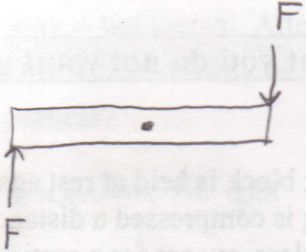
Q1

If the net force on a system is zero, is the net torque also zero? *Explain.*

No, for example :



$$\sum \vec{F} = 0$$

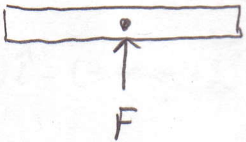
$$\sum \vec{\tau} \neq 0$$

If the net torque on a system is zero, is the net force also zero? *Explain.*

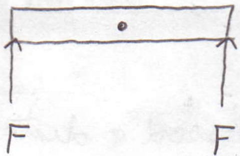
No, for example :

$$\sum \vec{\tau} = 0$$

$$\sum \vec{F} \neq 0$$



or



Q3

Q2

~~4)~~ Suppose a solid sphere was rolling smoothly across a level surface such that its total kinetic energy (translational plus rotational) was equal to 10.0 J. How much energy would a spherical shell have if it had the same mass and radius as the solid sphere and was rolling at the same speed?

sphere: $K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\left(\frac{v}{r}\right)^2$

$$K = \underline{\underline{\frac{7}{10}mv^2}}$$

shell: $K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{3}mr^2\right)\left(\frac{v}{r}\right)^2$

$$K = \underline{\underline{\frac{5}{6}mv^2}}$$

$$\frac{K_{shell}}{K_{sphere}} = \frac{\frac{5}{6}mv^2}{\frac{7}{10}mv^2} = \underline{\underline{1.19}}$$

$K_{shell} = (1.19)\,K_{sphere}$

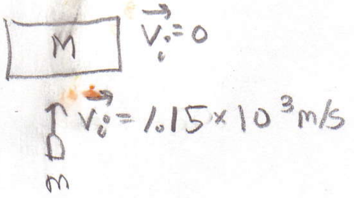
$= \boxed{11.9\ \text{J}}$

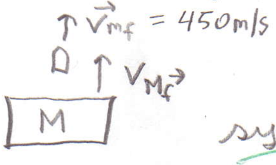
$\boxed{\text{Problem 1}}$ (a)

1) Use conservation of momentum to get speed of block after collision.

2) Use energy (or kinematics) to get height of block.

(1)





system → bullet + block

$$\vec{P}_f = \vec{P}_i \quad \left(\sum \vec{F}_{ext} = 0\right)$$

$$M\vec{v}_{Mf} + m\vec{v}_{mf} = \emptyset + m\vec{v}_i$$

$$\vec{v}_{mf} = \frac{m(\vec{v}_i - \vec{v}_{mf})}{M}$$

$$\vec{v}_{mf} = \frac{(9.50\times10^{-3}\,kg)(1.15\times10^3\,m/s - 450.0\,m/s)}{5.00\,Kg} = \boxed{1.33\,m/s}$$

(2)

system → block + bullet + earth

external forces → none

$$K_i + \overset{\nearrow 0}{(U_g)_i} + \overset{\nearrow 0}{W_{ext}} = \overset{\nearrow 0}{K_f} + (U_g)_f + \overset{\nearrow 0}{\Delta E_{th}}$$

$$\tfrac{1}{2}mv_i^2 = mgy_f \rightarrow y_f = \frac{v_i^2}{2g}$$

$$y_f = \frac{(1.33\,m/s)^2}{2(9.80\,m/s^2)} = \boxed{9.03\times10^{-2}\,m} = \underline{9.03\,cm}$$

(b) use impulse momentum theorem on bullet

$\vec{v}_i = 1.15\times10^3$ m/s

$\vec{v}_f = 450.0$ m/s

$\Delta t = 1.00\times10^{-3}$ s

$m = 9.50\times10^{-3}$ Kg

$\vec{F}_{ave} = ?$

$$\vec{F}_{ave}\Delta t = m(\vec{v}_f - \vec{v}_i)$$

$$\vec{F}_{ave} = \frac{m(\vec{v}_f - \vec{v}_i)}{\Delta t} = \frac{(9.50\times10^{-3}\,kg)(450\,m/s - 1150\,m/s)}{1.00\times10^{-3}\,s}$$

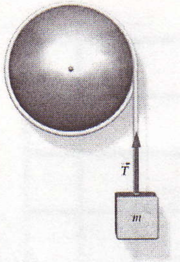
$$\vec{F}_{ave} = \underline{-(6.65\times10^3\,N)\hat{j}}$$

$= \boxed{6.65\times10^3\,N}$ ~~downward~~ Force on block is upwards

Problem 2

P6)

~~7)~~ A uniform sphere of mass 5.0 kg and radius 0.75 m is free to rotate about a horizontal axis through its center. A string is wrapped around the sphere and is attached to an object of mass 300 g. Find the *acceleration* of the object. (*Hint*: $I_{sphere} = \frac{2}{5}MR^2$)



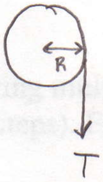
object :

$\downarrow a$

$$\sum \vec{F} = m\vec{a}$$

$$\underline{mg - T = ma} \quad (1)$$

sphere :



$$\sum \tau = I\alpha \qquad I = 2/5\,MR^2 \qquad \alpha = a/R$$

$\circlearrowright +$

define clockwise as positive

$$TR\sin 90° = (2/5\,MR^2)(a/R)$$

$$TR = 2/5\,MRa$$

$$\underline{T = 2/5\,Ma} \longrightarrow \text{put into (1)}$$

$$mg - (2/5\,Ma) = ma$$

$$mg = ma + 2/5\,Ma \longrightarrow a = \frac{mg}{(m + 2/5\,M)}$$

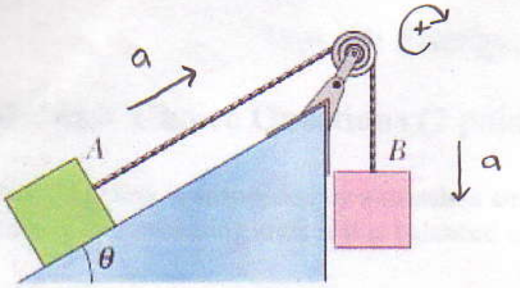
$$a = \frac{(0.300\,Kg)(9.8\,m/s^2)}{[0.300\,Kg + 2/5\,(5.0\,Kg)]}$$

$$\boxed{a = 1.3\,m/s^2}$$

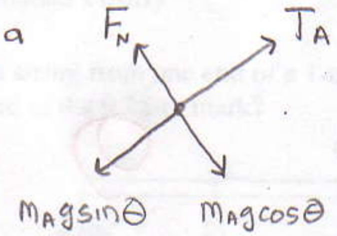
Problem 3

Problem 4

6) In the figure below, block A has a mass of 4.50 kg, block B has a mass of 3.75 kg, and the angle of the frictionless inclined plane is θ = 35.0°. The two blocks are connected by massless string that passes over a pulley (disk) of mass 1.50 kg and radius of 25 cm. If the system is released from rest, how long does it take the pulley to reach an angular velocity of 22.5 rad/s?



block A:



$\sum F_y = ma_y$

$T_A - M_A g \sin\theta = M_A a$

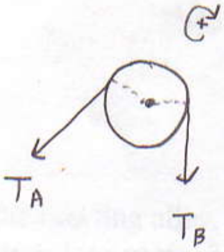
$T_A = M_A a + M_A g \sin\theta$

block B:

$\sum F_y = m a_y$

$M_B g - T_B = M_B a \longrightarrow T_B = M_B g - M_B a$

pulley:



$\sum \tau = I\alpha$

$I = \frac{1}{2}Mr^2$

$\alpha = a/r$

$T_B r \sin 90° - T_A r \sin 90 = (\frac{1}{2}Mr^2)(a/r)$

$T_B - T_A = \frac{1}{2}Ma$ (put in equations for $T_A + T_B$)

$(m_B g - m_B a) - (m_A a + m_A g \sin\theta) = \frac{1}{2}Ma$

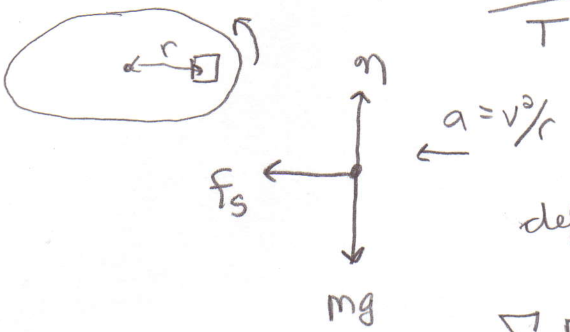
$$a = \frac{m_B g - m_A g \sin\theta}{m_A + m_B + \frac{1}{2}M} = \frac{(3.75\text{kg})(9.8\text{m/s}^2) - (4.50\text{kg})(9.8\text{m/s}^2)\sin 35°}{(4.50\text{kg} + 3.75\text{kg} + 1.50\text{kg}/2)}$$

$\underline{a = 1.27 \text{ m/s}^2} \longrightarrow \alpha = a/r = \frac{0.867 \text{ m/s}^2}{0.25\text{m}} \longrightarrow \underline{\alpha = 5.09 \text{ rad/s}^2}$

$\omega = \overset{=0}{\omega_0} + \alpha t \longrightarrow t = \omega/\alpha = \frac{22.5 \text{ rad/s}}{} \longrightarrow \boxed{t = 4.42\text{s}}$

Problem 4

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.35\,m)}{1.50\,s} = \underline{1.47\,m/s}$$



define left as + :

$$\sum F_y = ma_y = 0$$

$$\underline{\underline{n = mg}}$$

$$\sum F_y = ma_x = mv^2/r$$

$$\underline{\underline{f_s = mv^2/r}}$$

* since coin is on the verge of slipping,

$$\underline{f_s = f_{s,max} = \mu_s n}$$

$$f_s = mv^2/r$$

$$\mu_s n = mv^2/r \rightarrow \mu_s mg = mv^2/r$$

$$\mu_s = \frac{v^2}{rg}$$

$$\mu_s = \frac{(1.47\,m/s)^2}{(0.35\,m)(9.80\,m/s^2)}$$

$$\boxed{\mu_s = 0.627}$$

Problem 5

Problem 2

Step 1 ⇒ use cons. of energy to find speed of block after collision

Step 2 ⇒ use cons. of momentum to find speed of bullet after collision

Block-spring system: → since $W_{nc} = 0$, $E_i = E_f$

$V_i = ?$
$X_i = 0$
$V_f = 0$
$X_f = 5.00 \times 10^{-2} m$
$K = 900 N/m$
$m = 1.0 Kg$

$$\underset{\frac{1}{2}mv^2}{\underset{\shortparallel}{K_i}} + \overset{0}{\overset{=}{U_i}} = \overset{0}{\overset{=}{K_f}} + \underset{\frac{1}{2}KX_f^2}{\underset{\shortparallel}{U_f}}$$

$$\frac{1}{2} m V_i^2 = \frac{1}{2} K X_f^2 \longrightarrow V = \sqrt{\frac{K}{m}}\, X_f$$

$$V = \sqrt{\frac{(900 N/m)}{(1.0 Kg)}}\,(5.00 \times 10^{-2} m) \longrightarrow \underline{\underline{V = 1.5 m/s}}$$

Block-bullet system: → since $\sum F_{ext} = 0$, $\vec{P_i} = \vec{P_f}$

$m_1 = 5.00 \times 10^{-3} Kg$
$M_2 = 1.00 Kg$
$V_{1i} = 400 m/s$
$V_{2i} = 0$
$V_{1f} = ?$
$V_{2f} = 1.5 m/s$

$$\vec{P_i} = \vec{P_f}$$

$$m_1 V_{1i} + m_2 \overset{0}{\overset{=}{V_{2i}}} = m_1 V_{1f} + m_2 V_{2f}$$

$$m_1 V_{1i} - m_2 V_{2f} = m_1 V_{1f}$$

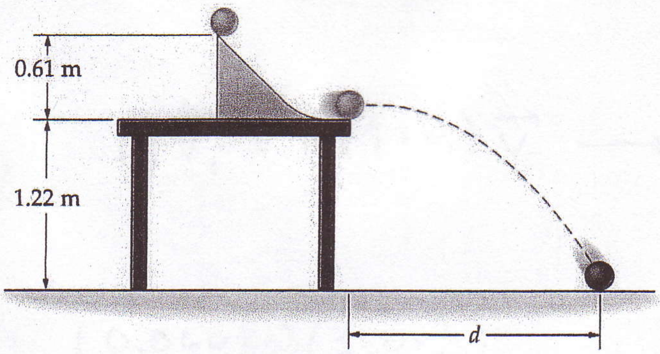
$$V_{1f} = \frac{m_1 V_{1i} - m_2 V_{2f}}{m_1}$$

$$V_{1f} = \frac{(5.00 \times 10^{-3} Kg)(400 m/s) - (1.00 Kg)(1.5 m/s)}{(5.00 \times 10^{-3} Kg)}$$

$$V = 100 m/s \rightsquigarrow V = \boxed{1.00 \times 10^2 m/s}$$

Problem 6

3) A solid sphere released from rest rolls without slipping down a ramp, dropping a vertical height of 0.61 m. The ball leaves the bottom of the ramp, which is 1.22 m above the floor, moving horizontally (see the figure below). How far from the edge of the table does the ball land?



$$mgy_i = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 \qquad I = \tfrac{2}{5}mR^2 \qquad v = r\omega$$

$$= \tfrac{1}{2}mv^2 + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\left(\tfrac{v}{r}\right)^2$$

$$= \tfrac{7}{10}mv^2$$

$$v = \sqrt{\tfrac{10}{7}gy_i} \longrightarrow \underline{\underline{v = 2.92\,m/s}}$$

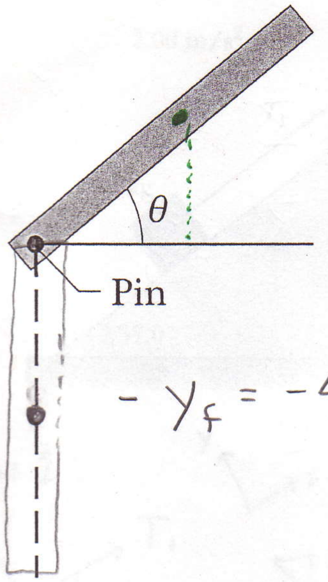
$$\overset{=0}{y} - y_0 = \overset{=0}{v_{0y}}t + \tfrac{1}{2}a_y t^2 \longrightarrow t = \sqrt{\frac{-2y_0}{a_y}} \longrightarrow \underline{\underline{t = 0.499s}}$$

$$x = v_{0x}t = (2.92\,m/s)(0.499s)$$

$$\boxed{x = 1.46m}$$

Problem 7

4) The thin uniform rod in the figure has length 2.40 m and can pivot about a horizontal, frictionless pin through one end as shown in the figure below. It is released from rest at angle θ = 40° above the horizontal. **(a)** What is the angular speed of the rod as it passes through the vertical dashed line? **(b)** What is the linear speed of the center of mass as it passes through the vertical dashed line?



$y=0$

$$y_i = (L/2)\sin 40^\circ = (1.20\text{m})\sin 40^\circ$$
$$= \underline{0.771\text{m}}$$

$$-y_f = -L/2 = \underline{-1.20\text{m}}$$

from conservation of energy: $K_f + U_f = \cancelto{0}{K_i} + U_i$

$$\tfrac{1}{2}I\omega^2 + Mgy_f = Mgy_i$$

$$\tfrac{1}{2}I\omega^2 = Mg(y_i - y_f)$$

$$\tfrac{1}{2}(\tfrac{1}{3}ML^2)\omega^2 = Mg(y_i - y_f) \longrightarrow \tfrac{1}{6}L^2\omega^2 = g(y_i - y_f)$$

$$\omega^2 = \frac{6g}{L^2}(y_i - y_f) \longrightarrow \omega = \sqrt{\frac{6g(y_i - y_f)}{L^2}}$$

$$\omega = \sqrt{\frac{6(9.80\text{m/s}^2)[0.771\text{m} - (-1.20\text{m})]}{(2.40\text{m})^2}} \longrightarrow \boxed{\omega = 4.49\text{rad/s}}$$

(b) $v = r\omega$ for the COM, $r = L/2 = 1.20\text{m}$

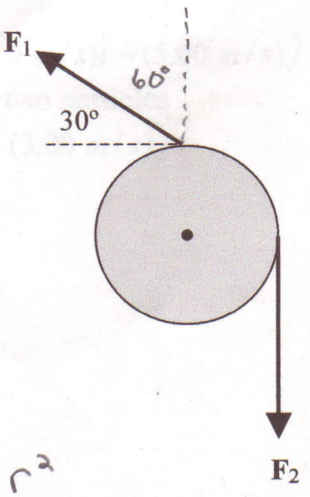
$$v = (1.20\text{m})(4.49\text{rad/s}) = \boxed{5.38\text{ m/s}}$$

Keep Going

you're doing GREAT!

Problem 8

The figure to the right shows an overhead view of a uniform disk that can rotate about its center like a merry-go-round. The disk has a radius of 25 cm and a mass of 1.50 kg and is initially at rest. Starting at t = 0 s, two forces are applied as indicated in the figure. The magnitude of F_1 is 5.50 N and the magnitude of F_2 is 6.00 N. The forces maintain their orientations as the disk rotates. What is the magnitude of total acceleration of a point on the rim of the disk at t = 0.50 s?



$\circlearrowright(+)$

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

$$F_2 r \sin 90° - F_1 r \sin 60° = I\alpha \qquad I = \tfrac{1}{2}Mr^2$$

$$r(F_2 - F_1 \sin 60°) = (\tfrac{1}{2}Mr^2)\,\alpha$$

$$\alpha = \frac{2(F_2 - F_1 \sin 60°)}{Mr} \longrightarrow \alpha = \frac{2\left[6.00\text{N} - (5.50\text{N})\sin 60°\right]}{(1.50\text{Kg})(0.25\text{m})}$$

$$\boxed{\alpha = 6.60\ \text{rad/s}^2}$$

$$a_t = r\alpha = (0.25\text{m})(6.60\ \text{rad/s}^2) = \underline{\underline{1.65\ \text{m/s}^2}}$$

$$a_r = r\omega^2 \quad (\text{we need } \omega \text{ at } t = 0.50\text{s})$$

$$\downarrow$$

$$\omega = \overset{0}{\cancel{\omega_0}} + \alpha t$$

$$\omega = \alpha t = (6.60\ \text{rad/s}^2)(0.50\text{s}) = 3.3\ \text{rad/s}$$

$$a_r = r\omega^2 = (0.25\text{m})(3.3\ \text{rad/s})^2 = \underline{\underline{2.72\ \text{m/s}^2}}$$

$$a = \sqrt{a_t^2 + a_r^2} = \sqrt{(1.65\ \text{m/s}^2)^2 + (2.72\ \text{m/s}^2)^2}$$

$$\boxed{a = 3.18\ \text{m/s}^2}$$