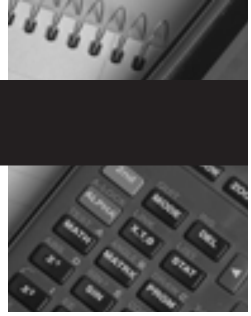

Student Edition Solutions

Circular Motion and Gravitation

I

Circular Motion and Gravitation, Practice A

Givens | *Solutions*

1. $a_c = 3.0 \text{ m/s}^2$

$r = 2.1 \text{ m}$

$$v_t = \sqrt{a_c r} = \sqrt{(3.0 \text{ m/s}^2)(2.1 \text{ m})} = \boxed{2.5 \text{ m/s}}$$

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2. $a_c = 250 \text{ m/s}^2$

$r = 0.50 \text{ m}$

$$v_t = \sqrt{a_c r} = \sqrt{(250 \text{ m/s}^2)(0.50 \text{ m})} = \boxed{11 \text{ m/s}}$$

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3. $r = 1.5 \text{ m}$

$v_t = 1.5 \text{ m/s}$

$$a_c = \frac{v_t^2}{r} = \frac{(1.5 \text{ m/s})^2}{1.5 \text{ m}} = \boxed{1.5 \text{ m/s}^2}$$

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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. $r = 2.10 \text{ m}$

$v_t = 2.50 \text{ m/s}$

$F_c = 88.0 \text{ N}$

$$m = F_c \frac{r}{v_t^2} = (88.0 \text{ N}) \frac{(2.10 \text{ m})}{(2.50 \text{ m/s})^2} = \boxed{29.6 \text{ kg}}$$

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2. $v_t = 13.2 \text{ m/s}$

$F_c = 377 \text{ N}$

$m = 86.5 \text{ kg}$

$$r = \frac{m v_t^2}{F_c} = \frac{(86.5 \text{ kg})(13.2 \text{ m/s})^2}{377 \text{ N}} = \boxed{40.0 \text{ m}}$$

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3. $r = 1.50 \text{ m}$

$v_t = 1.80 \text{ m/s}$

$m = 18.5 \text{ kg}$

$$F_c = \frac{m v_t^2}{r} = \frac{(18.5 \text{ kg})(1.80 \text{ m/s})^2}{1.50 \text{ m}} = \boxed{40.0 \text{ N}}$$

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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	$F_c = \dfrac{mv_t^2}{r} = \dfrac{(90.0 \text{ kg})(13.2 \text{ m/s})^2}{11.5 \text{ m}} = \boxed{1360 \text{ N}}$

Circular Motion and Gravitation, Practice C

1. $m_1 = m_2 = 0.800$ kg $F_g = 8.92 \times 10^{-11}$ N $G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$	$r = \sqrt{\dfrac{G\, m_1 m_2}{F_g}} = \sqrt{\dfrac{\left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)(0.800 \text{ kg})(0.800 \text{ kg})}{8.92 \times 10^{-11} \text{ N}}}$ $r = \boxed{0.692 \text{ m}}$
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 $G = 6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}$	$r = \sqrt{\dfrac{G\, m_1 m_2}{F_g}} = \sqrt{\dfrac{\left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right)(6.4 \times 10^{23} \text{ kg})(9.6 \times 10^{15} \text{ kg})}{4.6 \times 10^{15} \text{ N}}}$ $r = \boxed{9.4 \times 10^6 \text{ m} = 9.4 \times 10^3 \text{ km}}$
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.** $F_g = G\dfrac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right) \dfrac{(66.5 \text{ kg})(5.97 \times 10^{24} \text{ kg})}{(6.38 \times 10^6 \text{ m})^2} = \boxed{651 \text{ N}}$
$m_2 = 6.42 \times 10^{23}$ kg $r = 3.40 \times 10^6$ m	**b.** $F_g = G\dfrac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right) \dfrac{(66.5 \text{ kg})(6.42 \times 10^{23} \text{ kg})}{(3.40 \times 10^6 \text{ m})^2} = \boxed{246 \text{ N}}$
$m_2 = 1.25 \times 10^{22}$ kg $r = 1.20 \times 10^6$ m	**c.** $F_g = G\dfrac{m_1 m_2}{r^2} = \left(6.673 \times 10^{-11} \dfrac{\text{N•m}^2}{\text{kg}^2}\right) \dfrac{(66.5 \text{ kg})(1.25 \times 10^{22} \text{ kg})}{(1.20 \times 10^6 \text{ m})^2} = \boxed{38.5 \text{ N}}$

Givens	Solutions
3. $m_E = 5.97 \times 10^{24}$ kg $r_E = 6.38 \times 10^6$ m $m = 65.0$ kg $G = 6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}$	**a.** $F_g = G\frac{mm_E}{r_E^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}\right)\frac{(65.0 \text{ kg})(5.97 \times 10^{24} \text{ kg})}{(6.38 \times 10^6 \text{ m})^2} = \boxed{636 \text{ N}}$
$m_E = 5.97 \times 10^{24}$ kg $r = 7.38 \times 10^6$ m $m = 65.0$ kg	**b.** $F_g = G\frac{mm_E}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}\right)\frac{(65.0 \text{ kg})(5.97 \times 10^{24} \text{ kg})}{(7.38 \times 10^6 \text{ m})^2} = \boxed{475 \text{ N}}$
$m_S = 5.68 \times 10^{26}$ kg $r_S = 6.03 \times 10^7$ m $m = 65.0$ kg	**c.** $F_g = \frac{G\,mm_S}{r_S^2}$ $F = \left(6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}\right)\frac{(65.0 \text{ kg})(5.68 \times 10^{26} \text{ kg})}{(6.03 \times 10^7 \text{ m})^2} = \boxed{678 \text{ N}}$
$m_S = 5.68 \times 10^{26}$ kg $r = 6.13 \times 10^7$ m $m = 65.0$ kg	**d.** $F_g = G\frac{mm_S}{r^2}$ $F_g = \left(6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}\right)\frac{(65.0 \text{ kg})(5.68 \times 10^{26} \text{ kg})}{(6.13 \times 10^7 \text{ m})^2} = \boxed{656 \text{ N}}$
5. $r_E = 6.38 \times 10^6$ m $g = 9.81$ m/s^2 $G = 6.673 \times 10^{-11} \frac{N{\bullet}m^2}{kg^2}$	$g = G\frac{m_E}{r_E^2}$, so $m_E = \frac{gr_E^2}{G}$ $m_E = \frac{(9.81 \text{ m/s}^2)(6.38 \times 10^6 \text{ m})^2}{6.673 \times 10^{-11} \text{ N}{\bullet}\text{m}^2/\text{kg}^2} = \boxed{5.98 \times 10^{24} \text{ kg}}$

I

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 $G = 6.673 \times 10^{-11} \frac{N \bullet m^2}{kg^2}$	$T^2 = \frac{4\pi^2 r^3}{Gm_E}$ $r^3 = \frac{T^2 Gm_E}{4\pi^2}$ $r = \sqrt[3]{\frac{[(125\ \text{min})(60\ \text{s/min})]^2(6.673 \times 10^{-11}\ \text{N}\bullet\text{m}^2/\text{kg}^2)(5.97 \times 10^{24}\ \text{kg})}{4\pi^2}}$ $r = 8.28 \times 10^6$ 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 $G = 6.673 \times 10^{-11} \frac{N \bullet m^2}{kg^2}$	$v_t = \sqrt{G\frac{m_E}{r}}$ $v_t = \sqrt{\left(6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)\left(\frac{5.97 \times 10^{24}\ \text{kg}}{3.84 \times 10^8\ \text{m}}\right)} = \boxed{1.02 \times 10^3\ \text{m/s}}$ $T = 2\pi\sqrt{\frac{r^3}{Gm_E}}$ $T = 2\pi\sqrt{\frac{(3.84 \times 10^8\ \text{m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}\right)(5.97 \times 10^{24}\ \text{kg})}} = \boxed{2.37 \times 10^6\ \text{s}}$

Circular Motion and Gravitation, Practice E

1. $F = 3.0$ N $d = 0.25$ m $\theta = 90.0°$	$\tau = Fd(\sin\theta) = (3.0\ \text{N})(0.25\ \text{m})(\sin 90.0°) = \boxed{0.75\ \text{N}\bullet\text{m}}$
2. $m = 3.0$ kg $d = 2.0$ m $\theta_1 = 5.0°$ $g = 9.81$ m/s^2 $\theta_2 = 15.0°$	**a.** $\tau = Fd(\sin\theta_1) = mgd(\sin\theta_1)$ $\tau = (3.0\ \text{kg})(9.81\ \text{m/s}^2)(2.0\ \text{m})(\sin 5.0°) = \boxed{5.1\ \text{N}\bullet\text{m}}$ **b.** $\tau = mgd(\sin\theta_2) = (3.0\ \text{kg})(9.81\ \text{m/s}^2)(2.0\ \text{m})(\sin 15.0°) = \boxed{15\ \text{N}\bullet\text{m}}$
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, $F = \frac{\tau}{d} = \frac{40.0\ \text{N}\bullet\text{m}}{0.300\ \text{m}} = \boxed{133\ \text{N}}$

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	$eff = \frac{W_{out}}{W_{in}}$ $eff = \frac{F_{out}d_{out}}{F_{in}d_{in}}$ where $F_{out} = mg$ $F_{in} = \frac{mgd_{out}}{eff\,d_{in}} = \frac{(58\text{ kg})(9.81\text{ m/s}^2)(3.0\text{ m})}{(0.73)(18.0\text{ m})} = \boxed{1.3 \times 10^2\text{ N}}$
6. $F_g = 950$ N $F_{applied} = 350$ N	$MA = \frac{F_{out}}{F_{in}} = \frac{F_g}{F_{applied}} = \frac{950\text{ N}}{350\text{ N}} = \boxed{2.7}$
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	$\tau_{30} = F_{30}d_{30}(\sin\theta_{30}) = (30.0\text{ N})(0\text{ m})(\sin 45°) = \boxed{0\text{ N}\bullet\text{m}}$ $\tau_{25} = F_{25}d_{25}(\sin\theta_{25}) = (25.0\text{ N})(2.0\text{ m})(\sin 59°) = \boxed{43\text{ N}\bullet\text{m}}$ $\tau_{10} = F_{10}d_{10}(\sin\theta_{10}) = (-10.0\text{ N})(4.0\text{ m})(\sin 23°) = \boxed{-16\text{ N}\bullet\text{m}}$ 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

Givens	*Solutions*
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.** $F_{net} = F_n - F_g = F_n - mg$ $F_{net} = F_c = \frac{mv_t^2}{r_1}$ $F_n - mg = \frac{mv_t^2}{r_1}$ $mv_t^2 = r_1(F_n - mg)$ $m(v_t^2 + r_1g) = r_1F_n$ $m = \frac{r_1F_n}{v_t^2 + r_1g} = \frac{(10.0\text{ m})(2.06 \times 10^4\text{ N})}{(20.0\text{ m/s})^2 + (10.0\text{ m})(9.81\text{ m/s}^2)}$ $m = \frac{2.06 \times 10^5\text{ N}\bullet\text{m}}{4.00 \times 10^2\text{ m}^2/\text{s}^2 + 98.1\text{ m}^2/\text{s}^2} = \frac{2.06 \times 10^5\text{ N}\bullet\text{m}}{498\text{ m}^2/\text{s}^2}$ $m = \boxed{414\text{ kg}}$

Givens | *Solutions*

$r_2 = 15.0$ m

b. $F_c = mg$

$$\frac{mv_t^2}{r_2} = mg$$

$$v_t = \sqrt{gr_2} = \sqrt{(9.81 \text{ m/s}^2)(15.0 \text{ m})} = \boxed{12.1 \text{ m/s}}$$

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11. $r = 10.0$ m

$v_t = 8.0$ m/s

$F_{rope,\,max} = 1.0 \times 10^3$ N

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

$$F_{total} = F_c + F_g = \frac{mv_t^2}{r} + mg$$

$$F_{total} \leq F_{rope,\,max}$$

$$F_{rope,\,max} = m_{max}\left(\frac{v_t^2}{r} + g\right)$$

$$m_{max} = \frac{F_{rope,\,max}}{\frac{v_t^2}{r} + g} = \frac{1.0 \times 10^3 \text{ N}}{\left[\frac{(8.0 \text{ m/s})^2}{10.0 \text{ m}}\right] + 9.81 \text{ m/s}^2}$$

$$m_{max} = \frac{1.0 \times 10^3 \text{ N}}{6.4 \text{ m/s}^2 + 9.81 \text{ m/s}^2} = \frac{1.0 \times 10^3 \text{ N}}{16.2 \text{ m/s}^2}$$

$$m_{max} = \boxed{62 \text{ kg}}$$

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18. $F_g = 3.20 \times 10^{-8}$ N

$m_1 = 50.0$ kg

$m_2 = 60.0$ kg

$G = 6.673 \times 10^{-11} \text{ N}\bullet\text{m}^2/\text{kg}^2$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \sqrt{\frac{(6.673 \times 10^{-11} \text{ N}\bullet\text{m}^2/\text{kg}^2)(50.0 \text{ kg})(60. \text{ kg})}{3.20 \times 10^{-8} \text{ N}}}$$

$$r = \boxed{2.50 \text{ m}}$$

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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

$G = 6.673 \times 10^{-11} \text{ N}\bullet\text{m}^2/\text{kg}^2$

$$r = \sqrt{\frac{Gm_1m_2}{F_g}} = \frac{(6.673 \times 10^{-11} \text{ N}\bullet\text{m}^2/\text{kg}^3)(9.11 \times 10^{-31} \text{ kg})(1.67 \times 10^{-27} \text{ kg})}{1.0 \times 10^{-47} \text{ N}}$$

$$r = \boxed{1.0 \times 10^{-10} \text{ m} = 0.10 \text{ nm}}$$

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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

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

$\theta = 90°$

$\tau = Fd(\sin\theta) = mgr(\sin\theta)$

$\tau = (54\text{ kg})(9.81\text{ m/s}^2)(0.050\text{ m})(\sin 90°) = \boxed{26\text{ N•m}}$

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38. $\theta = 90.0° - 8.0° = 82.0°$

$m = 1130$ kg

$d = 3.05\text{ m} - 1.12\text{ m} - 0.40\text{ m} = 1.53$ 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 $\tau_{jack} = \boxed{1.68 \times 10^4\text{ N•m}}$

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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 $G = 6.673 \times 10^{-11} \frac{\text{N}\bullet\text{m}^2}{\text{kg}^2}$	$r = 1.50 \times 10^{11}\text{ m} - 0.00384 \times 10^{11}\text{ m} = 1.50 \times 10^{11}\text{ m}$ **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 $g = 9.81\text{ m/s}^2$	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 $g = 9.81\text{ m/s}^2$	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 $g = 9.81\text{ m/s}^2$	$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}}$ $F_{in} = \frac{F_{out}d_{out}}{d_{in}(eff)} = \frac{mgd_{out}}{d_{in}(eff)} = \frac{(78\text{ kg})(9.81\text{ m/s}^2)(4.0\text{ m})}{(24\text{ m})(0.64)}$ $F_{in} = \boxed{2.0 \times 10^{2}\text{ N}}$

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Givens | *Solutions*

46. $d = 2.0$ m

$\theta = 15°$

$\mu_k = 0.160$

$$W_{out} = F_g d(\sin\theta)$$

$$W_{in} = (F_f + F_{g,x})d = [\mu_k F_g(\cos\theta) + F_g(\sin\theta)]d$$

$$W_{in} = F_g d[\mu_k(\cos\theta) + (\sin\theta)]$$

$$eff = \frac{W_{out}}{W_{in}} = \frac{F_g d(\sin\theta)}{F_g d[\mu_k(\cos\theta) + (\sin\theta)]} = \frac{\sin\theta}{\mu_k(\cos\theta) + (\sin\theta)}$$

$$eff = \frac{\sin 15°}{(0.160)(\cos 15°) + (\sin 15°)} = \frac{0.26}{0.15 + 0.26}$$

$$eff = \frac{0.26}{0.41} = 0.63 = \boxed{63\%}$$

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47. $d_{out} = 3.0$ m

$F_{in} = 2200$ N

$d_{in} = 14$ m

$m = 750$ kg

$g = 9.81$ m/s^2

$$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}} = \frac{mgd_{out}}{F_{in}d_{in}}$$

$$eff = \frac{(750\text{ kg})(9.81\text{ m/s}^2)(3.0\text{ m})}{(2200\text{ N})(14\text{ m})} = 0.72 = \boxed{72\%}$$

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48. $eff = 0.875$

$F_{in} = 648$ N

$m = 150$ kg

$d_{out} = 2.46$ m

$g = 9.81$ m/s^2

$$eff = \frac{W_{out}}{W_{in}} = \frac{F_{out}d_{out}}{F_{in}d_{in}} = \frac{mgd_{out}}{F_{in}d_{in}}$$

$$d_{in} = \frac{mgd_{out}}{F_{in}(eff)} = \frac{(150\text{ kg})(9.81\text{ m/s}^2)(2.46\text{ m})}{(648\text{ N})(0.875)} = \boxed{6.4\text{ m}}$$

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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. $r = r_{Io} + d + r_J$

$$r = 1.82 \times 10^6\text{ m} + 4.22 \times 10^8\text{ m} + 7.15 \times 10^7\text{ m}$$

$$r = 4.95 \times 10^8\text{ m}$$

$$T = 2\pi\sqrt{\frac{r^3}{Gm_J}} = 2\pi\sqrt{\frac{(4.95 \times 10^8\text{ m})^3}{\left(6.673 \times 10^{-11}\frac{\text{N•m}^2}{\text{kg}^2}\right)(1.90 \times 10^{27}\text{ kg})}}$$

$$T = (1.94 \times 10^5\text{ s})(1\text{ h}/3600\text{ s})(1\text{ day}/24\text{ h}) = \boxed{2.25\text{ days}}$$

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. $a_c = \dfrac{v_t^2}{r} = \dfrac{(50.0 \times 10^3 \text{ m/h})^2(1 \text{ h}/3600 \text{ s})^2}{2.00 \times 10^2 \text{ m}} = \boxed{0.965 \text{ m/s}^2}$

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

$F_f = \mu_k F_n = \mu_k mg = (0.500)(1350 \text{ kg})(9.81 \text{ m/s}^2) = \boxed{6620 \text{ N}}$

$F_c = \dfrac{mv_t^2}{r} = \dfrac{(1350 \text{ kg})[(55.0 \times 10^3 \text{ m/h})(1 \text{ h}/3600 \text{ s})]^2}{40.0 \text{ m}} = \boxed{7880 \text{ N}}$

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 $G = 6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}$	$T = 2\pi\sqrt{\frac{r^3}{Gm_s}}$ $T = \left[2\pi\sqrt{\frac{(2.28 \times 10^{11} \text{ m})^3}{\left(6.673 \times 10^{-11} \frac{\text{N•m}^2}{\text{kg}^2}\right)(1.99 \times 10^{30} \text{ kg})}}\right]\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)\left(\frac{1 \text{ day}}{24 \text{ h}}\right)$ $T = \boxed{687 \text{ days}}$