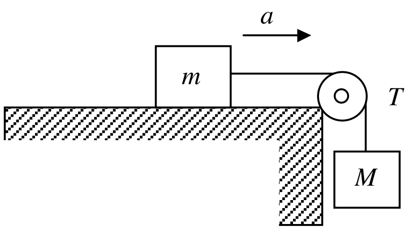
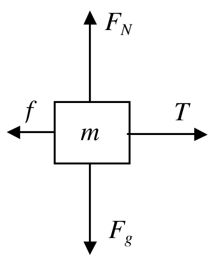
# HO 7 Solutions

1.) 


$m = 2.5\text{ kg},\ M = 5.0\text{ kg},\ \mu_k = 0.25$

The force diagram on *m*



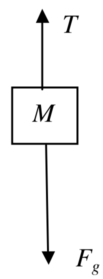

Newton's 2nd Law (in direction of *a*)

$$F_{net} = \sum F = ma$$

$$T - f = ma$$

(1) $T - \mu_k mg = ma$

The force diagram on *M*




Newton's 2nd Law (in direction of *a*)

$$F_{net} = \sum F = ma$$

$$F_g - T = Ma$$

(2) $Mg - T = Ma$

Combining equations (1) and (2)

$$Mg - \mu_k mg = ma + Ma = a(m + M) \quad \text{and} \quad a = \frac{g(M - \mu_k m)}{(m + M)} = \frac{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(5.0\text{ kg} - 0.25(2.5\text{ kg}))}{(5.0\text{ kg} + 2.5\text{ kg})} = \boxed{5.72\ \frac{\text{m}}{\text{s}^2}}$$

The tension can be obtained from (1) or (2)

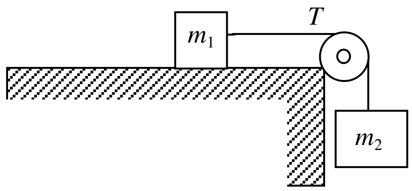
Using (1)

$$T = ma + \mu_k mg = m(a + \mu_k g) = (2.5\text{ kg})\left(5.72\ \frac{\text{m}}{\text{s}^2} + 0.25\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\right) = \boxed{20.4\text{ N}}$$

Using (2)

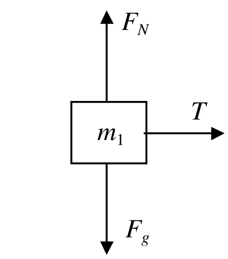
$$T = Mg - Ma = M(g - a) = (5.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2} - 5.72\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{20.4\text{ N}}$$

2.)

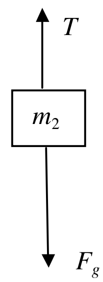



$m_1 = 5.0\text{ kg}$, $T = 9.0\text{ N}$ and frictionless surfaces

The force diagram on $m_1$




The force diagram on $m_2$




Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

(1) $T = m_1 a$

Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

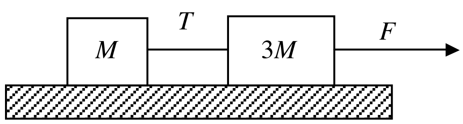
$$F_g - T = m_2 a$$

(2) $m_2 g - T = m_2 a$

From (1), $a = \dfrac{T}{m_1} = \dfrac{9.0\text{ N}}{5.0\text{ kg}} = 1.8\ \dfrac{\text{m}}{\text{s}^2}$

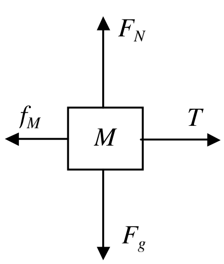
From (2), $m_2 g - m_2 a = T$ and $m_2 = \dfrac{T}{(g-a)} = \dfrac{9.0\text{ N}}{\left(9.8\ \dfrac{\text{m}}{\text{s}^2} - 1.8\ \dfrac{\text{m}}{\text{s}^2}\right)} = \boxed{1.13\text{ kg}}$

3.)

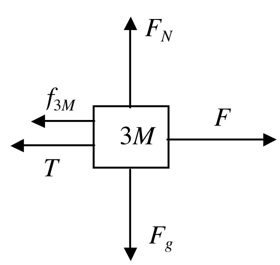



$F = 14\text{ N}$, $M = 1.0\text{ kg}$, $\mu_M = 0.30$, and $\mu_{3M} = 0.20$

The force diagram on $M$




The force diagram on $3M$




Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

$$T - f_M = Ma$$

(1) $T - \mu_M Mg = Ma$

Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

$$F - T - f_{3M} = 3Ma$$

(2) $F - T - \mu_{3M} 3Mg = 3Ma$

3.) cont'd

Combining (1) and (2)

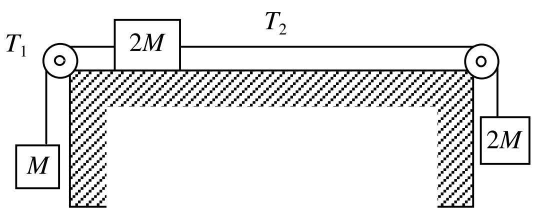
$$F - \mu_{3M}\, 3Mg - \mu_M Mg = 3Ma + Ma = 4Ma$$

$$a = \frac{F - \mu_{3M}\, 3Mg - \mu_M Mg}{4M} = \frac{14\ \text{N} - 0.20(3.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) - 0.30(1.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{(4.0\ \text{kg})} = \boxed{1.30\ \frac{\text{m}}{\text{s}^2}}$$

The tension can be obtained from (1) or (2)

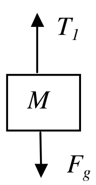
Using (1) $$T = Ma + \mu_M Mg = (1.0\ \text{kg})\left(1.30\ \frac{\text{m}}{\text{s}^2}\right) + 0.30(1.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{4.24\ \text{N}}$$

4.)

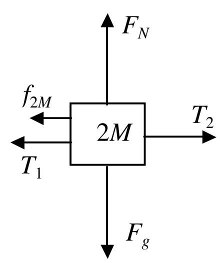



$a = 1.5\ \frac{\text{m}}{\text{s}^2},\ M = 2.0\ \text{kg}$

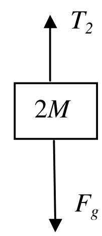
The force diagram on $M$




The force diagram on $2M$




The force diagram on $2M$




Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

$$T_1 - F_g = Ma$$

(1) $$T_1 - Mg = Ma$$

Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

$$T_2 - T_1 - f_{2M} = 2Ma$$

(2) $$T_2 - T_1 - f_{2M} = 2Ma$$

Newton's 2nd Law (in direction of $a$)

$$F_{net} = \sum F = ma$$

$$F_g - T_2 = 2Ma$$

(3) $$2Mg - T_2 = 2Ma$$

From (1)

$$T_1 = Ma + Mg = M(a+g) = (2.0\ \text{kg})\left(1.5\ \frac{\text{m}}{\text{s}^2} + 9.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{22.6\ \text{N}}$$

From (3)

$$T_2 = 2Mg - 2Ma = 2M(g-a) = 2(2.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2} - 1.5\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{33.2\ \text{N}}$$

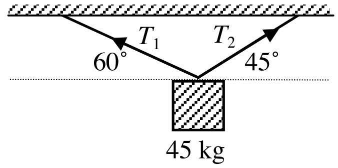
From (2)

$$f_{2M} = T_2 - T_1 - 2Ma = 33.2\ \text{N} - 22.6\ \text{N} - 2(2.0\ \text{kg})\left(1.5\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{4.6\ \text{N}}$$

so $$\mu_k = \frac{f_{2M}}{F_{N_{2M}}} = \frac{f_{2M}}{F_{N_{2M}}} = \frac{f_{2M}}{2Mg}$$

$$\mu_k = \frac{4.6\ \text{N}}{2(2.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{0.117}$$

1.)




$$F_g = mg = (45\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 441\text{ N}$$

Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma = 0$$

$$T_{2x} + T_{1x} = 0$$

$$(1)\quad T_2\cos\theta_2 + T_1\cos\theta_1 = 0$$

Newton's 2nd Law (in $y$-direction)

$$F_{net} = \sum F = ma = 0$$

$$T_{2y} + T_{1y} - F_g = 0$$

$$(2)\quad T_2\sin\theta_2 + T_1\sin\theta_1 = F_g$$

From equation (1)

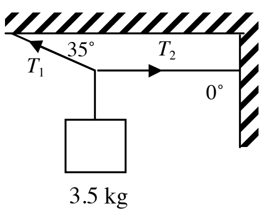
$$T_2 = \frac{-T_1\cos\theta_1}{\cos\theta_2}$$ substituting in equation (2) $$\left(\frac{-T_1\cos\theta_1}{\cos\theta_2}\right)\sin\theta_2 + T_1\sin\theta_1 = F_g$$

$$T_1(\sin\theta_1 - \cos\theta_1\tan\theta_2) = F_g$$

$$T_1 = \frac{F_g}{(\sin\theta_1 - \cos\theta_1\tan\theta_2)} = \frac{441\text{ N}}{(\sin 120° - \cos 120°\tan 45°)} = \boxed{323\text{ N}}$$

$$T_2 = \frac{-T_1\cos\theta_1}{\cos\theta_2} = \frac{-(323\text{ N})\cos 120°}{\cos 45°} = \boxed{228\text{ N}}$$

2.)




$$F_g = mg = (3.5\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 34.3\text{ N}$$

Using result from problem 1:

$$T_1 = \frac{F_g}{(\sin\theta_1 - \cos\theta_1\tan\theta_2)} = \frac{34.3\text{ N}}{(\sin 145° - \cos 145°\tan 0°)} = \boxed{59.8\text{ N}}$$

$$T_2 = \frac{-T_1\cos\theta_1}{\cos\theta_2} = \frac{-(59.8\text{ N})\cos 145°}{\cos 0°} = \boxed{49.0\text{ N}}$$

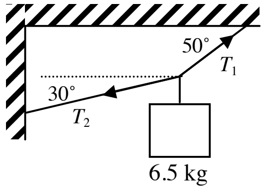
or

using (1) $T_2\cos\theta_2 + T_1\cos\theta_1 = 0$ and since $\theta_2 = 0$ $\quad T_2 = -T_1\cos\theta_1$

using (2) $T_2\sin\theta_2 + T_1\sin\theta_1 = F_g$ and since $\theta_2 = 0$ $\quad T_1 = \dfrac{F_g}{\sin\theta_1} = \dfrac{34.3\text{ N}}{\sin 145°} = \boxed{59.8\text{ N}}$

$$T_2 = -T_1\cos\theta_1 = -(59.8\text{ N})\cos 145° = \boxed{49.0\text{ N}}$$

3.)



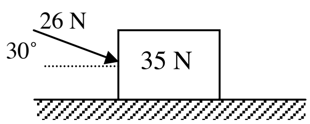

$$F_g = mg = (6.5\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 63.7\text{ N}$$

Using result from problem 1:

$$T_1 = \frac{F_g}{(\sin\theta_1 - \cos\theta_1\tan\theta_2)} = \frac{63.7\text{ N}}{(\sin 50° - \cos 50° \tan 210°)} = \boxed{161\text{ N}}$$

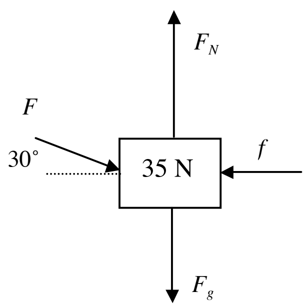
$$T_2 = \frac{-T_1\cos\theta_1}{\cos\theta_2} = \frac{-(161\text{ N})\cos 50°}{\cos 210°} = \boxed{120\text{ N}}$$

4.)




constant velocity so $a = 0$

a.)




b.)

Newton's 2nd Law (in $x$-direction)

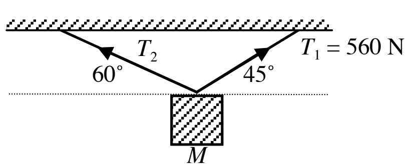
$$F_{net} = \sum F = ma = 0$$

$$F_x - f = 0 \text{ so } f = F_x = F\cos\theta = (26\text{ N})\cos 30° = \boxed{22.5\text{ N}}$$

c.) $f = \mu F_N$

$$\mu = \frac{f}{F_N} = \frac{f}{F_g + F_y} = \frac{f}{F_g + F\sin\theta} = \frac{22.5\text{ N}}{35\text{ N} + (26\text{ N})\sin 30°} = \boxed{0.47}$$

5.)




a.) From Problem 1

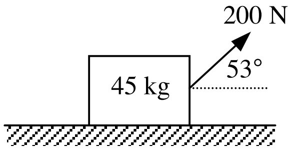
(1) $T_2\cos\theta_2 + T_1\cos\theta_1 = 0$

$$T_2 = \frac{-T_1\cos\theta_1}{\cos\theta_2} = \frac{-(560\text{ N})\cos 45°}{\cos 120°} = \boxed{792\text{ N}}$$

b.) From Problem 1

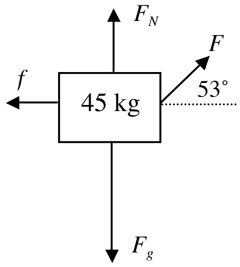
(2) $T_2\sin\theta_2 + T_1\sin\theta_1 = F_g = Mg$

$$M = \frac{T_2\sin\theta_2 + T_1\sin\theta_1}{g} = \frac{(792\text{ N})\sin 120° + (560\text{ N})\sin 45°}{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{110\text{ kg}}$$

6.) 


$\mu = 0.30$ and $F_g = mg = (45\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 441\text{ N}$

a.)




b.)

Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma$$

$$F_x - f = ma$$

$$a = \frac{F_x - f}{m} = \frac{F_x - \mu F_N}{m} = \frac{F_x - \mu\left(F_g - F_y\right)}{m}$$

$$a = \frac{F\cos\theta - \mu\left(F_g - F\sin\theta\right)}{m} = \frac{(200\text{ N})\cos 53° - 0.30\left(441\text{ N} - (200\text{ N})\sin 53°\right)}{45\text{ kg}} = \boxed{0.80\ \frac{\text{m}}{\text{s}^2}}$$

c.)

$$a = 1.60\ \frac{\text{m}}{\text{s}^2}$$

$$F_x - f = ma$$

$$F\cos\theta - \mu\left(F_g - F\sin\theta\right) = ma$$

$$F\left(\cos\theta + \mu\sin\theta\right) - \mu F_g = ma$$

$$F = \frac{ma + \mu F_g}{\cos\theta + \mu\sin\theta} = \frac{(45\text{ kg})\left(1.60\ \frac{\text{m}}{\text{s}^2}\right) + 0.30(441\text{ N})}{\cos 53° + 0.30\sin 53°} = \boxed{243\text{ N}}$$

7.) $v_o = 20.0\ \frac{\text{m}}{\text{s}}$, $\Delta x = 120\text{ m}$, and $v = 0$

$$v^2 = v_o^2 + 2a\Delta x \text{ so } a = \frac{v^2 - v_o^2}{2\Delta x} = \frac{0 - \left(20.0\ \frac{\text{m}}{\text{s}}\right)^2}{2(120\text{ m})} = -1.67\ \frac{\text{m}}{\text{s}^2}$$

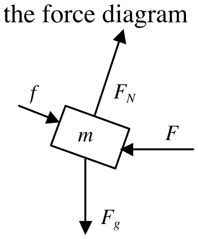
Newton's 2nd Law (in $x$-direction)

$F_{net} = \sum F = ma$ (only force is friction in the direction of $a$)

$$f = ma \text{ so } \mu F_g = \mu mg = ma \text{ and } \mu = \frac{a}{g} = \frac{\left(1.67\ \frac{\text{m}}{\text{s}^2}\right)}{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{0.17}$$

b.) $\mu = 0.20$

the force diagram




$$f = \mu F_N = \mu\left(F_g\cos\theta + F_y\right) = \mu\left(F_g\cos\theta + F\sin\theta\right)$$

Newton's 2nd Law (along the plane)

$$F_{net} = \sum F = ma$$
$$F_x - F_{\parallel} - f = ma$$
$$a = \frac{F_x - F_{\parallel} - f}{m} = \frac{F\cos\theta - F_g\sin\theta - \mu\left(F_g\cos\theta + F\sin\theta\right)}{m}$$

$$a = \frac{(40\text{ N})\cos30° - (4.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin30° - 0.20\left((4.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\cos30° + (40\text{ N})\sin30°\right)}{(4.0\text{ kg})} = \boxed{1.06\ \frac{\text{m}}{\text{s}^2}}$$

c.) $\mu = 0.20$, $a = 0$ up the incline

Newton's 2nd Law (along the plane)

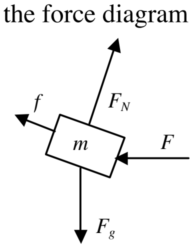
$$F_{net} = \sum F = ma = 0$$
$$F_x - F_{\parallel} - f = 0$$
$$F\cos\theta - F_g\sin\theta - \mu\left(F_g\cos\theta + F\sin\theta\right) = 0$$
$$F\cos\theta - \mu F\sin\theta - F_g\sin\theta - \mu F_g\cos\theta = F\left(\cos\theta - \mu\sin\theta\right) - F_g\sin\theta - \mu F_g\cos\theta = 0$$

$$F = \frac{F_g\sin\theta + \mu F_g\cos\theta}{\cos\theta - \mu\sin\theta} = \frac{mg\sin\theta + \mu mg\cos\theta}{\cos\theta - \mu\sin\theta} = \frac{mg\left(\sin\theta + \mu\cos\theta\right)}{\cos\theta - \mu\sin\theta}$$

$$F = \frac{(4.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(\sin30° + 0.20\cos30°)}{\cos30° - 0.20\sin30°} = \boxed{34.4\text{ N}}$$

d.) $\mu = 0.20$, $a = 0$ down the incline

the force diagram



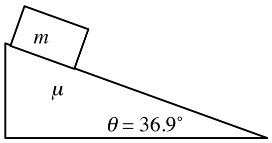

Newton's 2nd Law (along the plane)

$$F_{net} = \sum F = ma = 0$$
$$F_{\parallel} - F_x - f = 0$$
$$F_g\sin\theta - F\cos\theta - \mu\left(F_g\cos\theta + F\sin\theta\right) = 0$$
$$F_g\sin\theta - F\cos\theta - \mu F\sin\theta - \mu F_g\cos\theta = F_g\sin\theta - F\left(\cos\theta + \mu\sin\theta\right) - \mu F_g\cos\theta = 0$$

$$F = \frac{F_g\sin\theta - \mu F_g\cos\theta}{\cos\theta + \mu\sin\theta} = \frac{mg\sin\theta - \mu mg\cos\theta}{\cos\theta + \mu\sin\theta} = \frac{mg\left(\sin\theta - \mu\cos\theta\right)}{\cos\theta + \mu\sin\theta}$$

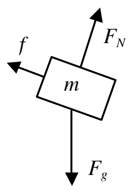
$$F = \frac{(4.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(\sin30° - 0.20\cos30°)}{\cos30° + 0.20\sin30°} = \boxed{13.3\text{ N}}$$

1.)

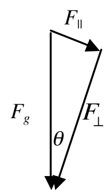



$m = 15\ \text{kg}$, $\mu = 0.20$, $v_o = 0$ and $F_g = mg = (15\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 147\ \text{N}$

the force-diagram




the components of the weight




$F_\parallel = F_g \sin\theta$

$F_\perp = F_g \cos\theta = F_N$

Newton's 2nd Law (along the plane)

$F_{net} = \sum F = ma$

$F_\parallel - f = ma$

$$F_\parallel - \mu F_N = ma \text{ so } a = \frac{F_\parallel - \mu F_N}{m} = \frac{F_g \sin\theta - \mu F_g \cos\theta}{m} = \frac{mg\sin\theta - \mu mg\cos\theta}{m} = g\sin\theta - \mu g\cos\theta$$

$$a = g(\sin\theta - \mu\cos\theta) = \left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(\sin 36.9° - 0.20\cos 36.9°) = 4.32\ \frac{\text{m}}{\text{s}^2}$$

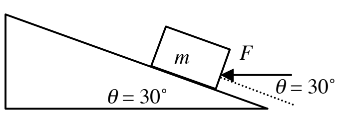
since the block is initially at rest and slides a distance of $\Delta x = 0.5\ \text{m}$

$$\Delta x = \frac{1}{2}at^2 + v_o t = \Delta x = \frac{1}{2}at^2 \text{ and } t = \sqrt{\frac{2\Delta x}{a}} = \sqrt{\frac{2(0.5\ \text{m})}{\left(4.32\ \frac{\text{m}}{\text{s}^2}\right)}} = \boxed{0.48\ \text{s}}$$

when $\Delta x = 1\ \text{m}$

$$v^2 = v_o^2 + 2a\Delta x = 2a\Delta x \text{ and } v = \sqrt{2a\Delta x} = \sqrt{2\left(4.32\ \frac{\text{m}}{\text{s}^2}\right)(1.0\ \text{m})} = \boxed{2.94\ \frac{\text{m}}{\text{s}}}$$

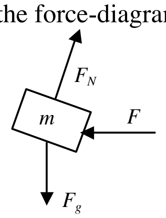
2.)



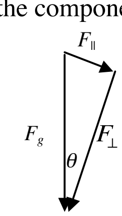

$m = 4.0\ \text{kg}$, $F = 40\ \text{N}$ and frictionless incline

a.)

the force-diagram



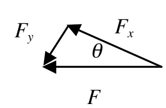

the components of the weight




$F_\parallel = F_g \sin\theta$

$F_\perp = F_g \cos\theta = F_N$

the components of $F$




$F_x = F\cos\theta$

$F_y = F\sin\theta$

Newton's 2nd Law (along the plane)

$F_{net} = \sum F = ma$

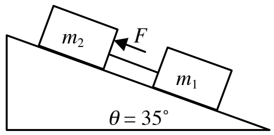
$F_x - F_\parallel = ma$

Newton's 2nd Law (perpendicular to the plane)

$F_N - F_\perp - F_y = 0$

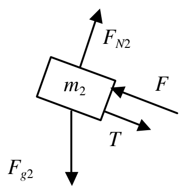
$F_N = F_\perp + F_y$

$$\text{and } a = \frac{F_x - F_\parallel}{m} = \frac{F\cos\theta - F_g\sin\theta}{m} = \frac{F\cos\theta - mg\sin\theta}{m} = \frac{(40\ \text{N})\cos 30° - (4.0\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin 30°}{(4.0\ \text{kg})} = \boxed{3.76\ \frac{\text{m}}{\text{s}^2}}$$

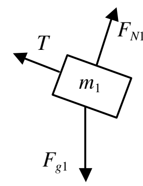
3.) 


$F = 50\text{ N}$ , $m_1 = 3.0\text{ kg}$ , $m_2 = 4.0\text{ kg}$ and frictionless

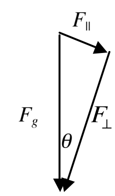
force-diagram on $m_2$




force-diagram on $m_1$




the components of weight




$$F_{\parallel} = F_g \sin\theta$$
$$F_{\perp} = F_g \cos\theta = F_N$$

Newton's 2nd Law (along the plane)

$$F_{net} = \sum F = ma = 0$$

$$F - F_{\parallel_2} - T = m_2 a$$

$$F - F_{g2}\sin\theta - T = m_2 a$$

(1) $F - m_2 g\sin\theta - T = m_2 a$

Newton's 2nd Law (along the plane)

$$F_{net} = \sum F = ma = 0$$

$$T - F_{\parallel_1} = m_1 a$$

$$T - F_{g1}\sin\theta = m_1 a$$

(2) $T - m_1 g\sin\theta = m_1 a$

Combining equations (1) and (2)

$$F - m_2 g\sin\theta - m_1 g\sin\theta = m_2 a + m_1 a$$

$$F - g\sin\theta(m_1 + m_2) = (m_1 + m_2)a$$

$$a = \frac{F - g\sin\theta(m_1 + m_2)}{(m_1 + m_2)}$$

$$a = \frac{50\text{ N} - \left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin 35^\circ(3.0\text{ kg} + 4.0\text{ kg})}{(3.0\text{ kg} + 4.0\text{ kg})} = \boxed{1.52\ \frac{\text{m}}{\text{s}^2}}$$

Using equation (2)

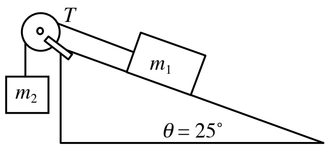
$$T = m_1 a + m_1 g\sin\theta = m_1(a + g\sin\theta)$$

$$T = (3.0\text{ kg})\left(\left(1.52\ \frac{\text{m}}{\text{s}^2}\right) + \left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin 35^\circ\right) = \boxed{21.4\text{ N}}$$

Using equation (1)

$$T = F - m_2 g\sin\theta - m_2 a = F - m_2(g\sin\theta + a)$$

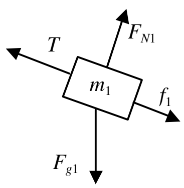
$$T = 50\text{ N} - (4.0\text{ kg})\left(\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin 35^\circ + \left(1.52\ \frac{\text{m}}{\text{s}^2}\right)\right) = \boxed{21.4\text{ N}}$$

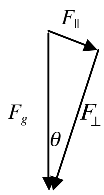
4.) 


$m_1 = 8.0 \text{ kg}$, $m_2 = 10.0 \text{ kg}$, and $\mu = 0.20$

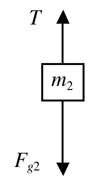
a.)

force-diagram for $m_1$




force-diagram for $m_2$




Newton's 2nd Law (along the plane)

$$F_{net} = \sum F = ma$$

$$T - F_{\parallel_1} - f_1 = m_1 a$$

$$T - F_{\parallel_1} - \mu F_{N_1} = m_1 a$$

$$T - F_{g1}\sin\theta - \mu F_{g1}\cos\theta = m_1 a$$

$$T - m_1 g\sin\theta - \mu m_1 g\cos\theta = m_1 a$$

(1) $T - m_1 g\left(\sin\theta + \mu\cos\theta\right) = m_1 a$

Newton's 2nd Law (perpendicular to the plane)

$$F_{N_1} - F_{\perp} - F_y = 0$$

$$F_{N_1} = F_{\perp} + F_y$$

Newton's 2nd Law (going downward)

$$F_{net} = \sum F = ma$$

$$F_{g2} - T = m_2 a$$

(2) $m_2 g - T = m_2 a$

Combining equations (1) and (2)

$$m_2 g - m_1 g\left(\sin\theta + \mu\cos\theta\right) = m_1 a + m_2 a$$

$$g\left(m_2 - m_1\left(\sin\theta + \mu\cos\theta\right)\right) = \left(m_1 + m_2\right)a$$

$$a = \frac{g\left(m_2 - m_1\left(\sin\theta + \mu\cos\theta\right)\right)}{\left(m_1 + m_2\right)} = \frac{\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right)\left(10.0 \text{ kg} - \left(8.0 \text{ kg}\right)\left(\sin 25° + 0.20\cos 25°\right)\right)}{\left(8.0 \text{ kg} + 10.0 \text{ kg}\right)} = \boxed{2.81 \ \frac{\text{m}}{\text{s}^2}}$$

Using equation (2)

$$T = m_2 g - m_2 a = m_2\left(g - a\right) = \left(10.0 \text{ kg}\right)\left(9.8 \ \frac{\text{m}}{\text{s}^2} - 2.81 \ \frac{\text{m}}{\text{s}^2}\right) = \boxed{69.6 \text{ N}}$$

b.) static case $\mu_s = 0.35$, $a = 0$ up the incline

For block $m_1$

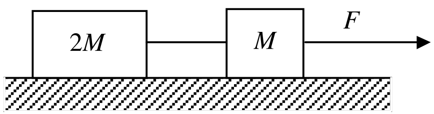
(1) $T - m_1 g\left(\sin\theta + \mu_s\cos\theta\right) = 0$

For block $m_2$

(2) $m_2 g - T = 0$

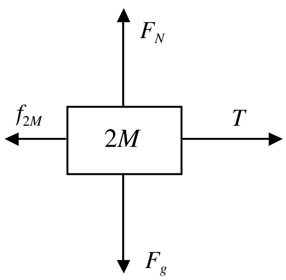
combining (1) and (2) $m_2 g - m_1 g\left(\sin\theta + \mu_s\cos\theta\right) = 0$ so $m_2 = \dfrac{m_1 g\left(\sin\theta + \mu_s\cos\theta\right)}{g} = m_1\left(\sin\theta + \mu_s\cos\theta\right)$

$$m_2 = \left(8.0 \text{ kg}\right)\left(\sin 25° + 0.35\cos 25°\right) = \boxed{5.92 \text{ kg}}$$

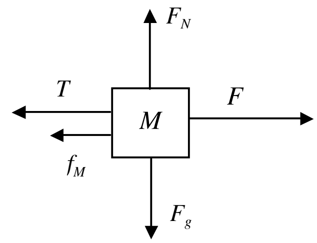
5.) 


$M = 1.0\text{ kg}$, $F = 10\text{ N}$, $\mu_{2M} = 0.20$, $\mu_M = 0.30$

force-diagram for $2M$




force-diagram for $M$




Newton's 2nd Law (in $x$-direction )

$$F_{net} = \sum F = ma$$

$$T - f_{2M} = 2Ma$$

$$T - \mu_{2M} F_N = 2Ma$$

(1) $T - \mu_{2M} 2Mg = 2Ma$

Newton's 2nd Law (in $x$-direction )

$$F_{net} = \sum F = ma$$

$$F - T - f_M = Ma$$

$$F - T - \mu_M F_N = Ma$$

(2) $F - T - \mu_M Mg = Ma$

combining (1) and (2)

$$F - \mu_M Mg - \mu_{2M} 2Mg = Ma + 2Ma = 3Ma$$

$$a = \frac{F - \mu_M Mg - 2\mu_{2M} Mg}{3M} = \frac{10\text{ N} - 0.30(1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) - 2(0.20)(1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{3(1.0\text{ kg})} = 1.05\ \frac{\text{m}}{\text{s}^2}$$

using (1)

$$T = 2Ma + 2\mu_{2M} Mg = 2(1.0\text{ kg})\left(1.05\ \frac{\text{m}}{\text{s}^2}\right) + 2(0.20)(1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{6.0\text{ N}}$$

or solving directly for $T$

from (1)

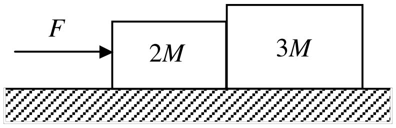
$$a = \frac{T - \mu_{2M} 2Mg}{2M}$$ into (2) $$F - T - \mu_M Mg = M\left(\frac{T - \mu_{2M} 2Mg}{2M}\right) = 0.5T - \mu_{2M} Mg$$

$$1.5T = F - \mu_M Mg + \mu_{2M} Mg = F - Mg(\mu_M - \mu_{2M})$$

$$T = \frac{F - Mg(\mu_M - \mu_{2M})}{1.5}$$

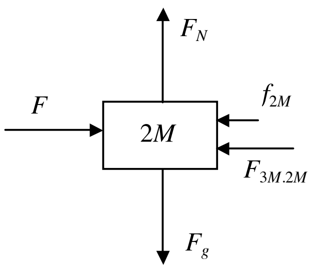
$$T = \frac{10\text{ N} - (1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(0.30 - 0.20)}{1.5} = \boxed{6.0\text{ N}}$$

6.)

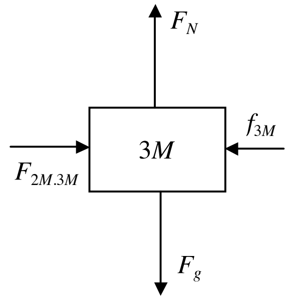



$M = 1.0\text{ kg}$, $F = 12\text{ N}$, $f_{2M} = 2.0\text{ N}$, $f_{3M} = 4.0\text{ N}$

force-diagram on $2M$




force-diagram on $3M$




Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma$$

(1) $F - f_{2M} - F_{3M,2M} = 2Ma$

Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma$$

(2) $F_{2M,3M} - f_{3M} = 3Ma$

$F_{3M,2M}$ and $F_{2M,3M}$ are third law pairs $\left(\vec{F}_{3M,2M} = -\vec{F}_{2M,3M}\right)$ so $F_{3M,2M} = F_{2M,3M}$

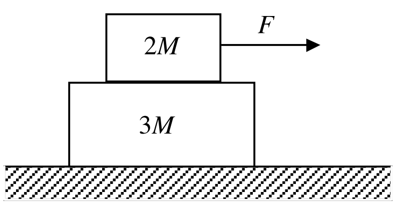
so when combining (1) and (2)

$$F - f_{2M} - f_{3M} = 2Ma + 3Ma = 5Ma \text{ and } a = \frac{F - f_{2M} - f_{3M}}{5M} = \frac{12\text{ N} - 2.0\text{ N} - 4.0\text{ N}}{5(1.0\text{ kg})} = 1.2\ \frac{\text{m}}{\text{s}^2}$$

using (2)

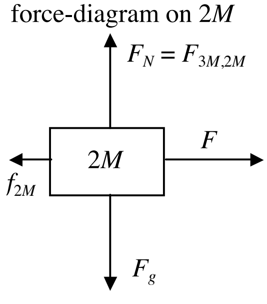
$$F_{2M,3M} = 3Ma + f_{3M} = 3(1.0\text{ kg})\left(1.2\ \frac{\text{m}}{\text{s}^2}\right) + 4.0\text{ N} = \boxed{7.6\text{ N}}$$

7.)

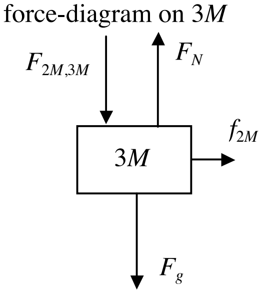



$F = 1.2\text{ N}$, $M = 1.0\text{ kg}$ and bottom surface is frictionless

force-diagram on $2M$




force-diagram on $3M$




Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma$$

(1) $F - f_{2M} = 2Ma$

Newton's 2nd Law (in $x$-direction)

$$F_{net} = \sum F = ma$$

(2) $f_{2M} = 3Ma$

from (2) $a = \dfrac{f_{2M}}{3M}$ into (1) $F - f_{2M} = 2M\left(\dfrac{f_{2M}}{3M}\right) = \dfrac{2f_{2M}}{3}$ so $F = \dfrac{5f_{2M}}{3}$ and $f_{2M} = \dfrac{3}{5}F = \dfrac{3}{5}(1.2\text{ N}) = \boxed{0.72\text{ N}}$

8.) $v_o = 14\ \frac{\text{m}}{\text{s}}$, $v = 0$, $\mu_s = 0.25$

the crates are being pulled along by the static friction between the crates and the railroad flatcar

Newton's 2nd Law (in $x$-direction)

$$f_s = ma \text{ or } \mu_s mg = ma \text{ so } a = \mu_s g = 0.25\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = 2.45\ \frac{\text{m}}{\text{s}^2} \text{ (static limit)}$$

since the flatcar is slowing down $a = -2.45\ \frac{\text{m}}{\text{s}^2}$ and for constant acceleration $v^2 = v_o^2 + 2a\Delta x$

$$\text{so } \Delta x = \frac{v^2 - v_o^2}{2a} = \frac{0 - \left(14\ \frac{\text{m}}{\text{s}}\right)^2}{2\left(-2.45\ \frac{\text{m}}{\text{s}^2}\right)} = \boxed{40 \text{ m}}$$

9.) inclined plane when $\theta = 30°$ the static friction limit is reached and $a = 0$

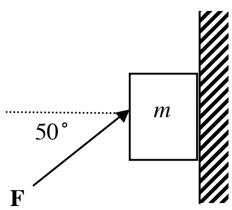
only forces acting on the block in the direction of motion are friction and the parallel component of its weight

Newton's 2nd Law (down the plane)

$$F_{net} = \sum F = ma$$

$$F_{\parallel} - f_s = 0 \text{ and } F_{\parallel} - \mu_s F_N = 0 \text{ or } F_g \sin\theta - \mu_s F_g \cos\theta = 0 \text{ and } \mu_s = \frac{F_g \sin\theta}{F_g \cos\theta} = \tan\theta = \tan 30° = \boxed{0.58}$$

10.)



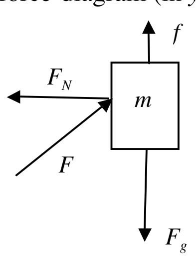

$m = 3.00$ kg, $\mu_s = 0.250$, static case $a = 0$

Case 1: The block just begins to slide downward.

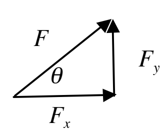
Case 2: The block just begins to slide upward.

Case 1:

force-diagram (in $y$-direction)




the components of $F$




$F_x = F\cos\theta = F_N$

$F_y = F\sin\theta$

Newton's 2nd Law (in $y$-direction)

$$F_{net} = \sum F = ma = 0$$

$$F_y + f - F_g = 0$$

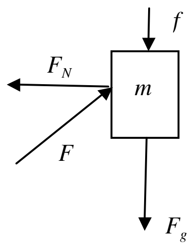
$$F_y + \mu_s F_N - F_g = 0 \text{ so } F\sin\theta + \mu_s F\cos\theta - mg = F(\sin\theta + \mu_s\cos\theta) - mg = 0$$

$$F = \frac{mg}{\sin\theta + \mu_s\cos\theta} = \frac{(3.00\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{(\sin 50° + 0.250\cos 50°)} = 31.7\text{ N}$$

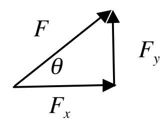
10.) cont'd

Case 2:

force-diagram (in $y$-direction)




the components of $F$




$F_x = F\cos\theta = F_N$

$F_y = F\sin\theta$

Newton's 2nd Law (in $y$-direction)

$F_{net} = \sum F = ma = 0$

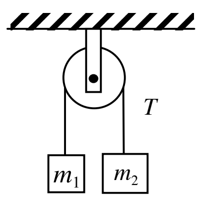
$F_y - f - F_g = 0$

$F_y - \mu_s F_N - F_g = 0$ so $F\sin\theta - \mu_s F\cos\theta - mg = F(\sin\theta - \mu_s\cos\theta) - mg = 0$

$$F = \frac{mg}{\sin\theta - \mu_s\cos\theta} = \frac{(3.00\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{(\sin 50° - 0.250\cos 50°)} = 48.6\text{ N}$$

therefore to keep the block from sliding upward or downward $\boxed{31.7\text{ N} < F < 48.6\text{ N}}$

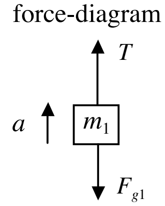
11.)



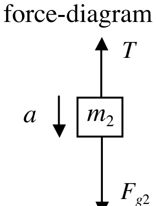

$m_1 = 0.40\text{ kg}$, $m_2 = 0.60\text{ kg}$ pulley has negligible mass and friction

a.)

force-diagram on $m_1$




force-diagram on $m_2$




Newton's 2nd Law (in +$y$-direction)

$F_{net} = \sum F = ma$

(1) $T - F_{g1} = m_1 a$

Newton's 2nd Law (in -$y$-direction)

$F_{net} = \sum F = ma$

(2) $F_{g2} - T = m_2 a$

Combining (1) and (2)

$F_{g2} - F_{g1} = m_1 a + m_2 a = (m_1 + m_2)a$

$m_2 g - m_1 g = (m_1 + m_2)a$

$g(m_2 - m_1) = (m_1 + m_2)a$

$$a = \frac{g(m_2 - m_1)}{(m_1 + m_2)} = \frac{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)(0.600\text{ kg} - 0.400\text{ kg})}{(0.400\text{ kg} + 0.600\text{ kg})} = \boxed{1.96\ \frac{\text{m}}{\text{s}^2}}$$

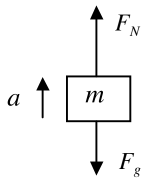
b.)

using (1) $T = m_1 a + F_{g_1} = m_1 a + m_1 g = m_1(a+g) = (0.400 \text{ kg})\left(9.8 \ \frac{\text{m}}{\text{s}^2} + 1.96 \ \frac{\text{m}}{\text{s}^2}\right) = \boxed{4.70 \text{ N}}$



12.) on Earth $F_g = 49 \text{ N}$ and $F_g = mg \Rightarrow m = \frac{F_g}{g} = \frac{49 \text{ N}}{9.8 \ \frac{\text{m}}{\text{s}^2}} = 5.0 \text{ kg}$

on the Moon $F_g = 8.10 \text{ N}$ and $a = 0.50 \ \frac{\text{m}}{\text{s}^2}$




Newton's 2[nd] Law (in +*y*-direction) $F_{net} = \sum F = ma$

$F_N - F_g = ma$ so $F_N = ma + F_g$

$F_N = (5.0 \text{ kg})\left(0.50 \ \frac{\text{m}}{\text{s}^2}\right) + 8.10 \text{ N} = \boxed{10.6 \text{ N}}$

13.) $\mu_s = 0.24$, $v_o = 0$

the box is being pulled along by the static friction between the box and the truck

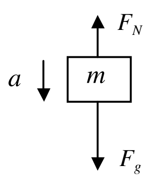
Newton's 2[nd] Law (in *x*-direction)

$f_s = ma$ or $\mu_s mg = ma$ so $a = \mu_s g = 0.24\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right) = 2.352 \ \frac{\text{m}}{\text{s}^2}$ (static limit)

after $t = 3.0 \text{ s}$

$$\Delta x = \frac{1}{2}at^2 + v_o t = \frac{1}{2}at^2 = \frac{1}{2}\left(2.352 \ \frac{\text{m}}{\text{s}^2}\right)(3.0 \text{ s})^2 = \boxed{10.6 \text{ m}}$$

14.) $m = 8.0 \text{ kg}$ in an elevator accelerating downward $a = 1.3 \ \frac{\text{m}}{\text{s}^2}$



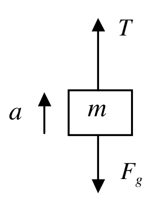

Newton's 2[nd] Law (in -*y*-direction) $F_{net} = \sum F = ma$

$F_g - F_N = ma$ so $F_N = F_g - ma$

$F_N = mg - ma = m(g-a)$

$F_N = (8.0 \text{ kg})\left(9.8 \ \frac{\text{m}}{\text{s}^2} - 1.3 \ \frac{\text{m}}{\text{s}^2}\right) = \boxed{68 \text{ N}}$

15.)




$m = 6.0 \text{ kg}$, $a = 1.8 \ \frac{\text{m}}{\text{s}^2}$ upward

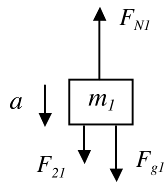
Newton's 2[nd] Law (in +*y*-direction) $F_{net} = \sum F = ma$

$T - F_g = ma$

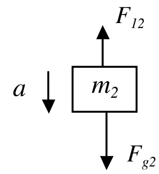
$T = ma + F_g$

$T = ma + mg = m(a+g)$

$T = (6.0 \text{ kg})\left(9.8 \ \frac{\text{m}}{\text{s}^2} + 1.8 \ \frac{\text{m}}{\text{s}^2}\right) = \boxed{69.6 \text{ N}}$

16.) 


$F_N = 80\text{ N}$
$m_1 = 5.0\text{ kg}$
$a = 1.0\ \frac{\text{m}}{\text{s}^2}$




Newton's 2nd Law (in -*y*-direction)

$$F_{net} = \sum F = ma$$

(1) $F_{21} + F_{g1} - F_{N_1} = m_1 a$

Newton's 2nd Law (in -*y*-direction)

$$F_{net} = \sum F = ma$$

(2) $F_{g2} - F_{12} = m_2 a$

$F_{21}$ and $F_{12}$ are third law pairs $\left(\vec{F}_{21} = -\vec{F}_{12}\right)$ so $F_{21} = F_{12}$

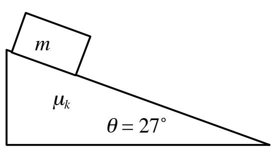
so when combining (1) and (2)

$$F_{g1} - F_{N_1} + F_{g2} = m_1 a + m_2 a \text{ or } m_1 g - F_{N_1} + m_2 g = m_1 a + m_2 a$$

$$m_1 g - m_1 a - F_{N_1} = m_2 a - m_2 g$$

$$m_1(g-a) - F_{N_1} = m_2(a-g)$$

$$m_2 = \frac{m_1(g-a) - F_{N_1}}{a-g} = \frac{F_{N_1} - m_1(g-a)}{g-a} = \frac{80\text{ N} - (5.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2} - 1.0\ \frac{\text{m}}{\text{s}^2}\right)}{9.8\ \frac{\text{m}}{\text{s}^2} - 1.0\ \frac{\text{m}}{\text{s}^2}} = \boxed{4.1\text{ kg}}$$

17.) 


$v_o = 0$, $\Delta x = 6.0\text{ m}$ after $t = 2.0\text{ s}$

$$\Delta x = \frac{1}{2}at^2 + v_o t = \frac{1}{2}at^2 \Rightarrow a = \frac{2\Delta x}{t^2} = \frac{2(6.0\text{ m})}{(2.0\text{ s})^2} = 3.0\ \frac{\text{m}}{\text{s}^2}$$

only forces acting on the block in the direction of motion are friction and the parallel component of its weight

Newton's 2nd Law (down the plane)

$$F_{net} = \sum F = ma$$

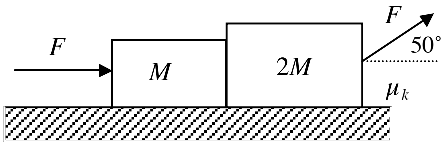
$$F_{\parallel} - f = ma \text{ so } F_{\parallel} - \mu_k F_N = ma \text{ or } F_g \sin\theta - \mu_k F_g \cos\theta = ma$$

$$mg\sin\theta - \mu_k mg\cos\theta = ma$$

$$g\sin\theta - \mu_k g\cos\theta = a$$

$$\mu_k = \frac{g\sin\theta - a}{g\cos\theta} = \frac{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\sin 27° - 3.0\ \frac{\text{m}}{\text{s}^2}}{\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)\cos 27°} = \boxed{0.17}$$

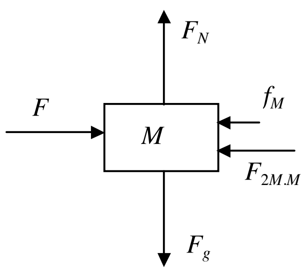
18.)



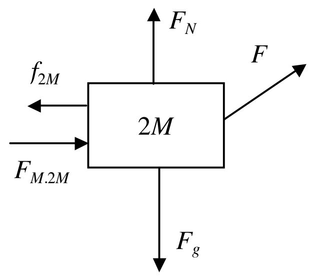

$F = 10.0\text{ N}$, $\mu_k = 0.40$, and $M = 1.0\text{ kg}$

a.)

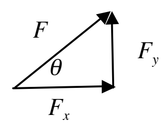
force-diagram for $M$




force-diagram for $2M$




the components of $F$




$$F_x = F\cos\theta$$

$$F_y = F\sin\theta$$

Newton's 2[nd] Law (in the $x$-direction)

$$F_{net} = \sum F = ma$$

$$F - f_M - F_{2M,M} = Ma$$

$$F - \mu_k F_N - F_{2M,M} = Ma$$

$$(1) \quad F - \mu_k Mg - F_{2M,M} = Ma$$

Newton's 2[nd] Law (in the $x$-direction)

$$F_{net} = \sum F = ma$$

$$F_x - f_{2M} + F_{M,2M} = 2Ma$$

$$F_x - \mu_k F_N + F_{M,2M} = 2Ma$$

$$F_x - \mu_k\left(F_g - F_y\right) + F_{M,2M} = 2Ma$$

$$(2) \quad F\cos\theta - \mu_k\left(2Mg - F\sin\theta\right) + F_{M,2M} = 2Ma$$

$F_{2M,M}$ and $F_{M,2M}$ are third law pairs $\left(\vec{F}_{2M,M} = -\vec{F}_{M,2M}\right)$ so $F_{2M,M} = F_{M,2M}$

so combining (1) and (2)

$$F + F\cos\theta - \mu_k Mg - \mu_k\left(2Mg - F\sin\theta\right) = Ma + 2Ma = 3Ma$$

$$a = \frac{F + F\cos\theta - \mu_k Mg - \mu_k\left(2Mg - F\sin\theta\right)}{3M} = \frac{F\left(1+\cos\theta\right) - \mu_k\left(3Mg - F\sin\theta\right)}{3M}$$

$$a = \frac{(10\text{ N})(1+\cos 50°) - 0.40\left(3(1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) - (10\text{ N})\sin 50°\right)}{3(1.0\text{ kg})} = \boxed{2.58\ \frac{\text{m}}{\text{s}^2}}$$

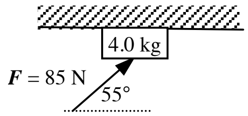
b.)

using (1) $\quad F_{2M,M} = F - \mu_k Mg - Ma$

$$F_{2M,M} = 10\text{ N} - 0.40(1.0\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) - (1.0\text{ kg})\left(2.58\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{3.5\text{ N}}$$

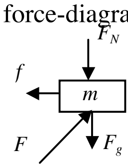
# HO 10 Solutions

1.)

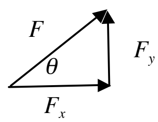



$a = 6.0\ \dfrac{\text{m}}{\text{s}^2}$ to the right

force-diagram




components of $F$




$$F_x = F\cos\theta$$
$$F_y = F\sin\theta$$

Newton's 2nd Law (in the $x$-direction)

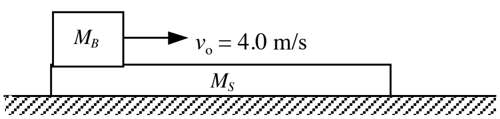
$$F_{net} = \sum F = ma$$

$F_x - f = ma$ so $F_x - \mu F_N = ma$ and $F_x - \mu\left(F_y - F_g\right) = ma$

$$F\cos\theta - \mu\left(F\sin\theta - mg\right) = ma$$

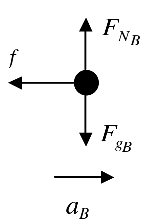
$$\mu = \frac{F\cos\theta - ma}{F\sin\theta - mg} = \frac{(85\ \text{N})\cos 55° - (4.0\ \text{kg})\left(6.0\ \dfrac{\text{m}}{\text{s}^2}\right)}{(85\ \text{N})\sin 55° - (4.0\ \text{kg})\left(9.8\ \dfrac{\text{m}}{\text{s}^2}\right)} = \boxed{0.81}$$

2.)

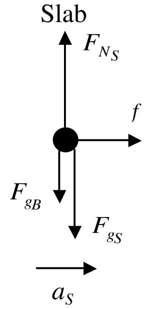



$M_B = 0.50$ kg, $M_S = 3.0$ kg
$\mu_k = 0.20$ (between block and slab)
no friction between slab and horizontal surface

a.) Block




Slab




b.) Newton's 2nd Law (in the $+x$-direction)

$$F_{net} = \sum F = ma$$

$$-f = M_B a_B$$

$$a_B = \frac{-f}{M_B} = \frac{-\mu_k F_{N_B}}{M_B} = \frac{-\mu_k F_{gB}}{M_B}$$

$$a_B = \frac{-\mu_k M_B g}{M_B} = -\mu_k g = -0.20\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = -1.96\ \frac{\text{m}}{\text{s}^2}$$

Newton's 2nd Law (in the $+x$-direction)

$$F_{net} = \sum F = ma$$

$$f = M_S a_S$$

$$a_S = \frac{f}{M_S} = \frac{\mu_k F_{N_B}}{M_S} = \frac{\mu_k F_{gB}}{M_S}$$

$$a_S = \frac{\mu_k M_B g}{M_S} = \frac{0.20(0.50\ \text{kg})\left(9.8\ \dfrac{\text{m}}{\text{s}^2}\right)}{(3.0\ \text{kg})} = 0.327\ \frac{\text{m}}{\text{s}^2}$$

the velocities as a function of time are

$v_B = a_B t + v_{B_o}$ and $v_S = a_S t + v_{S_o} = a_S t$



2.) b.) cont'd

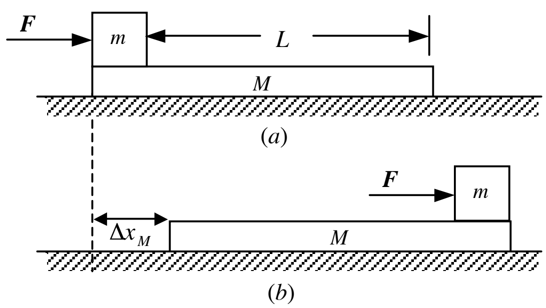
the time when the velocities are the same is when $v_B = v_S$ so

$$a_B t + v_{B_o} = a_S t \text{ so } v_{B_o} = (a_S - a_B)t \text{ and } t = \frac{v_{B_o}}{a_S - a_B} = \frac{4.0\ \frac{\text{m}}{\text{s}}}{0.327\ \frac{\text{m}}{\text{s}^2} - \left(-1.96\ \frac{\text{m}}{\text{s}^2}\right)} = 1.749\ \text{s}$$

the velocity is therefore $v_S = a_S t = \left(0.327\ \frac{\text{m}}{\text{s}^2}\right)(1.749\ \text{s}) = \boxed{0.57\ \frac{\text{m}}{\text{s}}}$

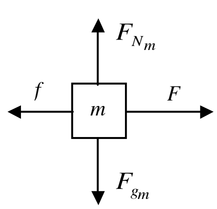
c.) $$\Delta x = \frac{1}{2}at^2 + v_o t \text{ so } \Delta x_S = \frac{1}{2}a_S t^2 = \frac{1}{2}\left(0.327\ \frac{\text{m}}{\text{s}^2}\right)(1.749\ \text{s})^2 = \boxed{0.50\ \text{m}}$$

3.)

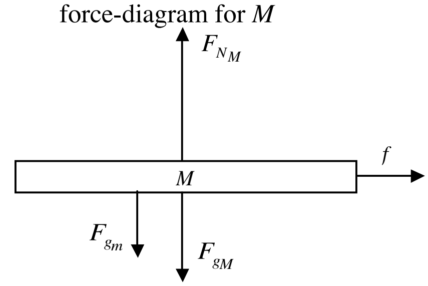



$m = 2.00$ kg, $M = 8.00$ kg, $\mu_k = 0.30$ (between blocks)
no friction between $M$ and surface on which it rests
$v_{o_m} = v_{o_M} = 0$

a.) force-diagram for $m$




force-diagram for $M$




Newton's 2nd Law (in the +$x$-direction)

$$F_{net} = \sum F = ma$$

$$F - f = ma_1$$

$$F - \mu_k F_{N_m} = ma_1$$

$$F - \mu_k mg = ma_1$$

$$a_1 = \frac{F - \mu_k mg}{m} = \frac{10\ \text{N} - 0.30(2.00\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{(2.00\ \text{kg})} = 2.06\ \frac{\text{m}}{\text{s}^2}$$

Newton's 2nd Law (in the +$x$-direction)

$$F_{net} = \sum F = ma$$

$$f = Ma_2$$

$$\mu_k F_{N_m} = Ma_2$$

$$\mu mg = Ma_2$$

$$a_2 = \frac{0.30(2.00\ \text{kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{(8.00\ \text{kg})} = 0.735\ \frac{\text{m}}{\text{s}^2}$$

Let $\Delta x_M$ equal the displacement of the 8.00 kg block and

(1) $$\Delta x_M = \frac{1}{2}a_2 t^2 + v_{o_M} t = \frac{1}{2}a_2 t^2$$

The block displacement of the 2.00 kg block is $\Delta x_m = \Delta x_M + L$

$$\Delta x_m = \Delta x_M + L = \frac{1}{2}a_1 t^2 + v_{o_m} t = \frac{1}{2}a_1 t^2 \text{ so} \quad (2) \quad \Delta x_M = \frac{1}{2}a_1 t^2 - L$$

3.) a.) continued

equating (1) and (2)

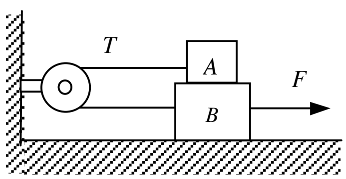
$$\frac{1}{2}a_2 t^2 = \frac{1}{2}a_1 t^2 - L \Rightarrow L = \frac{1}{2}a_1 t^2 - \frac{1}{2}a_2 t^2$$

$$L = \frac{1}{2}(a_1 - a_2)t^2 \text{ and } t = \sqrt{\frac{2L}{(a_1 - a_2)}} = \sqrt{\frac{2(3.00 \text{ m})}{\left(2.06 \frac{\text{m}}{\text{s}^2} - 0.735 \frac{\text{m}}{\text{s}^2}\right)}} = \boxed{2.13 \text{ s}}$$

b.)

$$\Delta x_M = \frac{1}{2}a_2 t^2 = \frac{1}{2}\left(0.735 \frac{\text{m}}{\text{s}^2}\right)(2.13 \text{ s})^2 = \boxed{1.67 \text{ m}}$$

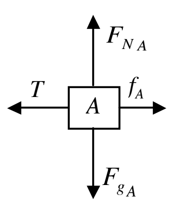
4.)



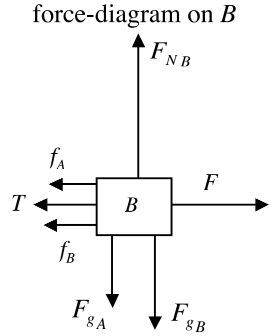

$F_{gA} = 2.70$ N, $F_{gB} = 5.40$ N, $\mu_k = 0.25$ for all surfaces

constant speed so $a = 0$

force-diagram on *A*




force-diagram on *B*




Newton's 2nd Law (in the -*x*-direction)

$$F_{net} = \sum F = ma = 0$$

$$T - f_A = 0$$

$$T - \mu_k F_{N_A} = 0$$

(1) $T - \mu_k F_{gA} = 0$

Newton's 2nd Law (in the +*x*-direction)

$$F_{net} = \sum F = ma = 0$$

$$F - T - f_A - f_B = 0$$

$$F - T - \mu_k F_{N_A} - \mu_k F_{N_B} = 0$$

(2) $F - T - \mu_k F_{gA} - \mu_k\left(F_{gB} + F_{gA}\right) = 0$

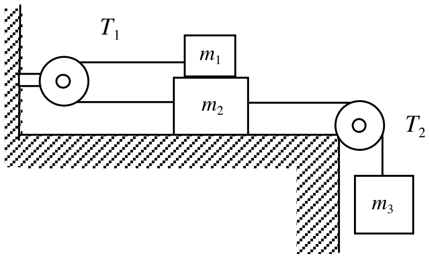
combining (1) and (2)

$$F - 3\mu_k F_{gA} - \mu_k F_{gB} = 0$$

$$F = 3\mu_k F_{gA} + \mu_k F_{gB}$$

$$F = 3(0.25)(2.70 \text{ N}) + 0.25(5.40 \text{ N}) = \boxed{3.375 \text{ N}}$$

5.)

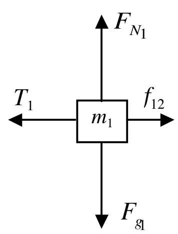



$m_1 = 2\text{ kg}$, $m_2 = 3\text{ kg}$, $m_3 = 10\text{ kg}$, $\mu_k = 0.30$ between blocks

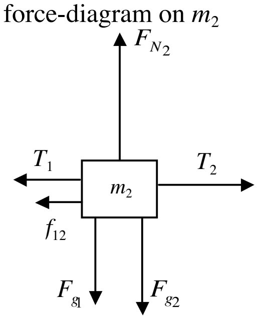
the table surface is frictionless

a.)

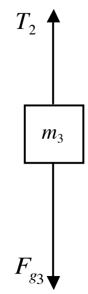
force-diagram on $m_1$




force-diagram on $m_2$




force-diagram on $m_3$




b.)

Newton's 2nd Law (in the -$x$-direction)

$$F_{net} = \sum F = ma$$

$$T_1 - f_{12} = m_1 a$$

$$T_1 - \mu_k F_{N_1} = m_1 a$$

$$T_1 - \mu_k F_{g1} = m_1 a$$

(1) $$T_1 - \mu_k m_1 g = m_1 a$$

Newton's 2nd Law (in the +$x$-direction)

$$F_{net} = \sum F = ma$$

$$T_2 - T_1 - f_{12} = m_2 a$$

$$T_2 - T_1 - \mu_k F_{N_1} = m_2 a$$

$$T_2 - T_1 - \mu_k F_{g1} = m_2 a$$

(2) $$T_2 - T_1 - \mu_k m_1 g = m_2 a$$

Newton's 2nd Law (in the -$y$-direction)

$$F_{net} = \sum F = ma$$

$$F_{g3} - T_2 = m_3 a$$

(3) $$m_3 g - T_2 = m_3 a$$

combining (1), (2), and (3)

$$m_3 g - 2\mu_k m_1 g = m_1 a + m_2 a + m_3 a = (m_1 + m_2 + m_3)a$$

$$a = \frac{m_3 g - 2\mu_k m_1 g}{m_1 + m_2 + m_3} = \frac{(10\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) - 2(0.30)(2\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right)}{2\text{ kg} + 3\text{ kg} + 10\text{ kg}} = 5.75\ \frac{\text{m}}{\text{s}^2}$$

using (1)

$$T_1 = m_1 a + \mu_k m_1 g = (2\text{ kg})\left(5.75\ \frac{\text{m}}{\text{s}^2}\right) + (0.30)(2\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{17.4\text{ N}}$$

using (3)

$$T_2 = m_3 g - m_3 a = m_3(g - a) = (10\text{ kg})\left(9.8\ \frac{\text{m}}{\text{s}^2} - 5.75\ \frac{\text{m}}{\text{s}^2}\right) = \boxed{40.5\text{ N}}$$