(All Answers)

CH1

Q1: The position of a particle moving under uniform acceleration is some function of time and the acceleration. Suppose we write this position $s = ka^m t^n$, where k is a dimensionless constant. Show by dimensional analysis that this expression is satisfied if $m = 1$ and $n = 2$. Can this analysis give the value of k?

Ans:

The term x has dimensions of L, a has dimensions of LT^{-2}, and t has dimensions of T. Therefore, the equation $x = ka^m t^n$ has dimensions of

$$L = \left(LT^{-2}\right)^m (T)^n \text{ or } L^1T^0 = L^m T^{n-2m}.$$

The powers of L and T must be the same on each side of the equation. Therefore,

$$L^1 = L^m \text{ and } \boxed{m = 1}.$$

Likewise, equating terms in T, we see that $n - 2m$ must equal 0. Thus, $\boxed{n = 2}$. The value of k, a dimensionless constant, $\boxed{\text{cannot be obtained by dimensional analysis}}$.

Q2: Which of the following equations are dimensionally correct?

(b) $v_f = v_i + ax$, (b) $y = (2\text{m})\cos(kx)$, where $k = 2\ \text{m}^{-1}$.

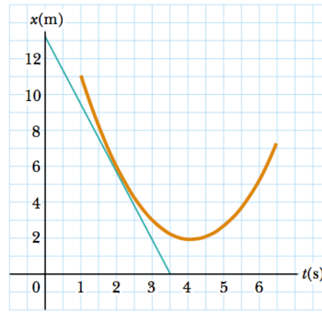
Ans:

(a) $\boxed{\text{This is incorrect}}$ since the units of $[ax]$ are m^2/s^2, while the units of $[v]$ are m/s.

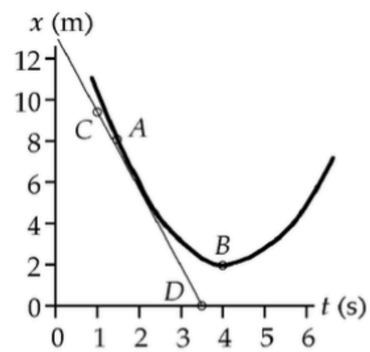
(b) $\boxed{\text{This is correct}}$ since the units of $[y]$ are m, and $\cos(kx)$ is dimensionless if $[k]$ is in m^{-1}.

CH2

Q3: A position-time graph for a particle moving along the x axis is shown in Figure below. (a) Find the average velocity in the time interval t= 1.50 s to t =4.00 s. (b) Determine the instantaneous velocity at t =2.00 s by measuring the slope of the tangent line shown in the graph. (c) At what value of t is the velocity zero?



Ans:



(a) at $t_i = 1.5$ s, $x_i = 8.0$ m (Point A)
at $t_f = 4.0$ s, $x_f = 2.0$ m (Point B)

$$\bar{v} = \frac{x_f - x_i}{t_f - t_i} = \frac{(2.0 - 8.0)\text{ m}}{(4 - 1.5)\text{ s}} = -\frac{6.0\text{ m}}{2.5\text{ s}} = \boxed{-2.4\text{ m/s}}$$

(b) The slope of the tangent line is found from points C and D. $(t_C = 1.0\text{ s}, x_C = 9.5\text{ m})$ and $(t_D = 3.5\text{ s}, x_D = 0)$,

$$v \cong \boxed{-3.8\text{ m/s}}.$$

(c) The velocity is zero when x is a minimum. This is at $t \cong \boxed{4\text{ s}}$.

Q4: A particle moves along the *x* axis according to the equation *x*= 2.00+ 3.00*t* - 1.00*t* ^{2}, where *x* is in meters and *t* is in seconds. At *t*= 3.00 s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

Ans:

$$x = 2.00 + 3.00t - t^2,\ v = \frac{dx}{dt} = 3.00 - 2.00t,\ a = \frac{dv}{dt} = -2.00$$

At $t = 3.00$ s:

(a) $x = (2.00 + 9.00 - 9.00)\text{ m} = \boxed{2.00\text{ m}}$

(b) $v = (3.00 - 6.00)\text{ m/s} = \boxed{-3.00\text{ m/s}}$

(c) $a = \boxed{-2.00\text{ m/s}^2}$

Q5: The driver of a car slams on the brakes when he sees a tree blocking the road. The car slows uniformly with an acceleration of -5.60m/s^2 for4.20s, making straight skid marks 62.4 m long ending at the tree. With what speed does the car then strike the tree?

Ans:

$$\left\{\begin{array}{c} v_{xf} = v_{xi} + a_x t \\ x_f - x_i = \frac{1}{2}(v_{xi} + v_{xf})t \end{array}\right\} \text{ we have } \left\{\begin{array}{c} v_{xf} = v_{xi} - (5.60 \text{ m/s}^2)(4.20 \text{ s}) \\ 62.4 \text{ m} = \frac{1}{2}(v_{xi} + v_{xf})(4.20 \text{ s}) \end{array}\right\}.$$

So substituting for v_{xi} gives $62.4 \text{ m} = \frac{1}{2}\left[v_{xf} + (56.0 \text{ m/s}^2)(4.20 \text{ s}) + v_{xf}\right](4.20 \text{ s})$

$$14.9 \text{ m/s} = v_{xf} + \frac{1}{2}(5.60 \text{ m/s}^2)(4.20 \text{ s}).$$

Thus

$$v_{xf} = \boxed{3.10 \text{ m/s}}.$$

Q6: A ball is dropped from rest from a height *h* above the ground. Another ball is thrown vertically upwards from the ground at the instant the first ball is released. Determine the speed of the second ball if the two balls are to meet at a height *h*/2 above the ground.

Ans:

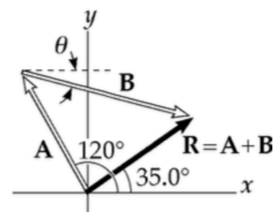
At any time t, the position of the ball released from rest is given by $y_1 = h - \frac{1}{2}gt^2$. At time t, the position of the ball thrown vertically upward is described by $y_2 = v_i t - \frac{1}{2}gt^2$. The time at which the first ball has a position of $y_1 = \frac{h}{2}$ is found from the first equation as $\frac{h}{2} = h - \frac{1}{2}gt^2$, which yields $t = \sqrt{\frac{h}{g}}$. To require that the second ball have a position of $y_2 = \frac{h}{2}$ at this time, use the second equation to obtain $\frac{h}{2} = v_i\sqrt{\frac{h}{g}} - \frac{1}{2}g\left(\frac{h}{g}\right)$. This gives the required initial upward velocity of the second ball as $\boxed{v_i = \sqrt{gh}}$.

CH3

Q7: A man pushing a mop across a floor causes it to undergo two displacements. The first has a magnitude of 150 cm and makes an angle of 120° with the positive *x* axis. The resultant displacement has a magnitude of 140 cm and is directed at an angle of 35.0° to the positive *x* axis. Find the magnitude and direction of the second displacement.

Ans:

We have $\mathbf{B} = \mathbf{R} - \mathbf{A}$:



$$A_x = 150\cos 120° = -75.0 \text{ cm}$$
$$A_y = 150\sin 120° = 130 \text{ cm}$$
$$R_x = 140\cos 35.0° = 115 \text{ cm}$$
$$R_y = 140\sin 35.0° = 80.3 \text{ cm}$$

Therefore,

$$\mathbf{B} = [115 - (-75)]\hat{\mathbf{i}} + [80.3 - 130]\hat{\mathbf{j}} = (190\hat{\mathbf{i}} - 49.7\hat{\mathbf{j}}) \text{ cm}$$
$$|\mathbf{B}| = \sqrt{190^2 + 49.7^2} = \boxed{196 \text{ cm}}$$
$$\theta = \tan^{-1}\left(-\frac{49.7}{190}\right) = \boxed{-14.7°}.$$

Q8: Vector A has a negative *x* component 3.00 units in length and a positive *y* component 2.00 units in length. (a) Determine an expression for A in unit–vector notation. (b) Determine the magnitude and direction of A. (c) What vector B when added to A gives a resultant vector with no *x* component and a negative *y* component 4.00 units in length?

Ans:

$A_x = -3.00$, $A_y = 2.00$

(a) $\mathbf{A} = A_x\hat{\mathbf{i}} + A_y\hat{\mathbf{j}} = \boxed{-3.00\hat{\mathbf{i}} + 2.00\hat{\mathbf{j}}}$

(b) $|\mathbf{A}| = \sqrt{A_x^2 + A_y^2} = \sqrt{(-3.00)^2 + (2.00)^2} = \boxed{3.61}$

$$\tan\theta = \frac{A_y}{A_x} = \frac{2.00}{(-3.00)} = -0.667,\ \tan^{-1}(-0.667) = -33.7°$$

θ is in the 2nd quadrant, so $\theta = 180° + (-33.7°) = \boxed{146°}$.

(c) $\mathbf{R}_x = 0$, $\mathbf{R}_y = -4.00$, $\mathbf{R} = \mathbf{A} + \mathbf{B}$ thus $\mathbf{B} = \mathbf{R} - \mathbf{A}$ and

$B_x = R_x - A_x = 0 - (-3.00) = 3.00$, $B_y = R_y - A_y = -4.00 - 2.00 = -6.00$.

Therefore, $\mathbf{B} = \boxed{3.00\hat{\mathbf{i}} - 6.00\hat{\mathbf{j}}}$.

CH4

Q9: A particle initially located at the origin has an acceleration of a 3.00$\hat{j}$ m/s^2 and an initial velocity of v_i=500i m/s. Find (a) the vector position and velocity at any time *t* and (b) the coordinates and speed of the particle at *t*= 2.00 s.

Ans:

$$\mathbf{a} = 3.00\hat{\mathbf{j}}\ \text{m/s}^2\,;\ \mathbf{v}_i = 5.00\hat{\mathbf{i}}\ \text{m/s}\,;\ \mathbf{r}_i = 0\hat{\mathbf{i}} + 0\hat{\mathbf{j}}$$

(a) $$\mathbf{r}_f = \mathbf{r}_i + \mathbf{v}_i t + \frac{1}{2}\mathbf{a}t^2 = \boxed{\left[5.00t\hat{\mathbf{i}} + \frac{1}{2}3.00t^2\hat{\mathbf{j}}\right]\ \text{m}}$$

$$\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t = \boxed{\left(5.00\hat{\mathbf{i}} + 3.00t\hat{\mathbf{j}}\right)\ \text{m/s}}$$

(b) $$t = 2.00\ \text{s},\ \mathbf{r}_f = 5.00(2.00)\hat{\mathbf{i}} + \frac{1}{2}(3.00)(2.00)^2\hat{\mathbf{j}} = \left(10.0\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}\right)\ \text{m}$$

$$\text{so } x_f = \boxed{10.0\ \text{m}},\ y_f = \boxed{6.00\ \text{m}}$$

$$\mathbf{v}_f = 5.00\hat{\mathbf{i}} + 3.00(2.00)\hat{\mathbf{j}} = \left(5.00\hat{\mathbf{i}} + 6.00\hat{\mathbf{j}}\right)\ \text{m/s}$$

$$v_f = \left|\mathbf{v}_f\right| = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{(5.00)^2 + (6.00)^2} = \boxed{7.81\ \text{m/s}}$$

Q10: A projectile is fired in such a way that its horizontal range is equal to three times its maximum height. What is the angle of projection?

Ans:

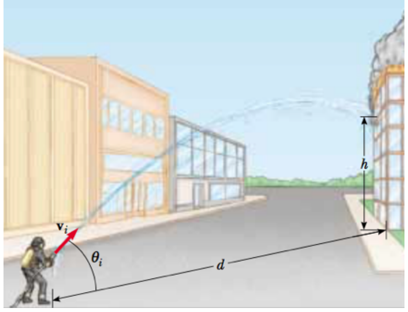
$$h = \frac{v_i^2 \sin^2\theta_i}{2g};\ R = \frac{v_i^2(\sin 2\theta_i)}{g};\ 3h = R,$$

$$\text{so } \frac{3v_i^2 \sin^2\theta_i}{2g} = \frac{v_i^2(\sin 2\theta_i)}{g}$$

$$\text{or } \frac{2}{3} = \frac{\sin^2\theta_i}{\sin 2\theta_i} = \frac{\tan\theta_i}{2}$$

$$\text{thus } \theta_i = \tan^{-1}\left(\frac{4}{3}\right) = \boxed{53.1°}.$$

Q11: A firefighter, a distance *d* from a burning building, directs a stream of water from a fire hose at angle θ$_i$ above the horizontal as in Figure below. If the initial speed of the stream is v_i, at what height *h* does the water strike the building?



Ans:

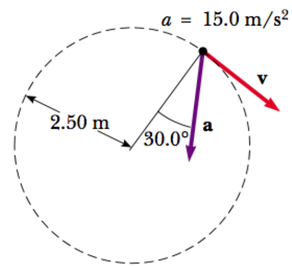
The horizontal component of displacement is $x_f = v_{xi}t = (v_i \cos\theta_i)t$. Therefore, the time required to reach the building a distance d away is $t = \dfrac{d}{v_i \cos\theta_i}$. At this time, the altitude of the water is

$$y_f = v_{yi}t + \frac{1}{2}a_y t^2 = v_i \sin\theta_i\left(\frac{d}{v_i \cos\theta_i}\right) - \frac{g}{2}\left(\frac{d}{v_i \cos\theta_i}\right)^2.$$

Therefore the water strikes the building at a height h above ground level of

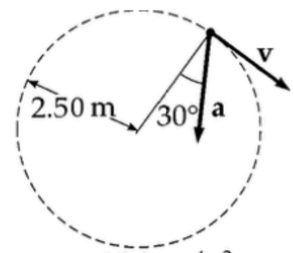
$$h = y_f = \boxed{d\tan\theta_i - \frac{gd^2}{2v_i^2\cos^2\theta_i}}.$$

Q12: Figure below represents the total acceleration of a particle moving clockwise in a circle of radius 2.50 m at a certain instant of time. At this instant, find (a) the radial acceleration, (b) the speed of the particl and (c) its tangential acceleration.



Ans:

$r = 2.50\text{ m},\ a = 15.0\ \text{m/s}^2$



(a) $a_c = a\cos 30.0° = (15.0\ \text{m/s}^2)(\cos 30°) = \boxed{13.0\ \text{m/s}^2}$

(b) $a_c = \dfrac{v^2}{r}$

so $v^2 = ra_c = 2.50\text{ m}(13.0\ \text{m/s}^2) = 32.5\ \text{m}^2/\text{s}^2$

$v = \sqrt{32.5}\ \text{m/s} = \boxed{5.70\ \text{m/s}}$

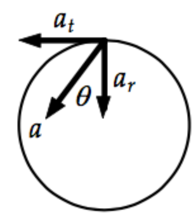
(c) $a^2 = a_t^2 + a_r^2$

so $a_t = \sqrt{a^2 - a_r^2} = \sqrt{(15.0\ \text{m/s}^2)^2 - (13.0\,\text{m/s}^2)} = \boxed{7.50\ \text{m/s}^2}$

. **Q13: A race car starts from rest on a circular track. The car in- creases its speed at a constant rate a_t as it goes once around the track. Find the angle that the total acceleration of the car makes—with the radius connecting the center of the track and the car—at the moment the car completes the circle**

Ans:

Let i be the starting point and f be one revolution later. The curvilinear motion with constant tangential acceleration is described by



$$\Delta x = v_{xi}t + \frac{1}{2}a_x t^2$$

$$2\pi r = 0 + \frac{1}{2}a_t t^2$$

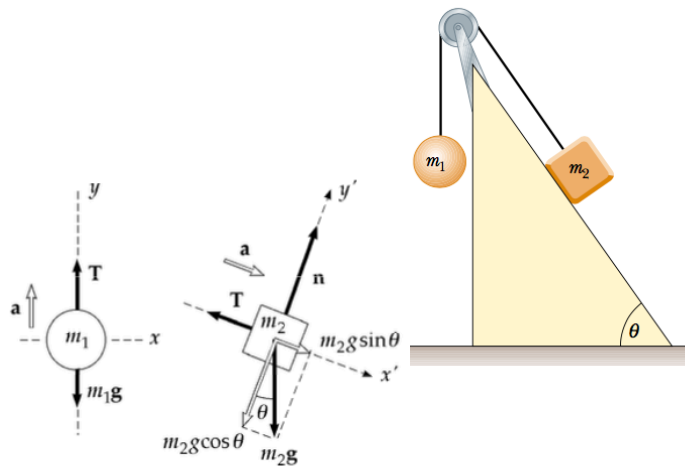
$$a_t = \frac{4\pi r}{t^2}$$

and $v_{xf} = v_{xi} + a_x t$, $v_f = 0 + a_t t = \frac{4\pi r}{t}$. The magnitude of the radial acceleration is $a_r = \frac{v_f^2}{r} = \frac{16\pi^2 r^2}{t^2 r}$

Then $\tan\theta = \frac{a_t}{a_r} = \frac{4\pi r t^2}{t^2 16\pi^2 r} = \frac{1}{4\pi}$ $\qquad \theta = \boxed{4.55°}$.

CH5

Q14: Two objects are connected by a light string that passes over a frictionless pulley, as in Figure below. Draw free-body diagrams of both objects. If the incline is frictionless and if m_1=2.00kg, m_2=6.00kg, and θ=55.0°, find (a) the accelerations of the objects, (b) the tension in the string, and (c) the speed of each object 2.00 s after being released from rest.



Ans:

$m_1 = 2.00$ kg, $m_2 = 6.00$ kg, $\theta = 55.0°$

(a) $\sum F_x = m_2 g\sin\theta - T = m_2 a$

and

$$T - m_1 g = m_1 a$$

$$a = \frac{m_2 g\sin\theta - m_1 g}{m_1 + m_2} = \boxed{3.57\ \text{m/s}^2}$$

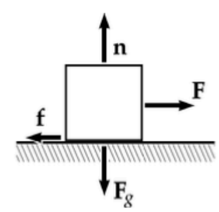
(b) $T = m_1(a+g) = \boxed{26.7\ \text{N}}$

(c) Since $v_i = 0$, $v_f = at = (3.57\ \text{m/s}^2)(2.00\ \text{s}) = \boxed{7.14\ \text{m/s}}$.

. Q15: **A 25.0-kg block is initially at rest on a horizontal surface. A horizontal force of 75.0 N is required to set the block in motion. After it is in motion, a horizontal force of 60.0 N is required to keep the block moving with constant speed. Find the coefficients of static and kinetic friction from this information.**

. Ans:

For equilibrium: $f = F$ and $n = F_g$. Also, $f = \mu n$ i.e.,



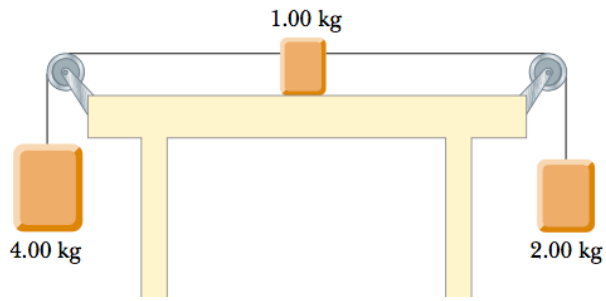
$$\mu = \frac{f}{n} = \frac{F}{F_g}$$

$$\mu_s = \frac{75.0\ \text{N}}{25.0(9.80)\ \text{N}} = \boxed{0.306}$$

and

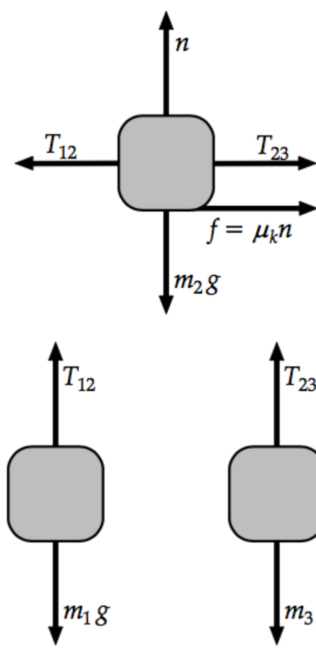
$$\mu_k = \frac{60.0\ \text{N}}{25.0(9.80)\ \text{N}} = \boxed{0.245}.$$

Q16: Three objects are connected on the table as shown in Figure below. The table is rough and has a coefficient of kinetic friction of 0.350. The objects have masses of 4.00 kg, 1.00 kg, and 2.00 kg, as shown, and the pulleys are frictionless. Draw free-body diagrams of each of the objects. (a) Determine the acceleration of each object and their directions. (b) Determine the tensions in the two cords.



Ans:

Let a represent the positive magnitude of the acceleration $-a\hat{\mathbf{j}}$ of m_1, of the acceleration $-a\hat{\mathbf{i}}$ of m_2, and of the acceleration $+a\hat{\mathbf{j}}$ of m_3. Call T_{12} the tension in the left rope and T_{23} the tension in the cord on the right.



For m_1, $\sum F_y = ma_y$ $\quad +T_{12} - m_1 g = -m_1 a$

For m_2, $\sum F_x = ma_x$ $\quad -T_{12} + \mu_k n + T_{23} = -m_2 a$

and $\sum F_y = ma_y$ $\quad n - m_2 g = 0$

for m_3, $\sum F_y = ma_y$ $\quad T_{23} - m_3 g = +m_3 a$

we have three simultaneous equations

$$-T_{12} + 39.2\text{ N} = (4.00\text{ kg})a$$
$$+T_{12} - 0.350(9.80\text{ N}) - T_{23} = (1.00\text{ kg})a$$
$$+T_{23} - 19.6\text{ N} = (2.00\text{ kg})a.$$

(a) Add them up:

$$+39.2\text{ N} - 3.43\text{ N} - 19.6\text{ N} = (7.00\text{ kg})a$$

$$a = \boxed{2.31\text{ m/s}^2\text{, down for } m_1\text{, left for } m_2\text{, and up for } m_3}.$$

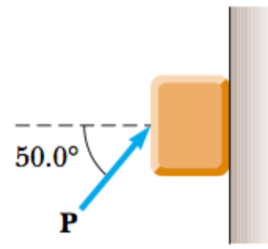
(b) Now $-T_{12} + 39.2\text{ N} = (4.00\text{ kg})(2.31\text{ m/s}^2)$

$$\boxed{T_{12} = 30.0\text{ N}}$$

and $T_{23} - 19.6\text{ N} = (2.00\text{ kg})(2.31\text{ m/s}^2)$

$$\boxed{T_{23} = 24.2\text{ N}}.$$

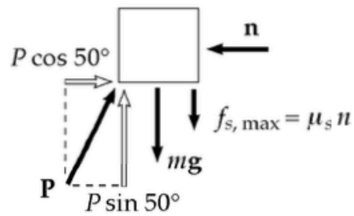
. Q17: **A block of mass 3.00 kg is pushed up against a wall by a force P that makes a 50.0° angle with the horizontal as shown in Figure below. The coefficient of static friction between the block and the wall is 0.250. Determine the possible values for the magnitude of P that allow the block to remain stationary.**



Ans:

(Case 1, impending upward motion)

Setting



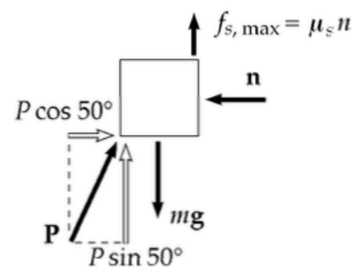
$$\sum F_x = 0: \quad P\cos 50.0° - n = 0$$

$$f_{s,\,max} = \mu_s n: \quad f_{s,\,max} = \mu_s P\cos 50.0° = 0.250(0.643)P = 0.161P$$

Setting

$$\sum F_y = 0: \quad P\sin 50.0° - 0.161P - 3.00(9.80) = 0$$

$$P_{max} = \boxed{48.6\ \text{N}}$$



(Case 2, impending downward motion)

As in Case 1,

$$f_{s,\,max} = 0.161P$$

Setting

$$\sum F_y = 0: \quad P\sin 50.0° + 0.161P - 3.00(9.80) = 0$$

$$P_{min} = \boxed{31.7\ \text{N}}$$

CH6

Q18: A coin placed 30.0 cm from the center of a rotating, horizontal turntable slips when its speed is 50.0 cm/s. (a) What force causes the centripetal acceleration when the coin is stationary relative to the turntable? (b) What is the coefficient of static friction between coin and turntable?

Ans:

(a) $\boxed{\text{static friction}}$

(b) $ma\hat{\mathbf{i}} = f\hat{\mathbf{i}} + n\hat{\mathbf{j}} + mg(-\hat{\mathbf{j}})$

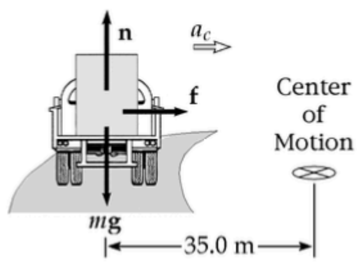
$\sum F_y = 0 = n - mg$

thus $n = mg$ and $\sum F_r = m\frac{v^2}{r} = f = \mu n = \mu mg$.

Then $\mu = \frac{v^2}{rg} = \frac{(50.0\ \text{cm/s})^2}{(30.0\ \text{cm})(980\ \text{cm/s}^2)} = \boxed{0.085\,0}$.

Q19: A crate of eggs is located in the middle of the flat bed of a pickup truck as the truck negotiates an unbanked curve in the road. The curve may be regarded as an arc of a circle of radius 35.0 m. If the coefficient of static friction between crate and truck is 0.600, how fast can the truck be moving without the crate sliding?

Ans:



$n = mg$ since $a_y = 0$

The force causing the centripetal acceleration is the frictional force f.

From Newton's second law $f = ma_c = \frac{mv^2}{r}$.

But the friction condition is $f \le \mu_s n$

i.e., $\frac{mv^2}{r} \le \mu_s mg$

$v \le \sqrt{\mu_s rg} = \sqrt{0.600(35.0\ \text{m})(9.80\ \text{m/s}^2)}$ $\qquad v \le \boxed{14.3\ \text{m/s}}$

CH7

Q20: A force F =(4$x\hat{i}$+ 3$y\hat{j}$)N acts on an object as the object moves in the *x* direction from the origin to *x*= 5.00 m. Find the work done on the object by the force $W = \int \mathbf{F} \cdot d\mathbf{r}$

Ans:

$$W = \int_i^f \mathbf{F} \cdot d\mathbf{r} = \int_0^{5\text{ m}} \left(4x\hat{\mathbf{i}} + 3y\hat{\mathbf{j}}\right) \text{N} \cdot dx\hat{\mathbf{i}}$$

$$\int_0^{5\text{ m}} (4\text{ N/m})x\,dx + 0 = (4\text{ N/m})\frac{x^2}{2}\bigg|_0^{5\text{ m}} = \boxed{50.0\text{ J}}$$

Q21: A 2 100-kg pile driver is used to drive a steel I-beam into the ground. The pile driver falls 5.00 m before coming into contact with the top of the beam, and it drives the beam 12.0 cm farther into the ground before coming to rest. Using energy considerations, calculate the average force the beam exerts on the pile driver while the pile driver is brought to rest.

Ans:

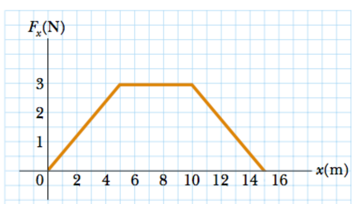
Consider the work done on the pile driver from the time it starts from rest until it comes to rest at the end of the fall. Let $d = 5.00$ m represent the distance over which the driver falls freely, and $h = 0.12$ m the distance it moves the piling.

$\sum W = \Delta K$: $W_{\text{gravity}} + W_{\text{beam}} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

so $(mg)(h+d)\cos 0° + (\bar{F})(d)\cos 180° = 0 - 0$.

Thus, $\bar{F} = \frac{(mg)(h+d)}{d} = \frac{(2\,100\text{ kg})(9.80\text{ m/s}^2)(5.12\text{ m})}{0.120\text{ m}} = \boxed{8.78 \times 10^5\text{ N}}$. The force on the pile driver is $\boxed{\text{upward}}$.

Q22: A 4.00-kg particle is subject to a total force that varies with position as shown in Figure below. The particle starts from rest at *x* 0. What is its speed at (a) *x*= 5.00 m, (b) *x*= 10.0 m, (c) *x* =15.0 m?



Ans:

(a) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W = $ (area under curve from $x = 0$ to $x = 5.00$ m)

$$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(7.50\text{ J})}{4.00\text{ kg}}} = \boxed{1.94\text{ m/s}}$$

(b) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W = $ (area under curve from $x = 0$ to $x = 10.0$ m)

$$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(22.5\text{ J})}{4.00\text{ kg}}} = \boxed{3.35\text{ m/s}}$$

(c) $\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \sum W = $ (area under curve from $x = 0$ to $x = 15.0$ m)

$$v_f = \sqrt{\frac{2(\text{area})}{m}} = \sqrt{\frac{2(30.0\text{ J})}{4.00\text{ kg}}} = \boxed{3.87\text{ m/s}}$$

Q23: A sled of mass *m* is given a kick on a frozen pond. The kick imparts to it an initial speed of 2.00 m/s. The coefficient of kinetic friction between sled and ice is 0.100. Use energy considerations to find the distance the sled moves before it stops.

Ans:

$$v_i = 2.00 \text{ m/s} \qquad \mu_k = 0.100$$

$$K_i - f_k \Delta x + W_{\text{other}} = K_f: \qquad \frac{1}{2}mv_i^2 - f_k \Delta x = 0$$

$$\frac{1}{2}mv_i^2 = \mu_k mg\Delta x \qquad \Delta x = \frac{v_i^2}{2\mu_k g} = \frac{(2.00 \text{ m/s})^2}{2(0.100)(9.80)} = \boxed{2.04 \text{ m}}$$

Q24: A 650-kg elevator starts from rest. It moves upward for 3.00 s with constant acceleration until it reaches its cruising speed of 1.75 m/s. (a) What is the average power of the elevator motor during this period? (b) How does this power compare with the motor power when the elevator moves at its cruising speed?

Ans:

(a) The distance moved upward in the first 3.00 s is

$$\Delta y = \bar{v}t = \left[\frac{0 + 1.75 \text{ m/s}}{2}\right](3.00 \text{ s}) = 2.63 \text{ m}.$$

The motor and the earth's gravity do work on the elevator car:

$$\frac{1}{2}mv_i^2 + W_{\text{motor}} + mg\Delta y \cos 180° = \frac{1}{2}mv_f^2$$

$$W_{\text{motor}} = \frac{1}{2}(650 \text{ kg})(1.75 \text{ m/s})^2 - 0 + (650 \text{ kg})g(2.63 \text{ m}) = 1.77 \times 10^4 \text{ J}$$

Also, $W = \bar{\mathcal{P}}t$ so $\bar{\mathcal{P}} = \frac{W}{t} = \frac{1.77 \times 10^4 \text{ J}}{3.00 \text{ s}} = \boxed{5.91 \times 10^3 \text{ W}} = 7.92 \text{ hp}.$

(b) When moving upward at constant speed $(v = 1.75 \text{ m/s})$ the applied force equals the weight $= (650 \text{ kg})(9.80 \text{ m/s}^2) = 6.37 \times 10^3 \text{ N}$. Therefore,

$$\mathcal{P} = Fv = (6.37 \times 10^3 \text{ N})(1.75 \text{ m/s}) = \boxed{1.11 \times 10^4 \text{ W}} = 14.9 \text{ hp}.$$

CH8

Q25: A block of mass 0.250 kg is placed on top of a light vertical spring of force constant 5 000 N/m and pushed downward so that the spring is compressed by 0.100 m. After the block is released from rest, it travels upward and then leaves the spring. To what maximum height above the point of release does it rise?

Ans:

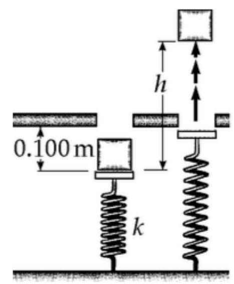
From conservation of energy for the block-spring-Earth system,

$$U_{gt} = U_{si},$$

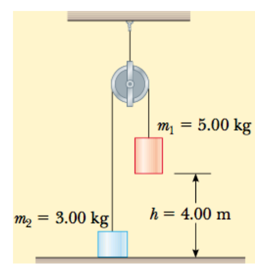
or

$$(0.250 \text{ kg})(9.80 \text{ m/s}^2)h = \left(\frac{1}{2}\right)(5\,000 \text{ N/m})(0.100 \text{ m})^2$$

This gives a maximum height $h = \boxed{10.2 \text{ m}}$.



Q26: Two objects are connected by a light string passing over a light frictionless pulley as shown in Figure below. The object of mass 5.00 kg is released from rest. Using the principle of conservation of energy, (a) determine the speed of the 3.00-kg object just as the 5.00-kg object hits the ground.
(b) Find the maximum height to which the 3.00-kg object rises.



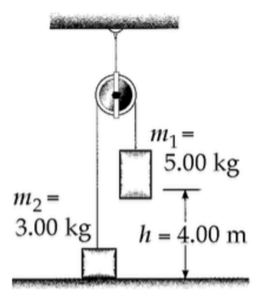
Ans:

Using conservation of energy for the system of the Earth and the two objects

(a) $(5.00 \text{ kg})g(4.00 \text{ m}) = (3.00 \text{ kg})g(4.00 \text{ m}) + \frac{1}{2}(5.00 + 3.00)v^2$

$v = \sqrt{19.6} = \boxed{4.43 \text{ m/s}}$

(b) Now we apply conservation of energy for the system of the 3.00 kg object and the Earth during the time interval between the instant when the string goes slack and the instant at which the 3.00 kg object reaches its highest position in its free fall.



$$\frac{1}{2}(3.00)v^2 = mg\,\Delta y = 3.00g\Delta y$$

$$\Delta y = 1.00 \text{ m}$$

$$y_{max} = 4.00 \text{ m} + \Delta y = \boxed{5.00 \text{ m}}$$

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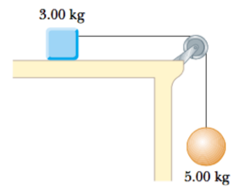
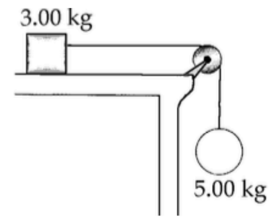
. **Q27: The coefficient of friction between the 3.00-kg block and the surface in Figure below is 0.400. The system starts from rest. What is the speed of the 5.00-kg ball when it has fallen 1.50 m?**



Ans:



$U_i + K_i + \Delta E_{\text{mech}} = U_f + K_f$: $m_2 gh - fh = \frac{1}{2} m_1 v^2 + \frac{1}{2} m_2 v^2$

$$f = \mu n = \mu m_1 g$$

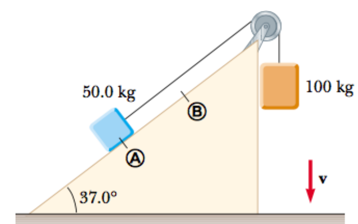
$$m_2 gh - \mu m_1 gh = \frac{1}{2}(m_1 + m_2) v^2$$

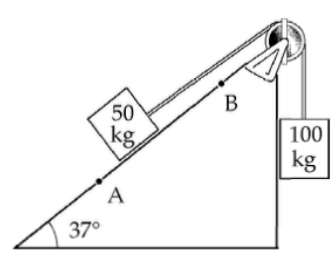
$$v^2 = \frac{2(m_2 - \mu m_1)(hg)}{m_1 + m_2}$$

$$v = \sqrt{\frac{2(9.80\ \text{m/s}^2)(1.50\ \text{m})[5.00\ \text{kg} - 0.400(3.00\ \text{kg})]}{8.00\ \text{kg}}} = \boxed{3.74\ \text{m/s}}$$

Q28: A 50.0-kg block and a 100-kg block are connected by a string as in Figure below. The pulley is frictionless and of negligible mass. The coefficient of kinetic friction between the 50.0 kg block and incline is 0.250. Determine the change in the kinetic energy of the 50.0-kg block as it moves from A to B , a distance of 20.0 m.

Ans:





$$\sum F_y = n - mg\cos 37.0° = 0$$

$$\therefore n = mg\cos 37.0° = 400\ \text{N}$$

$$f = \mu n = 0.250(400\ \text{N}) = 100\ \text{N}$$

$$-f\Delta x = \Delta E_{\text{mech}}$$

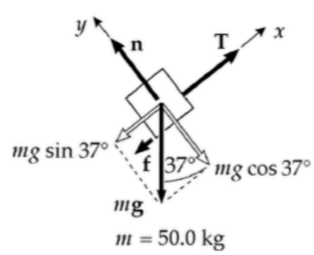
$$(-100)(20.0) = \Delta U_A + \Delta U_B + \Delta K_A + \Delta K_B$$

$$\Delta U_A = m_A g(h_f - h_i) = (50.0)(9.80)(20.0\sin 37.0°) = 5.90 \times 10^3$$

$$\Delta U_B = m_B g(h_f - h_i) = (100)(9.80)(-20.0) = -1.96 \times 10^4$$

$$\Delta K_A = \frac{1}{2} m_A (v_f^2 - v_i^2)$$

$$\Delta K_B = \frac{1}{2} m_B (v_f^2 - v_i^2) = \frac{m_B}{m_A} \Delta K_A = 2\Delta K_A$$



Adding and solving, $\Delta K_A = \boxed{3.92\ \text{kJ}}$.

CH9

. **Q29: A 3.00-kg particle has a velocity of (3.00i - 4.00j) m/s. (a) Find its *x* and *y* components of momentum. (b) Find the magnitude and direction of its momentum.**

Ans:

$$m = 3.00\text{ kg}, \qquad \mathbf{v} = \left(3.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}}\right)\text{ m/s}$$

(a) $$\mathbf{p} = m\mathbf{v} = \left(9.00\hat{\mathbf{i}} - 12.0\hat{\mathbf{j}}\right)\text{ kg}\cdot\text{m/s}$$

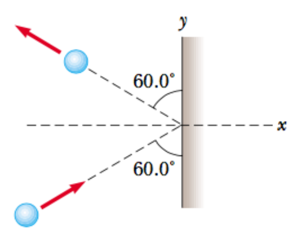
Thus, $$\boxed{p_x = 9.00\text{ kg}\cdot\text{m/s}}$$

and $$\boxed{p_y = -12.0\text{ kg}\cdot\text{m/s}}$$

(b) $$p = \sqrt{p_x^2 + p_y^2} = \sqrt{(9.00)^2 + (12.0)^2} = \boxed{15.0\text{ kg}\cdot\text{m/s}}$$

$$\theta = \tan^{-1}\left(\frac{p_y}{p_x}\right) = \tan^{-1}(-1.33) = \boxed{307°}$$

Q30: A 3.00-kg steel ball strikes a wall with a speed of 10.0 m/s at an angle of 60.0° with the surface. It bounces off with the same speed and angle below. If the ball is in contact with the wall for 0.200 s, what is the average force exerted by the wall on the ball ?



Ans:

$$\Delta\mathbf{p} = \mathbf{F}\Delta t$$

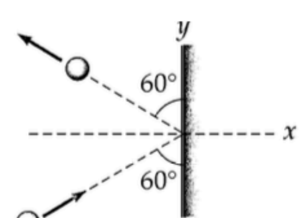
$$\Delta p_y = m\left(v_{fy} - v_{iy}\right) = m(v\cos 60.0°) - mv\cos 60.0° = 0$$

$$\Delta p_x = m(-v\sin 60.0° - v\sin 60.0°) = -2mv\sin 60.0°$$

$$= -2(3.00\text{ kg})(10.0\text{ m/s})(0.866)$$

$$= -52.0\text{ kg}\cdot\text{m/s}$$

$$F_{\text{ave}} = \frac{\Delta p_x}{\Delta t} = \frac{-52.0\text{ kg}\cdot\text{m/s}}{0.200\text{ s}} = \boxed{-260\text{ N}}$$



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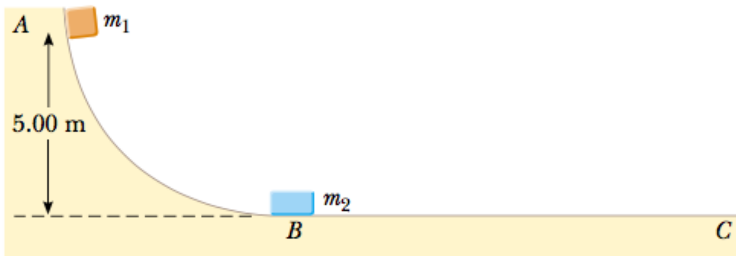
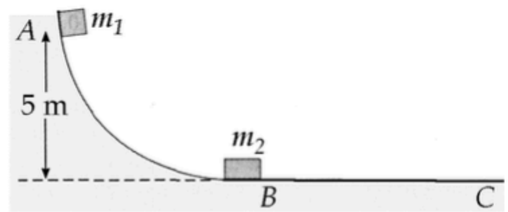
Q31: Two blocks are free to slide along the frictionless wooden track *ABC* shown in Figure below. The block of mass m_1 =5.00 kg is released from *A*. Protruding from its front end is the north pole of a strong magnet, repelling the north pole of an identical magnet embedded in the back end of the block of mass m_2 =10.0 kg, initially at rest. The two blocks never touch. Calculate the maximum height to which m_1 rises after the elastic collision.



Ans:



v_1, speed of m_1 at B before collision.

$$\frac{1}{2}m_1v_1^2 = m_1gh$$

$$v_1 = \sqrt{2(9.80)(5.00)} = 9.90 \text{ m/s}$$

v_{1f}, speed of m_1 at B just after collision.

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_1 = -\frac{1}{3}(9.90) \text{ m/s} = -3.30 \text{ m/s}$$

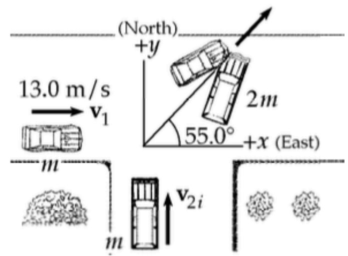
At the highest point (after collision)

$$m_1gh_{max} = \frac{1}{2}m_1(-3.30)^2 \qquad h_{max} = \frac{(-3.30 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = \boxed{0.556 \text{ m}}$$

. **Q32: Two automobiles of equal mass approach an intersection. One vehicle is traveling with velocity 13.0 m/s toward the east, and the other is traveling north with speed v_{2i}. Neither driver sees the other. The vehicles collide in the inter- section and stick together, leaving parallel skid marks at an angle of 55.0° north of east. The speed limit for both roads is 35 mi/h, and the driver of the northward-moving vehicle claims he was within the speed limit when the collision occurred. Is he telling the truth?**

Ans:

We use conservation of momentum for the system of two vehicles for both northward and eastward components.



For the eastward direction:

$$M(13.0\ \text{m/s}) = 2MV_f \cos 55.0°$$

For the northward direction:

$$Mv_{2i} = 2MV_f \sin 55.0°$$

Divide the northward equation by the eastward equation to find:

$$v_{2i} = (13.0\ \text{m/s})\tan 55.0° = 18.6\ \text{m/s} = \boxed{41.5\ \text{mi/h}}$$

Thus, the driver of the north bound car was untruthful.

CH10

Q33: A wheel starts from rest and rotates with constant angular acceleration to reach an angular speed of 12.0 rad/s in 3.00 s. Find (a) the magnitude of the angular acceleration of the wheel and (b) the angle in radians through which it rotates in this time.

Ans:

(a) $$\alpha = \frac{\omega - \omega_i}{t} = \frac{12.0 \text{ rad/s}}{3.00 \text{ s}} = \boxed{4.00 \text{ rad/s}^2}$$

(b) $$\theta = \omega_i t + \frac{1}{2}\alpha t^2 = \frac{1}{2}\left(4.00 \text{ rad/s}^2\right)(3.00 \text{ s})^2 = \boxed{18.0 \text{ rad}}$$

Q34: A disk 8.00 cm in radius rotates at a constant rate of 1200 rev/min about its central axis. Determine (a) its angular speed, (b) the tangential speed at a point 3.00 cm from its center, (c) the radial acceleration of a point on the rim, and (d) the total distance a point on the rim moves in 2.00 s.

Ans:

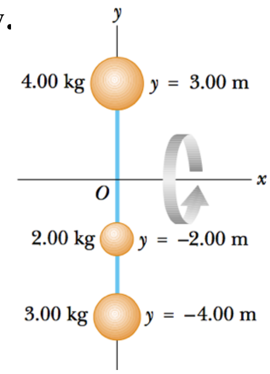
(a) $$\omega = 2\pi f = \frac{2\pi \text{ rad}}{1 \text{ rev}}\left(\frac{1\,200 \text{ rev}}{60.0 \text{ s}}\right) = \boxed{126 \text{ rad/s}}$$

(b) $$v = \omega r = (126 \text{ rad/s})\left(3.00 \times 10^{-2} \text{ m}\right) = \boxed{3.77 \text{ m/s}}$$

(c) $$a_c = \omega^2 r = (126)^2\left(8.00 \times 10^{-2}\right) = 1\,260 \text{ m/s}^2 \text{ so } \mathbf{a}_r = \boxed{1.26 \text{ km/s}^2 \text{ toward the center}}$$

(d) $$s = r\theta = \omega r t = (126 \text{ rad/s})\left(8.00 \times 10^{-2} \text{ m}\right)(2.00 \text{ s}) = \boxed{20.1 \text{ m}}$$

Q35: Rigid rods of negligible mass lying along the *y* axis connect three particles below. If the system rotates about the *x* axis with an angular speed of 2.00 rad/s, find (b) the moment of inertia about the *x* axis and the total rotational kinetic energy evaluated from $\frac{1}{2}I\omega^2$ and (b) the tangential speed of each particle and the total kinetic energy evaluated from $\Sigma\frac{1}{2}m_i v_i{}^2$



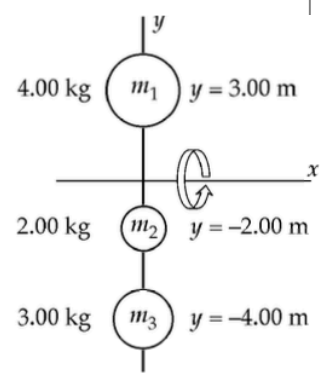
Ans:

$m_1 = 4.00$ kg, $r_1 = |y_1| = 3.00$ m;

$m_2 = 2.00$ kg, $r_2 = |y_2| = 2.00$ m;

$m_3 = 3.00$ kg, $r_3 = |y_3| = 4.00$ m;

$\omega = 2.00$ rad/s about the x-axis



(a) $I_x = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2$

$I_x = 4.00(3.00)^2 + 2.00(2.00)^2 + 3.00(4.00)^2 = \boxed{92.0\ \text{kg}\cdot\text{m}^2}$

$K_R = \frac{1}{2}I_x\omega^2 = \frac{1}{2}(92.0)(2.00)^2 = \boxed{184\ \text{J}}$

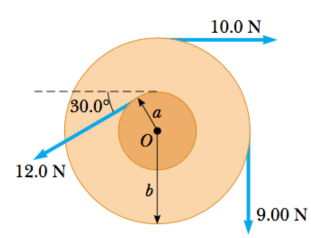
(b) $v_1 = r_1\omega = 3.00(2.00) = \boxed{6.00\ \text{m/s}}$ $\qquad K_1 = \frac{1}{2}m_1 v_1^2 = \frac{1}{2}(4.00)(6.00)^2 = 72.0\ \text{J}$

$v_2 = r_2\omega = 2.00(2.00) = \boxed{4.00\ \text{m/s}}$ $\qquad K_2 = \frac{1}{2}m_2 v_2^2 = \frac{1}{2}(2.00)(4.00)^2 = 16.0\ \text{J}$

$v_3 = r_3\omega = 4.00(2.00) = \boxed{8.00\ \text{m/s}}$ $\qquad K_3 = \frac{1}{2}m_3 v_3^2 = \frac{1}{2}(3.00)(8.00)^2 = 96.0\ \text{J}$

$K = K_1 + K_2 + K_3 = 72.0 + 16.0 + 96.0 = \boxed{184\ \text{J}} = \frac{1}{2}I_x\omega^2$

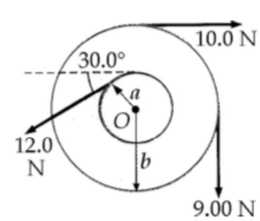
Q36: Find the net torque on the wheel in Figure below about the axle through *O* if *a*= 10.0 cm and *b*= 25.0 cm.



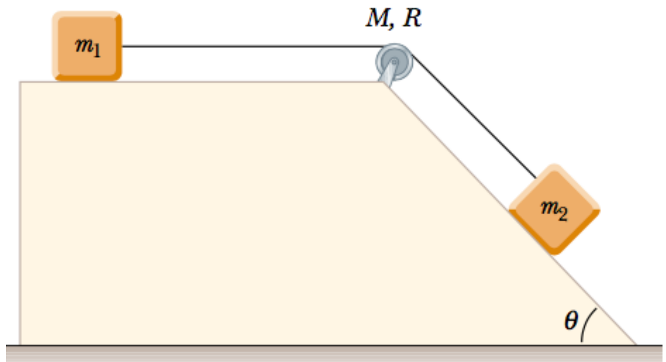
Ans:

$\sum\tau = 0.100\ \text{m}(12.0\ \text{N}) - 0.250\ \text{m}(9.00\ \text{N}) - 0.250\ \text{m}(10.0\ \text{N}) = \boxed{-3.55\ \text{N}\cdot\text{m}}$

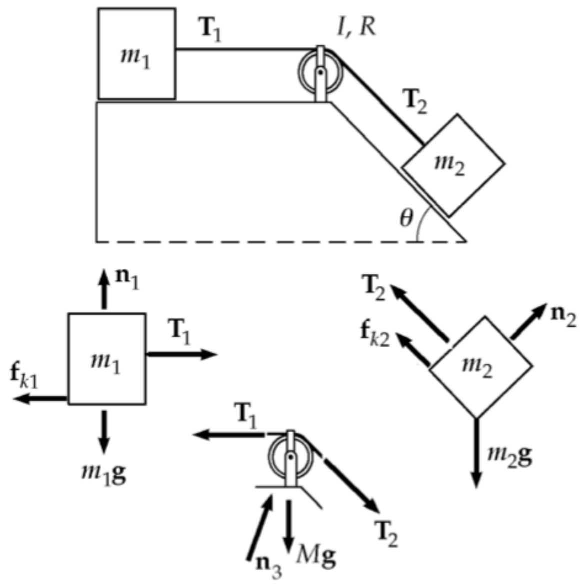
The thirty-degree angle is unnecessary information.



Q37: A block of mass m_1=2.00 kg and a block of mass m_2=6.00 kg are connected by a massless string over a pulley in the shape of a solid disk having radius R= 0.250 m and mass M= 10.0 kg. These blocks are allowed to move on a fixed block-wedge of angle 30.0° as in Figure below. The coefficient of kinetic friction is 0.360 for both blocks. Draw free-body diagrams of both blocks and of the pulley. Determine (a) the acceleration of the two blocks and (b) the tensions in the string on both sides of the pulley.



Ans:



For m_1,

$\sum F_y = ma_y$: $\quad +n - m_1 g = 0$

$$n_1 = m_1 g = 19.6\text{ N}$$
$$f_{k1} = \mu_k n_1 = 7.06\text{ N}$$

$\sum F_x = ma_x$: $\quad -7.06\text{ N} + T_1 = (2.00\text{ kg})a \qquad (1)$

For the pulley,

$\sum \tau = I\alpha$: $\quad -T_1 R + T_2 R = \frac{1}{2}MR^2\left(\frac{a}{R}\right)$

$$-T_1 + T_2 = \frac{1}{2}(10.0\text{ kg})a$$
$$-T_1 + T_2 = (5.00\text{ kg})a \qquad (2)$$

For m_2, $\quad +n_2 - m_2 g\cos\theta = 0$

$$n_2 = 6.00\text{ kg}\left(9.80\text{ m/s}^2\right)(\cos 30.0°)$$
$$= 50.9\text{ N}$$

$f_{k2} = \mu_k n_2$

$= 18.3\text{ N}$: $\quad -18.3\text{ N} - T_2 + m_2 \sin\theta = m_2 a$

$$-18.3\text{ N} - T_2 + 29.4\text{ N} = (6.00\text{ kg})a \qquad (3)$$

(a) Add equations (1), (2), and (3):

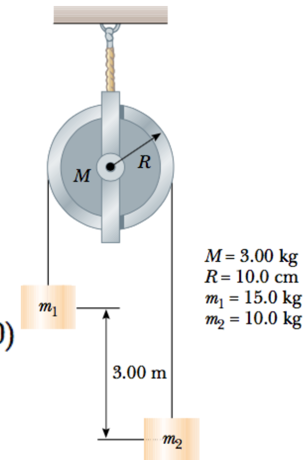
$$-7.06\text{ N} - 18.3\text{ N} + 29.4\text{ N} = (13.0\text{ kg})a$$
$$a = \frac{4.01\text{ N}}{13.0\text{ kg}} = \boxed{0.309\text{ m/s}^2}$$

(b) $T_1 = 2.00\text{ kg}\left(0.309\text{ m/s}^2\right) + 7.06\text{ N} = \boxed{7.67\text{ N}}$

$T_2 = 7.67\text{ N} + 5.00\text{ kg}\left(0.309\text{ m/s}^2\right) = \boxed{9.22\text{ N}}$

Q38: A 15.0-kg object and a 10.0-kg object are suspended, joined by a cord that passes over a pulley with a radius of 10.0 cm and a mass of 3.00 kg (Fig. below). The cord has a negligible mass and does not slip on the pulley. The pulley rotates on its axis without friction. The objects start from rest 3.00 m apart. Treat the pulley as a uniform disk, and determine the speeds of the two objects as they pass each other.

Ans:



Choose the zero gravitational potential energy at the level where the masses pass.

$$K_f + U_{gf} = K_i + U_{gi} + \Delta E$$

$$\frac{1}{2}m_1v^2 + \frac{1}{2}m_2v^2 + \frac{1}{2}I\omega^2 = 0 + m_1gh_{1i} + m_2gh_{2i} + 0$$

$$\frac{1}{2}(15.0 + 10.0)v^2 + \frac{1}{2}\left[\frac{1}{2}(3.00)R^2\right]\left(\frac{v}{R}\right)^2 = 15.0(9.80)(1.50) + 10.0(9.80)(-1.50)$$

$$\frac{1}{2}(26.5\text{ kg})v^2 = 73.5\text{ J} \Rightarrow v = \boxed{2.36\text{ m/s}}$$