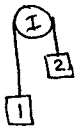
10.51



$m_1 = 460 g$
$m_2 = 500 g$
$R = 5$ cm
When released, block 2 falls 75 cm in 5 sec
No slipping

a) Acceleration of block 2

$X = \cancel{X_0} + \cancel{V_0 t} + \frac{1}{2} a_x t^2$

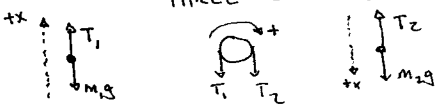
$0.75 = \frac{1}{2} a_x 5^2$

$a_x = 0.060$ m/s

b) Pulley's angular acceleration

$x = R\theta$
$v = R\omega$
$a = R\alpha$
0.060 m/s $= (0.05$ m$)\alpha$
$\alpha = 1.2$ rad/s²

Now set up the free body diagrams
THREE OBJECTS



$m_1 a = T_1 - m_1 g$ $\qquad$ $I\alpha = T_2 R - T_1 R$ $\qquad$ $m_2 a = m_2 g - T_2$

$0.460(0.060) = T_1 - 0.460(9.8)$

$T_1 = 4.54$ Newtons

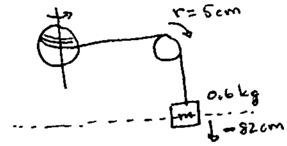
$0.500(0.060) = 0.500(9.8) - T_2$

$T_2 = 4.870$ Newtons

$I(1.2) = (4.870 - 4.54)(0.05)$

$I = 0.0138$ kg m²

10.66



$I_{ball} = \frac{2}{3} M_{ball} R^2_{ball}$ (thin shell)

$I_{pulley} = \frac{1}{2} M_{pulley} R^2_{pulley}$ (disk)

$M_{ball} = 4.5$ kg $\quad R_{ball} = 8.5$ cm

$I_{pulley} = 3\times10^{-3}$ kg m²

Total Init Energy = Total Final Energy

The ball & pulley do not change height, so we will not include their gravitational potential energy on both sides of the equation because it will just cancel.

no kinetic energies
define zero potential energy at starting location

$0 = \frac{1}{2} I_{ball}\omega^2_{ball} + \frac{1}{2} I_{pulley}\omega^2_{pulley} + \frac{1}{2}mv^2 + mgh$

$V_{ball} = R_{ball}\omega_{ball}$ $\qquad$ $V_{pulley} = r\,\omega_{pulley}$

$\omega_{ball} = \frac{V}{R_{ball}}$ $\qquad$ $\omega_{pulley} = \frac{V}{r_{pulley}}$

$0 = \frac{1}{2}\frac{I_{ball}}{R^2_{ball}} V^2 + \frac{1}{2}\frac{I_{pulley}}{r^2_{pulley}} V^2 + \frac{1}{2}mv^2 + mgh$

$0 = \frac{1}{2}\left[\frac{I_{ball}}{R^2_{ball}} + \frac{I_{pulley}}{r^2_{pulley}} + m\right] v^2 + mgh$

$= \frac{1}{2}\left[\frac{\frac{2}{3}M_{ball}R^2_{ball}}{R^2_{ball}} + \frac{I_{pulley}}{r^2_{pulley}} + m\right] v^2 + mgh$

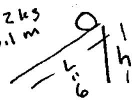
$0 = \frac{1}{2}\left[\frac{2}{3}(4.5) + \frac{3\times10^{-3}}{(0.05)^2} + 0.6\right] v^2 + (0.6)(9.8)(-0.85)$

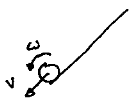
$2.4v^2$

$V = 1.44$ m/s

11.7 Need to first find the speed of the cylinder as it rolls off the roof in order to predict where it lands

$M = 12$ kg
$R = 0.1$ m





$I = \frac{1}{2}MR^2$ solid cyl

Tot Init Energy = Tot Final Energy

$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

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

$= \frac{1}{2}Mv^2 + \frac{1}{2}\frac{I}{R^2}v^2$

$Mgh = \frac{1}{2}\left(M + \frac{I}{R^2}\right)v^2$

$= \frac{1}{2}\left[M + \frac{\frac{1}{2}MR^2}{R^2}\right]v^2$

$Mgh = \frac{1}{2}\left[\frac{3}{2}M\right]v^2$

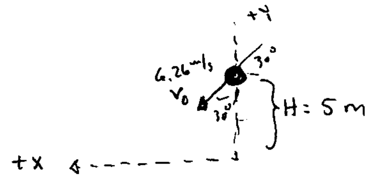
$9.8\left[6\sin 30^\circ\right] = \frac{1}{2}\,\frac{3}{2}\,v^2$

$v = 6.26$ m/s

and also

$\omega = \frac{V}{R} = \frac{6.26}{0.1} = 62.6$ rad/s

Now onto the projectile part of the problem



$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$
$x_0 = 0$
$V_{0x} = 6.26\cos 30^\circ$
$= 5.42$
$a_x = 0$

$x = 5.42t$

$y = y_0 + V_{0y}t + \frac{1}{2}a_y t^2$
$y_0 = 5$
$V_{0y} = -6.26\sin 30^\circ$
$= -3.13$
$a_y = -9.8$

$y = 5 - 3.13t + \frac{1}{2}(-9.8)t^2$

on ground when

$y = 0 = 5 - 3.13t - 4.9t^2$

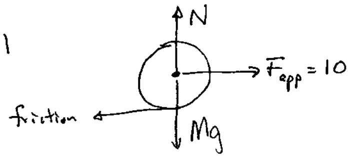
$t = \frac{3.13 \pm \sqrt{(3.13)^2 - 4(-4.9)5}}{-9.8}$

$t = \frac{3.13 \pm 10.30}{-9.8}$

$t = 0.740$ sec

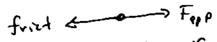
$x = 5.42(0.740)$
$= 4.01$ m

11.11



Mass = 10 kg
$R = 0.3$ m
$a = 0.6$ m/s

a) Examine horizontal forces



$M a_x = F_{app} - f$

$10(0.6) = 10 - f$

$f = 4$ Newtons

$\vec{f} = -4\,\hat{\imath}$ Newtons

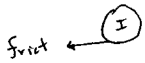
b) Linking angular & rot variables

$a_t = R\alpha$

$0.6 = 0.3\,\alpha$

$\alpha = 2$ rad/s^2

Now consider the rotational fbd



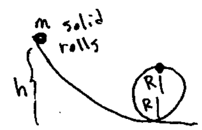
$I\alpha = \Sigma \tau$'s

$I\alpha = fR$

$I\,2 = 4(0.3)$

$I = 0.6$ kg m^2

11.12



$R = 14$ cm
$r \ll R$
$m = 0.280$ g
$I = \frac{2}{5} m r^2$

a) How high h for ball to just make it around the top of the loop

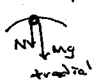
Tot Init Energy = Tot Energy at Top

$mgh = mg(2R) + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ $\quad v = r\omega$

$mgh = mg\,2R + \frac{1}{2}mv^2 + \frac{1}{2}\frac{I}{r^2}v^2$ $\quad I = \frac{2}{5}mr^2$

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

To get speed at top



$ma_{rad} = N + mg$

$m\frac{v^2}{R} = \cancel{N} + mg$ ← smallest

$v^2 = gR$

$gh = g\,2R + \frac{1}{2}gR + \frac{1}{2}\frac{2}{5}gR$

$h = 2R + \frac{1}{2}R + \frac{1}{5}R$

$h = 2.7\,R$

b) Consider situation on side of loop

$h = 6R = 6(0.14) = 0.84$ m

Tot Init E = Tot E at Q

$mgh = mgR + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$= mgR + \frac{1}{2}mv^2 + \frac{1}{2}\frac{I}{r^2}v^2$

$\cancel{m}gh = \cancel{m}gR + \frac{1}{2}\cancel{m}v^2 + \frac{1}{2}\frac{\frac{2}{5}\cancel{m}\cancel{r^2}}{\cancel{r^2}}v^2$

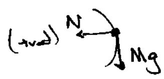
$gh = gR + \frac{1}{2}v^2 + \frac{1}{5}v^2$

$g(h - R) = 0.7\,v^2$

$9.8\,(0.84 - 0.14) = 0.7v^2$

$v = 3.13$ m/s

Look at the forces at Q



$ma_{rad} = N$ $\quad ma_y = -Mg$

$m\frac{v^2}{R} = N$

$(0.280)\frac{(3.13)^2}{0.14} = N$

$19.6 = N$
Newtons

"horizontal"

$Mg = 0.28(9.8)$
$= 2.74$ Newton

"vertical down"

11-22 $\vec{r} = 2\hat{i} - 3\hat{j} + 2\hat{k}$

$\vec{F} = F_x\hat{i} + 7\hat{j} - 6\hat{k}$

$\vec{\tau} = 4\hat{i} + 2\hat{j} - \cancel{1}\hat{k}$

$$\vec{\tau} = \vec{r}\times\vec{F} : \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -3 & 2 \\ F_x & 7 & -6 \end{vmatrix} = \begin{array}{l} \hat{i}(+18-14) \\ -\hat{j}(-12-2F_x) \\ +\hat{k}(14+3F_x) \end{array}$$

so $\tau_y = 2 = -(-12-2F_x)$

$2 = 12 + 2F_x$

$-10 = 2F_x$

$F_x = -5$ Newtons

this works for the τ_z also

11-27 $\vec{F} = 4\hat{j}$ $m = 0.25$ kg

$\vec{r} = 2\hat{i} - 2\hat{k}$

$\vec{v} = -5\hat{i} + 5\hat{k}$

a) Angular Momentum $\vec{L} = \vec{r}\times\vec{p}$

$= \vec{r}\times m\vec{v}$

$$\vec{L} = \overset{0.25}{m} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 0 & -2 \\ -5 & 0 & 5 \end{vmatrix} = 0.25 \begin{array}{l} \hat{i}\,(0\ 0) \\ -\hat{j}\,(10-10) \\ +\hat{k}\ \ 0 \end{array}$$

$\vec{L} = 0$ duh, the vectors are antiparallel

b) Torque $\vec{\tau} = \vec{r}\times\vec{F} : \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 0 & -2 \\ 0 & 4 & 0 \end{vmatrix} = \begin{array}{l} \hat{i}\ 0 \\ -\hat{j}\ 0 \\ +\hat{k}\ 8 \end{array}$

$\vec{\tau} = 8\hat{k}$ N·m

11.45

$I_{Tot} = 6$ kgm^2 $I_{Tot} = 2$ kgm^2

a) Tot Init Ang Mom = Tot Final Ang Mom

$I_i\omega_i = I_f\omega_f$

$6(1.2) = 2\omega_f$

$\omega_f = 3.6$ rev/sec

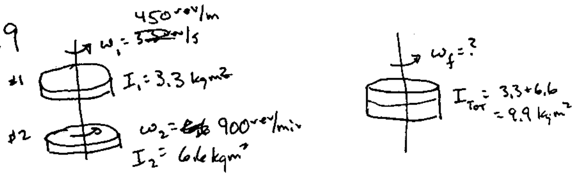
Note that we can get by without changing units.

b) $\dfrac{\text{rot }KE_f}{\text{rot }KE_i} = \dfrac{\frac{1}{2}I_f\omega_f^2}{\frac{1}{2}I_i\omega_i^2} = \dfrac{\frac{1}{2}\ 2\ (3.6)^2}{\frac{1}{2}\ 6\ (1.2)^2} = 3$

c) The work that the man did in pulling his arms in.

11.49

a)



$\omega_1 = 450$ rev/m ~~rev/s~~, $I_1 = 3.3$ kgm^2

$\omega_2 = 900$ rev/min, $I_2 = 6.6$ kgm^2

$\omega_f = ?$ $I_{Tot} = 3.3 + 6.6 = 9.9$ kgm^2

Tot Init $\vec{L}$ = Tot Final L

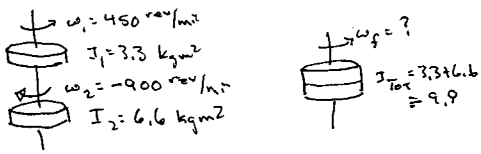
$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_f$

$3.3(450) + 6.6(900) = 9.9\,\omega_f$

$\omega_f = 750$ rev/min counter-clockwise

Again, we could get away without changing units

b)



$\omega_1 = 450$ rev/min, $I_1 = 3.3$ kgm^2

$\omega_2 = -900$ rev/min, $I_2 = 6.6$ kgm^2

$\omega_f = ?$ $I_{Tot} = 3.3 + 6.6 = 9.9$

Tot Init Ang Mom = Tot Final Ang Mom

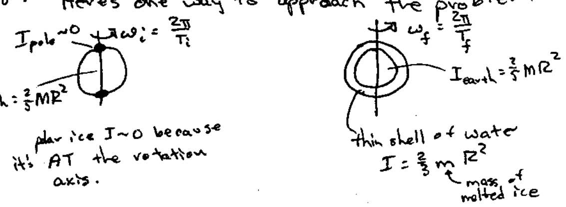
$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega_f$

$3.3(450) + 6.6(-900) = 9.9\,\omega_f$

$\omega_f = -450$ rev/min

Clockwise

11.87 Here's one way to approach the problem



Tot Init $\vec{L}$ = Tot Final $\vec{L}$

$(I_{earth} + \cancel{I_{poles}})\,\omega_i = (I_{earth} + I_{shell})\,\omega_f$

$I_{earth}\ \dfrac{2\pi}{T_i} = (I_{earth} + I_{shell})\ \dfrac{2\pi}{T_f}$

$\dfrac{T_f}{T_i} = \dfrac{I_{earth} + I_{shell}}{I_{earth}} = 1 + \dfrac{I_{shell}}{I_{earth}}$

Need to estimate mass of water shell

$m \simeq$ density · volume ~~$\frac{4}{3}\pi R^3_{out} - \frac{4}{3}\pi R^3_{in}$~~

$m \sim$ density · (surf area sphere) · thickness

$\sim$ density $4\pi R^2$ ΔR

Then

$$\frac{T_f}{T_i} = 1 + \frac{\frac{2}{3}\left(\text{density}\ 4\pi R^2\ \Delta R\right) R^2}{\frac{2}{5}M_{earth}R^2}$$

$$= 1 + \frac{\frac{2}{3}\ 10^3\frac{kg}{m^3}\ 4\pi\ \ 30\ \ (6370\times10^3)^2}{\frac{2}{5}\ (5.96\times10^{24}\,kg)}$$

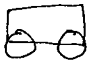
$= 1 + 4.28\times10^{-6}$

So if there are $T_i = 86400$ sec in 1 day

the day would get $\Delta T = 0.37$ sec longer

Your answer depends on what model you use.

11.92



Total Mass 1700 kg - assume this doesn't include the wheels

Wheels 32 kg each

treat wheels as solid disk

Accelerates $0 \longrightarrow 40 \frac{km}{h}$ in 10 sec

$$40 \frac{km}{h} \downarrow \quad 40 \frac{1000m}{3600s} = 11.1\ m/s$$

a) Rotational KE of a wheel

$$rot KE = \frac{1}{2} I \omega^2 = \frac{1}{2}\left[\frac{1}{2} mR^2\right]\omega^2$$

$$= \frac{1}{2}\,\frac{1}{2} MR^2 \left(\frac{V}{R}\right)^2$$

$$= \frac{1}{4} M v^2 = \frac{1}{2}\, 32\, (11.1)^2$$

$$= 986 \text{ Joules}$$

b) Total KE of Each wheel

$$tot KE = trans KE + rot KE$$

$$= \frac{1}{2} M \cancel{R}^2 + rot KE$$

$$= \frac{1}{2}\, 32 (11.1)^2 + 986$$

$$= 2957 \text{ Joules}$$

c) Total KE of whole vehicle

$$\frac{1}{2} M_{\substack{car\\body}} v^2 + 4\left(\frac{KE}{wheel}\right)$$

$$\frac{1}{2}\, 1700 (11.1)^2 + 4\,(2957)$$

$$1.17 \times 10^5 \text{ Joules}$$

••51 In Fig. 10-38, block 1 has mass $m_1 = 460$ g, block 2 has mass $m_2 = 500$ g, and the pulley, which is mounted on a horizontal axle with negligible friction, has radius $R = 5.00$ cm. When released from rest, block 2 falls 75.0 cm in 5.00 s without the cord slipping on the pulley. (a) What is the magnitude of the acceleration of the blocks? What are (b) tension T_2 and (c) tension T_1? (d) What is the magnitude of the pulley's angular acceleration? (e) What is its rotational inertia?

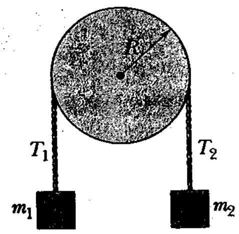


Fig. 10-38 Problems 51 and 83.

•••66 A uniform spherical shell of mass $M = 4.5$ kg and radius $R = 8.5$ cm can rotate about a vertical axis on frictionless bearings (Fig. 10-44). A massless cord passes around the equator of the shell, over a pulley of rotational inertia $I = 3.0 \times 10^{-3}$ kg·m² and radius $r = 5.0$ cm, and is attached to a small object of mass $m = 0.60$ kg. There is no friction on the pulley's axle; the cord does not slip on the pulley. What is the speed of the object when it has fallen 82 cm after being released from rest? Use energy considerations.

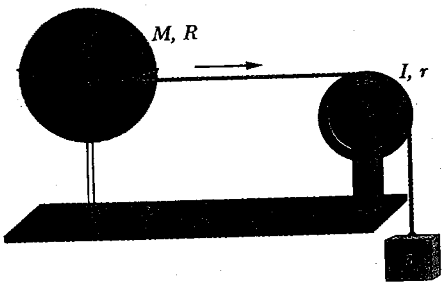


Fig. 10-44 Problem 66.

Fig. 11-30 Problem 6.

••7 In Fig. 11-31, a solid cylinder of radius 10 cm and mass 12 kg starts from rest and rolls without slipping a distance $L = 6.0$ m down a roof that is inclined at the angle $\theta = 30°$. (a) What is the angular speed of the cylinder about its center as it leaves the roof? (b) The roof's edge is at height $H = 5.0$ m. How far horizontally from the roof's edge does the cylinder hit the level ground?

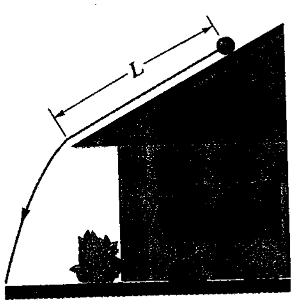


Fig. 11-31 Problem 7.

••11 In Fig. 11-34, a constant horizontal force $\vec{F}_{app}$ of magnitude 10 N is applied to a wheel of mass 10 kg and radius 0.30 m. The wheel rolls smoothly on the horizontal surface, and the acceleration of its center of mass has magnitude 0.60 m/s². (a) In unit-vector notation, what is the frictional force on the wheel? (b) What is the rotational inertia of the wheel about the rotation axis through its center of mass?

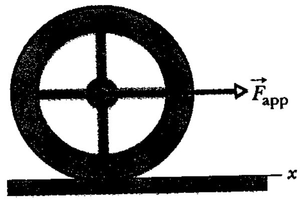


Fig. 11-34 Problem 11.

•12 In Fig. 11-35, a solid brass ball of mass 0.280 g will roll smoothly along a loop-the-loop track when released from rest along the straight section. The circular loop has radius $R = 14.0$ cm, and the ball has radius $r \ll R$. (a) What is h if the ball is on the verge of leaving the track when it reaches the top of the loop? If the ball is released at height $h = 6.00R$, what are the (b) magnitude and (c) direction of the horizontal force component acting on the ball at point Q?

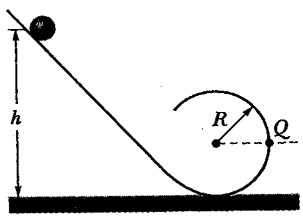


Fig. 11-35 Problem 12.

•••15 A bowler throws a bowling ball of radius $R = 11$ cm along a lane. The ball (Fig. 11-38) slides on the lane with initial speed $v_{com,0} = 8.5$ m/s and initial angular speed $\omega_0 = 0$. The coefficient of kinetic friction between the ball and the lane is 0.21. The kinetic frictional force $\vec{f}_k$ acting on the ball causes a linear acceleration of the ball while producing a torque that causes an angular acceleration of the ball. When speed v_{com} has decreased enough and angular speed ω has increased enough, the ball stops sliding and then rolls smoothly. (a) What then is v_{com} in terms of ω? During the sliding, what are the ball's (b) linear acceleration and (c) angular acceleration? (d) How long does the ball slide? (e) How far does the ball slide? (f) What is the linear speed of the ball when smooth rolling begins?

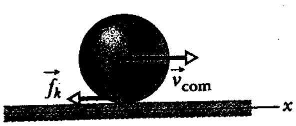


Fig. 11-38 Problem 15.

••22 A particle moves through an xyz coordinate system while a force acts on the particle. When the particle has the position vector $\vec{r} = (2.00\text{ m})\hat{i} - (3.00\text{ m})\hat{j} + (2.00\text{ m})\hat{k}$, the force is given by $\vec{F} = F_x\hat{i} + (7.00\text{ N})\hat{j} - (6.00\text{ N})\hat{k}$ and the corresponding torque about the origin is $\vec{\tau} = (4.00\text{ N}\cdot\text{m})\hat{i} + (2.00\text{ N}\cdot\text{m})\hat{j} - (1.00\text{ N}\cdot\text{m})\hat{k}$. Determine F_x.

•27 SSM At one instant, force $\vec{F} = 4.0\hat{j}$ N acts on a 0.25 kg object that has position vector $\vec{r} = (2.0\hat{i} - 2.0\hat{k})$ m and velocity vector $\vec{v} = (-5.0\hat{i} + 5.0\hat{k})$ m/s. About the origin and in unit-vector notation, what are (a) the object's angular momentum and (b) the torque acting on the object?

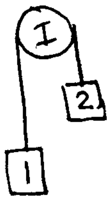
•45 SSM WWW A man stands on a platform that is rotating (without friction) with an angular speed of 1.2 rev/s; his arms are outstretched and he holds a brick in each hand. The rotational inertia of the system consisting of the man, bricks, and platform about the central vertical axis of the platform is 6.0 kg · m^2. If by moving the bricks the man decreases the rotational inertia of the system to 2.0 kg · m^2, what are (a) the resulting angular speed of the platform and (b) the ratio of the new kinetic energy of the system to the original kinetic energy? (c) What source provided the added kinetic energy?

•49 Two disks are mounted (like a merry-go-round) on low-friction bearings on the same axle and can be brought together so that they couple and rotate as one unit. The first disk, with rotational inertia 3.30 kg · m^2 about its central axis, is set spinning counterclockwise at 450 rev/min. The second disk, with rotational inertia 6.60 kg · m^2 about its central axis, is set spinning counterclockwise at 900 rev/min. They then couple together. (a) What is their angular speed after coupling? If instead the second disk is set spinning clockwise at 900 rev/min, what are their (b) angular speed and (c) direction of rotation after they couple together?

87 If Earth's polar ice caps fully melted and the water returned to the oceans, the oceans would be deeper by about 30 m. What effect would this have on Earth's rotation? Make an estimate of the resulting change in the length of the day.

92 An automobile has a total mass of 1700 kg. It accelerates from rest to 40 km/h in 10 s. Assume each wheel is a uniform 32 kg disk. Find, for the end of the 10 s interval, (a) the rotational kinetic energy of each wheel about its axle, (b) the total kinetic energy of each wheel, and (c) the total kinetic energy of the automobile.

10.51



$m_1 = 460g$
$m_2 = 500g$
$R = 5$ cm
When released, block 2 falls 75 cm in 5 sec
No slipping

a) Acceleration of block 2

$$x = \cancel{x_0} + \cancel{v_0}t + \tfrac{1}{2}a_x t^2$$

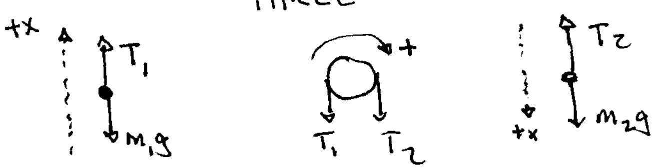
$$0.75 = \tfrac{1}{2}a_x 5^2$$

$$a_x = 0.060 \text{ m/s}$$

b) Pulley's angular acceleration

$$x = R\theta$$
$$v = R\omega$$
$$a = R\alpha$$
$$0.060 \text{ m/s} = (0.05 \text{ m})\alpha$$
$$\alpha = 1.2 \text{ rad/s}^2$$

Now set up the free body diagrams
THREE OBJECTS



$$m_1a = T_1 - m_1g \qquad I\alpha = T_2R - T_1R \qquad m_2a = m_2g - T_2$$

$$0.460(0.060) = T_1 - 0.460(9.8)$$

$T_1 = 4.54$ Newtons

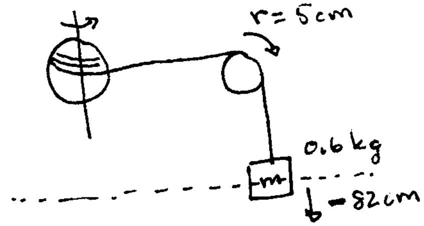
$$0.500(0.060) = 0.500(9.8) - T_2$$

$T_2 = 4.870$ Newtons

$$I(1.2) = (4.870 - 4.54)(0.05)$$

$$I = 0.0138 \text{ kg m}^2$$

10.66



$I_{ball} = \frac{2}{3} M_{ball} R_{ball}^2$ (thin shell)

$I_{pulley} = \frac{1}{2} M_{pulley} r_{pulley}^2$ (disk)

$M_{ball} = 4.5$ kg $\quad R_{ball} = 8.5$ cm

$I_{pulley} = 3 \times 10^{-3}$ kg m^2

Total Init Energy = Total Final Energy

The ball & pulley do not change height, so we will not include their gravitational potential energy on both sides of the equation because it will just cancel.

no kinetic energies

define zero potential energy at starting location

$$0 = \tfrac{1}{2} I_{ball}\omega_{ball}^2 + \tfrac{1}{2} I_{pulley}\omega_{pulley}^2 + \tfrac{1}{2}mv^2 + mgh$$

$$V_{ball} = R_{ball}\omega_{ball} \qquad V_{pulley} = r\,\omega_{pulley}$$

$$\omega_{ball} = \frac{V}{R_{ball}} \qquad \omega_{pulley} = \frac{V}{r_{pulley}}$$

$$0 = \tfrac{1}{2}\frac{I_{ball}}{R_{ball}^2}V^2 + \tfrac{1}{2}\frac{I_{pulley}}{r_{pulley}^2}V^2 + \tfrac{1}{2}mv^2 + mgh$$

$$0 = \tfrac{1}{2}\left[\frac{I_{ball}}{R_{ball}^2} + \frac{I_{pulley}}{r_{pulley}^2} + m\right]v^2 + mgh$$

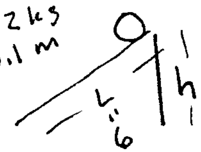
$$= \tfrac{1}{2}\left[\frac{\frac{2}{3}M_{ball}R_{ball}^2}{R_{ball}^2} + \frac{I_{pulley}}{r_{pulley}^2} + m\right]v^2 + mgh$$

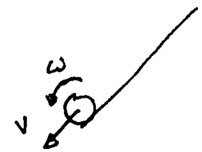
$$0 = \tfrac{1}{2}\left[\tfrac{2}{3}(4.5)\cancel{\tfrac{R^2}{R^2}} + \underbrace{\frac{3\times10^{-3}}{(0.05)^2}}_{2.4\ldots} + 0.6\right]v^2 + (0.6)(9.8)(-0.85)$$

$$V = 1.44 \text{ m/s}$$

11.7 Need to first find the speed of the cylinder as it rolls off the roof in order to predict where it lands

$M = 12$ kg
$R = 0.1$ m





$I = \frac{1}{2} MR^2$ solid cyl

Tot Init Energy = Tot Final Energy

$$Mgh = \frac{1}{2} M v^2 + \frac{1}{2} I \omega^2$$

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

$$= \frac{1}{2} Mv^2 + \frac{1}{2} \frac{I}{R^2} v^2$$

$$Mgh = \frac{1}{2}\left(M + \frac{I}{R^2}\right) v^2$$

$$= \frac{1}{2}\left[M + \frac{\frac{1}{2} M \cancel{R^2}}{\cancel{R^2}}\right] v^2$$

$$Mgh = \frac{1}{2}\left[\frac{3}{2} M\right] v^2$$

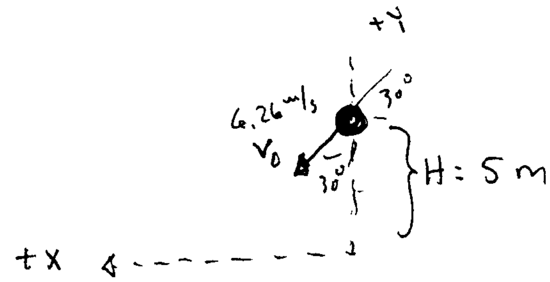
$$9.8\left[6 \sin 30^\circ\right] = \frac{1}{2}\,\frac{3}{2}\, v^2$$

$$v = 6.26 \text{ m/s}$$

and also

$$\omega = \frac{v}{R} = \frac{6.26}{0.1} = 62.6 \text{ rad/s}$$

Now onto the projectile part of the problem



$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$

$x_0 = 0$

$v_{0x} = 6.26 \cos 30^\circ = 5.42$

$a_x = 0$

$x = 5.42 t$

$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$

$y_0 = 5$

$v_{0y} = -6.26 \sin 30^\circ = -3.13$

$a_y = -9.8$

$y = 5 - 3.13t + \frac{1}{2}(-9.8) t^2$

on ground when

$y = 0 = 5 - 3.13t - 4.9t^2$

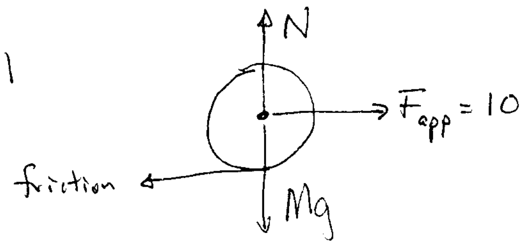
$$t = \frac{3.13 \pm \sqrt{(3.13)^2 - 4(-4.9)5}}{-9.8}$$

$$t = \frac{3.13 \pm 10.38}{-9.8}$$

$t = 0.740$ sec

$x = 5.42(0.740)$
$= 4.01$ m

11.11



Mass = 10 kg
$R = 0.3$ m
$a = 0.6$ m/s

a) Examine horizontal forces

frict $\longleftarrow \bullet \longrightarrow F_{app}$

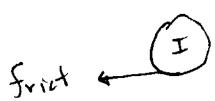
$$M a_x = F_{app} - f$$
$$10(0.6) = 10 - f$$
$$f = 4 \text{ Newtonss}$$

$$\vec{f} = -4\,\hat{i} \quad \text{Newtons}$$

b) Linking angular & rot variables

$$a_t = R\alpha$$
$$0.6 = 0.3\,\alpha$$
$$\alpha = 2 \text{ rad/s}^2$$

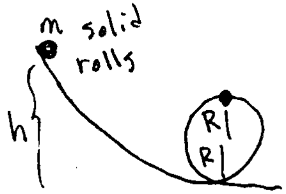
Now consider the rotational fbd



$$I\alpha = \Sigma \tau\text{'s}$$
$$I\alpha = fR$$
$$I\,2 = 4(0.3)$$

$$I = 0.6 \text{ kg m}^2$$

11.12



$R = 14$ cm
$r << R$
$m = 0.280$ g
$I = \frac{2}{5} m r^2$

a) How high h for ball to just make it around the top of the loop

Tot Init Energy = Tot Energy at Top

$$mgh = mg(2R) + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \quad v = r\omega$$

$$mgh = mg\,2R + \frac{1}{2}mv^2 + \frac{1}{2}\frac{I}{r^2}v^2 \quad I = \frac{2}{5}mr^2$$

$$\cancel{m}gh = \cancel{m}g\,2R + \frac{1}{2}\cancel{m}v^2 + \frac{1}{2}\frac{2/5\,\cancel{m}\cancel{r^2}}{\cancel{r^2}}v^2$$

To get speed at top

$$ma_{rad} = N + mg$$

$$m\frac{v^2}{R} = \cancel{N} + mg$$

↳ smallest

$$v^2 = gR$$

$$gh = g\,2R + \frac{1}{2}gR + \frac{1}{2}\frac{2}{5}gR$$

$$h = 2R + \frac{1}{2}R + \frac{1}{5}R$$

$$h = 2.7\,R$$

b) Consider situation on side of loop

$h = 6R = 6(0.14) = 0.84$ m

Tot Init E = Tot E at Q

$$mgh = mgR + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$= mgR + \frac{1}{2}mv^2 + \frac{1}{2}\frac{I}{r^2}v^2$$

$$\cancel{m}gh = \cancel{m}gR + \frac{1}{2}\cancel{m}v^2 + \frac{1}{2}\frac{2/5\,\cancel{m}r^2}{r^2}v^2$$

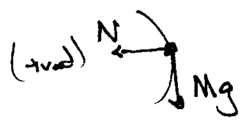
$$gh = gR + \frac{1}{2}v^2 + \frac{1}{5}v^2$$

$$g(h - R) = 0.7\,v^2$$

$$9.8\,(0.84 - 0.14) = 0.7v^2$$

$$v = 3.13 \text{ m/s}$$

Look at the forces at Q



$$ma_{rad} = N \qquad ma_y = -Mg$$

$$m\frac{v^2}{R} = N$$

$$(0.280)\frac{(3.13)^2}{0.14} = N$$

$$19.6 \text{ Newtons} = N \qquad Mg = 0.28(9.8) = 2.74 \text{ Newtons}$$

"horizontal" "vertical down"

11-22

$\vec{r} = 2\hat{i} - 3\hat{j} + 2\hat{k}$

$\bar{F} = F_x\hat{i} + 7\hat{j} - 6\hat{k}$

$\bar{\tau} = 4\hat{i} + 2\hat{j} - 1\hat{k}$

$$\bar{\tau} = \bar{r} \times \bar{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -3 & 2 \\ F_x & 7 & -6 \end{vmatrix} = \begin{array}{l} \hat{i}(+18-14) \\ -\hat{j}(-12-2F_x) \\ +\hat{k}(14+3F_x) \end{array}$$

so

$$\tau_y = 2 = -(-12-2F_x)$$

$$2 = 12 + 2F_x$$

$$-10 = 2F_x$$

$$F_x = -5 \text{ Newtons}$$

this works for the τ_z also

11-27

$\vec{F} = 4\hat{j}$ $\quad m = 0.25\text{ kg}$

$\vec{r} = 2\hat{i} - 2\hat{k}$

$\vec{v} = -5\hat{i} + 5\hat{k}$

a) Angular Momentum $\bar{L} = \bar{r} \times \bar{p}$
$= \vec{r} \times m\vec{v}$

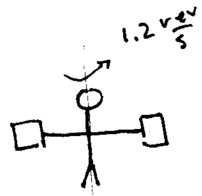
$$\vec{L} = \overset{0.25}{\underset{\shortparallel}{}} m \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 0 & -2 \\ -5 & 0 & 5 \end{vmatrix} = 0.25 \begin{array}{l} \hat{i}\,(10-10) \\ -\hat{j}\,(+10-10) \\ +\hat{k}\;\;0 \end{array}$$

$\vec{L} = 0$ duh, the vectors are antiparallel

b) Torque $\bar{\tau} = \bar{r} \times \bar{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 0 & -2 \\ 0 & 4 & 0 \end{vmatrix} = \begin{array}{l} \hat{i}\;\;0 \\ -\hat{j}\;\;0 \\ +\hat{k}\;\;8 \end{array}$

$\vec{\tau} = 8\hat{k}$ N-m

11.45



$I_{Tot} = 6\text{ kgm}^2$

$I_{Tot} = 2\text{ kgm}^2$

a) Tot Init Ang mom = Tot Final Ang Mom

$$I_i\omega_i = I_f\omega_f$$

$$6(1.2) = 2\,\omega_f$$

$$\omega_f = 3.6\text{ rev/sec}$$

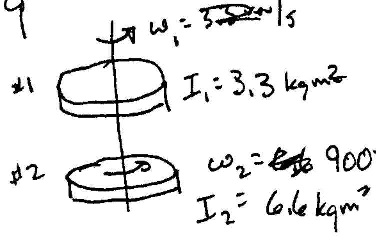
Note that we can get by without changing units.

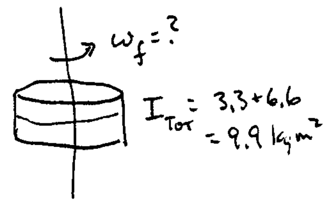
b) $\dfrac{\text{rot } KE_f}{\text{rot } KE_i} = \dfrac{\frac{1}{2} I_f \omega_f^2}{\frac{1}{2} I_i \omega_i^2} = \dfrac{\frac{1}{2}\; 2\; (3.6)^2}{\frac{1}{2}\; 6\; (1.2)^2} = 3$

c) The work that the man did in pulling his arms in.

11.49

a)





Tot Init $\vec{L}$ = Tot Final L

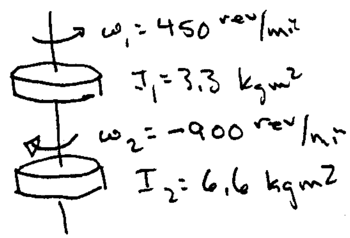
$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\,\omega_f$

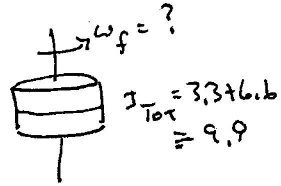
$3.3(450) + 6.6(900) = 9.9\ \omega_f$

$\omega_f = 750$ rev/min counter clockwise

Again we could get away without changing units

b)





Tot Init Ang Mom = Tot Final Ang Mom

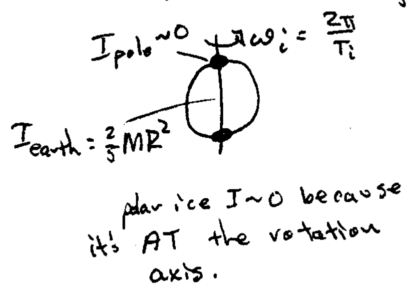
$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\,\omega_f$

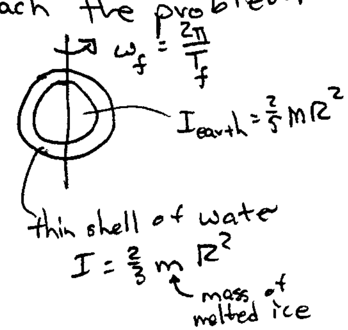
$3.3(450) + 6.6(-900) = 9.9\ \omega_f$

$\omega_f = -450$ rev/min

Clockwise

11.87 Here's one way to approach the problem





Tot Init $\vec{L}$ = Tot Final $\vec{L}$

$$(I_{earth} + \underbrace{I_{poles}}_{0})\,\omega_i = (I_{earth} + I_{shell})\,\omega_f$$

$$I_{earth}\frac{2\pi}{T_i} = (I_{earth} + I_{shell})\frac{2\pi}{T_f}$$

$$\frac{T_f}{T_i} = \frac{I_{earth} + I_{shell}}{I_{earth}} = 1 + \frac{I_{shell}}{I_{earth}}$$

Need to estimate mass of water shell

$m \simeq$ density $\cdot$ volume ~~$\frac{4}{3}\pi R^3_{out} - \frac{4}{3}\pi R^3_{in}$~~

$m \sim$ density $\cdot$ (surf area sphere) $\cdot$ thickness

$\sim$ density $4\pi R^2\ \Delta R$

Then

$$\frac{T_f}{T_i} = 1 + \frac{\frac{2}{3}(\text{density}\ 4\pi \cancel{R^2}\ \Delta R)\ R^2}{\frac{2}{5} M_{earth} \cancel{R^2}}$$

$$= 1 + \frac{\frac{2}{3}\ 10^3\frac{kg}{m^3}\ 4\pi\ 30\ (6370\times10^3)^2}{\frac{2}{5}(5.96\times10^{24}kg)}$$

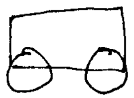
$$= 1 + 4.28\times10^{-6}$$

So if there are $T_i = 86400$ sec in 1 day

the day would get $\Delta T = 0.37$ sec longer

Your answer depends on what model you use.

11.92



Total Mass 1700 kg – assume this doesn't include the wheels

Wheels 32 kg each

treat wheels as solid disk

Accelerates $0 \longrightarrow 40 \frac{km}{h}$ in 10 sec

$40 \frac{1000\,m}{3600\,s} = 11.1\ m/s$

a) Rotational KE of a wheel

$$\text{rot KE} = \frac{1}{2} I \omega^2 = \frac{1}{2}\left[\frac{1}{2} MR^2\right]\omega^2$$
$$= \frac{1}{2}\,\frac{1}{2} MR^2 \left(\frac{V}{R}\right)^2$$
$$= \frac{1}{4} M v^2 = \frac{1}{2}\ 32\ (11.1)^2$$
$$= 986 \text{ Joules}$$

b) Total KE of Each wheel

$$\text{tot KE} = \text{trans KE} + \text{rot KE}$$
$$= \frac{1}{2} M v^2 + \text{rot KE}$$
$$= \frac{1}{2}\ 32 (11.1)^2 + 986$$
$$= 2957 \text{ Joules}$$

c) Total KE of whole vehicle

$$\frac{1}{2} M_{\text{car body}} v^2 + 4\left(\frac{KE}{\text{wheel}}\right)$$

$$\frac{1}{2}\ 1700\ (11.1)^2 + 4\ (2957)$$

$$1.17 \times 10^5 \text{ Joules}$$