Ex. 10.1

$\vec{p} = m\vec{v} = (8.00\ kg)(-6.0\ m/s)\hat{j} = -48.0\ kg\cdot m/s\ \hat{j}$

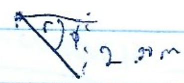
$L = \vec{r} \times \vec{p} = rp\sin\theta\ \hat{z}$; $\theta = 180$; $L = 0$

Ex. 10.2

$\vec{p} = m\vec{v} = (2.00\ kg)(5.00\ m/s \uparrow) = 10.0\ kg\ m/s \uparrow$

$L = \vec{r} \times \vec{p} = rp\sin\phi\ \hat{z}$

$L = \vec{r} \times \vec{p} = rp\sin\phi\ \cancel{\hat{k}}$



$r\sin\theta = 2.00\ m$

$= (2.00\ m)p$

$= (2.00\ m)(10.0\ kg\ m/s) = 20.0\ kg\ m^2/s\ -\hat{k}$, or

$\boxed{L = -20.0\ kg\ m^2/s\ \hat{k}}$

Ex. 10.3 $r = 20\ cm = 0.20\ m$

$\tau = 80\ N\cdot m$

$\tau = \vec{r} \times \vec{F} = rF\sin\theta$; $\sin\theta = 1$; $\theta = 90$

$= rF$

$F = \frac{\tau}{r} = \frac{80\ N.m}{0.20\ m} = \boxed{400\ N}$

Ex. 10.4

$\Sigma\tau = I\alpha$ $\quad \alpha = \frac{\omega_f - \cancel{\omega_0}^{0}}{t} = \frac{12\ rev/min}{1.5\ min} = 8\ \frac{rev}{min^2} \times \frac{1\ min}{60\ s} \times \frac{1\ min}{60\ s}$

$I = 2m(r^2)$ $\quad = 0.0022\ rev/s^2$

$\tau = 2(1500\ kg)(10\ m)^2(0.0022\ rev/s^2)$

$= \boxed{667\ N\cdot m}$

$\tau = r \times F = rF\sin\theta = rF$; $\sin\theta = 1$

$F = \frac{\tau}{r} = \frac{667\ N\cdot m}{2.0\ m} = \boxed{334\ N}$

$\omega_f = \cancel{\omega_0}^{0} + \alpha t$

$\omega_f = \frac{12\ \text{rev}}{\text{min}} \times \frac{2\pi\ \text{rad}}{1\ \text{rev}} \times \frac{1\ \text{min}}{60\ \text{s}} = 1.26\ \frac{\text{rad}}{\text{s}}$

$\alpha = \frac{\omega_f}{t} = \frac{1.26\ \text{rad/s}}{90\ \text{s}} = 0.014\ \frac{\text{rad}}{\text{s}^2}$

$\Sigma\tau = I\alpha = 2mr^2\alpha$

$= 2(1500\ \text{kg})(10\ \text{m})^2(0.014) = \boxed{4200\ \text{N}\cdot\text{m}\ \hat{k}}$ ccw

$F = \frac{\tau}{r} = \frac{4200\ \text{N}\cdot\text{m}}{2.0\ \text{m}} = \boxed{2100\ \text{N}}$

Ex. 10.5

a) the mass has both spin and orbital $\vec{L}$

b) $\vec{L} = I\vec{\omega}$

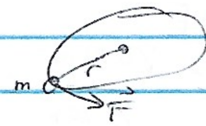
$\omega = \frac{v_t}{r} = \frac{8.00\ \text{m/s}}{1.20\ \text{m}} = 6.67\ \frac{\text{rad}}{\text{s}}$

$\vec{L} = mr^2\omega$

$= (7.30\ \text{kg})(1.20\ \text{m})^2(6.67\ \frac{\text{rad}}{\text{s}}) = \boxed{70.1\ \frac{\text{kg}\,\text{m}^2}{\text{s}}\ \hat{k}}$

Ex. 10.6

a) $m\vec{g}, \vec{N}, \vec{F}$



b) $\tau = \vec{r}\times\vec{F} = (0.500\ \text{m})(5.00\ \text{N})$

$= \boxed{2.5\ \text{N}\cdot\text{m}\ \hat{k}}$

c) $I = mr^2 = (3.00\ \text{kg})(0.500\ \text{m})^2 = \boxed{0.25\ \text{kg}\cdot\text{m}^2}$

d) $\Sigma\tau = I\alpha$

$\alpha = \frac{\Sigma\tau}{I} = \frac{2.5\ \text{N}\cdot\text{m}}{0.25\ \text{kg}\cdot\text{m}} = \cancel{1.67\ \text{rad/s}^2}\ \boxed{10\ \frac{\text{rad}}{\text{s}^2}}$

e) no; $L = \vec{r}\times\vec{p}$; $\vec{p}$ is increasing so $\vec{L}$ is not constant

f) $\omega_f = \cancel{\omega_0}^{0} + \alpha t = (10\ \frac{\text{rad}}{\text{s}^2})(3.00\ \text{s}) = \boxed{30\ \frac{\text{rad}}{\text{s}}}$

$L = I\omega = (0.25\ \text{kg}\cdot\text{m}^2)(30\ \frac{\text{rad}}{\text{s}}) = \boxed{7.5\ \frac{\text{kg}\cdot\text{m}^2}{\text{s}}}$

c) $I = mr^2 = (3.00\,kg)(0.500\,m)^2 = \boxed{0.75\ kg\cdot m^2}$

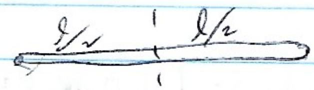
d) $\alpha = \frac{\Sigma\tau}{I} = \frac{2.50\,N\cdot m}{0.75\,kg\cdot m^2} = 3.33\ \frac{rad}{s^2}$

f) $\omega_f = \cancel{\omega_0} + \alpha t = (3.33\ \frac{rad}{s^2})(3.00\,s) = \boxed{10.0\ \frac{rad}{s}}$

$L = I\omega = (0.75\,kg\cdot m^2)(10.0\ \frac{rad}{s})$

$= \boxed{7.5\ \frac{kg\cdot m^2}{s}}$

Ex. 10.7



$I = \int r_\perp^2\,dm \qquad \lambda = \frac{m}{l}$ (mass per unit length)

$dm = \lambda\,dx$

$dI = x^2\,dm$

$= x^2\lambda\,dx$

$I = \lambda\int_{-l/2}^{l/2} x^2\,dx$

$= \lambda\frac{x^3}{3}\Big|_{-l/2}^{l/2} = \boxed{\frac{ml^2}{12}}$

Ex 10.8

a) $\omega_f = \cancel{\omega_0} + \alpha t$

$\alpha = \frac{\omega_f}{t} =$

$\frac{300\,rev}{min}\times\frac{2\pi\,rad}{rev}\times\frac{1\,min}{60\,s}\times\frac{1}{30.0\,s} = \boxed{1.05\ \frac{rad}{s^2}}$

b) $\Sigma\tau = I\alpha$

$= \frac{2}{5}mR^2\alpha = \frac{2}{5}(908\,kg)(0.300\,m)^2(1.05\ \frac{rad}{s^2})$

$= \boxed{34.2\ N\cdot m}$

c) $F = \frac{\tau}{r} = \frac{34.2\,N\cdot m}{0.300\,m} = \boxed{114\ N}$

Ex. 10.9

a) $KE_r = \frac{1}{2} I\omega^2 = \frac{1}{2}\left(\frac{1}{2}MR^2\right)(\omega^2)$

$= \frac{1}{4}(150.0\ kg)(0.250\ m)^2\left(1000\ \frac{rev}{min} \times \frac{2\pi}{60}\right)^2$

$= \boxed{2.57 \times 10^4\ J}$

b) $KE = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(2.57\times10^4\ J)}{1.00\ kg}} = \boxed{227\ \frac{m}{s}}$

Ex. 10.10

a) $L_{spin} = I\omega_{spin} = \left(\frac{1}{2}MR^2\right)(\omega)$

$= \frac{1}{2}(3.00\ kg)(0.100\ m)^2\left(15.0\ \frac{rev}{s} \times 2\pi\ \frac{rad}{rev}\right)$

$= \boxed{1.41\ \frac{kg \cdot m^2}{s}(+\hat{k})}$

b) $\vec{L}_{orb} = \vec{r} \times \vec{p} = rp\sin\theta(-\hat{k}) = rmv\sin\theta = (4.00\ m)(3.00\ kg)(5.00\ m/s)\sin 30(-\hat{k})$

$= \boxed{-30\ \frac{kg \cdot m^2}{s}\hat{k}}$

c) $L_{total} = L_{orb} + L_{spin} = \left(1.41\ \frac{kg\,m^2}{s}\right) - 30\ \frac{kg \cdot m^2}{s}\hat{k}$

$= \boxed{-28.59\ \frac{kg \cdot m^2}{s}\hat{k}}$

d) $KE_{total} = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$

$= \frac{1}{2}\left(\frac{1}{2}MR^2\right)\omega^2 + \frac{1}{2}mv^2$

$= \frac{1}{4}(3.00\ kg)(0.100\ m)^2\left(15 \cdot 2\pi\ \frac{rad}{s}\right)^2 + \frac{1}{2}(3.00\ kg)(5.00\ m/s)^2$

$= \boxed{104\ J}$

Ex 10.11

$$mgh_0 = \frac{1}{2} I\omega_f^2 + \frac{1}{2} m v_f^2$$

$$v_{cm} = R\omega$$

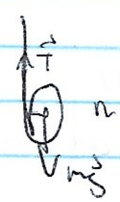
$$\omega = \frac{v}{R}$$

$$\cancel{m}gh = \frac{1}{2}\cdot\frac{2}{5}\cancel{m}\cancel{R^2}\frac{v^2}{\cancel{R^2}} + \frac{1}{2}\cancel{m}v^2$$

$$\frac{1}{5}v^2 + \frac{1}{2}v^2 = gh$$

$$\frac{7}{10}v^2 = gh \qquad v = \sqrt{\frac{10gh}{7}}$$

Ex. 10.12



$$\sum F = ma \qquad \sum \tau = I\alpha \qquad a = R\alpha \quad \alpha = \frac{a}{R}$$

$$\vec T - mg = ma \qquad R\vec T = I_{cm}\alpha\,\hat z$$

$$R\vec T = I_{cm}\frac{a}{R}$$

$$\vec T = \frac{I_{cm}a}{R^2}$$

$$\frac{I_{cm}a}{R^2} - ma = mg$$

$$I_{cm}a - maR^2 = mR^2 g$$

$$a(I_{cm} - mR^2) = mR^2 g$$

$$a = \frac{mR^2 g}{I_{cm} - mR^2}$$

$$m\vec g - T = ma$$

$$T = m(g - a)$$

$$\frac{I_{cm}a}{R^2} = m(g-a) = mg - ma$$

$$I_{cm}a = mR^2 g - mR^2 a \qquad a(I_{cm} + mR^2) = mR^2 g$$

$$\boxed{a = \frac{mR^2 g}{I_{cm} + mR^2}}$$

20.

Ex 10.14

a) $J = \Delta P = P_f - P_0$

$P_f \rightarrow$ translational $= 0$

$J = -P_0 = \boxed{-mv_0}$

b) ~~[illegible]~~

$\cancel{L_{orbital\,m_0}} + L_{spin_0} = L_{orbital_{mf}} + L_{spin\,f}$ $\qquad v = R\omega$

$I\omega_0 = I\omega_f + rp = I\omega_f + Rmv_t$

$I\omega_0 = I\omega_f + mR^2\omega_f$

$$\boxed{\omega_f = \frac{I\omega_0}{I + mR^2}}$$

c) based on ↑, there's no speed you could run at to bring the merry go round to a halt; it would depend only on your mass.

b) ~~[illegible]~~ L_{total} is constant

$L_{orb_0} + L_{spin_0} = L_{orb_f} + L_{spin_f}$ $\qquad v_{tf} = R\omega_f$

$r \times p_0 + I\omega_0 = \cancel{R \times m\vec{v}_t}\; r \times p_f + I\omega_f$

$\underbrace{rmv\sin\theta} + I\omega_0 = RmR\omega_f + I\omega_f$

$r\sin\theta = R$

$mRv_0 + I\omega_0 = mR^2\omega_f + I\omega_f$

$\omega_f(mR^2 + I) = mRv_0 + I\omega_0$

$$\omega_f = \boxed{\frac{mRv_0 + I\omega_0}{mR^2 + I}}$$

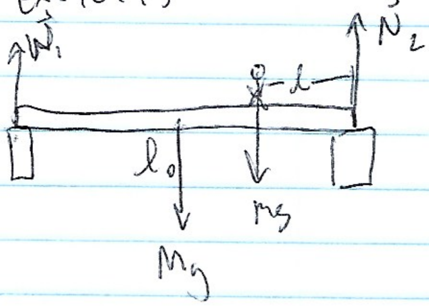
c) $\omega_f = 0$ $\qquad mRv_0 + I\omega_0 = 0$

$$\boxed{v_0 = \frac{-I\omega_0}{mR}}$$

b) $\omega_f = \boxed{\dfrac{\frac{1}{2}MR^2\omega_0 - mv_0R}{\left(\frac{M}{2}+m\right)R^2}}$

c) $v_0 = \boxed{\dfrac{MR\omega_0}{2m}}$

Ex. 10.15



$N_2 > N_1$

$\downarrow +$ $(+)$

$\sum F = ma = 0$

$\vec{N}_1^{\uparrow} + \vec{N}_2^{\uparrow} + \vec{Mg}^{\downarrow} + \vec{mg}^{\downarrow} = 0$

$\sum \tau = I\alpha = 0$

$-\frac{l_0}{2}N_1 + \frac{l_0}{2}N_2 - \left(\frac{l_0}{2} - l\right)mg = 0$

$Mg + mg - N_1 - N_2 = 0$

$N_1 + N_2 = Mg + mg$

$mg\left(\frac{l_0 - 2l}{2}\right) = \frac{l_0}{2}N_2 - \frac{l_0}{2}N_1$

$\cancel{mg\,l\,N_1 l_0\,N_2 l_0\,(l_0 - 2l)}$

$N_1 = Mg + mg - N_2$

$mg\left(\frac{l_0 - 2l}{\cancel{2}}\right) = \frac{l_0}{\cancel{2}}N_2 - \frac{l_0}{\cancel{2}}(Mg + mg - N_2)$

$mg(l_0 - 2l) = l_0N_2 - l_0Mg - l_0mg + l_0N_2$

$2l_0N_2 = mg(l_0 - 2l) + l_0Mg + l_0mg$

$2l_0N_2 = mg(2l_0 - 2l) + l_0Mg$

$N_2 = mg - mg\frac{l}{l_0} + \frac{1}{2}Mg = \boxed{mg\left(1 - \frac{l}{l_0}\right) + \frac{1}{2}Mg}$

$N_1 = Mg + mg - N_2 = Mg \cancel{+mg} \cancel{-mg} + mg\frac{l}{l_0} - \frac{1}{2}Mg$

$= \boxed{\frac{1}{2}Mg + mg\frac{l}{l_0}}$