(1.008\ 665\ \text{u}) - 4.002\ 602\ \text{u}$ $\Delta m = 0.030\ 378$ u $E = (0.030\ 378\ \text{u})\left(931.49\ \frac{\text{MeV}}{\text{u}}\right)$ $E = 28.297$ MeV $\frac{n}{\Delta t} = \frac{P_{tot}}{E} = \frac{(3.9 \times 10^{26}\ \text{J/s})(1 \times 10^{-6}\ \text{MeV/eV})}{(1.60 \times 10^{-19}\ \text{J/eV})(28.297\ \text{MeV})}$ $\frac{n}{\Delta t} = \boxed{8.6 \times 10^{37}\ \text{reactions/s}}$
6. $P = 42$ MW $= 42 \times 10^6$ W atomic mass of $^{14}_{7}$N = 14.003 074 u atomic mass of H = 1.007 825 u $m_n = 1.008\ 665$ u $Z = 7$ $N = 14 - 7 = 7$ $\Delta t = 24$ h	$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } ^{14}_{7}\text{N}$ $\Delta m = 7(1.007\ 825\ \text{u}) + 7(1.008\ 665\ \text{u}) - 14.003\ 074\ \text{u}$ $\Delta m = 0.112\ 356$ u $E_{bind} = (0.112\ 356\ \text{u})\left(931.49\ \frac{\text{MeV}}{\text{u}}\right) = 104.66\ \text{MeV}$ $E_{bind} = (104.66 \times 10^6\ \text{eV})\left(1.60 \times 10^{-19}\ \frac{\text{J}}{\text{eV}}\right) = 1.67 \times 10^{-11}\ \text{J}$ $n = \frac{P\Delta t}{E_{bind}} = \frac{(42 \times 10^6\ \text{W})(24\ \text{h})(3600\ \text{s/h})}{1.67 \times 10^{-11}\ \text{J}} = 2.2 \times 10^{23}$ reactions $m_{tot} = (2.2 \times 10^{23})(14.003\ 074\ \text{u})\left(1.66 \times 10^{-27}\ \frac{\text{kg}}{\text{u}}\right) = \boxed{5.1 \times 10^{-3}\ \text{kg} = 5.1\ \text{g}}$

Givens | *Solutions*

7. $P = 3.84 \times 10^7$ W

atomic mass of ${}^{12}_{6}\text{C}$ = 12.000 000 u

atomic mass of H = 1.007 825 u

$m_n = 1.008\ 665$ u

$Z = 6$

$N = 12 - 6 = 6$

$\Delta m = Z(\text{atomic mass of H}) + Nm_n - \text{atomic mass of } {}^{12}_{6}\text{C}$

$\Delta m = 6(1.007\ 825 \text{ u}) + 6(1.008\ 665 \text{ u}) - 12.000\ 000 \text{ u}$

$\Delta m = 9.8940 \times 10^{-2}$ u

$$E_{bind} = (9.8940 \times 10^{-2} \text{ u})\left(931.49 \times 10^6 \frac{\text{eV}}{\text{u}}\right)\left(1.60 \times 10^{-19} \frac{\text{J}}{\text{eV}}\right)$$

$E_{bind} = 1.47 \times 10^{-11}$ J

$$\frac{n}{\Delta t} = \frac{P}{E_{bind}} = \frac{3.84 \times 10^7 \text{ W}}{1.47 \times 10^{-11} \text{ J}} = 2.61 \times 10^{18} \text{ reactions/s}$$

$$\frac{m_{tot}}{\Delta t} = (2.61 \times 10^{18} \text{ s}^{-1})(12.000\ 000 \text{ u})\left(1.66 \times 10^{-27} \frac{\text{kg}}{\text{u}}\right) = \boxed{5.20 \times 10^{-8} \text{ kg/s}}$$

Additional Practice B

1. ${}^{238}_{92}\text{U} + {}^{1}_{0}n \rightarrow \text{X}$

$\text{X} \rightarrow {}^{939}_{93}\text{Np} + {}^{0}_{-1}e + \overline{v}$

${}^{239}_{93}\text{Np} \rightarrow {}^{239}_{94}\text{Pu} + {}^{0}_{-1}e + \overline{v}$

mass number of X = 238 + 1 = 239

atomic number of X = 92 + 0 = 92 (uranium)

$\text{X} = {}^{239}_{92}\text{U}$

The equations are as follows:

$$\boxed{\begin{array}{l} {}^{238}_{92}\text{U} + {}^{1}_{0}n \rightarrow {}^{239}_{92}\text{U} \\ {}^{239}_{92}\text{U} \rightarrow {}^{939}_{93}\text{Np} + {}^{0}_{-1}e + \overline{v} \\ {}^{239}_{93}\text{Np} \rightarrow {}^{239}_{94}\text{Pu} + {}^{0}_{-1}e + \overline{v} \end{array}}$$

2. $\text{X} \rightarrow \text{Y} + {}^{4}_{2}\text{He}$

$\text{Y} \rightarrow \text{Z} + {}^{4}_{2}\text{He}$

$\text{Z} \rightarrow {}^{212}_{83}\text{Bi} + {}^{0}_{-1}e + \overline{v}$

mass number of Z = 212 + 0 = 212

atomic number of Z = 83 − 1 = 82 (lead)

$Z = {}^{212}_{82}\text{Pb}$

mass number of Y = 212 + 4 = 216

atomic number of Y = 82 + 2 = 84 (polonium)

$\text{Y} = {}^{216}_{84}\text{Po}$

mass number of X = 216 + 4 = 220

atomic number of X = 84 + 2 = 86 (radon)

$\text{X} = {}^{220}_{86}\text{Rn}$

The equations are as follows:

$$\boxed{\begin{array}{l} {}^{220}_{86}\text{Rn} \rightarrow {}^{216}_{84}\text{Po} + {}^{4}_{2}\text{He} \\ {}^{216}_{84}\text{Po} \rightarrow {}^{212}_{82}\text{Pb} + {}^{4}_{2}\text{He} \\ {}^{212}_{82}\text{Pb} \rightarrow {}^{212}_{83}\text{Bi} + {}^{0}_{-1}e + \overline{v} \end{array}}$$

3. $\text{X} \rightarrow {}^{135}_{56}\text{Ba} + {}^{0}_{-1}e + \overline{v}$

mass number of X = 135 + 0 = 135

atomic number of X = 56 + (−1) = 55 (cesium)

$\text{X} = {}^{135}_{55}\text{Cs}$

$$\boxed{{}^{135}_{55}\text{Cs} \rightarrow {}^{135}_{56}\text{Ba} + {}^{0}_{-1}e + \overline{v}}$$

II

Givens	*Solutions*
4. ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + X$	mass number of X = 235 + 1 − 144 − 89 = 3 atomic number of X = 92 + 0 − 56 − 36 = 0 (neutron) $X = 3\,{}^{1}_{0}n$ $\boxed{{}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n}$
${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{54}Xe + Y + 2\,{}^{1}_{0}n$	mass number of Y = 235 + 1 − 140 − 2 = 94 atomic number of Y = 92 + 0 − 54 − 0 = 38 (strontium) $Y = {}^{94}_{38}Sr$ $\boxed{{}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2\,{}^{1}_{0}n}$
5. ${}^{228}_{90}Th \rightarrow X + {}^{4}_{2}He + \gamma$	mass number of X = 228 − 4 = 224 atomic number X = 90 − 2 = 88 (radium) $X = {}^{224}_{88}Ra$ $\boxed{{}^{228}_{90}Th \rightarrow {}^{224}_{88}Ra + {}^{4}_{2}He + \gamma}$
6. ${}^{1}_{1}p + {}^{7}_{3}Li \rightarrow X + {}^{4}_{2}He$	mass number of X = 1 + 7 − 4 = 4 atomic number of X = 1 + 3 − 2 = 2 (helium) $X = {}^{4}_{2}He$ $\boxed{{}^{1}_{1}p + {}^{7}_{3}Li \rightarrow {}^{4}_{2}He + {}^{4}_{2}He}$
7. ${}^{217}_{85}At \rightarrow X + {}^{4}_{2}He$	mass number of X = 217 − 4 = 213 atomic number of X = 85 − 2 = 83 (bismuth) $X = {}^{213}_{83}Bi$ $\boxed{{}^{217}_{85}At \rightarrow {}^{213}_{83}Bi + {}^{4}_{2}He}$

Additional Practice C

1. $T_{1/2} = 26$ min, 43.53 s

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{(26\text{ min})(60\text{ s/min}) + 43.53\text{ s}}$$

$$\lambda = \boxed{4.32 \times 10^{-4}\text{ s}^{-1}}$$

5 times the run time = 5 half-lives

percent of sample remaining = $(0.5)^5(100)$

percent decayed = 100 − percent remaining = $100 - (0.5)^5(100) = \boxed{96.875\text{ percent}}$

Givens	*Solutions*
2. $T_{1/2} = 1.91$ years decrease = 93.75 percent = 0.9375	If 0.9375 of the sample has decayed, 1.0000 − 0.9375 = 0.0625 of the sample remains. $0.0625 = (0.5)^4$, so 4 half-lives have passed. $\Delta t = 4T_{1/2} = (4)(1.91 \text{ years}) = \boxed{7.64 \text{ years}}$
3. $T_{1/2} = 11.9$ s $N_i = 1.00 \times 10^{13}$ atoms $N_f = 1.25 \times 10^{12}$ atoms	$\frac{\Delta N}{N_i} = \frac{1.00 \times 10^{13} - 1.25 \times 10^{12}}{1.00 \times 10^{13}} = 0.875$ If 0.875 of the sample has decayed, 1.000 − 0.875 = 0.125 of the sample remains. $0.125 = (0.5)^3$, so 3 half-lives have passed. $\Delta t = 3T_{1/2} = (3)(11.9 \text{ s}) = \boxed{35.7 \text{ s}}$
4. $\Delta t = 4800$ years $T_{1/2} = 1600$ years	$\frac{\Delta t}{T_{1/2}} = \frac{4800 \text{ years}}{1600 \text{ years}} = 3$ half-lives amount remaining after $3T_{1/2} = (0.5)^3 = 0.125 = \boxed{12.5 \text{ percent}}$
5. $\Delta t = 88$ years amount of sample remaining $= \frac{1}{16} = 0.0625$	$0.0625 = (0.5)^4$, so 4 half-lives have passed. $T_{1/2} = \frac{1}{4}\Delta t = \frac{88 \text{ years}}{4} = 22$ years $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{22 \text{ years}}$ $\lambda = \boxed{3.2 \times 10^{-2} \text{ years}^{-1}}$
6. $\Delta t = 34$ days, 6 h, 26 min amount of sample remaining $= \frac{1}{512} = 1.95 \times 10^{-3}$	$\Delta t = (34 \text{ days})\left(\frac{24 \text{ h}}{\text{day}}\right)\left(\frac{60 \text{ min}}{\text{h}}\right) + (6 \text{ h})\left(\frac{60 \text{ min}}{\text{h}}\right) + 26 \text{ min}$ $\Delta t = 4.9346 \times 10^4$ min $1.95 \times 10^{-3} = (0.5)^9$, so 9 half-lives have passed. $T_{1/2} = \frac{1}{9}\Delta t = \frac{4.9346 \times 10^4 \text{ min}}{9} = 5482.9$ min $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{5482.9 \text{ min}}$ $\lambda = \boxed{1.26 \times 10^{-4} \text{ min}^{-1} = 0.182 \text{ days}^{-1}}$
7. $T = 4.4 \times 10^{-22}$ s	$\frac{1}{T} = \lambda = \frac{0.693}{T_{1/2}}$ $T = \frac{T_{1/2}}{0.693}$ $T_{1/2} = (0.693)(T) = (0.693)(4.4 \times 10^{-22} \text{ s}) = \boxed{3.0 \times 10^{-22} \text{ s}}$

II

Appendix J

Additional Practice A

Givens | *Solutions*

1. $r = 10.0$ km

$\Delta\theta = +15.0$ rad

$\Delta s = r\Delta\theta = (10.0 \text{ km})(15.0 \text{ rad}) = \boxed{1.50 \times 10^2 \text{ km}}$

The particle moves in the positive, or $\boxed{\text{counterclockwise}}$, direction around the neutron star's "north" pole.

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2. $\Delta\theta = 3(2\pi \text{ rad})$

$r = 6560$ km

$\Delta s = r\Delta\theta = (6560 \text{ km})[(3)(2\pi \text{ rad})] = \boxed{1.24 \times 10^5 \text{ km}}$

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3. $r = \dfrac{1.40 \times 10^5 \text{ km}}{2}$

$= 7.00 \times 10^4$ km

$\Delta\theta = 1.72$ rad

$r_E = 6.37 \times 10^3$ km

a. $\Delta s = r\Delta\theta = (7.00 \times 10^4 \text{ km})(1.72 \text{ rad}) = \boxed{1.20 \times 10^5 \text{ km}}$

b. $\Delta\theta_E = \dfrac{\Delta s}{r_E} = \dfrac{(1.20 \times 10^5 \text{ km})(1 \text{ rev}/2\pi \text{ rad})}{6.37 \times 10^3 \text{ km}} = \boxed{3.00 \text{ rev, or } 3.00 \text{ orbits}}$

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4. $\Delta\theta = 225$ rad

$\Delta s = 1.50 \times 10^6$ km

$r = \dfrac{\Delta s}{\Delta\theta} = \dfrac{1.50 \times 10^6 \text{ km}}{225 \text{ rad}} = \boxed{6.67 \times 10^3 \text{ km}}$

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5. $r = 5.8 \times 10^7$ km

$\Delta s = 1.5 \times 10^8$ km

$\Delta\theta = \dfrac{\Delta s}{r} = \dfrac{1.5 \times 10^8 \text{ km}}{5.8 \times 10^7 \text{ km}} = \boxed{2.6 \text{ rad}}$

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6. $\Delta s = -1.79 \times 10^4$ km

$r = 6.37 \times 10^3$ km

$\Delta\theta = \dfrac{\Delta s}{r} = \dfrac{-1.79 \times 10^4 \text{ km}}{6.37 \times 10^3 \text{ km}} = \boxed{-2.81 \text{ rad}}$

Additional Practice B

1. $r = 1.82$ m

$\omega_{avg} = 1.00 \times 10^{-1}$ rad/s

$\Delta t = 60.0$ s

$\Delta\theta = \omega_{avg}\Delta t = (1.00 \times 10^{-1} \text{ rad/s})(60.0 \text{ s}) = \boxed{6.00 \text{ rad}}$

$\Delta s = r\Delta\theta = (1.82 \text{ m})(6.00 \text{ rad}) = \boxed{10.9 \text{ m}}$

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2. $\Delta t = 120$ s

$\omega_{avg} = 0.40$ rad/s

$\Delta\theta = \omega_{avg}\Delta t = (0.40 \text{ rad/s})(120 \text{ s}) = \boxed{48 \text{ rad}}$

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3. $r = 30.0$ m

$\Delta s = 5.0 \times 10^2$ m

$\Delta t = 120$ s

$\omega_{avg} = \dfrac{\Delta\theta}{\Delta t} = \dfrac{\Delta s}{r\Delta t} = \dfrac{5.0 \times 10^2 \text{ m}}{(30.0 \text{ m})(120 \text{ s})} = \boxed{0.14 \text{ rad/s}}$

Givens	*Solutions*
4. $\Delta\theta = 16$ rev $\Delta t = 4.5$ min	$\omega_{avg} = \frac{\Delta\theta}{\Delta t} = \frac{(16 \text{ rev})(2\pi \text{ rad/rev})}{(4.5 \text{ min})(60 \text{ s/min})} = \boxed{0.37 \text{ s}}$
5. $\omega_{avg} = 2\pi$ rad/24 h $\Delta\theta = 0.262$ rad	$\Delta t = \frac{\Delta\theta}{\omega_{avg}} = \frac{0.262 \text{ rad}}{\left(\frac{2\pi \text{ rad}}{24 \text{ h}}\right)} = \boxed{1.00 \text{ h}}$
6. $r = 2.00$ m $\Delta s = 1.70 \times 10^2$ km $\omega_{avg} = 5.90$ rad/s	$\Delta t = \frac{\Delta\theta}{\omega_{avg}} = \frac{\Delta s}{r\omega_{avg}} = \frac{1.70 \times 10^5 \text{ m}}{(2.00 \text{ m})(5.90 \text{ rad/s})} = \boxed{1.44 \times 10^4 \text{ s} = 4.00 \text{ h}}$

Additional Practice C

1. $\alpha_{avg} = 2.0$ rad/s^2 $\omega_1 = 0$ rad/s $\omega_2 = 9.4$ rad/s	$\Delta t = \frac{\omega_2 - \omega_1}{\alpha_{avg}}$ $\Delta t = \frac{9.4 \text{ rad/s} - 0.0 \text{ rad/s}}{2.0 \text{ rad/s}^2}$ $\Delta t = \boxed{4.7 \text{ s}}$
2. $\Delta t_J = 9.83$ h $\alpha_{avg} = -3.0 \times 10^{-8}$ rad/s^2 $\omega_2 = 0$ rad/s	$\omega_1 = \frac{\Delta\theta}{\Delta t_J} = \frac{2\pi \text{ rad}}{(9.83 \text{ h})(3600 \text{ s/h})} = 1.78 \times 10^{-4} \text{ rad/s}$ $\Delta t = \frac{\omega_2 - \omega_1}{\alpha_{avg}} = \frac{0.00 \text{ rad/s} - 1.78 \times 10^{-4} \text{ rad/s}}{-3.0 \times 10^{-8} \text{ rad/s}^2}$ $\Delta t = \boxed{5.9 \times 10^3 \text{ s}}$
3. $\omega_1 = 2.00$ rad/s $\omega_2 = 3.15$ rad/s $\Delta t = 3.6$ s	$\alpha_{avg} = \frac{\omega_2 - \omega_1}{\Delta t} = \frac{3.15 \text{ rad/s} - 2.00 \text{ rad/s}}{3.6 \text{ s}} = \frac{1.15 \text{ rad/s}}{3.6 \text{ s}}$ $\alpha_{avg} = \boxed{0.32 \text{ rad/s}^2}$
4. $\omega_1 = 8.0$ rad/s $\omega_2 = 3\omega_1 = 24$ rad/s $\Delta t = 25$ s	$\alpha_{avg} = \frac{\omega_2 - \omega_1}{\Delta t} = \frac{24 \text{ rad/s} - 8.0 \text{ rad/s}}{25 \text{ s}} = \frac{16 \text{ rad/s}}{25 \text{ s}}$ $\alpha_{avg} = \boxed{0.64 \text{ rad/s}^2}$
5. $\Delta t_1 = 365$ days $\Delta\theta_1 = 2\pi$ rad $\alpha_{avg} = 6.05 \times 10^{-13}$ rad/s^2 $\Delta t_2 = 12.0$ days	$\omega_1 = \frac{\Delta\theta_1}{\Delta t_2} = \frac{2\pi \text{ rad}}{(365 \text{ days})(24 \text{ h/day})(3600 \text{ s/h})} = 1.99 \times 10^{-7} \text{ rad/s}$ $\omega_2 = \omega_1 + \alpha_{avg}\Delta t_2 = 1.99 \times 10^{-7} \text{ rad/s} + (6.05 \times 10^{-13} \text{ rad/s}^2)(12.0 \text{ days})(24 \text{ h/day})(3600 \text{ s/h})$ $w_2 = 1.99 \times 10^{-7} \text{ rad/s} + 6.27 \times 10^{-7} \text{ rad/s} = \boxed{8.26 \times 10^{-7} \text{ rad/s}}$
6. $\omega_1 = 0$ rad/s $\alpha_{avg} = 0.800$ rad/s^2 $\Delta t = 8.40$ s	$\alpha_{avg} = \frac{\omega_2 - \omega_1}{\Delta t}$ $\omega_2 = \omega_1 + \alpha_{avg}\Delta t$ $\omega_2 = 0 \text{ rad/s} + (0.800 \text{ rad/s}^2)(8.40 \text{ s})$ $\omega_2 = \boxed{6.72 \text{ rad/s}}$

II

Additional Practice D

Givens	*Solutions*
1. $\omega_i = 5.0$ rad/s $\alpha = 0.60$ rad/s^2 $\Delta t = 0.50$ min	$\omega_f = \omega_i + \alpha\Delta t$ $\omega_f = 5.0 \text{ rad/s} + (0.60 \text{ rad/s}^2)(0.50 \text{ min})(60.0 \text{ s/min})$ $\omega_f = 5.0 \text{ rad/s} + 18 \text{ rad/s}$ $\omega_f = \boxed{23 \text{ rad/s}}$
2. $\alpha = 1.0 \times 10^{-10}$ rad/s^2 $\Delta t = 12$ h $\omega_i = \dfrac{2\pi \text{ rad}}{27.3 \text{ days}}$	$\omega_i = \left(\dfrac{2\pi \text{ rad}}{27.3 \text{ days}}\right)\left(\dfrac{1 \text{ day}}{24 \text{ h}}\right)\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right) = 2.66 \times 10^{-6} \text{ rad/s}$ $\omega_f = \omega_i + \alpha\Delta t = 2.66 \times 10^{-6} \text{ rad/s} + (1.0 \times 10^{-10} \text{ rad/s}^2)(12 \text{ h})(3600 \text{ s/h})$ $\omega_f = 2.66 \times 10^{-6} \text{ rad/s} + 4.3 \times 10^{-6} \text{ rad/s} = \boxed{7.0 \times 10^{-6} \text{ rad/s}}$
3. $r = \dfrac{43 \text{ m}}{2\pi \text{ rad}}$ $\omega_i = 0$ rad/s $\Delta s = 160$ m $\alpha = 5.00 \times 10^{-2}$ rad/s^2	$\Delta\theta = \dfrac{\Delta s}{r}$ $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta = \omega_i^2 + \dfrac{2\alpha\Delta s}{r}$ $\omega_f = \sqrt{\omega_i^2 + \dfrac{2\,\alpha\Delta s}{r}} = \sqrt{(0 \text{ rad/s})^2 + \dfrac{(2)(5.00 \times 10^{-2} \text{ rad/s}^2)(160 \text{ m})}{\left(\dfrac{43 \text{ m}}{2\pi \text{ rad}}\right)}}$ $\omega_f = \boxed{1.5 \text{ rad/s}}$
4. $\Delta s = 52.5$ m $\alpha = -3.2 \times 10^{-5}$ rad/s^2 $\omega_f = 0.080$ rad/s $r = 8.0$ cm	$\Delta\theta = \dfrac{\Delta s}{r}$ $\omega_f^2 = w_i^2 + 2\alpha\Delta\theta = w_i^2 + \dfrac{2\alpha\Delta s}{r}$ $\omega_i = \sqrt{{w_f}^2 - \dfrac{2\alpha\Delta s}{r}} = \sqrt{(0.080 \text{ rad/s})^2 - \dfrac{(2)(-3.2 \times 10^{-5} \text{ rad/s}^2)(52.5 \text{ m})}{8.0 \times 10^{-2} \text{ m}}}$ $\omega_i = \sqrt{6.4 \times 10^{-3} \text{ rad}^2/\text{s}^2 + 4.2 \times 10^{-2} \text{ rad}^2/\text{s}^2} = \sqrt{4.8 \times 10^{-2} \text{ rad}^2/\text{s}^2}$ $\omega_i = \boxed{0.22 \text{ rad/s}}$
5. $r = 3.0$ m $\omega_i = 0.820$ rad/s $\omega_f = 0.360$ rad/s $\Delta s = 20.0$ m	$\Delta\theta = \dfrac{\Delta s}{r}$ $\alpha = \dfrac{{\omega_f}^2 - {\omega_i}^2}{2\Delta\theta} = \dfrac{\omega_f^2 - \omega_i^2}{2\left(\dfrac{\Delta s}{r}\right)} = \dfrac{(0.360 \text{ rad/s})^2 - (0.820 \text{ rad/s})^2}{(2)\left(\dfrac{20.0 \text{ m}}{3.0 \text{ m}}\right)}$ $\alpha = \dfrac{0.130 \text{ rad}^2/\text{s}^2 - 0.672 \text{ rad}^2/\text{s}^2}{(2)\left(\dfrac{20.0 \text{ m}}{3.0 \text{ m}}\right)} = \dfrac{-0.542 \text{ rad}^2/\text{s}^2}{(2)\left(\dfrac{20.0 \text{ m}}{3.0 \text{ m}}\right)}$ $\alpha = \boxed{-4.1 \times 10^{-2} \text{ rad/s}^2}$

II

Givens | *Solutions*

6. $r = 1.0$ km

$\omega_i = 5.0 \times 10^{-3}$ rad/s

$\Delta t = 14.0$ min

$\Delta\theta = 2\pi$ rad

$$\Delta\theta = \omega_i \Delta t + \tfrac{1}{2}\alpha\Delta t^2$$

$$\alpha = \frac{2(\Delta\theta - \omega_i\Delta t)}{\Delta t^2} = \frac{(2)[2\pi \text{ rad} - (5.0\times10^{-3}\text{ rad/s})(14.0\text{ min})(60\text{ s/min})]}{[(14.0\text{ min})(60\text{ s/min})]^2}$$

$$\alpha = \frac{(2)(6.3\text{ rad} - 4.2\text{ rad})}{[(14.0\text{ min})(60\text{ s/min})]^2} = \frac{(2)(2.1\text{ rad})}{[(14.0\text{ min})(60\text{ s/min})]^2} = \boxed{6.0\times10^{-6}\text{ rad/s}^2}$$

7. $\omega_i = 7.20 \times 10^{-2}$ rad/s

$\Delta\theta = 12.6$ rad

$\Delta t = 4$ min, 22 s

$$\Delta t = (4\text{ min})(60\text{ s/min}) + 22\text{ s} = 262\text{ s}$$

$$\Delta\theta = \omega_i \Delta t + \tfrac{1}{2}\alpha\Delta t^2$$

$$\alpha = \frac{2(\Delta\theta - \omega_i\Delta t)}{\Delta t^2} = \frac{(2)[12.6\text{ rad} - (7.20\times10^{-2}\text{ rad/s})(262\text{ s})]}{(262\text{ s})^2}$$

$$\alpha = \frac{(2)(12.6\text{ rad} - 18.9\text{ rad})}{(262\text{ s})^2} = \frac{(2)(-6.3\text{ rad/s})}{(262\text{ s})^2} = \boxed{-1.8\times10^{-4}\text{ rad/s}^2}$$

8. $\omega_i = 27.0$ rad/s

$\omega_f = 32.0$ rad/s

$\Delta t = 6.83$ s

$$\alpha_{avg} = \frac{\omega_f - \omega_i}{\Delta t} = \frac{32.0\text{ rad/s} - 27.0\text{ rad/s}}{6.83\text{ s}} = \frac{5.0\text{ rad/s}}{6.83\text{ s}}$$

$$\alpha_{avg} = \boxed{0.73\text{ rad/s}^2}$$

9. $\alpha = 2.68 \times 10^{-5}$ rad/s^2

$\Delta t = 120.0$ s

$\omega_i = \dfrac{2\pi\text{ rad}}{12}$

$$\Delta\theta = \omega_i \Delta t + \tfrac{1}{2}\alpha\Delta t^2$$

$$\Delta\theta = \left(\frac{2\pi\text{ rad}}{12\text{ h}}\right)(1\text{ h}/3600\text{ s})(120.0\text{ s}) + \tfrac{1}{2}(2.68\times10^{-5}\text{ rad/s}^2)(120.0\text{ s})^2$$

$$\Delta\theta = 1.7\times10^{-2}\text{ rad} + 1.93\times10^{-1}\text{ rad} = \boxed{0.210\text{ rad}}$$

10. $w_i = 6.0 \times 10^{-3}$ rad/s

$w_f = 3w_i = 18 \times 10^{-3}$ rad/s

$\alpha = 2.5 \times 10^{-4}$ rad/s^2

$$\Delta\theta = \frac{\omega_f^2 - \omega_i^2}{2\alpha}$$

$$\Delta\theta = \frac{(18\times10^{-3}\text{ rad/s})^2 - (6.0\times10^{-3}\text{ rad/s})^2}{(2)(2.5\times10^{-4}\text{ rad/s}^2)} = \frac{3.2\times10^{-4}\text{ rad}^2/\text{s}^2 - 3.6\times10^{-5}\text{ rad}^2/\text{s}^2}{(2)(2.5\times10^{-4}\text{ rad/s}^2)}$$

$$\Delta\theta = \frac{2.8\times10^{-4}\text{ rad}^2/\text{s}^2}{5.0\times10^{-4}\text{ rad/s}^2} = \boxed{0.56\text{ rad}}$$

11. $\omega_i = 9.0 \times 10^{-7}$ rad/s

$\omega_f = 5.0 \times 10^{-6}$ rad/s

$\alpha = 7.5 \times 10^{-10}$ rad/s^2

$$\Delta t = \frac{\omega_f - \omega_i}{\alpha}$$

$$\Delta t = \frac{5.0\times10^{-6}\text{ rad/s} - 9.0\times10^{-7}\text{ rad/s}}{7.5\times10^{-10}\text{ rad/s}^2} = \frac{4.1\times10^{-6}\text{ rad/s}}{7.5\times10^{-10}\text{ rad/s}^2}$$

$$\Delta t = \boxed{5.5\times10^{3}\text{ s} = 1.5\text{ h}}$$

Givens	*Solutions*
12. $r = 7.1$ m $\Delta s = 500.0$ m $\omega_i = 0.40$ rad/s $\alpha = 4.0 \times 10^{-3}$ rad/s^2	$\Delta\theta = \frac{\Delta s}{r} = \omega_i \Delta t + \frac{1}{2}\alpha\Delta t^2$ $\frac{1}{2}\alpha\Delta t^2 + \omega_i\Delta t - \frac{\Delta s}{r} = 0$ Using the quadratic equation:

$$\Delta t = \frac{-\omega_i \pm \sqrt{\omega_i^{\,2} - 4\left(\frac{1}{2}\alpha\right)\left(\frac{-\Delta s}{r}\right)}}{2\left(\frac{1}{2}\alpha\right)}$$

$$\Delta t = \frac{-0.40 \text{ rad/s} \pm \sqrt{(0.40 \text{ rad/s})^2 + (4)\left(\frac{1}{2}\right)(4.0 \times 10^{-3} \text{ rad/s}^2)\left(\frac{500.0 \text{ m}}{7.1 \text{ m}}\right)}}{(2)\left(\frac{1}{2}\right)(4.0 \times 10^{-3} \text{ rad/s}^2)}$$

$$\Delta t = \frac{-0.40 \text{ rad/s} \pm \sqrt{0.16 \text{ rad}^2/\text{s}^2 + 0.56 \text{ rad}^2/\text{s}^2}}{4.0 \times 10^{-3} \text{ rad/s}^2} = \frac{-0.40 \text{ rad/s} \pm \sqrt{0.72 \text{ rad}^2/\text{s}^2}}{4.0 \times 10^{-3} \text{ rad/s}^2}$$

Choose the positive value:

$$\Delta t = \frac{-0.40 \text{ rad/s} + 0.85 \text{ rad/s}}{4.0 \times 10^{-3} \text{ rad/s}^2} = \frac{0.45 \text{ rad/s}}{\text{rad/s}^2} = \boxed{1.1 \times 10^2 \text{ s}}$$

II

Additional Practice E

1. $\omega = 4.44$ rad/s
$v_t = 4.44$ m/s

$$r = \frac{v_t}{\omega} = \frac{4.44 \text{ m/s}}{4.44 \text{ rad/s}} = \boxed{1.00 \text{ m}}$$

2. $v_t = 16.0$ m/s
$\omega = 1.82 \times 10^{-5}$ rad/s

$$r = \frac{v_t}{\omega} = \frac{16.0 \text{ m/s}}{1.82 \times 10^{-5} \text{ rad/s}} = \boxed{8.79 \times 10^5 \text{ m} = 879 \text{ km}}$$

circumference $= 2\pi r = (2\pi)(879 \text{ km}) = \boxed{5.52 \times 10^3 \text{ km}}$

3. $\omega = 5.24 \times 10^3$ rad/s
$v_t = 131$ m/s

$$r = \frac{v_t}{\omega} = \frac{131 \text{ m/s}}{5.24 \times 10^3 \text{ rad/s}} = \boxed{2.50 \times 10^{-2} \text{ m} = 2.50 \text{ cm}}$$

4. $v_t = 29.7$ km/s
$r = 1.50 \times 10^8$ km

$$\omega = \frac{v_t}{r} = \frac{29.7 \text{ km/s}}{1.50 \times 10^8 \text{ km}} = \boxed{1.98 \times 10^{-7} \text{ rad/s}}$$

5. $r = \frac{19.0 \text{ mm}}{2} = 9.50$ mm
$\omega = 25.6$ rad/s

$$v_t = r\omega = (9.50 \times 10^{-3} \text{ m})(25.6 \text{ rad/s}) = \boxed{0.243 \text{ m/s}}$$

Additional Practice F

Givens | *Solutions*

1. $r = 32$ m

$a_t = 0.20$ m/s^2

$$\alpha = \frac{a_t}{r} = \frac{0.20 \text{ m/s}^2}{32 \text{ m}}$$

$$\alpha = \boxed{6.2 \times 10^{-3} \text{ rad/s}^2}$$

2. $r = 8.0$ m

$a_t = -1.44$ m/s^2

$$\alpha = \frac{a_t}{r} = \frac{-1.44 \text{ m/s}^2}{8.0 \text{ m}} = \boxed{-0.18 \text{ rad/s}^2}$$

3. $\Delta\omega = -2.4 \times 10^{-2}$ rad/s

$\Delta t = 6.0$ s

$a_t = -0.16$ m/s^2

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{-2.4 \times 10^{-2} \text{ rad/s}}{6.0 \text{ s}} = -4.0 \times 10^{-3} \text{ rad/s}^2$$

$$r = \frac{a_t}{\alpha} = \frac{-0.16 \text{ m/s}^2}{-4.0 \times 10^{-3} \text{ rad/s}^2} = \boxed{4.0 \times 10^1 \text{ m}}$$

4. $\Delta\theta' = 14\,628$ turns

$\Delta t' = 1.000$ h

$a_t = 33.0$ m/s^2

$\omega_i = 0$ rad/s

$\Delta\theta = 2\pi$ rad

$$r = \frac{a_t}{\alpha}$$

$$\alpha = \frac{w_f^2 - w_i^2}{2\Delta\theta}$$

$$\omega_f = \frac{\Delta\theta'}{\Delta t'}$$

$$r = \left[\frac{a_t}{\frac{\left(\frac{\Delta\theta'}{\Delta t'}\right)^2 - w_i^2}{2\Delta\theta}}\right] = \frac{2a_t\Delta\theta}{\left(\frac{\Delta\theta'}{\Delta t'}\right)^2 - w_i^2}$$

$$r = \frac{(2)(33.0 \text{ m/s}^2)(2\pi \text{ rad})}{\left[\frac{(14\,628 \text{ turns})(2\pi \text{ rad/turn})}{(1.000 \text{ h})(3600 \text{ s/h})}\right]^2 - (0 \text{ rad/s})^2} = \boxed{0.636 \text{ m}}$$

5. $r = 56.24$ m

$\omega_i = 6.00$ rad/s

$\omega_f = 6.30$ rad/s

$\Delta t = 0.60$ s

$$a_t = r\alpha$$

$$\alpha = \frac{\omega_f - \omega_i}{\Delta t}$$

$$a_t = r\left(\frac{\omega_f - \omega_i}{\Delta t}\right) = (56.24 \text{ m})\left(\frac{6.30 \text{ rad/s} - 6.00 \text{ rad/s}}{0.60 \text{ s}}\right) = \frac{(56.24 \text{ m})(0.30 \text{ rad/s})}{0.60 \text{ s}}$$

$$a_t = \boxed{28 \text{ m/s}^2}$$

6. $r = 1.3$ m

$\Delta\theta = 2\pi$ rad

$\Delta t = 1.8$ s

$\omega_i = 0$ rad/s

$$a_t = r\alpha$$

$$\alpha = \frac{2(\Delta\theta - \omega_i\Delta t)}{\Delta t^2}$$

$$a_t = r\left[\frac{2(\Delta\theta - \omega_i\Delta t)}{\Delta t^2}\right] = (1.3 \text{ m})\left[\frac{(2)[2\pi \text{ rad} - (0 \text{ rad/s})(1.8 \text{ s})]}{(1.8 \text{ s})^2}\right]$$

$$a_t = \boxed{5.0 \text{ m/s}^2}$$

II

Additional Practice G

Givens	*Solutions*

1. $\tau_1 = 2.00 \times 10^5$ N•m

$\tau_2 = 1.20 \times 10^5$ N•m

$h = 24$ m

Apply the second condition of equilibrium, choosing the base of the cactus as the pivot point.

$\tau_{net} = \tau_1 - \tau_2 - Fd(\sin\theta) = 0$

$Fd(\sin\theta) = \tau_1 - \tau_2$

For F to be minimum, d and $\sin\theta$ must be maximum. This occurs when the force is perpendicular to the cactus ($\theta = 90°$) and is applied to the top of the cactus ($d = h =$ 24 m).

$$F_{min} = \frac{\tau_1 - \tau_2}{h} = \frac{2.00 \times 10^5 \text{ N•m} - 1.20 \times 10^5 \text{ N•m}}{24 \text{ m}}$$

$$F_{min} = \frac{8.0 \times 10^4 \text{ N•m}}{24 \text{ m}} = \boxed{3.3 \times 10^3 \text{ N applied to the top of the cactus}}$$

---

2. $m_1 = 40.0$ kg

$m_2 = 5.4$ kg

$d_1 = 70.0$ cm

$d_2 = 100.0$ cm $- 70.0$ cm $= 30.0$ cm

$g = 9.81$ m/s^2

Apply the first condition of equilibrium.

$F_n - m_1g - m_2g - F_{applied} = 0$

$F_n = m_1g + m_2g + F_{applied} = (40.0 \text{ kg})(9.81 \text{ m/s}^2) + (5.4 \text{ kg})(9.81 \text{ m/s}^2) + F_{applied}$

$F_n = 392 \text{ N} + 53 \text{ N} + F_{applied} = 455 \text{ N} + F_{applied}$

Apply the second condition of equilibrium, using the fulcrum as the location for the axis of rotation.

$F_{applied}d_2 + m_2gd_2 - m_1gd_1 = 0$

$$F_{applied} = \frac{m_1gd_1 - m_2gd_2}{d_2} = \frac{(40.0 \text{ kg})(9.81 \text{ m/s}^2)(0.700 \text{ m}) - (5.4 \text{ kg})(9.81 \text{ m/s}^2)(0.300 \text{ m})}{0.300 \text{ m}}$$

$$F_{applied} = \frac{275 \text{ N•m} - 16 \text{ N•m}}{0.300 \text{ m}} = \frac{259 \text{ N•m}}{0.300 \text{ m}}$$

$F_{applied} = \boxed{863 \text{ N}}$

Substitute the value for $F_{applied}$ into the first-condition equation to solve for F_n.

$F_n = 455 \text{ N} + 863 \text{ N} = \boxed{1318 \text{ N}}$

---

3. $m = 134$ kg

$d_1 = 2.00$ m

$d_2 = 7.00$ m $- 2.00$ m $= 5.00$ m

$\theta = 60.0°$

$g = 9.81$ m/s^2

Apply the first condition of equilibrium in the x and y directions.

$F_x = F_{applied}(\cos\theta) - F_f = 0$

$F_y = F_n - F_{applied}(\sin\theta) - mg = 0$

To solve for $F_{applied}$, apply the second condition of equilibrium, using the fulcrum as the pivot point.

$F_{applied}(\sin\theta)d_2 - mgd_1 = 0$

$$F_{applied} = \frac{mgd_1}{d_2(\sin\theta)} = \frac{(134 \text{ kg})(9.81 \text{ m/s}^2)(2.00 \text{ m})}{(5.00 \text{ m})(\sin 60.0°)}$$

$F_{applied} = \boxed{607 \text{ N}}$

Substitute the value for $F_{applied}$ into the first-condition equations to solve for F_n and F_f.

$F_n = F_{applied}(\sin\theta) + mg = (607 \text{ N})(\sin 60.0°) + (134 \text{ kg})(9.81 \text{ m/s}^2)$

$F_n = 526 \text{ N} + 1.31 \times 10^3 \text{ N} = \boxed{1.84 \times 10^3 \text{ N}}$

$F_f = F_{applied}(\cos\theta) = (607 \text{ N})(\cos 60.0°) = \boxed{304 \text{ N}}$

II

Givens	Solutions

4. $m = 8.8 \times 10^3$ kg

$d_1 = 3.0$ m

$d_2 = 15$ m $- 3.0$ m $= 12$ m

$\theta = 20.0°$

$g = 9.81$ m/s^2

Apply the first condition of equilibrium in the x and y directions.

$$F_x = F_{fulcrum,x} - F(\sin\theta) = 0$$

$$F_y F_{fulcrum,y} - F(\cos\theta) - mg = 0$$

To solve for F, apply the second condition of equilibrium •, using the fulcrum as the pivot point.

$$Fd_2 - mg\,d_1(\cos\theta) = 0$$

$$F = \frac{mg\,d_1(\cos\theta)}{d_2} = \frac{(8.8\times10^3\text{ kg})(9.81\text{ m/s}^2)(3.0\text{ m})(\cos 20.0°)}{12\text{ m}}$$

$$F = \boxed{2.0\times10^4\text{ N}}$$

Substitute the value for F into the first-condition equations to solve for the components of $F_{fulcrum}$.

$$F_{fulcrum,x} = F(\sin\theta) = (2.0\times10^4\text{ N})(\sin 20.0°)$$

$$F_{fulcrum,x} = \boxed{6.8\times10^3\text{ N}}$$

$$F_{fulcrum,y} = F(\cos\theta) + mg = (2.0\times10^4\text{ N})(\cos 20.0°) + (8.8\times10^4\text{ kg})(9.81\text{ m/s}^2)$$

$$F_{fulcrum,y} = 1.9\times10^4\text{ N} + 8.6\times10^5\text{ N} = \boxed{8.8\times10^5\text{ N}}$$

II

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5. $m_1 = 64$ kg

$m_2 = 27$ kg

$d_1 = d_2 = \dfrac{3.00\text{ m}}{2} = 1.50$ m

$F_n = 1.50 \times 10^3$ N

$g = 9.81$ m/s^2

Apply the first condition of equilibrium to solve for $F_{applied}$.

$$F_n - m_1 g - m_2 g - F_{applied} = 0$$

$$F_{applied} = F_n - m_1 g - m_2 g = 1.50\times10^3\text{ N} - (64\text{ kg})(9.81\text{ m/s}^2) - (27\text{ kg})(9.81\text{ m/s}^2)$$

$$F_{applied} = 1.50\times10^3\text{ N} - 6.3\times10^2\text{ N} - 2.6\times10^3\text{ N} = 6.1\times10^2\text{ N}$$

To solve for the lever arm for $F_{applied}$, apply the second condition of equilibrium, using the fulcrum as the pivot point.

$$F_{applied}\,d + m_2 g\,d_2 - m_1 g\,d_1 = 0$$

$$d = \frac{m_1 g\,d_1 - m_2 g\,d_2}{F_{applied}} = \frac{(64\text{ kg})(9.81\text{ m/s}^2)(1.50\text{ m}) - (27\text{ kg})(9.81\text{ m/s}^2)(1.50\text{ m})}{6.1\times10^2\text{ N}}$$

$$d = \frac{9.4\times10^2\text{ N•m} - 4.0\times10^2\text{ N•m}}{6.1\times10^2\text{ N}} = \frac{5.4\times10^2\text{ N•m}}{6.1\times10^2\text{ N}}$$

$$d = \boxed{0.89\text{ m from the fulcrum, on the same side as the less massive seal}}$$

---

6. $m_1 = 3.6 \times 10^2$ kg

$m_2 = 6.0 \times 10^2$ kg

$\ell = 15$ m

$\ell_1 = 5.0$ m

$g = 9.81$ m/s^2

Apply the second condition of equilibrium, using the pool's edge as the pivot point.

Assume the total mass of the board is concentrated at its center.

$$m_1 g\,d - m_2 g\left(\frac{\ell}{2} - \ell_1\right) = 0$$

$$d = \frac{m_2 g\left(\frac{\ell}{2} - \ell_1\right)}{m_1 g} = \frac{m_2\left(\frac{\ell}{2} - \ell_1\right)}{m_1}$$

$$d = \frac{(6.0\times10^2\text{ kg})\left(\frac{15\text{m}}{2} - 5.0\text{ m}\right)}{3.6\times10^2\text{ kg}} = \frac{(6.0\times10^2\text{ kg})(7.5\text{ m} - 5.0\text{ m})}{3.6\times10^2\text{ kg}}$$

$$d = \frac{(6.0\times10^2\text{ kg})(2.5\text{ m})}{3.6\times10^2\text{ kg}} = \boxed{4.2\text{ m from the pool's edge}}$$

Givens	*Solutions*

7. $m = 449$ kg

$\ell = 5.0$ m

$F_1 = 2.70 \times 10^3$ N

$g = 9.81$ m/s^2

Apply the first condition of equilibrium to solve for F_2.

$F_1 + F_2 - mg = 0$

$F_2 = mg - F_1$

$F_2 = (449 \text{ kg})(9.81 \text{ m/s}^2) - 2.70 \times 10^3 \text{ N} = 4.40 \times 10^3 \text{ N} - 2.70 \times 10^3 \text{ N} = 1.70 \times 10^3 \text{ N}$

Apply the second condition of equilibrium, using the left end of the platform as the pivot point.

$F_2 \ell - m\,g\,d = 0$

$$d = \frac{F_2 \ell}{m\,g} = \frac{(1.70 \times 10^3 \text{ N})(5.0 \text{ m})}{(449 \text{ kg})(9.81 \text{ m/s}^2)}$$

$d = \boxed{\text{1.9 m from the platform's left end}}$

---

8. $m_1 = 414$ kg

$\ell = 5.00$ m

$m_2 = 40.0$ kg

$F_1 = 50.0$ N

$g = 9.81$ m/s^2

Apply the first condition of equilibrium to solve for F_2.

$F_1 + F_2 - m_1 g - m_2 g = 0$

$F_2 = m_1 g + m_2 g - F_1 = (m_1 + m_2)\,g - F_1$

$F_2 = (414 \text{ kg} + 40.0 \text{ kg})(9.81 \text{ m/s}^2) - 50.0 \text{ N} = (454 \text{ kg})(9.81 \text{ m/s}^2) - 50.0 \text{ N} = 4.45 \times 10^3 \text{ N} - 50.0 \text{ N}$

$F_2 = 4.40 \times 10^3$ N

Apply the second condition of equilibrium, using the supported end (F_1) of the stick as the rotation axis.

$$F_2\,d - m_1\,g\left(\frac{\ell}{2}\right) - m_2\,g\,\ell = 0$$

$$d = \frac{\left(\frac{m_1}{2} + m_2\right) g\,\ell}{F_2} = \frac{\left(\frac{414 \text{ kg}}{2} + 40.0 \text{ kg}\right)(9.81 \text{ m/s}^2)(5.0 \text{ m})}{4.40 \times 10^3 \text{ N}}$$

$$d = \frac{(207 \text{ kg} + 40.0 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m})}{4.40 \times 10^3 \text{ N}} = \frac{(247 \text{ kg})(9.81 \text{ m/s}^2)(5.00 \text{ m})}{4.40 \times 10^3 \text{ N}}$$

$d = \boxed{\text{2.75 m from the supported end}}$

II

Additional Practice H

1. $R = 50.0$ m

$M = 1.20 \times 10^6$ kg

$\tau = 1.0 \times 10^9$ N•m

$$\alpha = \frac{\tau}{I} = \frac{\tau}{MR^2} = \frac{1.0 \times 10^9 \text{ N•m}}{(1.20 \times 10^6 \text{ kg})(50.0^2)}$$

$\alpha = \boxed{0.33 \text{ rad/s}^2}$

---

2. $M = 22$ kg

$R = 0.36$ m

$\tau = 5.7$ N•m

$$\alpha = \frac{\tau}{I} = \frac{\tau}{MR^2} = \frac{5.7 \text{ N•m}}{(22 \text{ kg})(0.36 \text{ m})^2}$$

$\alpha = \boxed{2.0 \text{ rad/s}^2}$

Givens	*Solutions*
3. $M = 24$ kg $\ell = 2.74$ m $F = 1.8$ N	The force is applied perpendicular to the lever arm, which is half the pencil's length. Therefore, $\tau = F\,d\,(\sin\theta) = F\left(\frac{\ell}{2}\right)$ $\alpha = \frac{\tau}{I} = \frac{F\left(\frac{\ell}{2}\right)}{\frac{1}{12}M\ell^2} = \frac{(1.8\text{ N})\left(\frac{2.74\text{ m}}{2}\right)}{\frac{1}{12}(24\text{ kg})(2.74\text{ m})^2}$ $\alpha = \boxed{0.16\text{ rad/s}^2}$
4. $M = 4.07 \times 10^5$ kg $R = 5.0$ m $\tau = 5.0 \times 10^4$ N•m	$\alpha = \frac{\tau}{I} = \frac{\tau}{\frac{1}{2}MR^2}$ $\alpha = \frac{(5.0 \times 10^4\text{ N}\bullet\text{m})}{\frac{1}{2}(4.07 \times 10^5\text{ kg})(5.0\text{ m})^2}$ $\alpha = \boxed{9.8 \times 10^{-3}\text{ rad/s}^2}$
5. $R = 2.00$ m $F = 208$ N $\alpha = 3.20 \times 10^{-2}$ rad/s^2	The force is applied perpendicular to the lever arm, which is the ball's radius. Therefore, $\tau = F\,d\,(\sin\theta) = F\,R$ $T = \frac{\tau}{\alpha} = \frac{FR}{\alpha} = \frac{(208\text{ N})(2.00\text{ m})}{3.20 \times 10^{-2}\text{ rad/s}^2}$ $I = \boxed{1.30 \times 10^4\text{ kg}\bullet\text{m}^2}$
6. $r = 8.0$ m $\tau = 7.3 \times 10^3$ N•m $\alpha = 0.60$ rad/s^2	$I = \frac{\tau}{\alpha} = mr^2$ $I = \frac{7.3 \times 10^3\text{ N}\bullet\text{m}}{0.60\text{ rad/s}^2} = \boxed{1.2 \times 10^4\text{ kg}\bullet\text{m}^2}$ $m = \frac{I}{r^2} = \frac{1.2 \times 10^4\text{ kg}\bullet\text{m}^2}{(8.0\text{ m})^2} = \boxed{1.9 \times 10^2\text{ kg}}$
7. $v_{t,i} = 2.0$ km/s $\ell = 15.0$ cm $\Delta t = 80.0$ s $\tau = -0.20$ N•m $v_{t,f} = 0$ m/s	$I = \frac{\tau}{\alpha} = \frac{\tau}{\left(\frac{\omega_f - \omega_i}{\Delta t}\right)} = \frac{\tau}{\left[\frac{v_{t,f} - v_{t,i}}{\left(\frac{d}{\ell^2}\right)\Delta t}\right]}$ $I = \frac{-0.20\text{ N}\bullet\text{m}}{\left[\frac{0\text{ m/s} - 2.0 \times 10^3\text{ m/s}}{\left(\frac{0.150\text{ m}}{2}\right)(80.0\text{ s})}\right]} = \frac{-0.20\text{ N}\bullet\text{m}}{\left(\frac{-2.0 \times 10^3\text{ m/s}}{(0.075\text{ m})(80.0\text{ s})}\right)}$ $I = \boxed{6.0 \times 10^{-4}\text{ kg}\bullet\text{m}^2}$

II

Givens	*Solutions*
8. $R = \frac{1.70\text{ m}}{2} = 0.85\text{ m}$ $\tau = 125\text{ N}\bullet\text{m}$ $\Delta t = 2.0\text{ s}$ $\omega_i = 0\text{ rad/s}$ $\omega_f = 12\text{ rad/s}$	$I = \frac{\tau}{\alpha} = MR^2$ $I = \frac{\tau}{\alpha} = \frac{\tau}{\left(\frac{\omega_f - \omega_i}{\Delta t}\right)} = \frac{125\text{ N}\bullet\text{m}}{\left(\frac{12\text{ rad/s} - 0\text{ rad/s}}{2.0\text{ s}}\right)} = \frac{125\text{ N}\bullet\text{m}}{6.0\text{ rad/s}^2}$ $I = \boxed{21\text{ kg}\bullet\text{m}^2}$ $M = \frac{I}{R^2} = \frac{21\text{ kg}\bullet\text{m}^2}{(0.85\text{ m})^2} = \boxed{29\text{ kg}}$
9. $R = 3.00\text{ m}$ $M = 17 \times 10^3\text{ kg}$ $\omega_i = 0\text{ rad/s}$ $\omega_f = 3.46\text{ rad/s}$ $\Delta t = 12\text{ s}$	$\tau = I\,\alpha = \left(\frac{1}{2}MR^2\right)\left(\frac{\omega_f - \omega_i}{\Delta t}\right)$ $\tau = \frac{(17 \times 10^3\text{ kg})(3.00\text{ m})^2(3.46\text{ rad/s} - 0\text{ rad/s})}{(2)(12\text{ s})} = \boxed{2.2 \times 10^4\text{ N}\bullet\text{m}}$
10. $R = 4.0\text{ m}$ $M = 1.0 \times 10^8\text{ kg}$ $\omega_i = 0\text{ rad/s}$ $\omega_f = 0.080\text{ rad/s}$ $\Delta t = 60.0\text{ s}$	$\tau = I\alpha = \left(\frac{1}{2}MR^2\right)\left(\frac{\omega_f - \omega_i}{\Delta t}\right)$ $\tau = \frac{(1.0 \times 10^8\text{ kg})(4.0\text{ m})^2\,(0.080\text{ rad/s} - 0\text{ rad/s})}{(2)(60.0\text{ s})} = \boxed{1.1 \times 10^6\text{ N}\bullet\text{m}}$
11. $I = 2.40 \times 10^3\text{ kg}\bullet\text{m}^2$ $\Delta\theta = 2(2\pi\text{ rad}) = 4\pi\text{ rad}$ $\Delta t = 6.00\text{ s}$ $\omega_i = 0\text{ rad/s}$	$\Delta\theta = \omega_i\,\Delta t + \frac{1}{2}\,\alpha\,\Delta t^2$ Because $\omega_i = 0$, $\Delta\theta = \frac{1}{2}\,\alpha\Delta t^2$ $\alpha = \frac{2\Delta\theta}{\Delta t^2}$ $\tau = I\alpha = \frac{2\,I\,\Delta\theta}{\Delta t^2} = \frac{(2)(2.40 \times 10^3\text{ kg}\bullet\text{m}^2)(4\pi\text{ rad})}{(6.00\text{ s})^2}$ $\tau = \boxed{1.68 \times 10^3\text{ N}\bullet\text{m}}$
12. $m = 7.0 \times 10^3\text{ kg}$ $r = 18.3\text{ m}$ $a_t = 25\text{ m/s}^2$	$\tau = I\alpha = (mr^2)\left(\frac{a_t}{r}\right) = mra_t$ $\tau = (7.0 \times 10^3\text{ kg})(18.3\text{ m})(25\text{ m/s}^2)$ $\tau = \boxed{3.2 \times 10^6\text{ N}\bullet\text{m}}$

II

Additional Practice I

Givens — *Solutions*

1. $r_i = 4.95 \times 10^7$ km

$v_i = 2.54 \times 10^5$ Km/h

$v_f = 1.81 \times 10^5$ km/h

$L_i = L_f$

$I_i \omega_i = I_f \omega_f$

$mr_i^2 \left(\frac{v_i}{r_i}\right) = mr_f^2 \left(\frac{v_f}{r_f}\right)$

$r_i v_i = r_f v_f$

$r_f = \frac{r_i v_i}{v_f} = \frac{(4.95 \times 10^7 \text{ km})(2.54 \times 10^5 \text{ km/h})}{1.81 \times 10^5 \text{ km/h}}$

$r_f = \boxed{6.95 \times 10^7 \text{ km}}$

---

2. $v_i = 399$ km/h

$v_f = 456$ km/h

$R = 0.20$ m

$\Delta\theta = 20$ rev

$L_i = L_f$

$I_i \omega_i = I_f \omega_f$

$m r_i^2 \left(\frac{v_i}{r_i}\right) = mr_f^2 \left(\frac{v_f}{r_f}\right)$

$r_i v_i = r_f v_f$

$r_f = r_i - \Delta s = r_i - R\,\Delta\theta$

$r_i v_i = (r_i - R\,\Delta\theta)\, v_f$

$r_i (v_f - v_i) = (R\,\Delta\theta)\, v_f$

$r_i = \frac{v_f R\,\Delta\theta}{v_f - v_i} = \frac{(456 \text{ km/h})(0.20 \text{ m})(20 \text{ rev})(2\pi \text{ rad/rev})}{456 \text{ km/h} - 399 \text{ km/h}}$

$= \frac{(456 \text{ km/h})(0.20 \text{ m})(20 \text{ rev})(2\pi \text{ rad/rev})}{57 \text{ km/h}}$

$r_i = \boxed{2.0 \times 10^2 \text{ m}}$

---

3. $M = 25.0$ kg

$R = 15.0$ cm

$\omega_i = 4.70 \times 10^{-3}$ rad/s

$\omega_f = 4.74 \times 10^{-3}$ rad/s

$L_i = L_f$

$I_i \omega_i = I_f \omega_f$

$I_f = \frac{I_i \omega_i}{\omega_f} = \frac{\left(\frac{2}{5}MR^2\right) \omega_i}{\omega_f}$

$I_f = \frac{(2)(25.0 \text{ kg})(0.150 \text{ m})^2(4.70 \times 10^{-3} \text{ rad/s})}{(5)(4.74 \times 10^{-3} \text{ rad/s})} = 0.223 \text{ kg•m}^2$

$I_i = \frac{2}{5} MR^2 = \frac{2}{5}(25.0 \text{ kg})(0.150 \text{ m})^2 = 0.225 \text{ kg•m}^2$

$\Delta I = I_f - I_i = 0.223 \text{ kg•m}^2 - 0.225 \text{ kg•m}^2 = -0.002 \text{ kg•m}^2$

$\boxed{\text{The moment of inertia decreases by } 0.002 \text{ kg•m}^2.}$

II

Givens | *Solutions*

4. $v_i = 395$ km/h

$r_i = 1.20 \times 10^2$ m

$\frac{\Delta r}{\Delta t} = 0.79$ m/s

$\Delta t = 33$ s

$$r_f = r_i - \left(\frac{\Delta r}{\Delta t}\right)\Delta t$$

$$L_i = L_f$$

$$I_i \omega_i = L_f \omega_f$$

$$mr_i^2\left(\frac{v_i}{r_i}\right) = mr_f^2\left(\frac{v_f}{r_f}\right)$$

$$r_i v_i = r_f v_f = \left[r_i - \left(\frac{\Delta r}{\Delta t}\right)\Delta t\right]v_f$$

$$v_f = \frac{r_i v_i}{[r_i - \left(\frac{\Delta r}{\Delta t}\right)\Delta t]} = \frac{(1.20 \times 10^2 \text{ m})(395 \text{ km/h})}{1.20 \times 10^2 - (0.79 \text{ m/s})(33 \text{ s})}$$

$$v_f = \frac{(1.20 \times 10^2 \text{ m})(395 \text{ km/h})}{1.20 \times 10^2 \text{ m} - 26 \text{ m}} = \frac{(1.20 \times 10^2 \text{ m})(395 \text{ km/h})}{94 \text{ m}}$$

$$v_f = \boxed{5.0 \times 10^2 \text{ km/h}}$$

---

5. $r_i = \frac{10.0 \text{ m}}{2} = 5.00$ m

$r_f = \frac{4.00 \text{ m}}{2} = 2.00$ m

$\omega_i = 1.26$ rad/s

$$L_i = L_f$$

$$I_i\omega_i = I_f\omega_f$$

$$mr_i^2\omega_i = mr_f^2\omega_f$$

$$\omega_f = \frac{r_i^2\omega_i}{r_f^2} = \frac{(5.00 \text{ m})^2(1.26 \text{ rad/s})}{(2.00 \text{ m})^2}$$

$$\omega_f = \boxed{7.88 \text{ rad/s}}$$

---

6. $R = 3.00$ m

$M = 1.68 \times 10^4$ kg

$r_i = 2.50$ m

$r_f = 3.00$ m

$m = 2.00 \times 10^2$ kg

$\omega_i = 3.46$ rad/s

$$L_i = L_f$$

$$I_i\omega_i = I_f\omega_f$$

$$\left(\tfrac{1}{2}MR^2 + mr_i^2\right)\omega_i = \left(\tfrac{1}{2}MR^2 + mr_f^2\right)\omega_f$$

$$\omega_f = \frac{\left(\tfrac{1}{2}MR^2 + mr_i^2\right)\omega_i}{\left(\tfrac{1}{2}MR^2 + mr_f^2\right)}$$

$$\omega_f = \frac{\left[\tfrac{1}{2}(1.68 \times 10^4 \text{ kg})(3.00 \text{ m})^2 + (2.00 \times 10^2 \text{ kg})(2.50 \text{ m})^2\right](3.46 \text{ rad/s})}{\left[\tfrac{1}{2}(1.68 \times 10^4 \text{ kg})(3.00 \text{ m})^2 + (2.00 \times 10^2 \text{ kg})(3.00 \text{ m})^2\right]}$$

$$\omega_f = \frac{(7.56 \times 10^4 \text{ kg}\bullet\text{m}^2 + 1.25 \times 10^3 \text{ kg}\bullet\text{m}^2)(3.46 \text{ rad/s})}{7.56 \times 10^4 \text{ kg}\bullet\text{m}^2 + 1.80 \times 10^3 \text{ kg}\bullet\text{m}^2}$$

$$\omega_f = \frac{(7.68 \times 10^4 \text{ kg}\bullet\text{m}^2)(3.46 \text{ rad/s})}{7.74 \times 10^4 \text{ kg}\bullet\text{m}^2}$$

$$\omega_f = 3.43 \text{ rad/s}$$

$$\Delta\omega = \omega_f - \omega_i = 3.43 \text{ rad/s} - 3.46 \text{ rad/s} = -0.03 \text{ rad/s}$$

$\boxed{\text{The angular speed decreases by 0.03 rad/s.}}$

II

Givens | *Solutions*

1. $m = 407$ kg
$h = 57.0$ m
$v_f = 12.4$ m/s
$\omega_f = 28.0$ rad/s
$g = 9.81$ m/s^2

$ME_i = ME_f$

$mgh = \frac{1}{2} mv_f^2 + \frac{1}{2} I\omega_f^2$

$\frac{1}{2} I\omega_f^2 = mgh - \frac{1}{2} mv_f^2$

$$I = \frac{2mgh - mv_f^2}{\omega_f^2} = \frac{m(2gh - v_f^2)}{\omega_f^2}$$

$$I = \frac{(407\text{ kg})[(2)(9.81\text{ m/s}^2)(57.0\text{ m}) - (12.4\text{ m/s})^2]}{(28.0\text{ rad/s})^2}$$

$$I = \frac{(407\text{ kg})(1.12 \times 10^3\text{ m}^2/\text{s}^2 - 154\text{ m}^2/\text{s}^2)}{(28.0\text{ rad/s})^2} = \frac{(407\text{ kg})(9.7 \times 10^2\text{ m}^2/\text{s}^2)}{(28.0\text{ rad/s})^2}$$

$I = \boxed{5.0 \times 10^2\text{ kg}\bullet\text{m}^2}$

2. $h = 5.0$ m
$g = 9.81$ m/s^2

$ME_i = ME_f$

$mgh = \frac{1}{2}mv_f^2 + \frac{1}{2}I\omega_f^2$

$mgh = \frac{1}{2}mv_f^2 + \frac{1}{2}(mr^2)\left(\frac{v_f^2}{r^2}\right)$

$mgh = mv_f^2\left(\frac{1}{2} + \frac{1}{2}\right) = mv_f^2$

$v_f = \sqrt{gh} = \sqrt{(9.81\text{ m/s}^2)(5.0\text{ m})}$

$v_f = \boxed{7.0\text{ m/s}}$ $\boxed{\text{the mass is not required}}$

3. $h = 1.2$ m
$g = 9.81$ m/s^2

$ME_i = ME_f$

$\frac{1}{2}mv_i^2 + \frac{1}{2}I\omega_i^2 = mgh$

$\frac{1}{2}mv_i^2 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\left(\frac{v_i^2}{r^2}\right) = mgh$

$mv_i^2\left(\frac{1}{2} + \frac{1}{4}\right) = \frac{3}{4} mv_i^2 = mgh$

$$v_i = \sqrt{\frac{4gh}{3}} = \sqrt{\frac{(4)(9.81\text{ m/s}^2)(1.2\text{ m})}{3}} = \boxed{4.0\text{ m/s}}$$

4. $v_f = 12.0$ m/s
$I = 0.80mr^2$
$g = 9.81$ m/s^2

$ME_i = ME_f$

$mgh = \frac{1}{2}mv_f^2 + \frac{1}{2}I\omega_f^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}(0.80\ mr^2)\left(\frac{v_f}{r}\right)^2$

$mgh = mv_f^2\left(\frac{1}{2} + \frac{0.80}{2}\right) = 0.90\ mv_f^2$

$$h = \frac{0.90\ v_f^2}{g} = \frac{(0.90)(12.0\text{ m/s})^2}{9.81\text{ m/s}^2}$$

$h = \boxed{13\text{ m}}$

Givens	Solutions

Givens — *Solutions*

5. $v_i = 5.4$ m/s

$g = 9.81 \text{ m/s}^2$

$\theta = 30.0°$

$$ME_i = ME_f$$

$$\tfrac{1}{2}mv_i^2 + \tfrac{1}{2}I\omega_i^2 = mgh = mgd(\sin\theta)$$

$$mgd(\sin\theta) = \tfrac{1}{2}mv_i^2 + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\left(\frac{v_i^2}{r^2}\right)$$

$$mgd(\sin\theta) = mv_i^2\left(\tfrac{1}{2}+\tfrac{1}{5}\right) = \tfrac{7}{10}mv_i^2$$

$$d = \frac{7\,v_i^2}{10\,g(\sin\theta)} = \frac{(7)(5.4 \text{ m/s})^2}{(10)(9.81 \text{ m/s}^2)(\sin 30.0°)} = \boxed{4.2 \text{ m}}$$

---

6. $r = 2.0$ m

$\omega_f = 5.0$ rad/s

$g = 9.81 \text{ m/s}^2$

$m = 4.8 \times 10^3$ kg

$$ME_i = ME_f$$

$$mgh = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}I\omega_f^2$$

$$mgh = \tfrac{1}{2}mr^2\omega_f^2 + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\omega_f^2$$

$$mgh = mr^2\omega_f^2\left(\tfrac{1}{2}+\tfrac{1}{5}\right) = \tfrac{7}{10}mr^2\omega_f^2$$

$$h = \frac{\tfrac{7}{10}r^2\omega_f^2}{g} = \frac{(7)(2.0 \text{ m})^2(5.0 \text{ rad/s})^2}{(10)(9.81 \text{ m/s}^2)}$$

$$h = \boxed{7.1 \text{ m}}$$

$$KE_{trans} = \tfrac{1}{2}mv_f^2 = \tfrac{1}{2}mr^2\omega_f^2$$

$$KE_{trans} = \tfrac{1}{2}(4.8 \times 10^3 \text{ kg})(2.0 \text{ m})^2(5.0 \text{ rad/s})^2$$

$$KE_{trans} = \boxed{2.4 \times 10^5 \text{ J}}$$

---

7. $m = 5.55$ kg

$h = 1.40$ m

$g = 9.81 \text{ m/s}^2$

$$ME_i = ME_f$$

$$mgh = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}I\omega_f^2$$

$$mgh = \tfrac{1}{2}mv_f^2 + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\left(\frac{v_f^2}{r^2}\right)$$

$$mgh = mv_f^2\left(\tfrac{1}{2}+\tfrac{1}{5}\right) = \tfrac{7}{10}mv_f^2$$

$$v_f = \sqrt{\frac{10gh}{7}} = \sqrt{\frac{(10)(9.81 \text{ m/s}^2)(1.40 \text{ m})}{7}} = 4.43 \text{ m/s}$$

$$KE_{rot} = \tfrac{1}{2}I\omega_f^2 = \tfrac{1}{5}mv_f^2$$

$$KE_{rot} = \frac{(5.55 \text{ kg})(4.43 \text{ m/s})^2}{5} = \boxed{21.8 \text{ J}}$$

II

Givens / *Solutions*

1. $P_1 = (1 + 0.12)P_2 = 1.12\ P_2$

$v_1 = 0.60$ m/s

$v_2 = 4.80$ m/s

$\rho = 1.00 \times 10^3$ kg/m^3

$h_1 = h_2$

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

$h_1 = h_2$, and $P_2 = \dfrac{P_1}{1.12}$, so the equation simplifies to

$$P_1 + \tfrac{1}{2}\rho v_1^2 = \frac{P_1}{1.12} + \tfrac{1}{2}\rho v_2^2$$

$$P_1\left(1 - \frac{1}{1.12}\right) = \tfrac{1}{2}\rho(v_2^2 - v_1^2)$$

$$P_1 = \frac{\rho(v_2^2 - v_1^2)}{(2)\left(1 - \dfrac{1}{1.12}\right)} = \frac{(1.00 \times 10^3\ \text{kg/m}^3)[(4.80\ \text{m/s})^2 - (0.60\ \text{m/s})^2]}{(2)\left(1 - \dfrac{1}{1.12}\right)}$$

$$P_1 = \frac{(1.00 \times 10^3\ \text{kg/m}^3)(23.0\ \text{m}^2/\text{s}^2 - 0.36\ \text{m}^2/\text{s}^2)}{(2)(1 - 0.893)}$$

$$P_1 = \frac{(1.00 \times 10^3\ \text{kg/m}^3)(22.6\ \text{m}^2/\text{s}^2)}{(2)(0.107)} = \boxed{1.06 \times 10^5\ \text{Pa}}$$

II

2. $r_1 = \dfrac{4.10\ \text{m}}{2} = 2.05$ m

$v_1 = 3.0$ m/s

$r_2 = \dfrac{2.70\ \text{m}}{2} = 1.35$ m

$P_2 = 82$ kPa

$\rho = 1.00 \times 10^3$ kg/m^3

$h_1 = h_2$

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{\pi r_1^2 v_1}{\pi r_2^2} = \frac{r_1^2 v_1}{r_2^2}$$

$$v_2 = \frac{(2.05\ \text{m})^2(3.0\ \text{m/s})}{(1.35\ \text{m})^2} = 6.9\ \text{m/s}$$

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

$h_1 = h_2$, so the equation simplifies to

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2$$

$$P_1 = P_2 + \tfrac{1}{2}\rho(v_2^2 - v_1^2)$$

$$P_1 = 82 \times 10^3\ \text{Pa} + \tfrac{1}{2}(1.00 \times 10^3\ \text{kg/m}^3)[(6.9\ \text{m/s})^2 - (3.0\ \text{m/s})^2]$$

$$P_1 = 82 \times 10^3\ \text{Pa} + \tfrac{1}{2}(1.00 \times 10^3\ \text{kg/m}^3)(48\ \text{m}^2/\text{s}^2 - 9.0\ \text{m}^2\text{s}^2)$$

$$P_1 = 82 \times 10^3\ \text{Pa} + \tfrac{1}{2}(1.00 \times 10^3\ \text{kg/m}^3)(39\ \text{m}^2/\text{s}^2)$$

$$P_1 = 82 \times 10^3\ \text{Pa} + 2.0 \times 10^4\ \text{Pa} = 10.2 \times 10^4\ \text{Pa} = \boxed{102\ \text{kPa}}$$

3. $h_2 - h_1 = \tfrac{1}{2} h$

$\Delta x = 19.7$ m

To find the horizontal speed of the cider, recall that for a projectile with no initial vertical speed,

$$\Delta x = v \Delta t$$

$$\Delta y = -\tfrac{1}{2} g\, \Delta t^2 = -\tfrac{1}{2} h$$

$$\Delta t = \sqrt{\frac{h}{g}}$$

$$v = \frac{\Delta x}{\Delta t} = \frac{\Delta x}{\sqrt{\dfrac{h}{g}}} = \sqrt{\frac{g\,\Delta x^2}{h}}$$

$$P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

Givens | *Solutions*

Assuming the vat is open to the atmosphere, $P_1 = P_2$.

Also assume $v_2 \approx 0$. Therefore, the equation simplifies to

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \rho g h_2$$

$$\frac{1}{2}v_1^2 = \frac{1}{2}\left(\sqrt{\frac{g\Delta x^2}{h}}\right)^2 = g(h_2 - h_1) = g\left(\frac{1}{2}h\right)$$

$$\frac{g\Delta x^2}{h} = gh$$

$$h^2 = \Delta x^2$$

$$h = \Delta x = \boxed{19.7 \text{ m}}$$

---

4. $v_1 = 59$ m/s

$g = 9.81$ m/s^2

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Assume $v_2 \approx 0$ and $P_1 = P_2 = P_0$.

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \rho g h_2$$

$$h_2 - h_1 = \frac{v_1^2}{2g} = \frac{(59 \text{ m/s})^2}{(2)(9.81 \text{ m/s}^2)} = \boxed{1.8 \times 10^2 \text{ m}}$$

---

5. $h_2 - h_1 = 66.0$ m

$g = 9.81$ m/s^2

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Assume $v_2 \approx 0$ and $P_1 = P_2 = P_0$.

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \rho g h_2$$

$$v_1 = \sqrt{2g(h_2 - h_1)} = \sqrt{(2)(9.81 \text{ m/s}^2)(66.0 \text{ m})} = \boxed{36.0 \text{ m/s}}$$

---

6. $h_2 - h_1 = 3.00 \times 10^2$ m

$g = 9.81$ m/s^2

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Assume $v_2 \approx 0$ and $P_1 = P_2 = P_0$.

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \rho g h_2$$

$$v_1 = \sqrt{2g(h_2 - h_1)} = \sqrt{(2)(9.81 \text{ m/s}^2)(3.00 \times 10^2 \text{ m})} = \boxed{76.7 \text{ m/s}}$$

---

7. $h_2 - h_1 = 6.0$ m

$g = 9.81$ m/s^2

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Assume $v_2 \approx 0$ and $P_1 = P_2 = P_0$.

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \rho g h_2$$

$$v_1 = \sqrt{2g(h_2 - h_1)} = \sqrt{(2)(9.81 \text{ m/s}^2)(6.0 \text{ m})} = \boxed{11 \text{ m/s}}$$

Additional Practice L

Givens	*Solutions*
1. $V = 3.4 \times 10^5\ m^3$ $T = 280\ K$ $N = 1.4 \times 10^{30}$ atoms $k_B = 1.38 \times 10^{-23}\ J/K$	$PV = Nk_BT$ $P = \frac{Nk_BT}{V} = \frac{(1.4 \times 10^{30}\ \text{atoms})(1.38 \times 10^{-23}\ J/K)(280\ K)}{3.4 \times 10^5\ m^3}$ $P = \boxed{1.6 \times 10^4\ Pa}$
2. $V = 1.0 \times 10^{-3}\ m^3$ $N = 1.2 \times 10^{13}$ molecules $T = 300.0\ K$ $k_B = 1.38 \times 10^{-23}\ J/K$	$PV = Nk_BT$ $P = \frac{Nk_BT}{V} = \frac{(1.2 \times 10^{13}\ \text{molecules})(1.38 \times 10^{-23}\ J/K)(300.0\ K)}{1.0 \times 10^{-3}\ m^3}$ $P = \boxed{5.0 \times 10^{-5}\ Pa}$
3. $V = 3.3 \times 10^6\ m^3$ $N = 1.5 \times 10^{32}$ molecules $T = 360\ K$ $k_B = 1.38 \times 10^{-23}\ J/K$	$PV = Nk_BT$ $P = \frac{Nk_BT}{V} = \frac{(1.5 \times 10^{32}\ \text{molecules})(1.38 \times 10^{-23}\ J/K)(360\ K)}{3.3 \times 10^6\ m^3}$ $P = \boxed{2.3 \times 10^5\ Pa}$
4. $N = 1.00 \times 10^{27}$ molecules $T = 2.70 \times 10^2\ K$ $P = 36.2\ Pa$ $k_B = 1.38 \times 10^{-23}\ J/K$	$PV = Nk_BT$ $V = \frac{Nk_BT}{P} = \frac{(1.00 \times 10^{27}\ \text{molecules})(1.38 \times 10^{-23}\ J/K)(2.70 \times 10^2\ K)}{36.2\ Pa}$ $V = \boxed{1.03 \times 10^5\ m^3}$
5. $V_1 = 3.4 \times 10^5\ m^2$ $T_1 = 280\ K$ $P_1 = 1.6 \times 10^4\ Pa$ $T_2 = 240\ K$ $P_2 = 1.7 \times 10^4\ Pa$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{(1.6 \times 10^4\ Pa)(3.4 \times 10^5\ m^3)(240\ K)}{(1.7 \times 10^4\ Pa)(280\ K)}$ $V_2 = \boxed{2.7 \times 10^5\ m^3}$
6. $A = 2.50 \times 10^2\ m^2$ $T = 3.00 \times 10^2\ K$ $P = 101\ kPa$ $N = 4.34 \times 10^{31}$ molecules $k_B = 1.38 \times 10^{-23}\ J/K$	$PV = Nk_BT$ $V = \frac{Nk_BT}{P} = \frac{(4.34 \times 10^{31}\ \text{molecules})(1.38 \times 10^{-23}\ J/K)(3.00 \times 10^2\ K)}{101 \times 10^3\ Pa}$ $V = \boxed{1.78 \times 10^6\ m^3}$ $V = \ell A$ $\ell = \frac{V}{A} = \frac{1.78 \times 10^6\ m^3}{2.50 \times 10^2\ m^2} = \boxed{7.12 \times 10^3\ m}$

II

Givens	*Solutions*
7. $V = 7.36 \times 10^4\ m^3$ $P = 1.00 \times 10^5$ Pa $N = 1.63 \times 10^{30}$ particles $k_B = 1.38 \times 10^{-23}$ J/K	$PV = Nk_BT$ $T = \dfrac{PV}{Nk_B} = \dfrac{(1.00 \times 10^5\ \text{Pa})(7.36 \times 10^4\ \text{m}^3)}{(1.63 \times 10^{30}\ \text{particles})(1.38 \times 10^{-23}\ \text{J/K})}$ $T = \boxed{327\ \text{K}}$
8. $\ell = 3053$ m $A = 0.040\ m^2$ $N = 3.6 \times 10^{27}$ molecules $P = 105$ kPa $k_B = 1.38 \times 10^{-23}$ J/K	$P\,V = Nk_BT$ $T = P\dfrac{V}{Nk_B} = \dfrac{PA\ell}{Nk_B}$ $T = \dfrac{(105 \times 10^3\ \text{Pa})(0.040\ \text{m}^2)(3053\ \text{m})}{(3.6 \times 10^{27}\ \text{molecules})(1.38 \times 10^{-23}\ \text{J/K})} = \boxed{260\ \text{K}}$
9. $P_1 = 2.50 \times 10^6$ Pa $T_1 = 495$ K $V_1 = 3.00\ m^3$ $V_2 = 57.0\ m^3$ $P_2 = 1.01 \times 10^5$ Pa	$\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$ $T_2 = \dfrac{P_2V_2T_1}{P_1V_1} = \dfrac{(1.01 \times 10^5\ \text{Pa})(57.0\ \text{m}^3)(495\ \text{K})}{(2.50 \times 10^6\ \text{Pa})(3.00\ \text{m}^3)}$ $T_2 = \boxed{3.80 \times 10^2\ \text{K}}$ $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}T_2 = \dfrac{P_2V_2T_1}{P_1V_1} = \dfrac{(1.01 \times 10^5\ \text{Pa})(57.0\ \text{m}^3)(495\ \text{K})}{(2.50 \times 10^6\ \text{Pa})(3.00\ \text{m}^3)}$

II

Additional Practice M

1. $f = 833$ Hz $D = 5.0$ cm $= 0.050$ m $B = 8.0 \times 10^{-2}$ T maximum emf $= 330$ V	maximum emf $= NAB\omega = NAB(2\pi f)$ $A = \pi r^2 = \pi\left(\dfrac{D}{2}\right)^2 = \pi\left(\dfrac{0.05\ \text{m}}{2}\right)^2 = 2.0 \times 10^{-3}\ \text{m}^2$ $N = \dfrac{\text{maximum emf}}{AB(2\pi f)} = \dfrac{330\ \text{V}}{(2.0 \times 10^{-3}\ \text{m}^2)(2\pi)(833\ \text{Hz})(8.0 \times 10^{-2}\ \text{T})}$ $N = \boxed{4.0 \times 10^2\ \text{turns}}$
2. $\omega = 335$ rad/s maximum emf $= 214$ V $B = 8.00 \times 10^{-2}$ T $A = 0.400\ m^2$	maximum emf $= NAB\omega$ $N = \dfrac{\text{maximum emf}}{AB\omega}$ $N = \dfrac{214\ \text{V}}{(0.400\ \text{m}^2)(0.0800\ \text{T})(335\ \text{rad/s})}$ $N = \boxed{20.0\ \text{turns}}$
3. $r = \dfrac{19.3\ \text{m}}{2} = 9.65$ m $\omega = 0.52$ rad/s maximum emf $= 2.5$ V $N = 40$ turns	maximum emf $= NAB\omega$ $B = \dfrac{\text{maximum emf}}{N(\pi r^2)\omega}$ $B = \dfrac{2.5\ \text{V}}{(40)(\pi)(9.65\ \text{m})^2(0.52\ \text{rad/s})}$ $B = \boxed{4.1 \times 10^{-4}\ \text{T}}$

Givens	Solutions
4. maximum emf = 8.00×10^3 V $N = 236$ $A = (6.90\ \text{m})^2$ $\omega = 57.1$ rad/s	maximum emf = $NAB\omega$ $B = \dfrac{\text{maximum emf}}{NA\omega}$ $B = \dfrac{8.00 \times 10^3\ \text{V}}{(236)(6.90\ \text{m})^2(57.1\ \text{rad/s})}$ $B = \boxed{1.25 \times 10^{-2}\ \text{T}}$
5. $N = 1000$ turns $A = 8.0 \times 10^{-4}\ \text{m}^2$ $B = 2.4 \times 10^{-3}$ T maximum emf = 3.0 V	maximum emf = $NAB\omega$ $\omega = \dfrac{\text{maximum emf}}{NAB}$ $\omega = \dfrac{3.0\ \text{V}}{(1000)(8.0 \times 10^{-4}\ \text{m}^2)(2.4 \times 10^{-3}\ \text{T})}$ $\omega = \boxed{1.6 \times 10^3\ \text{rad/s}}$
6. $N = 640$ turns $A = 0.127\ \text{m}^2$ maximum emf = 24.6×10^3 V $B = 8.00 \times 10^{-2}$ T	maximum emf = $NAB\omega$ $\omega = \dfrac{\text{maximum emf}}{NAB}$ $\omega = \dfrac{24.6 \times 10^3\ \text{V}}{(640)(0.127\ \text{m}^2)(8.00 \times 10^{-2}\ \text{T})}$ $\omega = \boxed{3.78 \times 10^3\ \text{rad/s}}$
7. $f = 1.0 \times 10^3$ Hz $B = 0.22$ T $N = 250$ turns $r = 12 \times 10^{-2}$ m	maximum emf = $NAB\omega = NAB(2\pi f) = N(\pi r^3)B\omega = N(\pi r^2)B(2\pi f)$ maximum emf = $(250)(\pi)(12 \times 10^{-2}\ \text{m})^2(0.22\ \text{T})(2\pi)(1.0 \times 10^3\ \text{Hz})$ maximum emf = $\boxed{1.6 \times 10^4\ \text{V} = 16\ \text{kV}}$

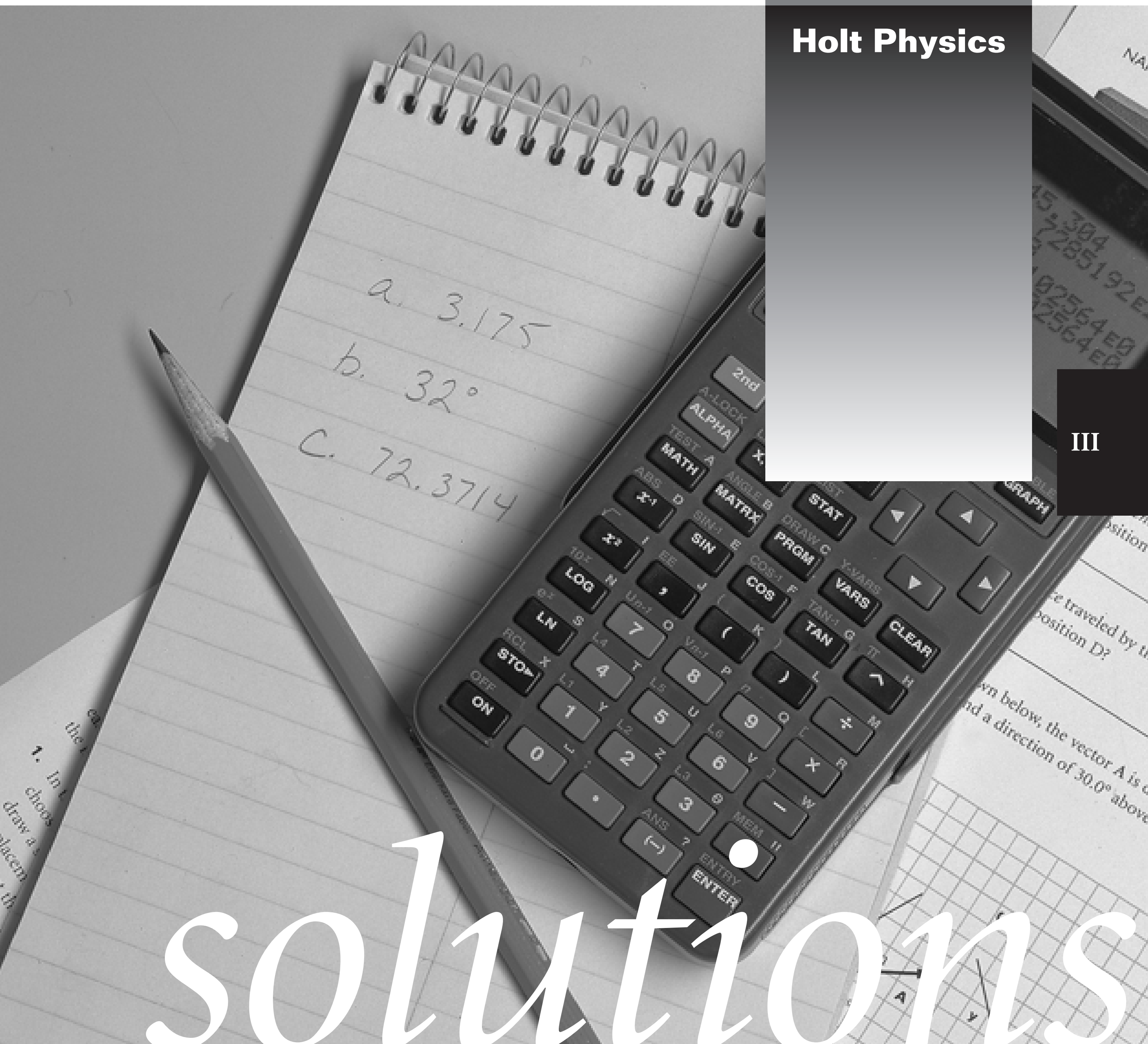
II

Section

III

Study Guide Worksheets Answers

Holt Physics



III

solutions

The Science of Physics

What Is Physics? p. 1

1. a. mechanics (laws of motion)

b. vibrations and waves (sound or acoustics)

c. optics

d. thermodynamics

e. electricity

f. nuclear physics

2. a. No. Scientist do not vote about their knowledge. They use evidence to support or disprove scientific arguments

b. No. Speed of light is determined in nature. We can only measure it.

c. Yes, by sharing their scientific arguments. Science is a body of knowledge about the universe. Scientists around the world work together to make it grow.

Measurements in Experiments, p. 2

1. 10^{18}

2. 10^{9}

3. 10^{7}

4. a. 3.582×10^{12} bytes

b. 9.2331×10^{-7} W

c. 5.3657×10^{-5} s

d. 5.32×10^{-3} g

e. 8.8900×10^{10} Hz

f. 8.3×10^{-9} m

5. a. 36.582472 Mgrams

b. 452 nm

c. 53.236 kV

d. 4.62 ms

6. 4.2947842; 4.29478; 4.295; 4.3

The Language of Physics, p. 3

1. a. 6.0×10^{8}

b. 1.5×10^{2}

c. 1.5×10^{-3}

d. 6.0×10^{3}

e. 1.5×10^{3}

f. 6.0×10^{-7}

2. a. 4×10^{5}

b. 6×10^{5}

c. 8×10^{-9}

d. 7×10^{-5}

e. 7×10^{6}

f. 7×10^{-4}

3. a. 10^{4}

b. 10^{-1}

4. a. about 10 cm by 25 cm

b. Check student responses, which should indicate that volume = $(\text{width})^2 \times (\text{height})$.

c. Check student responses for consistency with a and b.

Mixed Review, pp. 5–6

1. a. 2.2×10^{5} s

b. 3.5×10^{7} mm

c. 4.3×10^{-4} km

d. 2.2×10^{-5} kg

e. 6.71×10^{11} μg

f. 8.76×10^{-5} GW

g. 1.753×10^{-1} ps

2. a. 3

b. 4

c. 10

d. 3

e. 2

f. 4

3. a. 4

b. 5

c. 3

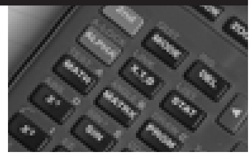
4. a. 1.0054; –0.9952; 5.080×10^{-3}; 5.076×10^{-3}

b. 4.597×10^{7}; 3.866×10^{7}; 1.546×10^{14}; 11.58

5. 15.9 m^2

6. The graph should be a straight line.

Study Guide Answers



Motion In One Dimension

Displacement and Velocity, p. 7

1. Yes, from t_1 to t_4 and from t_6 to t_7.

2. Yes, from t_4 to t_5.

3. greater than

4. greater than

5. Yes, from 0 to t_1 and from t_5 to t_6.

6. Yes, from t_1 to t_2, from t_2 to t_4, from t_4 to t_5, and from t_6 to t_7.

7. –5.0 m (or 5.0 m to the west of where it started)

Acceleration, p. 8

1. $v_f = 0$. The car is stopped.

2. $v_i = \dfrac{2\Delta x}{\Delta t}$

3. $a = \dfrac{-v_i}{\Delta t}$

4. $a = \dfrac{-v_i^2}{2\Delta x}$

5. $v_i = -a\Delta t \; \Delta x = \frac{1}{2} v_i \Delta t$

Falling Objects, p. 9

1. a. $-g$

b. initial speed = $g(\Delta t/2)$

c. elapsed time = $\Delta t/2$

d. height = $g\Delta t^2/8$

2. a. –9.81 m/s^2

b. 12 m/s

c. 1.2 s

Mixed Review, pp. 11–12

III

1. a. $t_1 = d_1/v_1$; $t_2 = d_2/v_2$; $t_3 = d_3/v_3$

b. total distance = $d_1 + d_2 + d_3$

c. total time = $t_1 + t_2 + t_3$

2. a. $v_f = a(\Delta t)$

b. $v_f = v_i + a(\Delta t)$; $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$ or $\Delta x = v_i(\Delta t) + \frac{1}{2}a(\Delta t)^2$

3.

Time interval	Type of motion	v (m/s)	a(m/s^2)
A	speeding up	+	+
B	speeding up	+	+
C	constant velocity	+	0
D	slowing down	+	–
E	slowing down	+	–

4. a.

Time (s)	Position (m)	v (m/s)	a(m/s^2)
1	4.9	0	–9.81
2	0	–9.8	–9.81
3	–14.7	–19.6	–9.81
4	–39.2	–29.4	–9.81

b. 1 s

c. 2 s

Study Guide Answers

Two-Dimensional Motion and Vectors

Introduction to Vectors, p. 13

1. {**A, C, E, H, I**}; {**D, G**}, {**B, F, J**}

2. {**A, D, H**}, {**B, C, G**}, {**I, J**}

3. {**A, H**}

4. Both diagrams should show a vector **A** that is twice as long as the original vector **A,** but still pointing up. The first diagram should have the tip of 2**A** next to the tail of **B.** The second diagram should have the tip of **B** next to the tail of 2**A.** The resultant vectors should have the same magnitude and direction, slanting towards the upper right.

5. Both diagrams should show a vector **B** that is half as long as the original vector **B.** The first diagram should have the tip of **A** next to the tail of –**B**/2, and –**B**/2 should be pointing to the left. The second diagram should have the tip of **B**/2 next to the tail of –**A,** and –**A** should be pointing down. The resultant vectors should have the same magnitude but opposite directions. The first will slant towards the upper left. The second will slant towards the lower right.

Vector Operations, p. 14

1. Check students' graph for accuracy.

2. Shot 1: 45 m; 45 m

Shot 2: 110 m; 64 m

Shot 3: 65 m; 33 m

Shot 4: 0 m; 14.89 m

3. 220 m

Projectile Motion, p. 15

1. $\Delta t = v_i \sin \theta / g$

2. $h = v_i^2 (\sin \theta)^2 / 2g$

3. $x = v_i(\cos \theta)(\Delta t) = \dfrac{v_i^2 \sin \theta \cos \theta}{g}$

4. $R = \dfrac{2v_i^2 \sin \theta \cos \theta}{g}$

5.

Launch angle	Maximum height (m)	Range (m)
15°	8.5	130
30°	32	220
45°	64	250
60°	96	220
75°	119	130

III

Relative Motion, p. 16

1. $\mathbf{v_{BL}} = \mathbf{v_{BW}} + \mathbf{v_{WL}}$

2. Student diagrams should show $\mathbf{v_{BW}}$ twice as long as $\mathbf{v_{WL}}$ but both are in the same direction as $\mathbf{v_{BL}}$, which is long as both together.

3. Student diagrams should show $\mathbf{v_{WL}}$ and $\mathbf{v_{BW}}$, longer and opposite in direction. The vector $\mathbf{v_{BL}}$ should be as long as the difference between the two, and in the same direction and in the same direction as $\mathbf{v_{BW}}$.

4. Student diagrams should show $\mathbf{v_{WL}}$ and $\mathbf{v_{BW}}$ at a right angle with $\mathbf{v_{BL}}$ forming the hypotenuse of a right triangle.

5. a. 6.0 km/h, due east

b. 2.0 km/h, due west

c. 4.5 km/h, $\theta = 26.6°$

Mixed Review, pp. 17–18

1. **a.** The diagram should indicate the relative distances and directions for each segment of the path.
   b. 5.0 km, slightly north of northwest
   c. 11.0 km
2. **a.** The same
   b. Twice as large
   c. 1.58
3. **a.** 2.5 m/s, in the direction of the sidewalk's motion
   b. 1.0 m/s, in the direction of the sidewalk's motion
   c. 4.5 m/s, in the direction of the sidewalk's motion
   d. 2.5 m/s, in the direction opposite to the sidewalk's motion
   e. 4.7 m/s, $\theta = 32°$
4. **a.** 4.0×10^1 seconds
   b. 6.0×10^1 seconds

III

Study Guide Answers

Forces and the Laws of Motion

Changes in Motion, p. 19

1. The diagram should show two forces: 1) $\mathbf{F_g}$ (or mg) pointing down; 2) an equal and opposite force of the floor on the box pointing up.

2. The diagram should show four forces: 1) $\mathbf{F_g}$ (or mg) pointing down; 2) an equal and opposite force of the floor on the box pointing up; 3) $\mathbf{F}$ pointing to the right, parallel to the ground; 4) $\mathbf{F_{resistance}}$ pointing to the left, parallel to the ground.

3. The diagram should show four forces: 1) $\mathbf{F_g}$ (or mg) pointing down; 2) $\mathbf{F}$ pointing to the right at a 50° angle to the horizontal; 3) a force equal to $\mathbf{F_g}$ minus the vertical component of the force $\mathbf{F}$ being applied at a 50° angle; and 4) $\mathbf{F_{resistance}}$ to the left, parallel to the ground.

Newton's First Law, p. 20

1. $\mathbf{F_{net}} = \mathbf{F_1} + \mathbf{F_2} + \mathbf{F_3} = 0$

2. String 1: $0, -mg$

String 2: $-F_2 \cos \theta_1, F_2 \sin \theta_1$

String 3: $F_3 \cos \theta_2, F_3 \sin \theta_2$

3. $F_{x\ net} = -F_2 \cos \theta_1 + F_3 \cos \theta_2 = 0$

$F_{y\ net} =$
$-F_2 \sin \theta_1 + F_3 \sin \theta_2 + F_1 = 0$

4. $F_1 = 20.6$ N

$F_2 = 10.3$ N

$F_3 = 17.8$ N

Newton's Second and Third Laws, p. 21

1. $\mathbf{F_{s\text{ on }b}}$ and $\mathbf{F_{b\text{ on }s}}$; $\mathbf{F_{g\text{ on }s}}$ and $\mathbf{F_{s\text{ on }g}}$; $\mathbf{F_{fr,1}}$ and $-\mathbf{F_{fr,1}}$; $\mathbf{F_{fr,2}}$ and $-\mathbf{F_{fr,2}}$.

2. $\mathbf{F_{s\text{ on }b}}$, $\mathbf{F_{b\text{ on }s}}$, $-\mathbf{F_{fr,1}}$

3. $\mathbf{F_{g\text{ on }s}}$, $\mathbf{F_{s\text{ on }g}}$; $\mathbf{F_{b\text{ on }s}}$, $\mathbf{F_{fr,1}}$, $\mathbf{F}$, $\mathbf{F_{fr,2}}$

4. $\mathbf{F_{x,box}} = m\mathbf{a} = -\mathbf{F_{fr,1}}$

5. $\mathbf{F_{y,box}} = \mathbf{F_{s\text{ on }b}} - m\mathbf{g} = 0$

6. $\mathbf{F_{x,sled}} = \mathbf{Ma} = \mathbf{F} \cos \theta - \mathbf{F_{fr,1}} - \mathbf{F_{fr,2}}$

7. $\mathbf{F_{y,sled}} = \mathbf{F_{g\text{ on }s}} + \mathbf{F} \sin \theta - \mathbf{F_{b\text{ on }s}} - M\mathbf{g} = 0$

III

Everyday Forces, p. 22

1. 44 N

2. 31 N

3. a. 21 N, up the ramp

b. yes

4. a. 18 N, down the ramp

b. yes

Mixed Review, pp. 23–24

1. a. at rest, moves to the left, hits back wall

b. moves to the right (with velocity v), at rest, neither

c. moves to the right, moves to the right, hits front wall

2. a. mg, down

b. mg, up

c. no

d. yes

3. a. $a = \dfrac{F}{m_1 + m_2}$

b. $m_2 a$

c. $F - m_2 a = m_1 a$

d. $\left(\dfrac{m_1}{m_1 + m_2}\right) F$

4. a. $a = \dfrac{F - F_k}{m_1 + m_2}$

b. $m_2 a - F_k$

c. $F - m_2 a - F_k = m_1 a - F_k$

d. $\left(\dfrac{m_1}{m_1 + m_2}\right)(F - F_k)$

Study Guide Answers

Work and Energy

Work, p. 25

1. Fd

2. $\frac{-mgd}{2}$

3. 0 J

4. $F_k d$

5. 0 N

6. 0 J

Energy, p. 26

1. a. $\frac{1}{2}mv_i^2$

b. 0

c. $\frac{1}{2}mv_i^2$

2. a. $\frac{1}{2}mv^2$

b. $\frac{1}{2}kx_1^2$

c. $\frac{1}{2}mv^2 + \frac{1}{2}kx_1^2$

3. a. 0

b. $\frac{1}{2}kx_2^2$

c. $\frac{1}{2}kx_1^2$

4. a. $\frac{1}{2}mv_i^2$

b. 0

c. $\frac{1}{2}mv_i^2$

Conservation of Energy, p. 27

1. a. 0

b. mgh_A

c. $\frac{1}{2}mv_B^2$

d. mgh_B

2. a. $v_A = 0$

b. $v_B = \sqrt{2g(h_A - h_B)}$

3.

Location	KE_A	PE_A	$KE_{location}$	$PE_{location}$	$v_{location}$
C	0	1.9×10^4 J	9×10^3 J	9.6×10^3 J	17 m/s
D	0	1.9×10^4 J	1.3×10^4 J	6.4×10^3 J	2.0×10^1 m/s
E	0	1.9×10^4 J	1.6×10^4 J	3.2×10^3 J	22 m/s
F	0	1.9×10^4 J	3×10^3 J	1.6×10^4 J	10 m/s
G	0	1.9×10^4 J	6×10^3 J	1.3×10^4 J	14 m/s

4. The sums are the same.

Power, p. 28

1. $v = -gt$

2. $d = -\frac{1}{2}gt^2$

3. $F = mg$

4. $W = Fd$

5. The graph should be a curved line.

6. 4.20×10^2 W

Mixed Review, pp. 29–30

1. a. 60 J

b. –60 J

2. a. mgh

b. mgh

c. $v_B = \sqrt{v_A^2 + 2gh}$

d. no

e. no

3. a. 2.9 J

b. 1.8 J

c. 1.2 J

d. a, b: different; c: same

4. a. $\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f + F_k d$

b. $F_k = \mu mg(\cos 23°)$

c. $v_f = \sqrt{mv_i^2 + 2g(d \sin 23° - \mu \cos 23°)}$

III

Study Guide Answers

Momentum and Collisions

Momentum and Impulse, p. 31

1. Student drawings should show a vector with a length of 9.5 squares to the right.

2. Student drawings should show a vector with a length of 5.0 squares pointing down.

3. 10.7 squares, angle –28°

4. 11 kg•m/s

5. 12 m/s

6. use a protractor, or use $\tan^{-1}(5.0/9.5)$

7. Student drawings should show one vector with a length of 6.0 squares to the right and another with a length of 12.5 squares to the right. Final momentum is about 6.5 kg•m/s with a final speed of about 43 m/s.

Conservation of Momentum, p. 32

1. 0 kg•m/s

2. 0 kg•m/s

3. The vectors have equal length and opposite direction.

4. $\frac{v_{small}}{v_{big}} = 50$

5. The ratio of velocities is the inverse ratio of the masses.

Elastic and Inelastic Collisions, p. 33

1. vector **A** added head-to-tail with vector **K**

2. **F**

3. **F**

4. vector **F** subtracted (tail-to-tail) with vector **H**

5. **J**

Mixed Review, pp. 35–36

1. a. The change due to the bat is greater than the change due to the mitt.

b. The impulse due to the bat is greater than the impulse due to the mitt.

c. Check student diagrams. Bat: vector showing initial momentum and a larger vector in the opposite direction showing impulse of bat, result is the sum of the vectors. Mitt: vector showing initial momentum and an equal length vector showing impulse of mitt, result is the sum, which is equal to zero.

2. a. The impulses are equal, but opposite forces, occurring during the same time interval.

b. The total force on the bowling ball is the sum of forces on pins. The force on the pins is equal but opposite of total force on ball.

3. $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f$;

$m_1v_{1i}/(m_1 + m_2) + m_2v_{2i}/(m_1 + m_2) = v_f$

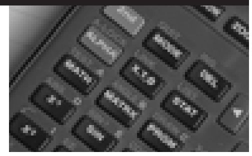
4. a. $M(6 \text{ m/s})$

b. 2 m/s

c. objects trade momentum; if masses are equal, objects trade velocities

III

Study Guide Answers



Circular Motion and Gravitation

Circular Motion, p. 37

1. a. yes

b. The car has a non-zero acceleration because the direction of motion is changing.

c. The direction of centripetal acceleration is toward the center of the circle. In this case, the direction is toward the center of the Ferris wheel.

d. 4.8×10^{-2} m/s^2

2. a. the wire

b. centripetal force

c. The centripetal force acts toward the center of the circular motion.

d. inertia

e. 32.0 m/s

Newton's Law of Universal Gravitation, p. 38

1. a. 2

b. 4

c. $\frac{1}{4}$

d. 1

2. a. double one mass, double the force

b. double both masses, quadruple the force

c. double the radius, decrease the force to $\frac{1}{4}$

d. If measured in the opposite direction, the force will be in the opposite direction.

3. Because of inertia, objects tend to go in a straight line. A force is needed to change the direction of travel.

Motion in Space, p. 39

1. a. According to Copernicus, Earth and the other planets each move in a perfect circle around the sun.

b. According to Kepler's First Law, Earth and the other planets each move in an elliptical orbit with the sun at one focus.

2. $\Delta t_1 = \Delta t_2$

3. $T^2 \propto r^3$

4. Newton derived Kepler's laws from the universal law of gravitation.

5. $T = 3.17 \times 10^7$ s; $v_t = 2.98 \times 10^4$ m/s

Torque and Simple Mechanics, p. 40

1. a. $\mathbf{F_d}$, $\mathbf{F_e}$, $\mathbf{F_f}$, $\mathbf{F_g}$

b. $\mathbf{F_e}$ exerts the largest torque because it has the largest lever arm.

2. a. 1.2×10^4 J

b. 120 N

c. 110 m

d. greater

3. a. 0.92

b. 0.90

c. 0.94

Mixed Review, pp. 41–42

1. a. Inertia tends to carry the passenger in a straight line tangent to the circular motion.

b. Friction between the car's tires and the road provides a centripetal force that keeps the car moving in a circle.

c. $1.4\ m/s^2$

d. $1.4 \times 10^3\ N$

2. a. doubled

b. quadrupled

c. reduced to $\frac{1}{4}$

d. quadrupled

e. reduced to $\frac{1}{9}$

3. Student diagrams should show vectors for weight and normal force from elevator; descent should show normal force less than weight; stopping should show normal force greater than weight; "weightlessness" feeling is due to acceleration.

4. a. 10.0 N

b. $2.22 \times 10^{-1}\ m/s^2$

c. 8.66×10^4 s

d. 3.07×10^3 m/s

5. a. If the knob is farther from the hinge, there is increased torque for a given force.

b. twice as much

c. 2.5 N•m

6. a. 4.0×10^4 J

b. 4.4×10^4 J

c. 4.9×10^4 J

d. 0.81

III

Fluid Mechanics

Fluids and Buoyant Force, p. 43

1. $V = 30.0\ m^3$
2. 1.95×10^4 kg
3. $F_g = 1.91 \times 10^5$ N
4. 0
5. $F_b = 1.91 \times 10^5$ N
6. 1.95×10^4 kg
7. $19.5\ m^3$
8. $19.5\ m^3$; $10.5\ m^3$
9. Ethanol: $F_b = 1.91 \times 10^5$ N; 1.95×10^4 kg; $24.2\ m^3$; $24.2\ m^3$; $5.8\ m^3$

Fluid Mechanics, p. 44

1. $P = 6.94 \times 10^3$ Pa
2. $P = 6.94 \times 10^3$ Pa
3. $P = 6.94 \times 10^3$ Pa
4. 12.5 N
5. **a.** $V = 1.44 \times 10^{-5}\ m^3 (14.4\ cm^3)$

   b. 0.02 m

Fluids in Motion, p. 45

1. $1.20\ m^3/s$; $1.20\ m^3/s$; $1.20\ m^3/s$
2. 6.00 m; 2.00 m; 12.0 m
3. 1 s, 1 s, 1 s
4. 6.00 m/s; 2.00 m/s; 12.0 m/s
5. Speed increases in order to keep the flow rate constant.

Mixed Review, pp. 47–48

1. **a.** $2.01 \times 10^5\ N/m^2$ (top); $2.51 \times 10^5\ N/m^2$ (bottom)

   b. $3.02 \times 10^5\ N/m^2$; $3.52 \times 10^5\ N/m^2$

   c. $F_{top} = 1.81 \times 10^6$ N; $F_{bottom} = 2.11 \times 10^6$ N

   d. F_{top} is downward; F_{bottom} is upward and greater

   e. net force = 3.0×10^5 N; F_{bottom}

   f. The crate will sink because the buoyant force is less than the weight of the crate.

   g. $V = 30.0\ m^3$

   h. $F_b = 3.00 \times 10^5$ N. The buoyant force is equal to the weight of water displace by the crate.

2. **a.** $P_1 = P_2$

   $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

   b. $A = \pi r^2$

   $$\frac{F_1}{\pi {r_1}^2} = \frac{F_2}{\pi {r_2}^2}$$

   c. $$F_2 = F_1\left(\frac{r_2}{r_1}\right)^2$$

   $$F_2 = (750.0\ \text{N})\left(\frac{0.050\ \text{m}}{0.500\ \text{m}}\right)^2$$

3. **a.** $A_1 v_1 = A_2 v_2$

   b. $A = \pi r^2$

   $\pi {r_1}^2 v_1 = \pi {r_2}^2 v_2$

   c. $$v_2 = v_1\left(\frac{r_1}{r_2}\right)^2$$

   $$v_2 = (0.750\ \text{m/s})\left(\frac{1.50\ \text{m}}{0.250\ \text{m}}\right)^2$$

   $v_2 = 27.0$ m/s

III

Study Guide Answers

Heat

Temperature and Thermal Equilibrium, p. 49

1. 183 K to 268 K

2. a. 6.30×10^2 K; 2.34×10^2 K

b. no; yes

3. a. no—tub is 36°C

b. cold

4. a. 77.4 K; 90.2 K

b. The nitrogen is a gas because the temperature is above its boiling point. The oxygen is a liquid because the temperature is below its boiling point.

Defining Heat, p. 50

1. a. 3.12×10^5 J

b. 5.00×10^4 J

c. increase, 2.62×10^5 J

d. yes; 2.62×10^5 J

2. a. 3.92×10^4 J; 2.50×10^3 J; 4.17×10^4 J

b. 0 J; 2.50×10^3 J; 2.50×10^3 J

c. decreased by 3.92×10^4 J

d. increase by 3.92×10^4 J; melting the ice

Changes in Temperature and Phase, p. 51

1. 1.04×10^6 J

2. 6.66×10^6 J

3. 4.19×10^5 J

4. 3-part graph with energy in joules on horizontal axis and temperature in degrees celsius on the vertical axis: graph goes up from {0 J, –25°C to 1.04×10^6 J, 0°C}, is horizontal until {7.70×10^6 J, 0°C}, then goes up to 8.12×10^6 J, 0°C}

Mixed Review, pp. 53–54

1. a. 78.5 J

b. 78.5 J

c. 51.2 J; less than loss in PE

d. 27.3 J

2. a. 2.26×10^9 J

b. 1.49×10^5 kg

c. 3.62°C

d. 19.4°C

3. a. They are at thermal equilibrium.

b. $(100.0 - x)$°C; $(y - 20.0)$°C

c. (2.000 kg)(4.19×10^3 J/kg•°C) $(100.0 - x)$°C

d. (5.000 kg) (8.99×10^2 J/kg•°C) $(y - 20.0)$°C

e. all of the energy was transferred from the water to the pipe, no loss and no other source of energy

f. 72°C

Thermodynamics

Relationships Between Heat and Work, p. 55

1. a. $0.020\ m^3$

b. 7.0×10^3 J

c. 2.0×10^3 J increase

2. a. yes, marble to water

b. no, ΔU by heat only

c. decrease; temperature dropped

d. increase; more water, less ice

e. no change, the cup is insulated

The First Law of Thermodynamics, p. 56

1. a. –320 J

b. The gas lost energy because ΔU was less than 0.

c. Student diagrams should show the W arrow and the Q arrow pointing OUT of the container.

2. a. 0

b. 540 J out

c. Student diagrams should show the W arrow pointing IN and the Q arrow pointing OUT.

The Second Law of Thermodynamics, p. 57

1. a. 8.0×10^3 J

b. 20%

c. 3.2×10^2 N

2. a. 7.00×10^3 J

b. 1.30×10^4 J

c. 4.0×10^1 m

3. a. 5.0×10^2 J

b. 3.4×10^2 J

c. 1.9×10^2 J

Mixed Review, pp. 59–60

III

1. $\Delta U = 700$ J increase

2. a. $0.005\ m^3$

b. 1.5×10^3 J

c. 1.5×10^3 J

3. a. 5.00×10^4 J

b. 1.40×10^4 J

4. a. ΔU (compressed air) = W (added by person) – Q (things warm up)

b. Disorder is increased by increasing internal energy through heat.

5. Graph bars should convey that: $PE_1 = \text{max}$, $KE_1 = 0$, $U_1 = 0$ or U_1 is any amount. Then, $PE_2 = 0$, $KE_2 \leq \frac{1}{2}PE_1$, $U_2 \geq U_1 + \frac{1}{2}PE_1$. Then, $PE_3 \leq \frac{1}{2}PE_1$, $KE_3 = 0$, $U_3 \approx U_2$. Last: $PE_4 = 0$, $KE_4 \leq \frac{1}{4}PE_1$, and $U_4 \geq \frac{3}{4}PE_1$.

Vibrations and Waves

Simple Harmonic Motion, p. 61

1. a. 0.21 m

b. 2.0 s

c. 0.5 Hz

d. 0.50 m, 2.0 s, 0.5 Hz

2. a. 49.0 N

b. 4.90×10^2 N

c. 41.6 N

d. 15.9 cm

Measuring Simple Harmonic Motion, p. 62

1. 0.1 s, 10 Hz

2. a. 5.0 Hz

b. 10, 70

3. a. 4.0 Hz, 0.25 s

b. 4.0 Hz, 0.25 s, 5.0 cm

4. 0.500 Hz, 2.00 s, 0.0621 m

5. a. 1267 kg, 5066 kg

b. increase

Properties of Waves, p. 63

1. 37.5 m, 250 m

2. a. 0.02 s, 5×10^1 Hz

b. 40.00 m, 2.000×10^3 m/s

Wave Interactions, p. 64

1. a. Students' drawings of amplitudes should have magnitudes corresponding to 0.25 and 0.35.

b. Students' drawings should indicate constructive interference, with a net amplitude of 0.60.

2. a. 1.5 s

b. 10.0 m

c. yes

Mixed Review, pp. 65–66

1. a. 0.20 s; 5.0 Hz

b. same, same, increase, increase

2. a. 60.0 N/m

b. 0.574 seconds; 1.74 Hz

3. 6.58 m/s^2; no

4. a. A: 0 s, 2 s, 4 s; B: 0.5 s, 1.5 s, 2.5 s, 3.5 s; C: 1, 3 s

b. PE: 0 s at A, 1 s at C, 2 s at A, 3 s at C, 4 s at A; KE: 0.5 s, 1.5 s, 2.5 s, 3.5 s at B

c. 0.5 s, 2.5 s at B to the right 1.5 s, 3.5 s at B to the left; 0 s, 2 s, 4 s at A to the right, 1 s, 3 s at C to the left

5. 3.00×10^2 m/s

6. 3.0 s; 6.0

III

Study Guide Answers

Sound

Sound Waves, p. 67

1. 336 m/s

2. 1030 m

3. a. 3.00 cm

b. 1.50 cm

c. 3.51 s; 0.234 s

d. 1.14×10^4 Hz (no Doppler effect because the train was stationary)

e. pitch decrease; same; increase

Sound Intensity and Resonance, p. 68

1. a. 9.95×10^{-3} to 2.49×10^{-3} W/m^2

b. 6.22×10^{-4} to 2.76×10^{-4} W/m^2

c. 1.59×10^{-5} W/m^2, about 70

2. a. 1.00×10^{-2} W/m^2

b. 3.14 W

c. 5000 m

Harmonics, p. 69

1. a. 462 m/s

b. Student diagrams should show antinodes, nodes at both ends; first has one antinode, second has two, third has three.

c. 69.0 cm

2. a. 880 Hz, 1320 Hz, 1760 Hz

b. Check student graphs for accuracy. Wavelength of first harmonic should be two wavelengths of second harmonic, three wavelengths of third harmonic. The second and third harmonics should have half the amplitude. The resultant will be a wave with a large maximum, a smaller peak, a small minimum, and a large minimum.

III

Mixed Review, pp. 71–72

1. a. 2.19 m; 2.27 m

b. wavelength increases when temperature increases

2. a. arrows pointing East on ambulance, police, and truck, West on van.

b. police and ambulance (equal), truck, small car, van

3. These objects had the same natural frequency of 330 Hz, so resonance occurred.

4. a. 1460 Hz, 2440 Hz

b. 70.8 cm, 23.6 cm, 14.1 cm

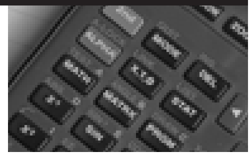
c. 0.177 m

d. 974 Hz, 1460 Hz; 70.8 cm, 35.4 cm, 23.6 cm; 0.354 m

5. a. 5

b. 435 Hz, because it will also provide a difference of 5 Hz.

Study Guide Answers



Light and Reflection

Characteristics of Light, p. 73

1. a. 499 s

b. 193 s

c. 1.97×10^4 s

2. a. 7.1×10^{14} Hz; 6.7×10^{14} Hz; 5.5×10^{14} Hz; 5.0×10^{14} Hz; 4.3×10^{14} Hz

b. Frequency decreases when wavelength increases.

c. No, no

Flat Mirrors, p. 74

1. a. Check student drawings for accuracy. Angles of reflection should be equal.

b. Extensions intersect on the normal through *A,* 25 cm inside the mirror.

c. 50 cm

d. No, but the person will see image by receiving the reflection of some other ray.

e. The person will see the image by receiving reflected Ray from *C.*

f. angle at *A* close to 50°, angle at *B* close to 60°

g. The eraser's image is 15 cm inside.

Curved Mirrors, p. 75

1. a. midpoint between mirror and *O*

b. markings should be at scale: 1 cm for 1 m

c. *A*'s image is 2.6 m inside.

d. Image locations: *B* at 3.33 m inside the mirror; *C* at 2.00 m outside the mirror

2. 2.60 m; 3.33 m; –2.00 m

Color and Polarization, p. 76

1. a. all but green because green is reflected

b. red, because it lets the type of light best absorbed by plants to be transmitted

2. a. white

b. blue

c. black

d. black

3. black

Mixed Review, pp. 77–78

1. 4.07×10^{16} m

2. a. 3.33×10^{-5} s

b. 1.00×10^{-4} m

3. 3.84×10^8 m

4. 3.00×10^{11} Hz

5. Diffuse reflection: (nonshiny surfaces) table top, floor, walls, car paint, posters (answers will vary)

Specular reflection: metallic surfaces, water, mirrors (answers will vary)

6. a. Check student drawings for accuracy.

b. *B* is 4 m from *A* horizontally, *C* is 2 m below *B* vertically

c. *D* is 2 m below *A* vertically, *E* coincides with *C*

d. they will overlap the existing images or objects

III

7. a. 9.00 cm

b. $p = 30.0$ cm; $q = 12.9$ cm; real; inverted; 2.58 cm tall

$p = 24.0$ cm; $q = 14.4$ cm; real, inverted; 3.60 cm tall

$p = 18.0$ cm; $q = 18.0$ cm; real; inverted; 6.00 cm tall

$p = 12.0$ cm; $q = 36.0$ cm; real; inverted; 2.00 cm tall

$p = 6.0$ cm; $q = -18$ cm; virtual; upright; 18 cm tall

8. $p = 30.0$ cm; $q = -6.92$ cm; virtual; upright; 1.38 cm tall

$p = 24.0$ cm; $q = -6.55$ cm; virtual, upright; 1.64 cm tall

$p = 18.0$ cm; $q = -6.00$ cm; virtual; upright; 2.00 cm tall

$p = 12.0$ cm; $q = -5.14$ cm; virtual; upright; 2.57 cm tall

$p = 6.0$ cm; $q = -3.6$ cm; virtual; upright; 3.6 cm tall

III

Refraction

Refraction, p. 79

1. a. $n = c/v$

b. 2.25×10^8 m/s

2. a. 13.0°

b. 13.0°, 20.0°

c. Angles inside glass: 25°, 35°, 40°; Angles coming out of glass: 40°, 60°, 80°

d. Student sketches should indicate that the rays exiting the glass are parallel to the rays entering it.

Thin Lenses, p. 80

1. a. Check student diagrams. Rays should be drawn straight, according to rules for ray tracing.

b. *A* is real, inverted, and smaller.

c. *B* is real, inverted, and smaller; *C* is virtual, upright, and larger

2. *A:* 4.80 cm; *B:* 7.5 cm; *C:* −6.00 cm

Optical Phenomena, p. 81

1. a. $\theta_r = 55.8°$

b. sin $\theta_r = 1.28 > 1$: internal reflection

c. $\theta_r = 24.4°$

d. $\theta_r = 38.5°$; $\theta_r = 74.5°$; $\theta_r = 33.4°$

2. $\theta_r = 48.8°$, the angle is too large, light with 45° incident angle will be refracted and exit

Mixed Review, pp. 83–84

1. a. Ray 1 at 45°; Ray 2 at 14.9°

b. Rays should intersect inside the aquarium.

c. Because the rays are no longer parallel, they will intersect in the water.

2. a. First boundary: 70.0°, 45.0°

Second boundary: 45.0°, 40.4°

Third boundary: 40.3°, 36.8°

b. Incoming rays get closer and closer to the normal. Reflected rays get farther away from the normal with the same angles.

3. a. 9.00 cm

b. 12.9 cm, 14.4 cm, 18.0 cm, 36.0 cm, −18.0 cm

2.58 cm, 3.6 cm, 6.00 cm, 18.0 cm, −18.0 cm

real, real, real, real, virtual

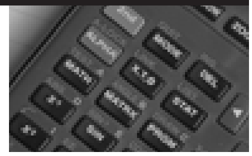
4. 18.0 cm, with all images virtual and on the left of the lens

−11.2, −10.3, −9.00, −7.20, −4.50

5. a. 6.00 cm in front of the lens

b. 0.857 cm

Study Guide Answers



Interference and Diffraction

Interference, p. 85

1. a. First: 1.6°, Second: 3.2°, Third: 4.8°

b. Bright: 16.2°, 34.0°, 4.01°

c. A smaller slit results in more separation between fringes. With 2 cm, fringes would be so close they would not be distinguishable.

2. a. 475 nm

b. 7.80°, 11.7°, 15.7°

Diffraction, p. 86

1. a. 1.25×10^{-6} m

b. 18° spacing for 400 nm light and 34° for 700 nm light. More lines per centimeter will give better resolution

2. a. 1250 lines/cm

b. 4.4°, 8.9°, 13°

3. 565 nm

4. 4.38×10^{-6} m

Lasers, p. 87

1. Coherent light is individual light waves of the same wavelength that have the properties of a single light wave.

2. Student diagrams should show a coherent light source with light waves moving in the same direction. The incoherent light should have a light source with waves radiating out in different directions.

3. Lasers convert light, electrical energy, or chemical energy into coherent light.

4. Answers will vary. Examples are CD players, laser scalpels, laser range finders.

III

Mixed Review, pp. 89–90

1. a. 6.74×10^{-6} m

b. 47.9°

c. The maximum angle for light to reach the screen in this arrangement is 45°.

2. a. Longer wavelengths are diffracted with a greater angle.

b. First order group of lines: blue, green, red; second order: the same

c. White

3. a. $A = 5.0 \times 10^{-6}$ m, $B = 1.1 \times 10^{-7}$ m, $C = 3.3 \times 10^{-8}$ m

b. visible: A; x-ray: A, B, or C; IR: none

4. a. Neither would work because they would act as different sources, so even with the same frequency, they should not be in phase.

b. Interference is occurring.

Electric Forces and Fields

Electric Charge, p. 91

1. a. Experiment A, no charges were transferred. Experiment B, charges were transferred between the sphere and the ground. Experiment C, charges were transferred between the sphere and the rod

b. Student diagrams should show: Sphere A, negative charges (–) on the left, positive (+) on the right; Sphere B, excess (–) all over; Sphere C, excess (+) all over.

c. Sphere B has excess (–); Sphere C has excess (+)

d. Experiment A

e. no change in Experiment A or Experiment B; reduced charge in Experiment C

Electric Force, p. 92

1. a. 20.0 cm

b. 0.899 N (attraction along the line $q_1 - q_3$)

c. 0.899 N (attraction along the line $q_1 - q_2$)

d. 1.40 N repulsion pulling to the right

e. Student diagrams should show $\mathbf{F_1}$ pointing from q_3 toward q_1 and $\mathbf{F_2}$ pointing from q_3 toward q_2.

f. 36.9°

g. $F_{1x} = -0.719$ N; $F_{2x} = 0.719$ N; $F_{1y} = -0.540$ N; $F_{2y} = -0.540$ N

h. −1.08 N pointing down

i. downward along the y-axis

The Electric Field, p. 93

1. a. 21.2 cm

b. all same strength of 1.60×10^{-6} N/C along the diagonal lines, with $\mathbf{E_1}$ pointing away from q_1, $\mathbf{E_2}$ from q_2, $\mathbf{E_3}$ from q_3, and $\mathbf{E_4}$ from q_4

c. Resultant electric field $\mathbf{E} = 0$

2. a. 4.61×10^{-14} N down

b. 4.61×10^{-14} N up

c. 1.44×10^{-18} C

d. 9 electrons

III

Mixed Review, pp. 95–96

1. a. A; 1.87×10^{13} electrons; B: 3.12×10^{13} electrons

b. the forces are equal and opposite, no

2. a. Resultant = 1.49 N, left; F(A-C) = 1.35 N, left; F(B-C) = 0.140 N, left

b. Resultant = 0.788 N, right; F(A-C) = 1.35 N, right; F(B-C) = 0.562 N, left

c. Resultant = 0.400 N, left; F(A-C) = 0.599 N, right; F(B-C) = 0.999 N, left

3. a. 1.92×10^{16} N

b. 2.87×10^{10} m/s^2

c. 9.81 m/s^2; this is negligible in comparison with the acceleration a; alpha particles will move horizontally

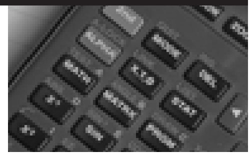
4. a. Check students diagrams for accuracy.

b. 1.53×10^{-2} N

c. 7.65×10^{3} N/C

5. 1 C = 6.25×10^{18}; 1 μC = 6.25×10^{12}

Study Guide Answers



Electrical Energy and Current

Electric Potential, p. 97

1. a. 8.99×10^5 V

b. $y = -10.0$ cm; $V = 3.33 \times 10^5$ V

$y = -2.00$ cm; $V = 8.08 \times 10^5$ V

$y = 2.00$ cm; $V = 8.08 \times 10^5$ V

$y = 10.0$ cm; $V = 3.32 \times 10^5$ V

c. $x = -10.0$ cm; $V = 4.28 \times 10^5$ V

$x = -2.00$ cm; $V = 1.20 \times 10^6$ V

$x = 2.00$ cm; $V = 1.20 \times 10^6$ V

$x = 10.0$ cm; $V = 4.28 \times 10^5$ V

2. a. 2.16×10^6 V

b. 0

c. 0

Capacitance, p. 98

1. pF = 10^{-12} F; nF = 10^{-9} F; μC = 10^{-6} C; Farads measure the ratio of charge to potential difference. Coulombs measure the amount of charge.

2. 1 pF < 1 nF. The 1 pF capacitor has a higher potential difference (1000 times) because $\Delta V = Q/C$

3. a. 4.00×10^{-7} F = 4.00×10^2 nF

b. Capacitance does not change. Charge doubles (Q is proportional to ΔV, ΔV doubled and C was the same)

c. 5.00×10^{-2} J; 2.00×10^1 J

Current and Resistance, p. 99

1. 2.50×10^2 A

2. a. 320 s

b. 320 s

c. 320 s

3. a. 1.80×10^{-3} A; 1.80 A; 1.80×10^2 A

b. C (smaller resistor)

4. 134 V

5. a. 343 Ω to 286 Ω

b. R > 285 Ω

c. R < 387 Ω

III

Electric Power, p. 100

1. a. 932 W

b. 1.68×10^7 J = 4.66 kWh

c. 32.6 ¢

2. a. 417 W

b. 3.5 A

3. a. 5.1 Ω

b. 24 A

Mixed Review, pp. 101–102

1. a. -1.28×10^{-15} J; decreases

b. 1.28×10^{-15} J; increases

c. 5.3×10^7 *m/s*

2. a. 5.000×10^3 V/m; yes, the field is constant

b. ΔV(+plate, A) = 50.0 V; ΔV(+plate, B) = 1.50×10^2 V; ΔV(+plate, C) = 2.50×10^2 V

c. PE at positive plate = 4.80×10^{-17} J; $PE_A = 4.00 \times 10^{-17}$ J; $PE_B = 2.40 \times 10^{-17}$ J; $PE_C = 8.00 \times 10^{-18}$ J; PE at negative plate = 0 J

3. a. 2.00×10^2 V

b. 4.00×10^{-3} J

4. a. 4.8 A

b. 8.64×10^4 C

c. 580 W

d. 1.0×10^7 J

5. a. 144 V

b. 864 W

c. 104 seconds

Study Guide Answers

Circuits and Circuit Elements

Schematic Diagrams and Circuits, p. 103

1. a. Check student diagrams, which should contain 2 bulbs, 2 resistors, 3 switches, and 1 battery, in a closed cirucit.

b. Check student diagrams to be certain that the switches labeled S1 and S2 cause short circuits when closed.

c. Check student diagrams to be certain that switch S3 causes a short circuit when closed.

2. a. Students should connect one end of bulb A to the battery, the other to the switch, then the other end of the switch to the battery. Also connect one end of B to the battery, and the other end of B to the switch.

b. Students should connect one end of B to the battery, the other to the switch, then the other end of the switch to the battery. Bulb A should simply be left out with no connections.

c. Students should connect each end of B to one end of the battery, the other to the switch, then the other end of the switch to the battery. Also each end of A should be connected to an end of the battery.

Resistors in Series or in Parallel, p. 104

1. a. 16.0 Ω

b. 0.750 A for both

c. 12.0 V; 9.0 V; 3.0 V

2. a. 3.00 Ω

b. 12 V

c. 4 A, $I_1 = 1$ A; $I_2 = 3$ A

d. 12.0 V

Complex Resistor Combinations, p. 105

1. a. 40 Ω

b. $I_a = I_b = I_c = 0.600$ A; $I_d = I_e = I_f = 0.200$ A;

$\Delta V_a = \Delta V_b = \Delta V_c = 7.20$ V; $\Delta V_d = \Delta V_e = \Delta V_f = 2.40$ V

2. a. Check diagram

b. 54 Ω; $I_a = I_b = I_c = I_f = 0.444$ A; $I_d = I_e = 0.222$ A;

$\Delta V_a = \Delta V_b = \Delta V_c = \Delta V_f = 5.33$ V; $\Delta V_d = \Delta V_e = 2.67$ V

III

Mixed Review, pp. 107–108

1. a. D

b. switch 5

c.
- switches 1 and 3 open, switches 2, 4, and 5 closed
- switches 1 and 4 open, switches 2, 3, and 5 closed
- switch 2 open, switches 1, 3, 4, and 5 closed; or switches 3 and 4 open, switches 1, 2, and 5 closed; or switches 2, 3, and 4 open, switches 1 and 5 closed

2. a. Check students' diagrams, which should show a bulb and a resistor in series with a battery.

b. 15 Ω

c. 6 Ω

3. a. Check students diagrams.

b. 12.0 V, 12.0 V

c. 0.25 A, 2.25 A

d. 5.33 Ω

4. a. $R = 6.15$ Ω

b. $R = 30.4$ Ω

Magnetism

Magnets and Magnetic Fields, p. 109

1. a. No

b. No

c. Magnet: A; Iron: B and C.

2. Arrows should point away from S, toward N, building a composite picture of the magnetic field.

3. Arrows should point away from S, toward N, mostly in the area between the ends of the magnet and around it.

Magnetism from Electricity, p. 110

1. a. the field at A, B, C is pointing out (dot symbol); the field at D, E, F is pointing in (× symbol).

b. all reversed: the field at A, B, C is pointing in (× symbol); the field at D, E, F is pointing out (dot symbol)

2. the strength at point A is weaker than B, C, D or E, and about equal to that at F.

3. All directions of field are opposite to the answers in questions 1. The relative strengths remain the same.

Magnetic Force, p. 111

1. a. **v**-arrow to the right, **B**-arrow upward

b. •; $\mathbf{F} = 4.8 \times 10^{-14}$ N, upward, out of the page

c. 0

2. a. **v**-arrow to the left, **B**-arrow upward

b. ×; $\mathbf{F} = 4.8 \times 10^{-14}$ N, downward, into the page

c. 0

3. a. **v**-arrow to the right, **B**-arrow upward

b. •; $\mathbf{F} = 9.6 \times 10^{-14}$ N, upward, out of the page

c. 0

4. No. When the force is not zero, it acts perpendicular to velocity. They move in a circle perpendicular to the magnetic field.

Mixed Review, pp. 113–114

1. a. The magnetic field from the leftmost segment is • and stronger. The magnetic field from the rightmost segment is × and weaker.

b. At A, both horizontal segments contribute a × magnetic field of equal strength

c. B; ×; × weaker; ×; × same

C; ×; × same; ×; × same

D; ×; × stronger; ×; × same

E; ×; • stronger; ×; × same

d. No. They reinforce each other in the same direction.

e. inside

2. a. $\mathbf{F} = 4.3$ N into the page

b. $\mathbf{F} = 0$

3. a. Diagrams should show clockwise current.

b. Starting from the left side: $\mathbf{F} = 1.1$ N into the page; $\mathbf{F} = 0$; $\mathbf{F} = 1.1$ N out of the page; $\mathbf{F} = 0$

c. Forces are equal and opposite, so no translational motion will occur, but it could rotate around a vertical axis.

Electromagnetic Induction

Electricity from Magnetism, p. 115

1. side a: none, down, down, none, none
side b: none, none, none, none, none
side c: none, none, down, down, none
side d: none, none, none, none, none

2. none, clockwise, none, counterclockwise, none

3. a. 2.56×10^{-2} m^2
b. 2.0 s
c. 2.0×10^{-2} V
d. 5.7×10^{-2} A

Generators, Motors, and Mutual Inductance, p. 116

1. *A* to *B*

2. increase, increase, increase

3. a. horizontal
b. vertical
c. 0.25 s
d. 1.9×10^{-3} V

AC Circuits and Transformers, p. 117

1. down through primary coil, and up elsewhere, including through the secondary coil

2. a –, b +

3. 24 V

4. no change in field

5. disappearing field is a change which secondary coil opposes

Electromagnetic Waves, p. 118

1. The electromagnetic spectrum

2. "High energy" should be on the right side; "low energy" should be on the left side

3. Both wavelength and frequency, and wavelength and energy, show an inverse relationship, that is, as one factor increases, the other decreases. Frequency and energy display a direct relationship, that is, both factors increase or decrease together.

4. Answers may include one or more of the following:
a. heat lamps, remote controls, burglar alarms, night-vision goggles
b. photography, medical, security screening
c. disinfection, science, astronomy, dentistry
d. ovens, communication, cell phones, radar
e. light bulbs, lasers, art, science
f. communication, television, astronomy
g. medicine, astronomy, scientific research

Mixed Review, pp. 119–120

1. e

2. a. 0.50 s
b. 0.26 m^2
c. 2.6 V

3. a. magnetic field, conductor, relative motion
b. answers may vary, but could include the following: water wheel, windmill, electric motor, combustion engine

4. a. 6.28 rad/s
b. 7.1×10^{-2} m^2

III

c. 110 V

d. 78 V

5. A motor converts electric energy to rotational energy; generators converts rotational energy to electric energy.

6. a. increases

b. induces current while change occurs

c. It decreases magnetic field which will induce a current while the change occurs.

III

Study Guide Answers

Atomic Physics

Quantization of Energy, p. 121

1. a. This implies that there is an infinite energy output.

b. quantization of energy

c. As wavelength gets shorter, energy in photon gets smaller.

2. a. 2.9×10^{-31} J

b. 1.8×10^{-12} eV

3. a. $hf_t = hf - KE_{max}$

b. 2.30 eV

Models of the Atom, p. 122

1. small positively charged nucleus and electrons in planetary orbits

2. He expected diffuse positive charge with no scattering.

3. Most atoms went through.

4. As electrons radiated energy, they would spiral in toward nucleus.

Quantum Mechanics, p. 123

1. a. light radiating from the sun to Earth

b. light scattering off electrons

2. The precision of measurements for very small objects is relatively less than the precision of measurements of very large objects.

3. a. 1.47×10^{-38} m

b. 5.41×10^{-40} m

c. 8.4×10^{-37} m

d. 3.7×10^{-35} m

4. It allowed for electron uncertainty and gave electrons probable but not definite orbits.

Mixed Review, pp. 125–126

1. There is not enough energy in any individual photon to liberate the electron.

2. Some energy is used in liberating the electron.

3. a. Atoms contained areas of dense positive charge.

b. The foil is mostly empty space.

4. a. 1.5×10^{-8} m

b. 5.3×10^{-34} m

c. The wavelength is too small to detect.

5. a. Simultaneous measurements of position and momentum cannot be completely certain.

b. A theory of distinct orbits would require precise knowledge of their location at any given time.

6. A photon does not measurably deflect a planet.

7. 1.16×10^{15} m

8. No electrons were ejected.

9. It is absorbed by atoms into vibrational motion, etc.

10. Energy is observed in increased temperature.

Study Guide Answers

Subatomic Physics

The Nucleus, p. 127

1. a. 16

b. 8

c. 16

d. 2.81 MeV

e. Energy is required to separate the nucleus.

f. No, it is the same element but a different isotope.

2. a. strong interaction

b. decreases

Nuclear Decay, p. 128

1. alpha—helium nucleus; beta—electron or positron; gamma—photons

2. a. O-17

b. Th-231

c. Np-238

d. U-235

3. It is the time required for half of the sample to decay.

4. It gives decay rate for sample.

5. half-life = 0.693/decay constant

6. $0.050\ s^{-1}$

7. 3.15×10^7 s

8. 25.0% or 1/4

Nuclear Reactions, p. 129

1. a. fission

b. neutron and uranium nucleus

c. barium, krypton, and 3 neutrons

d. yes

e. more fission

f. It has high energy output. In a nuclear reactor, the high heat leads to a meltdown.

2. a. fusion

b. proton and helium-3 nucleus

c. alpha (He-4), positron and neutrino

d. yes

III

Particle Physics, p. 130

1. Strong: 1, hold nucleons, 10^{-15} m; electromagnetic: 10^{-2}, charged particles, $1/r^2$; weak: 10^{-13}, fission, 10^{-18} m; gravitational: 10^{-38}, all mass, $1/r^2$

2. a. graviton; W and Z bosons; photons; gluons

b. graviton

3. a. It can unify weak and electromagnetic interactions at high energy.

b. It requires very high energy interaction (1 TeV).

Mixed Review, pp. 131–132

1. a. 143

b. 146

c. 146

d. 1

e. 2

f. 8

g. 10

h. 22

2. a. atomic number

b. number of neutrons

c. same number of neutrons

d. different atomic numbers

e. Both pairs increase mass by one amu.

f. First pair are isotopes; second pair are different elements.

3. a. almost the same

b. one higher

c. New one is higher; otherwise, it wouldn't decay.

d. new one

4. gravitational interaction

5. No, there are not enough nucleons to form an alpha particle.

6. mass and charge