10.51

10.56

a) Acceleration of block 1

\[ a = \frac{F}{m} = \frac{4.0 \text{ kg}}{\text{m}} \]

\[ a = 4 \text{ m/s}^2 \]

b) Ball’s angular acceleration

\[ \alpha = \frac{\tau}{I_{ball}} = \frac{9.0 \text{ m} \cdot \text{kg} \cdot \text{m} \cdot \text{s}^{-2}}{3.0 \text{ kg} \cdot \text{m}^2} \]

\[ \alpha = 3 \text{ rad/s}^2 \]

d) Pulley’s angular acceleration

\[ \alpha = \frac{\tau}{I_{pulley}} = \frac{9.0 \text{ m} \cdot \text{kg} \cdot \text{m} \cdot \text{s}^{-2}}{2.0 \text{ kg} \cdot \text{m}^2} \]

\[ \alpha = 4.5 \text{ rad/s}^2 \]

Now set up the free body diagrams.

THREE OBJECTS

\[ T_1, T_2, m_1, m_2 \]

\[ m_1a = T_1 - m_1g \]

\[ \tau - T_1R = I \omega \]

\[ m_2a = T_2 - m_2g \]

\[ \tau + T_2R = I \omega \]

\[ 4.5 \text{ N} \cdot \text{m} \cdot \text{s} \]

\[ T_1 = 4.5 \text{ N} \cdot \text{m} \]

\[ T_2 = 9.0 \text{ N} \cdot \text{m} \]

\[ I = 0.05 \text{ kg} \cdot \text{m}^2 \]

11.7

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

\[ M = 12 \text{ kg} \]

\[ R = 0.5 \text{ m} \]

\[ I = \frac{1}{2} MR^2 \text{ with } M = 12 \text{ kg} \]

Total Init Energy = Total Final Energy

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

\[ V = R\omega \]

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

\[ Mgh = \frac{1}{2} \left( M + \frac{1}{2} M \right) v^2 \]

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

\[ Mgh = \frac{3}{2} \frac{1}{2} v^2 \]

\[ V = 6.26 \text{ m/s} \]

and also

\[ \omega = \frac{V}{R} = 62.6 \text{ rad/s} \]

Now onto the projectile part of the problem.
11.11

\[ \text{Mass} = 10 \text{ kg} \]
\[ R = 0.3 \text{ m} \]
\[ a = 0.6 \text{ m/s}^2 \]

(a) Examine horizontal forces

\[ F_\text{eff} = 10 \]
\[ M_a = F_\text{eff} \cdot f \]
\[ 10 \cdot \mu c = 10 - f \]
\[ f = 4 \text{ Newtons} \]
\[ f = 4 \text{ Newtons} \]

(b) Linking angular & net variables

\[ a_x = Rx \]
\[ 0.6 = 0.3 \cdot a \]
\[ a = 2 \text{ rad/s}^2 \]

Now consider the rotational fbd

\[ I_a = \Sigma I \]
\[ I\alpha = \Sigma F \]
\[ I \cdot \alpha = 4(0.3) \]
\[ I = 0.6 \text{ kg m}^2 \]

11.12

R = 14 \text{ cm}

m = 0.230 \text{ g}

h = \frac{a}{g}

\[ m = 0.230 \text{ g} \]

\[ h = \frac{a}{g} \]

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

\[ \text{Total Initial Energy} = \text{Total Energy at Top} \]
\[ \text{Initial Energy} = mg \cdot h = mg (2R) + \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \]
\[ mgh = mg \cdot 2R + \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \]

\[ \text{Top of Loop} \]

\[ mgh = mg \cdot 2R + \frac{1}{2} mv^2 + \frac{1}{2} \cdot \frac{I}{mr^2} \cdot v^2 \]

To get speed at top

\[ \frac{mv^2}{2} = \frac{I}{mr^2} \cdot v^2 \]

\[ v^2 = gR \]

\[ gh = g \cdot 2R + \frac{1}{2} gR + \frac{1}{2} \cdot \frac{I}{mr^2} \cdot v^2 \]

\[ h = 2R + \frac{1}{2} gR + \frac{1}{2} \cdot \frac{I}{mr^2} \cdot v^2 \]

\[ h = 2R + \frac{1}{2} gR \]

\[ h = 2R \]

(b) Consider situation on side of loop

h = 6R = 6(0.3) = 1.8 \text{ m}

\[ \text{Total Initial Energy} = \text{Total Energy at Q} \]
\[ \text{Initial Energy} = mg \cdot h = mg (2R) + \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \]
\[ mgh = mg \cdot 2R + \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \]

\[ \text{mg} \cdot \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2 \]

\[ gh = g \cdot 2R + \frac{1}{2} gR + \frac{1}{2} \cdot \frac{I}{mr^2} \cdot v^2 \]

\[ gh = 0.7 \text{ m} \]

\[ v = 3.13 \text{ m/s} \]

Look at the forces on Q

\[ \text{mg} \]

\[ \text{mg} \]

\[ m_a = N \]

\[ m_a = N \]

\[ v^2 = gR \]

\[ 2R \]

\[ v = 2.74 \text{ m/s} \]

\[ \text{Vertical down} \]

\[ \text{Horizontal} \]

\[ \text{mg} = 0.230 \text{ g} \]

\[ g = 2.74 \text{ m/s} \]
11.22 \( \frac{v}{F} = \frac{F_x - m \cdot \frac{dv}{dt}}{F_y - m \cdot \frac{d^2v}{dt^2}} \)
\( v = \frac{1}{c} \cdot \lambda \cdot \frac{3}{2} \cdot \frac{v^2}{c^2} \)
\( v = \frac{1}{c} \cdot \lambda \cdot \frac{3}{2} \cdot \frac{(1 - v^2)}{c^2} \)
\( v = \frac{1}{c} \cdot \lambda \cdot \frac{3}{2} \cdot \frac{1}{c^2} \)
\( T = 2 \cdot \frac{v}{c} - 1 \)
\( T = 2 \cdot \frac{v}{c} - 1 \)
\( T = 2 \cdot \frac{v}{c} - 1 \)

11.27 \( \Phi = 4 \) \( m = 0.25 \text{ kg} \)
\( \ddot{r} = 7 \cdot \ddot{r} - 2 \ddot{r} \)
\( \ddot{r} = -5 \cdot \ddot{r} + 5 \ddot{r} \)

a) Axial movement
\( \ddot{L} = \ddot{F} \cdot \ddot{v} \)
\( \ddot{L} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} \)
\( \ddot{L} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} \)
\( \ddot{L} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} = \ddot{F} \cdot \ddot{v} \)

b) Torque
\( \ddot{T} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} \)
\( \ddot{T} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} \)
\( \ddot{T} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} = \ddot{F} \cdot \ddot{r} \)

11.49
a) \( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
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\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
\( \omega = \frac{450 \text{rev}}{10 \text{sec}} \)
Twin mass 1700 kg - assume thin wheels 32 kg each, treat wheels as solid disk

Acceleration 0 → 40 km/hr in 10 sec

\[
\begin{align*}
\text{final speed} & = 40 \text{ km/hr} \\
\text{velocity} & = 11.11 \text{ m/s}
\end{align*}
\]

a) Rotational KE of a wheel
\[
\text{rot KE} = \frac{1}{2} I \omega^2 = \frac{1}{2} \left[ \frac{4}{3} M R^2 \right] \omega^2 = \frac{1}{2} M R^2 \left( \frac{v}{R} \right)^2
\]
\[
= \frac{1}{2} M v^2 = \frac{1}{2} \times 32 \times (11.11)^2
\]
\[
= 986 \text{ Joules}
\]

b) Total KE of each wheel
\[
\text{tot KE} = \text{trans KE} + \text{rot KE}
\]
\[
= \frac{1}{2} M v^2 + \text{rot KE}
\]
\[
= \frac{1}{2} \times 32 \times (11.11)^2 + 986
\]
\[
= 2957 \text{ Joules}
\]

c) Total KE of whole vehicle
\[
\frac{1}{2} M \text{ (body)} v^2 + 4 \text{ (KE wheel)}
\]
\[
= \frac{1}{2} \times 1700 \times (11.11)^2 + 4 \times 2957
\]
\[
= 1.17 \times 10^5 \text{ Joules}
\]
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 axis 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 \( T_1 \) and (c) tension \( T_2 \)? (d) What is the magnitude of the pulley’s angular acceleration? (e) What is its rotational inertia?

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 \( \cdot \) m\(^2\) 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.

7. In Fig. 11-31, a solid brass 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 \( \theta = 30^\circ \). (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?

11. In Fig. 11-34, a constant horizontal force \( \vec{F}_{\text{app}} \) 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/s\(^2\). (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?

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 \( Q \)?

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 \( v_{\text{com}0} = 8.5 \) 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 \( v_{\text{com}} \) has decreased enough and angular speed \( \omega \) has increased enough, the ball stops sliding and then rolls smoothly. (a) What then is \( v_{\text{com}} \) in terms of \( \omega \)? 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?
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. At one instant, force \( \vec{F} = 4.0 \, \text{N} \hat{j} \) 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. 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 \cdot m^2. If by moving the bricks the man decreases the rotational inertia of the system to 2.0 kg \cdot 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 \cdot m^2 about its central axis, is set spinning counterclockwise at 450 rev/min. The second disk, with rotational inertia 6.60 kg \cdot 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

m₁ = 460 g
m₂ = 560 g
R = 5 cm

When released, block 2 falls 75 cm in 5 sec. No slipping.

a) Acceleration of block 2:

\[ x = x_0 + \frac{1}{2}a_x t^2 + v_x t \]

\[ 0.75 = \frac{1}{2}a_x 5^2 \]

\[ a_x = 0.060 \text{ m/s}^2 \]

b) Pulley's angular acceleration:

\[ x = R \theta \]

\[ v = R \omega \]

\[ a = d \omega /dt \]

\[ a = 0.060 \text{ m/s}^2 \]

Now set up the free body diagrams.

THREE OBJECTS:

\[ m_a = T_1 - m_g \]

\[ I_a = T_2 R - T_1 R \]

\[ m_2 a = m_2 g - T_2 \]

0.460 (0.060) = T₁ - 0.460 (9.8)

T₁ = 4.54 Newtons

0.560 (0.060) = 0.560 (9.8) - T₂

T₂ = 4.570 Newtons

I (0.02) = (4.570 - 4.540)(0.05)

I = 0.0135 kg m²

10.66

I_{ball} = \frac{2}{3} M R^2 (\text{thick})

I_{pulley} = \frac{1}{2} M_{pulley} \text{ pulley (disk)}

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

b = 82 \text{ cm} \quad I_{pulley} = 3 \times 10^{-3} \text{ kg m}^2

Total Initial 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.

\[ 0 = \frac{1}{2} I_{ball} \omega_{ball}^2 + \frac{1}{2} I_{pulley} \omega_{pulley}^2 + \frac{1}{2} m v^2 + \text{mg} h \]

\[ v_{ball} = R_{ball} \omega_{ball} \]

\[ v_{pulley} = R \omega_{pulley} \]

\[ \omega_{ball} = \frac{v}{R_{ball}} \]

\[ \omega_{pulley} = \frac{v}{R_{pulley}} \]

\[ 0 = \frac{1}{2} I_{ball} \left( \frac{v}{R_{ball}} \right)^2 + \frac{1}{2} I_{pulley} \left( \frac{v}{R_{pulley}} \right)^2 + \frac{1}{2} m v^2 + \text{mg} h \]

\[ 0 = \frac{1}{2} \left[ \frac{I_{ball} + I_{pulley}}{R_{ball}^2} + m \right] v^2 + \text{mg} h \]

\[ 0 = \frac{1}{2} \left[ \frac{\frac{2}{3} M_{ball} R_{ball}^2 + \frac{1}{2} M_{pulley} R_{pulley}^2}{R_{ball}^2} + m \right] v^2 + \text{mg} h \]

\[ 0 = \frac{1}{2} \left[ \frac{\frac{2}{3} (4.5) R^2}{R^2} + \frac{3 \times 10^{-3}}{(0.05)^2} + 0.6 \right] v^2 + (0.6)(9.8)(-0.8) \]

\[ v = 1.44 \text{ m/s} \]
11.7 Need to first find the speed of the cylinder as it rolls off the roof in order to predict where it lands.

\[ M = 12 \text{ kg} \]
\[ R = 0.1 \text{ m} \]
\[ I = \frac{1}{2} M R^2 \]
\[ M g h = \frac{1}{2} M V^2 + \frac{1}{2} I \omega^2 \]
\[ V = R \omega \]
\[ \omega = \frac{V}{R} \]
\[ M g h = \frac{1}{2} \left( M + \frac{I}{R^2} \right) V^2 \]
\[ M g h = \frac{1}{2} \left( M + \frac{1}{2} M R^2 \right) V^2 \]
\[ M g h = \frac{1}{2} \left[ M + \frac{3}{2} M \right] V^2 \]

9.8 \[ [6 \sin 30^\circ] = \frac{1}{2} \cdot \frac{3}{2} \cdot V^2 \]
\[ V = 6.26 \text{ m/s} \]

and also
\[ \omega = \frac{V}{R} = \frac{6.26}{0.1} = 62.6 \text{ rad/s} \]

Now onto the projectile part of the problem.

- \[ x = x_0 + V_{ox} t + \frac{1}{2} a_x t^2 \]
- \[ y = y_0 + V_{oy} t + \frac{1}{2} a_y t^2 \]
- \[ x_0 = 0 \]
- \[ V_{ox} = 6.26 \cos 30^\circ \]
- \[ a_x = 0 \]
- \[ y_0 = 5 \]
- \[ V_{oy} = -6.26 \sin 30^\circ \]
- \[ a_y = -9.8 \]
- \[ x = 5.42 t \]
- \[ y = 5 - 3.13 t + \frac{1}{2} (9.8) t^2 \]
- \[ y = 0 = 5 - 3.13 t - 4.9 t^2 \]
- \[ t = \frac{3.13 \pm \sqrt{(3.13)^2 - 4(4.9)(-5)}}{-9.8} \]
- \[ t = \frac{3.13 \pm 10.85}{-9.8} \]
- \[ t = 0.74 \text{ sec} \]

- \[ x = 5.42 (0.740) \]
- \[ = 4.01 \text{ m} \]
11.11

\[ F_{\text{app}} = 10 \]

\[ N \]

\[ M_g \]

\[ \text{Mass} = 16 \text{ kg} \]
\[ R = 0.3 \text{ m} \]
\[ a = 0.6 \text{ m/s}^2 \]

a) Examine horizontal forces

\[ f = \mu N \]
\[ \mu = \frac{F_{\text{app}} - f}{10} \]
\[ 0.6 = \frac{10 - f}{10} \]
\[ f = 4 \text{ Newtons} \]
\[ \overrightarrow{f} = -4 \hat{\text{N}} \text{ Newtons} \]

b) Angular motion variables

\[ \alpha = R\dot{x} \]
\[ 0.6 = 0.3 \alpha \]
\[ x = 2 \text{ rad/s}^2 \]

Now consider the rotational field

\[ I \alpha = \sum I' \]
\[ I \alpha = fR \]
\[ I 2 = 4(0.3) \]
\[ I = 0.6 \text{ kg m}^2 \]
a) How high h for ball to just make it around the top of the loop

\[ \text{Tot Init Energy} = \text{Tot Energy at Top} \]
\[ mgh = mg(2R) + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \]
\[ V = \omega R \]
\[ mgh = mg2R + \frac{1}{2}mv^2 + \frac{1}{2}I\frac{\omega^2}{R} \]
\[ I = \frac{2}{5}mv^2 \]
\[ mgh = mg2R + \frac{1}{2}mv^2 + \frac{1}{2} \frac{4}{5}mv^2 \]
To get speed at top

\[ v^2 = gR \]
\[ gh = g2R + \frac{1}{2}gR + \frac{1}{2} \frac{4}{5}gR \]
\[ h = 2R + \frac{1}{2}R + \frac{1}{5}R \]
\[ h = 2.7R \]

b) Consider situation on side of loop

\[ h = 6R = 6(0.14) = 0.84 \text{ m} \]

\[ \text{Tot Init Energy} = \text{Tot Energy at Q} \]
\[ mg \cdot h = mg \cdot R + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \]
\[ = mgR + \frac{1}{2}mv^2 + \frac{1}{2} \frac{4}{5} \frac{v^2}{R} \]
\[ mg \cdot h = mgR + \frac{1}{2}mv^2 + \frac{1}{2} \frac{4}{5} \frac{v^2}{R} \]
\[ g \cdot h = gR + \frac{1}{2}v^2 + \frac{1}{5} \frac{v^2}{R} \]
\[ g(0.84 - 0.14) = 0.7v^2 \]
\[ 9.8(0.7) = 0.7v^2 \]
\[ v = 3.13 \text{ m/s} \]

Look at the forces at Q:

\[ (\text{N}) \rightarrow Mg \]
\[ m\omega = -Mg \]
\[ m\frac{\omega^2}{R} = N \]
\[ (0.29)(3.13)^2 = N \]
\[ 19.16 = N \text{ Newton} \]
\[ Mg = 0.29 \times 9.8 \]
\[ \approx 2.74 \text{ Newton} \]
\[ \vec{F} = 2 \hat{i} - 3 \hat{j} + 2 \hat{k} \]
\[ \vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k} \]
\[ \vec{C} = 4 \hat{i} + 2 \hat{j} - \frac{3}{2} \hat{k} \]

\[ \vec{C} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \ell & \gamma & \chi \\ 2 & -3 & 2 \end{vmatrix} = \hat{\ell} (18-14) + \hat{\gamma} (-12-2F_x) + \hat{\chi} (14+3F_y) \]
\[ \vec{C} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \ell & \gamma & \chi \\ 2 & -3 & 2 \end{vmatrix} = \hat{\ell} (18-14) + \hat{\gamma} (-12-2F_x) + \hat{\chi} (14+3F_y) \]

So
\[ \vec{T} = \vec{z} = -(-12-2F_x) \]
\[ \vec{z} = 12 + 2F_x \]
\[ -100 = 2F_x \]
\[ F_x = -50 \text{ N m/s} \]

This works for the \( \vec{T} \) also.

11-27 \[ \vec{F} = 4 \hat{i} \quad m = 0.25 \text{ kg} \]
\[ \vec{v} = 2 \hat{i} - 2 \hat{k} \]
\[ \vec{v} = -5 \hat{i} + 5 \hat{k} \]

a) Angular Momentum
\[ \vec{L} = \vec{r} \times \vec{p} = \vec{r} \times m \vec{v} \]
\[ \vec{L} = m \begin{vmatrix} \hat{\ell} & \hat{\gamma} & \hat{\chi} \\ \ell & \gamma & \chi \\ 2 & 0 & -2 \end{vmatrix} = 0.25 \hat{\ell} (14-10) \]
\[ \vec{L} = m \begin{vmatrix} \hat{\ell} & \hat{\gamma} & \hat{\chi} \\ \ell & \gamma & \chi \\ 2 & 0 & -2 \end{vmatrix} = 0.25 \hat{\ell} (14-10) \]
\[ \vec{L} = 0 \text{ J h} \text{ m}, \text{ the vectors are antiparallel} \]

b) Torque
\[ \vec{C} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{\ell} & \hat{\gamma} & \hat{\chi} \\ \ell & \gamma & \chi \\ 2 & 0 & -2 \end{vmatrix} = \hat{\ell} 0 \]
\[ \vec{C} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{\ell} & \hat{\gamma} & \hat{\chi} \\ \ell & \gamma & \chi \\ 2 & 0 & -2 \end{vmatrix} = \hat{\ell} 0 \]
\[ \vec{C} = 8 \hat{k} \text{ N m} \]

11.45
\[ I_{1r} = 6 \text{ Kg m}^2 \]
\[ I_{1r} = 2 \text{ Kg m}^2 \]

a) Total Initial Angular = Total Final Average
\[ I \omega_i = I \omega_f \]
\[ I \omega_i = I \omega_f \]
\[ 0 \]
\[ 0 \]
\[ \omega_f = 3.6 \text{ rev/sec} \text{ changing units} \]

b) \[ \frac{\text{rotKE}_i}{\text{rotKE}_f} = \frac{\frac{1}{2} I_f \omega_f^2}{\frac{1}{2} I_i \omega_i^2} = \frac{1}{2} \frac{2}{6} (3.6)^2 = 3 \]

c) The work that the man did in pulling his arms in.
Here’s one way to approach the problem

\[ \omega_s = \frac{3\pi}{T_i} \]

\[ I_{\text{pole}} = 4\pi R^2 \]

place ice \( I = 0 \) because it’s AT the rotation axis.

\[ I_{\text{earth}} = \frac{2}{3} M R^2 \]

thin shell of water

\[ I = \frac{2}{3} m R^2 \]

mass of melted ice

\[ T_i = \frac{I_{\text{earth}} + I_{\text{shell}}}{I_{\text{earth}}} = 1 + \frac{I_{\text{shell}}}{I_{\text{earth}}} \]

Need to estimate mass of water shell

\[ m = \text{density} \times \text{volume} \]

\[ m \sim \text{density} \times \frac{\text{surface area}}{\text{thickness}} \]

Then

\[ T_i \frac{T_i}{T_i} = 1 + \frac{\frac{2}{3} (\text{density} \times 4\pi R^2 \times \Delta R) R^2}{\frac{2}{5} M \text{ earth} R^2} \]

\[ = 1 + \frac{2}{3} \frac{10^3 \text{ kg}}{m^3} \frac{4\pi}{3} \frac{30 (6378 \times 10^3)^2}{(5.96 \times 10^{24} \text{ kg})} \]

\[ = 1 + 4.28 \times 10^{-6} \]

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.
Total mass 1700 kg - assume
total weight.
Wheels 32 kg each (not include the wheels)

Treat wheels as solid disk - 7.5 kg.

accelerates from 0 to 40 km/h in 10 sec

\[
\begin{align*}
40 \frac{\text{km}}{\text{h}} & \quad \text{to} \quad 40 \frac{\text{m}}{\text{s}} \\
11.1 \text{ m/s}
\end{align*}
\]

\( a \) Rotational KE of a wheel

\[
\text{rot KE} = \frac{1}{2} I \omega^2 = \frac{1}{2} \left[\frac{1}{2} M R^2\right] \omega^2
= \frac{1}{2} \left[\frac{1}{2} (7.5 \text{ kg})(0.5 \text{ m})^2\right] \left(\frac{11.1 \text{ m/s}}{0.5 \text{ m}}\right)^2 = \frac{1}{4} M V^2 = \frac{1}{2} \times 32 (11.1)^2
= 986 \text{ Joules}
\]

\( b \) Total KE of Each wheel

\[
\text{tot KE} = \text{trans KE} + \text{rot KE}
= \frac{1}{2} M V^2 + \text{rot KE}
= \frac{1}{2} \times 32 (11.1)^2 + 986
= 2957 \text{ Joules}
\]

\( b \) Total KE of whole vehicle

\[
\frac{1}{2} M_{\text{body}} V^2 + 4 \left(\frac{\text{KE}}{\text{wheel}}\right)
\]

\[
\frac{1}{2} 1700 (11.1)^2 + 4 (2957)
= 1.17 \times 10^5 \text{ Joules}
\]