Chapter 5 Solutions

P5.1 $m = 3.00\ \text{kg}$

$\vec{\mathbf{a}} = \left(2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}}\right)\ \text{m/s}^2$

$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}} = \boxed{\left(6.00\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}\right)\ \text{N}}$

$\left|\sum \vec{\mathbf{F}}\right| = \sqrt{(6.00)^2 + (15.0)^2}\ \text{N} = \boxed{16.2\ \text{N}}$

P5.3 $m = 4.00\ \text{kg}$, $\vec{\mathbf{v}}_i = 3.00\hat{\mathbf{i}}\ \text{m/s}$, $\vec{\mathbf{v}}_8 = \left(8.00\hat{\mathbf{i}} + 10.0\hat{\mathbf{j}}\right)\ \text{m/s}$, $t = 8.00\ \text{s}$

$\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{t} = \frac{5.00\hat{\mathbf{i}} + 10.0\hat{\mathbf{j}}}{8.00}\ \text{m/s}^2$

$\vec{\mathbf{F}} = m\vec{\mathbf{a}} = \boxed{\left(2.50\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}}\right)\ \text{N}}$

$F = \sqrt{(2.50)^2 + (5.00)^2} = \boxed{5.59\ \text{N}}$

P5.5 (a) $\sum F = ma$ and $v_f^2 = v_i^2 + 2ax_f$ or $a = \frac{v_f^2 - v_i^2}{2x_f}$

Therefore,

$$\sum F = m\frac{\left(v_f^2 - v_i^2\right)}{2x_f}$$

$$\sum F = 9.11\times10^{-31}\ \text{kg}\frac{\left[\left(7.00\times10^5\ \text{m/s}^2\right)^2 - \left(3.00\times10^5\ \text{m/s}^2\right)^2\right]}{2\left(0.050\,0\ \text{m}\right)} = \boxed{3.64\times10^{-18}\ \text{N}}$$

(b) The gravitational force exerted by the Earth on the electron is its weight,

$$F_g = mg = \left(9.11\times10^{-31}\ \text{kg}\right)\left(9.80\ \text{m/s}^2\right) = 8.93\times10^{-30}\ \text{N}$$

The accelerating force is $\boxed{4.08 + 10^{11}\ \text{times the weight of the electron}}$.

P5.9 (a) $\sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 = \left(20.0\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}}\right)$ N

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}: \quad 20.0\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}} = 5.00\vec{\mathbf{a}}$$

$$\vec{\mathbf{a}} = \left(4.00\hat{\mathbf{i}} + 3.00\hat{\mathbf{j}}\right)\ \text{m/s}^2$$

or

$$\boxed{a = 5.00\ \text{m/s}^2 \text{ at } \theta = 36.9^\circ}$$

(b)

$$F_{2x} = 15.0\cos 60.0^\circ = 7.50\ \text{N}$$

$$F_{2y} = 15.0\sin 60.0^\circ = 13.0\ \text{N}$$

$$\vec{\mathbf{F}}_2 = \left(7.50\hat{\mathbf{i}} + 13.0\hat{\mathbf{j}}\right)\ \text{N}$$

$$\sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 = \left(27.5\hat{\mathbf{i}} + 13.0\hat{\mathbf{j}}\right)\ \text{N} = m\vec{\mathbf{a}} = 5.00\vec{\mathbf{a}}$$

$$\vec{\mathbf{a}} = \boxed{\left(5.50\hat{\mathbf{i}} + 2.60\hat{\mathbf{j}}\right)\ \text{m/s}^2 = 6.08\ \text{m/s}^2 \text{ at } 25.3^\circ}$$

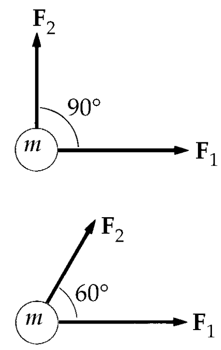

FIG. P5.9

P5.17

$$m = 1.00\ \text{kg}$$

$$mg = 9.80\ \text{N}$$

$$\tan\alpha = \frac{0.200\ \text{m}}{25.0\ \text{m}}$$

$$\alpha = 0.458^\circ$$

Balance forces,

$$2T\sin\alpha = mg$$

$$T = \frac{9.80\ \text{N}}{2\sin\alpha} = \boxed{613\ \text{N}}$$

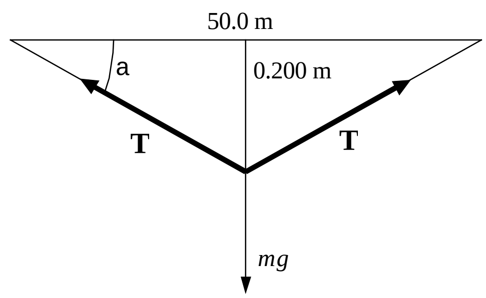

FIG. P5.17

P5.20 From equilibrium of the sack: $T_3 = F_g$ (1)

From $\sum F_y = 0$ for the knot: $T_1 \sin\theta_1 + T_2\sin\theta_2 = F_g$ (2)

From $\sum F_x = 0$ for the knot: $T_1\cos\theta_1 = T_2\cos\theta_2$ (3)

Eliminate $T_2 =$ $T_2 = T_1\cos\theta_1/\cos\theta_2$ and solve for T_1

$$T_1 = \frac{F_g\cos\theta_2}{(\sin\theta_1\cos\theta_2 + \cos\theta_1\sin\theta_2)} = \frac{F_g\cos\theta_2}{\sin(\theta_1+\theta_2)}$$

$$T_3 = F_g = \boxed{325\ \text{N}}$$

$$T_1 = F_g\left(\frac{\cos 25.0^\circ}{\sin 85.0^\circ}\right) = \boxed{296\ \text{N}}$$

$$T_2 = T_1\left(\frac{\cos\theta_1}{\cos\theta_2}\right) = 296\ \text{N}\left(\frac{\cos 60.0^\circ}{\cos 25.0^\circ}\right) = \boxed{163\ \text{N}}$$

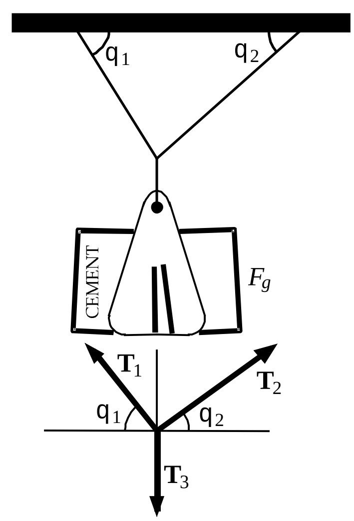

FIG. P5.20

P5.21 See the solution for T_1 in Problem 5.20. The equation indicates that the tension is directly proportional to F_g. As $\theta_1 + \theta_2$ approaches zero (as the angle between the two upper ropes approaches 180°) the tension goes to infinity. Making the right-hand rope horizontal maximizes the tension in the left-hand rope, according to the proportionality of T_1 to $\cos\theta_2$.

*P5.23 (a) Isolate either mass

$$T + mg = ma = 0$$

$$|T| = |mg|$$

The scale reads the tension T, so

$$T = mg = 5.00\text{ kg}\left(9.80\text{ m/s}^2\right) = \boxed{49.0\text{ N}}$$

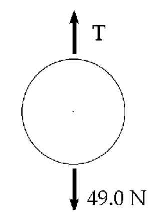

FIG. P5.23(a) and (b)

(b) The solution to part (a) is also the solution to (b).

(c) Isolate the pulley

$$\vec{\mathbf{T}}_2 + 2\vec{\mathbf{T}}_1 = 0$$

$$T_2 = 2|T_1| = 2mg = \boxed{98.0\text{ N}}$$

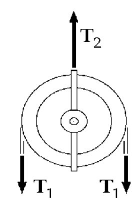

FIG. P5.23(c)

(d) $\sum \vec{\mathbf{F}} = \vec{\mathbf{n}} + \vec{\mathbf{T}} + m\vec{\mathbf{g}} = 0$

Take the component along the incline

$$n_x + T_x + mg_x = 0$$

or

$$0 + T - mg\sin 30.0° = 0$$

$$T = mg\sin 30.0° = \frac{mg}{2} = \frac{5.00(9.80)}{2}$$

$$= \boxed{24.5\text{ N}}$$

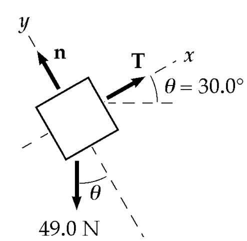

FIG. P5.23(d)

P5.25 Choose a coordinate system with $\hat{\mathbf{i}}$ East and $\hat{\mathbf{j}}$ North.

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}} = 1.00\text{ kg}\left(10.0\text{ m/s}^2\right)\text{ at }30.0°$$

$$(5.00\text{ N})\hat{\mathbf{j}} + \vec{\mathbf{F}}_1 = (10.0\text{ N})\angle 30.0° = (5.00\text{ N})\mathbf{j} + (8.66\text{ N})\mathbf{i}$$

$$\therefore F_1 = \boxed{8.66\text{ N (East)}}$$

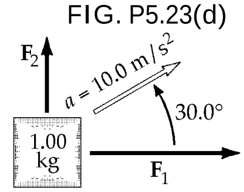

FIG. P5.25

P5.26 First, consider the block moving along the horizontal. The only force in the direction of movement is T. Thus, $\sum F_x = ma$

$$T = (5\text{ kg})a \qquad (1)$$

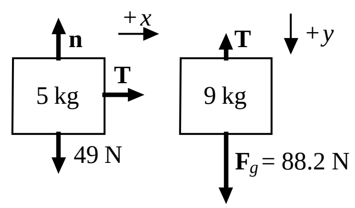

FIG. P5.26

Next consider the block that moves vertically. The forces on it are the tension T and its weight, 88.2 N.

We have $\sum F_y = ma$

$$88.2\text{ N} - T = (9\text{ kg})a \qquad (2)$$

Note that both blocks must have the same magnitude of acceleration. Equations (1) and (2) can be added to give $88.2\text{ N} = (14\text{ kg})a$. Then

$$\boxed{a = 6.30\text{ m/s}^2 \text{ and } T = 31.5\text{ N}}$$

*P5.27 (a) and (b) The slope of the graph of upward velocity versus time is the acceleration of the person's body. At both time 0 and time 0.5 s, this slope is (18 cm/s)/0.6 s = 30 cm/s^2.

For the person's body, $\Sigma F_y = ma_y$: $+F_{bar} - 64\text{ kg}(9.8\text{ m/s}^2) = 64\text{ kg}(0.3\text{ m/s}^2)$

Note that there is no floor touching the person to exert a normal force. Note that he does not exert any extra force 'on himself.' Solving, $F_{bar} = \boxed{646\text{ N}}$ up.

(c) a_y = slope of v_y versus t graph = 0 at t = 1.1 s. The person is moving with maximum speed and is momentarily in equilibrium:

$$+F_{bar} - 64\text{ kg}(9.8\text{ m/s}^2) = 0 \qquad F_{bar} = \boxed{627\text{ N}} \text{ up.}$$

(d) a_y = slope of v_y versus t graph = (0 – 24 cm/s)/(1.7 s – 1.3 s) = –60 cm/s^2

$$+F_{bar} - 64\text{ kg}(9.8\text{ m/s}^2) = 64\text{ kg}(-0.6\text{ m/s}^2) \qquad F_{bar} = \boxed{589\text{ N}} \text{ up.}$$

P5.29 After it leaves your hand, the block's speed changes only because of one component of its weight:

$$\sum F_x = ma_x \quad -mg\sin 20.0° = ma$$

$$v_f^2 = v_i^2 + 2a\left(x_f - x_i\right)$$

Taking $v_f = 0$, $v_i = 5.00$ m/s, and $a = -g\sin(20.0°)$ gives

$$0 = (5.00)^2 - 2(9.80)\sin(20.0°)\left(x_f - 0\right)$$

or

$$x_f = \frac{25.0}{2(9.80)\sin(20.0°)} = \boxed{3.73\text{ m}}$$

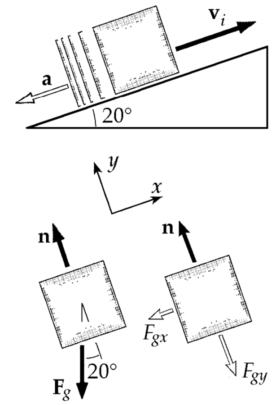

FIG. P5.29

P5.31 Forces acting on 2.00 kg block:

$$T - m_1 g = m_1 a \qquad (1)$$

Forces acting on 8.00 kg block:

$$F_x - T = m_2 a \qquad (2)$$

(a) Eliminate T and solve for a:

$$a = \frac{F_x - m_1 g}{m_1 + m_2}$$

$$\boxed{a > 0 \text{ for } F_x > m_1 g = 19.6\text{ N}}$$

(b) Eliminate a and solve for T:

$$T = \frac{m_1}{m_1 + m_2}\left(F_x + m_2 g\right)$$

$$\boxed{T = 0 \text{ for } F_x \le -m_2 g = -78.4\text{ N}}$$

(c)

F_x, N	•100	•78.4	•50.0	0	50.0	100
a_x, m/s^2	•12.5	•9.80	•6.96	•1.96	3.04	8.04

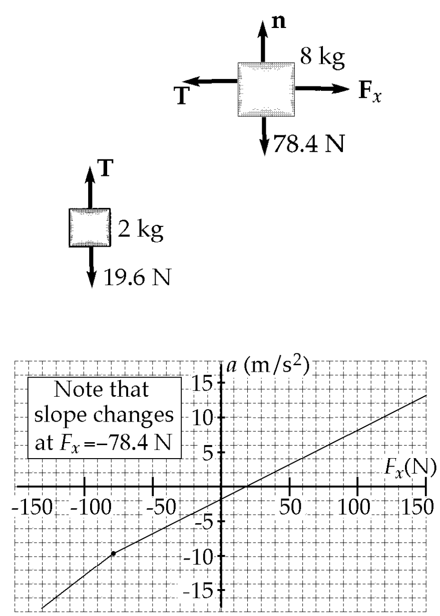

FIG. P5.31

*P5.37 (a) The car's acceleration in stopping is given by $v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$

$0 = (20\text{ m/s})^2 + 2a_x(45\text{ m} - 0)$ $\qquad a_x = -4.44\text{ m/s}^2$.

For the book not to slide on the horizontal seat we need

$$\sum F_x = ma_x: \quad -f_s = ma = 3.8\text{ kg}(-4.44\text{ m/s}^2) \qquad f_s = 16.9\text{ N}$$

$$\sum F_y = ma_y: \quad n - mg = 0 \qquad n = 3.8\ \text{kg}(9.8\ \text{m/s}^2) = 37.2\ \text{N}$$

To test whether the book starts to slide, we see if this required static friction force is available in the allowed range

$$f_s \le \mu_s n = 0.65(37.2\ \text{N}) = 24.2\ \text{N}$$

Because 16.9 N is less than 24.2 N, $\boxed{\text{the book does not start to slide}}$.

(b) The actual friction force is 16.9 N backwards, and the whole force exerted by the seat on the book is $\boxed{16.9\ \text{N backward} + 37.2\ \text{N upward}}$ = 40.9 N upward and backward at 65.6° with the horizontal.

P5.39 $m = 3.00\ \text{kg}$, $\theta = 30.0°$, $x = 2.00\ \text{m}$, $t = 1.50\ \text{s}$

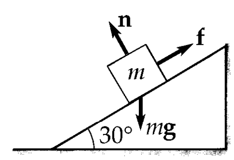

FIG. P5.39

(a) $x = \frac{1}{2}at^2$:

$$2.00\ \text{m} = \frac{1}{2}a(1.50\ \text{s})^2$$

$$a = \frac{4.00}{(1.50)^2} = \boxed{1.78\ \text{m/s}^2}$$

$$\sum \vec{\mathbf{F}} = \vec{\mathbf{n}} + \vec{\mathbf{f}} + m\vec{\mathbf{g}} = m\vec{\mathbf{a}}:$$

Along x: $0 - f + mg\sin 30.0° = ma$

$f = m(g\sin 30.0° - a)$

Along y: $n + 0 - mg\cos 30.0° = 0$

$n = mg\cos 30.0°$

(b) $\mu_k = \dfrac{f}{n} = \dfrac{m(g\sin 30.0° - a)}{mg\cos 30.0°}$, $\mu_k = \tan 30.0° - \dfrac{a}{g\cos 30.0°} = \boxed{0.368}$

(c) $f = m(g\sin 30.0° - a)$, $f = 3.00(9.80\sin 30.0° - 1.78) = \boxed{9.37\ \text{N}}$

(d) $v_f^2 = v_i^2 + 2a(x_f - x_i)$

where

$$x_f - x_i = 2.00\ \text{m}$$

$$v_f^2 = 0 + 2(1.78)(2.00) = 7.11\ \text{m}^2/\text{s}^2$$

$$v_f = \sqrt{7.11\ \text{m}^2/\text{s}^2} = \boxed{2.67\ \text{m/s}}$$

P5.42 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

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

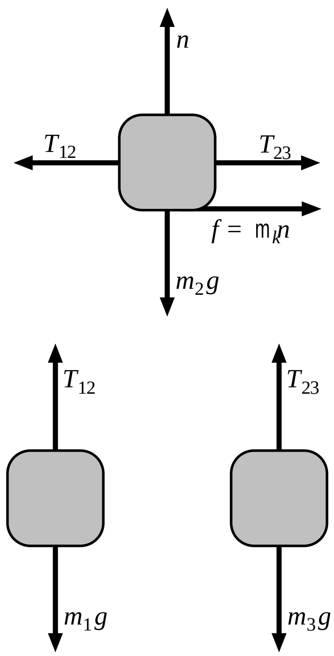

FIG. P5.42

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

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

P5.43 (a) See the figure adjoining

(b)
$$68.0 - T - \mu m_2 g = m_2 a \quad \text{(Block \#2)}$$
$$T - \mu m_1 g = m_1 a \quad \text{(Block \#1)}$$

Adding,

$$68.0 - \mu(m_1 + m_2)g = (m_1 + m_2)a$$
$$a = \frac{68.0}{(m_1 + m_2)} - \mu g = \boxed{1.29\text{ m/s}^2}$$
$$T = m_1 a + \mu m_1 g = \boxed{27.2\text{ N}}$$

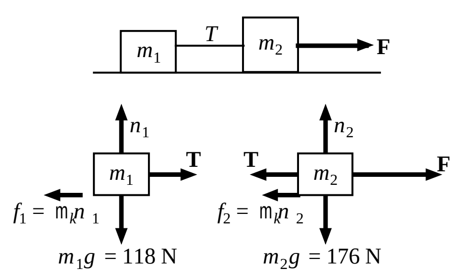

FIG. P5.43

P5.51 (a) see figure to the right

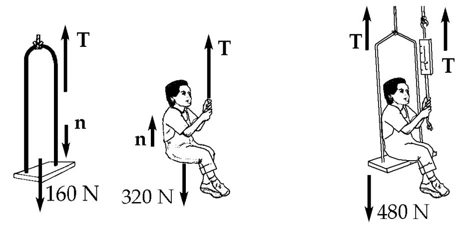

FIG. P5.51

(b) First consider Pat and the chair as the system. Note that two ropes support the system, and $T = 250\text{ N}$ in each rope. Applying $\sum F = ma$

$$2T - 480 = ma\text{, where } m = \frac{480}{9.80} = 49.0\text{ kg}$$

Solving for a gives

$$a = \frac{500 - 480}{49.0} = \boxed{0.408\ \text{m/s}^2}$$

(c) $\sum F = ma$ on Pat:

$$\sum F = n + T - 320 = ma\text{, where } m = \frac{320}{9.80} = 32.7\text{ kg}$$

$$n = ma + 320 - T = 32.7(0.408) + 320 - 250 = \boxed{83.3\text{ N}}\,.$$

P5.54 (a) We write $\Sigma F_x = ma_x$ for each object.

$$18\text{ N} - P = (2\text{ kg})a$$
$$P - Q = (3\text{ kg})a$$
$$Q = (4\text{ kg})a$$

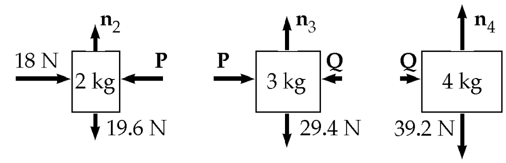

FIG. P5.54

Adding gives $18\text{ N} = (9\text{ kg})a$ so

$$a = \boxed{2.00\ \text{m/s}^2}$$

(b) $Q = 4\text{ kg}(2\text{ m/s}^2) = \boxed{8.00\text{ N net force on the 4 kg}}$

$P - 8\text{ N} = 3\text{ kg}(2\text{ m/s}^2) = \boxed{6.00\text{ N net force on the 3 kg}}$ and $P = 14\text{ N}$

$18\text{ N} - 14\text{ N} = 2\text{ kg}(2\text{ m/s}^2) = \boxed{4.00\text{ N net force on the 2 kg}}$

(c) From above, $Q = \boxed{8.00\text{ N}}$ and $P = \boxed{14.0\text{ N}}$.

(d) The 3-kg block models the heavy block of wood. The contact force on your back is represented by Q, which is much less than the force F. The difference between F and Q is the net force causing acceleration of the 5-kg pair of objects. The acceleration is real and nonzero, but lasts for so short a time that it never is associated with a large velocity. The frame of the building and your legs exert forces, small relative to the hammer blow, to bring the partition, block, and you to rest again over a time large relative to the hammer blow. This problem lends itself to interesting lecture demonstrations. One person can hold a lead brick in one hand while another hits the brick with a hammer.

P5.62 (a) Following the in-chapter example about a block on a frictionless incline, we have

$$a = g\sin\theta = (9.80\ \text{m/s}^2)\sin 30.0°$$

$$\boxed{a = 4.90\ \text{m/s}^2}$$

(b) The block slides distance x on the incline, with $\sin 30.0° = \frac{0.500\text{ m}}{x}$

$$x = 1.00\text{ m}: \; v_f^2 = v_i^2 + 2a\left(x_f - x_i\right) = 0 + 2\left(4.90\text{ m/s}^2\right)(1.00\text{ m})$$

$$v_f = \boxed{3.13\text{ m/s}} \text{ after time } t_s = \frac{2x_f}{v_f} = \frac{2(1.00\text{ m})}{3.13\text{ m/s}} = 0.639\text{ s}$$

(c) Now in free fall $y_f - y_i = v_{yi}t + \frac{1}{2}a_y t^2$:

$$-2.00 = (-3.13\text{ m/s})\sin 30.0° t - \frac{1}{2}\left(9.80\text{ m/s}^2\right)t^2$$

$$\left(4.90\text{ m/s}^2\right)t^2 + (1.56\text{ m/s})t - 2.00\text{ m} = 0$$

$$t = \frac{-1.56\text{ m/s} \pm \sqrt{(1.56\text{ m/s})^2 - 4\left(4.90\text{ m/s}^2\right)(-2.00\text{ m})}}{9.80\text{ m/s}^2}$$

Only the positive root is physical

$$t = 0.499\text{ s}$$

$$x_f = v_x t = \left[(3.13\text{ m/s})\cos 30.0°\right](0.499\text{ s}) = \boxed{1.35\text{ m}}$$

(d) total time $= t_s + t = 0.639\text{ s} + 0.499\text{ s} = \boxed{1.14\text{ s}}$

(e) $\boxed{\text{The mass of the block makes no difference.}}$

P5.67 $\sum F = ma$

For m_1: $T = m_1 a$

For m_2: $T - m_2 g = 0$

Eliminating T,

$$a = \frac{m_2 g}{m_1}$$

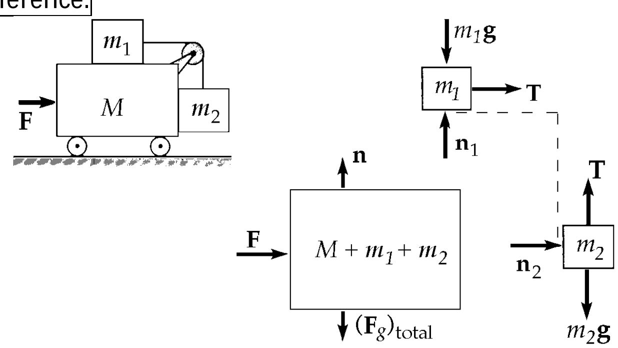

FIG. P5.67

For all 3 blocks:

$$F = (M + m_1 + m_2)a = \boxed{(M + m_1 + m_2)\left(\frac{m_2 g}{m_1}\right)}$$