Chapter 5 Solutions

***5.1** For the same force F, acting on different masses

$$F = m_1 a_1 \quad \text{and} \quad F = m_2 a_2$$

(a) $\dfrac{m_1}{m_2} = \dfrac{a_2}{a_1} = \boxed{\dfrac{1}{3}}$

(b) $F = (m_1 + m_2)a = 4m_1 a = m_1(3.00 \text{ m/s}^2)$

$a = \boxed{0.750 \text{ m/s}^2}$

***5.2** $F = 10.0$ N, $m = 2.00$ kg

(a) $a = \dfrac{F}{m} = \dfrac{10.0 \text{ N}}{2.00 \text{ kg}} = \boxed{5.00 \text{ m/s}^2}$

(b) $F_g = mg = (2.00 \text{ kg})(9.80 \text{ m/s}^2) = \boxed{19.6 \text{ N}}$

(c) $a = \dfrac{2F}{m} = \dfrac{2(10.0 \text{ N})}{2.00 \text{ kg}} = \boxed{10.0 \text{ m/s}^2}$

5.3 $m = 3.00$ kg, $\mathbf{a} = (2.00\mathbf{i} + 5.00\mathbf{j}) \text{ m/s}^2$

$\mathbf{F} = m\mathbf{a} = \boxed{(6.00\mathbf{i} + 15.0\mathbf{j}) \text{ N}}$

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

5.4 $m_{\text{train}} = 15{,}000{,}000$ kg

$F = 750{,}000$ N

$$a = \frac{F}{m} = \frac{75.0 \times 10^4 \text{ N}}{15.0 \times 10^6 \text{ kg}} = 5.00 \times 10^{-2} \text{ m/s}^2$$

$v_f = v_i + at \qquad v_i = 0$

$$t = \frac{v_f - v_i}{a} = \frac{(80.0 \text{ km/h})(1000 \text{ m/km})(1 \text{ h}/3600 \text{ s})}{5.00 \times 10^{-2} \text{ m/s}^2}$$

$\boxed{t = 444 \text{ s}}$

5.5 We suppose the barrel is horizontal.

$m = 5.00 \times 10^{-3}$ kg, $v_f = 320$ m/s, $v_i = 0$, $x = 0.820$ m

$$\bar{F}_x = m\bar{a} = m\frac{\Delta v}{\Delta t} \quad \text{(Eq. 5.2)}$$

Find Δt from Eq. 2.2 $\quad \Delta t = \dfrac{\Delta x}{\bar{v}} = \dfrac{0.820 \text{ m}}{160 \text{ m/s}} = 5.13 \times 10^{-3}$ s

$$\therefore \bar{F}_x = (5.00 \times 10^{-3} \text{ kg})\frac{(320 \text{ m/s})}{(5.13 \times 10^{-3})} = \boxed{312 \text{ N}}$$

Along with this force, which we assume is horizontal, exerted by the exploding gunpowder, the bullet feels a downward 49.0 mN force of gravity and an upward 49.0 mN force exerted by the barrel surface under it.

5.6 $F_g = mg = 1.40$ N, $m = 0.143$ kg

$v_f = 32.0$ m/s, $v_i = 0$, $\Delta t = 0.0900$ s

$\bar{v} = 16.0$ m/s $\quad \bar{a} = \dfrac{\Delta v}{\Delta t} = 356$ m/s^2

(a) Distance $x = \bar{v}\,t = (16.0 \text{ m/s})(0.0900 \text{ s}) = \boxed{1.44 \text{ m}}$

(b) $\sum \mathbf{F} = m\mathbf{a}$

$$\mathbf{F}_{\text{pitcher}} - 1.40 \text{ N}\mathbf{j} = (0.143 \text{ kg})(356\mathbf{i} \text{ m/s}^2)$$

$$\mathbf{F}_{\text{p}} = \boxed{(50.9\mathbf{i} + 1.40\mathbf{j}) \text{ N}}$$

5.7 F_g = weight of ball = mg

$v_{\text{release}} = v$, time to accelerate = t

$$\boldsymbol{a} = \frac{\Delta v}{\Delta t} = \frac{v}{t} = \frac{v}{t}\,\mathbf{i}$$

(a) Distance $x = \bar{v}\,t = \left(\dfrac{v}{2}\right)t = \boxed{\dfrac{vt}{2}}$

(b) $\mathbf{F}_{\text{p}} - F_g\,\mathbf{j} = \dfrac{F_g}{g}\dfrac{v}{t}\,\mathbf{i}$

$$\mathbf{F}_{\text{p}} = \boxed{\frac{F_g v}{gt}\mathbf{i} + F_g\,\mathbf{j}}$$

***5.8** $F_g = mg$

$$1 \text{ pound} = (0.453\,592\,37 \text{ kg})(32.1740 \text{ ft/s}^2)\left(\frac{12.0 \text{ in}}{1 \text{ ft}}\right)\left(\frac{0.0254 \text{ m}}{1 \text{ in.}}\right) = \boxed{4.45 \text{ N}}$$

5.9 $m = 4.00$ kg, $\mathbf{v}_i = 3.00\mathbf{i}$ m/s, $\mathbf{v}_8 = (8.00\mathbf{i} + 10.0\mathbf{j})$ m/s, $t = 8.00$ s

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

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

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

5.10 (a) Let the x-axis be in the original direction of the molecule's motion.

$$v_f = v_i + at$$

$$-670 \text{ m/s} = 670 \text{ m/s} + a(3.00 \times 10^{-13} \text{ s})$$

$$a = \boxed{-4.47 \times 10^{15} \text{ m/s}^2}$$

(b) For the molecule $\sum\mathbf{F} = m\mathbf{a}$. Its weight is negligble.

$$\mathbf{F}_{\text{wall on molecule}} = 4.68 \times 10^{-26} \text{ kg } (-4.47 \times 10^{15} \text{ m/s}^2)$$

$$= -2.09 \times 10^{-10} \text{ N}$$

$$\bar{\mathbf{F}}_{\text{molecule on wall}} = \boxed{+2.09 \times 10^{-10} \text{ N}}$$

5.11 (a) $F = ma$ and $v_f^2 = v_i^2 + 2ax$ or $a = \dfrac{v_f^2 - v_i^2}{2x}$

Therefore,

$$F = m\frac{(v_f^2 - v_i^2)}{2x}$$

$$F = (9.11 \times 10^{-31} \text{ kg})\frac{[(7.00 \times 10^5 \text{ m/s}^2)^2 - (3.00 \times 10^5 \text{ m/s})^2]}{(2)(0.0500 \text{ m})}$$

$$= \boxed{3.64 \times 10^{-18} \text{ N}}$$

(b) The weight of the electron is

$$F_g = mg = (9.11 \times 10^{-31}\text{ kg})(9.80\text{ m/s}^2) = \boxed{8.93 \times 10^{-30}\text{ N}}$$

The accelerating force is 4.08×10^{11} times the weight of the electron.

Goal Solution

G: We should expect that only a very small force is required to accelerate an electron, but this force is probably much greater than the weight of the electron if the gravitational force can be neglected.

O: Since this is simply a linear acceleration problem, we can use Newton's second law to find the force as long as the electron does not approach relativistic speeds (much less than 3×10^8 m/s), which is certainly the case for this problem. We know the initial and final velocities, and the distance involved, so from these we can find the acceleration needed to determine the force.

A: From $v_f^2 = v_i^2 + 2ax$ and $\sum F = ma$ we can solve for the acceleration and the force.

$$a = \frac{(v_f^2 - v_i^2)}{2x} \quad \text{and so} \quad \sum F = \frac{m(v_f^2 - v_i^2)}{2x}$$

(a) $$F = \frac{(9.11 \times 10^{-31}\text{ kg})\,[(7.00 \times 10^5\text{ m/s}^2) - (3.00 \times 10^5\text{ m/s})^2]}{(2)(0.0500\text{ m})} = 3.64 \times 10^{-18}\text{ N}$$

(b) The weight of the electron is

$$Fg = mg = (9.11 \times 10^{-31}\text{ kg})(9.80\text{ m/s}^2) = 8.93 \times 10^{-30}\text{ N}$$

The ratio of the accelerating force to the weight is $\frac{F}{F_g} = 4.08 \times 10^{11}$

L: The force that causes the electron to accelerate is indeed a small fraction of a newton, but it is much greater than the gravitational force. For this reason, it is quite reasonable to ignore the weight of the electron in electric charge problems.

5.12 (a) $$F_g = mg = 120\text{ lb} = \left(4.448\,\frac{\text{N}}{\text{lb}}\right)(120\text{ lb}) = \boxed{534\text{ N}}$$

(b) $$m = \frac{F_g}{g} = \frac{534\text{ N}}{9.80\text{ m/s}^2} = \boxed{54.5\text{ kg}}$$

5.13 $F_g = mg = 900$ N

$$m = \frac{900\text{ N}}{9.80\text{ m/s}^2} = 91.8\text{ kg}$$

$$(F_g)_{\text{on Jupiter}} = (91.8\text{ kg})(25.9\text{ m/s}^2) = \boxed{2.38\text{ kN}}$$

***5.14** Imagine a quick trip by jet, on which you do not visit the rest room and your perspiration is just canceled out by a glass of tomato juice. By subtraction, $(F_g)_p = mg_p$ and $(F_g)_C = mg_C$ give $\Delta F_g = m(g_P - g_C)$. For a person whose mass is 88.7 kg, the change in weight is

$$\Delta F_g = (88.7)(9.8095 - 9.7808) = \boxed{2.55\text{ N}}$$

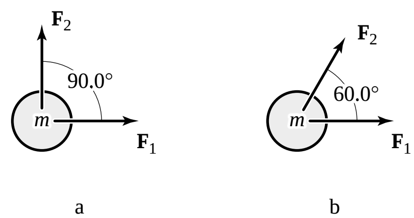
A precise balance scale, as in a doctor's office, reads the same in different locations because it compares you with the standard masses on its beams. A typical bathroom scale is not precise enough to reveal this difference.

5.15 (a) $\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = (20.0\mathbf{i} + 15.0\mathbf{j})\text{ N}$

$\sum \mathbf{F} = m\mathbf{a}$, $20.0\mathbf{i} + 15.0\mathbf{j} = 5.00\ \mathbf{a}$

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

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



(b) $F_{2x} = 15.0 \cos 60.0° = 7.50\text{ N}$

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

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

$\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$

$= (27.5\mathbf{i} + 13.0\mathbf{j})\text{ N} = m\mathbf{a} = 5.00\mathbf{a}$

$\mathbf{a} = (5.50\mathbf{i} + 2.60\mathbf{j})\text{ m/s}^2$

5.16 We find acceleration: $\mathbf{r} - \mathbf{r}_i = \mathbf{v}_i t + \frac{1}{2}\ \mathbf{a}t^2$

$$4.20\text{ m }\mathbf{i} - 3.30\text{ m }\mathbf{j} = 0 + \frac{1}{2}\ \mathbf{a}(1.20\text{ s})^2 = 0.720\text{ s}^2\ \mathbf{a}$$

$\mathbf{a} = (5.83\ \mathbf{i} - 4.58\mathbf{j})\text{ m/s}^2$

Now $\sum \mathbf{F} = m\mathbf{a}$ becomes

$\mathbf{F}_2 = 2.80\text{ kg }(5.83\mathbf{i} - 4.58\mathbf{j})\text{ m/s}^2 + (2.80\text{ kg})9.80\text{ m/s}^2\ \mathbf{j}$

$\mathbf{F}_2 = \boxed{(16.3\mathbf{i} + 14.6\mathbf{j})\text{ N}}$

5.17 (a) You and earth exert equal forces on each other:

$$m_y g = M_e a_e$$

If your mass is 70.0 kg,

$$a_e = \frac{(70.0\ \text{kg})(9.80\ \text{m/s}^2)}{5.98 \times 10^{24}\ \text{kg}} = \boxed{\sim 10^{-22}\ \text{m/s}^2}$$

(b) You and planet move for equal times in $x = \frac{1}{2}at^2$. If the seat is 50.0 cm high,

$$\sqrt{\frac{2x_y}{a_y}} = \sqrt{\frac{2x_e}{a_e}}$$

$$x_e = \frac{a_e}{a_y}x_y = \frac{m_y}{m_e}x_y = \frac{70.0\text{ kg}}{5.98\times10^{24}\text{ kg}}(0.500\text{ m})\ \boxed{\sim 10^{-23}\text{ m}}$$

5.18 $F = \sqrt{(20.0)^2 + (10.0 - 15.0)^2} = 20.6\text{ N}$

$a = \frac{F}{m}$

$a = \boxed{5.15\text{ m/s}^2\text{ at }14.0°\text{ S of E}}$

***5.19** Choose the x-axis forward. Then

$$\sum F_x = ma_x$$

$$(2000\text{ N}\mathbf{i}) - (1800\text{ N}\mathbf{i}) = (1000\text{ kg})\mathbf{a}$$

$$\boxed{\mathbf{a} = 0.200\text{ m/s}^2\mathbf{i}}$$

(b) $x_f - x_i = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(0.200\text{ m/s}^2)(10.0\text{ s})^2 = \boxed{10.0\text{ m}}$

(c) $\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t = 0 + (0.200\text{ m/s}^2\mathbf{i})(10.0\text{ s}) = \boxed{2.00\text{ m/s }\mathbf{i}}$

5.20 $\sum\mathbf{F} = m\mathbf{a}$ reads

$$(-2.00\mathbf{i} + 2.00\mathbf{j} + 5.00\mathbf{i} - 3.00\mathbf{j} - 45.0\mathbf{i})\text{ N} = m(3.75\text{ m/s}^2)\hat{\mathbf{a}}$$

where $\hat{\mathbf{a}}$ represents the direction of $\mathbf{a}$

$$(-42.0\mathbf{i} - 1.00\mathbf{j})\text{ N} = m(3.75\text{ m/s}^2)\hat{\mathbf{a}}$$

$$F = \sqrt{(42.0)^2 + (1.00)^2}\text{ N at Arctan}\left(\frac{1.00}{42.0}\right)\text{ below the }-x\text{-axis}$$

$$= m(3.75\text{ m/s}^2)\hat{\mathbf{a}}$$

$$F = 42.0\text{ N at }181° = m(3.75\text{ m/s}^2)\hat{\mathbf{a}}$$

For the vectors to be equal, their magnitudes and their directions must be equal:

(a) $\therefore$ $\boxed{\hat{\mathbf{a}} \text{ is at } 181°}$ counterclockwise from the *x*-axis

(b) $m = \dfrac{42.0 \text{ N}}{3.75 \text{ m/s}^2} = \boxed{11.2 \text{ kg}}$

(d) $\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t = 0 + (3.75 \text{ m/s}^2 \text{ at } 181°)10.0 \text{ s}$

$= 37.5 \text{ m/s at } 181°$

$= 37.5 \text{ m/s} \cos 181° \mathbf{i} + 37.5 \text{ m/s} \sin 181° \mathbf{j}$

$\mathbf{v} = \boxed{(-37.5\mathbf{i} - 0.893\mathbf{j}) \text{ m/s}}$

(c) $|\mathbf{v}| = \sqrt{37.5^2 + 0.893^2} \text{ m/s} = \boxed{37.5 \text{ m/s}}$

***5.21** (a) $\boxed{15.0 \text{ lb up}}$ (b) $\boxed{5.00 \text{ lb up}}$ (c) $\boxed{0}$

***5.22** $v_x = \dfrac{dx}{dt} = 10t$, $v_y = \dfrac{dy}{dt} = 9t^2$

$a_x = \dfrac{dv_x}{dt} = 10$, $a_y = \dfrac{dv_y}{dt} = 18t$

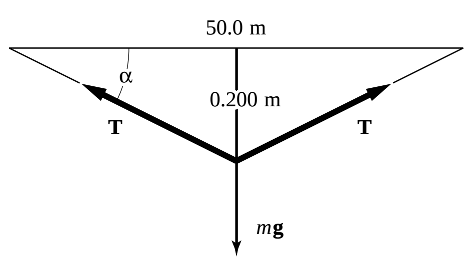
At $t = 2.00$ s, $a_x = 10.0 \text{ m/s}^2$, $a_y = 36.0 \text{ m/s}^2$

$F_x = ma_x = (3.00 \text{ kg})(10.0 \text{ m/s}^2) = 30.0 \text{ N}$

$F_y = ma_y = (3.00 \text{ kg})(36.0 \text{ m/s}^2) = 108 \text{ N}$

$F = \sqrt{F_x^2 + F_y^2} = \boxed{112 \text{ N}}$

5.23 $m = 1.00$ kg



$mg = 9.80$ N

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

$\alpha = 0.458°$

Balance forces,

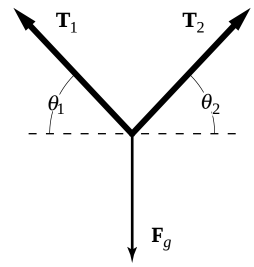
$2T \sin \alpha = mg$

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

5.24 $T_3 = F_g$ (1)

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

$T_1 \cos\theta_1 = T_2 \cos\theta_2$ (3)



Eliminate T_2 and solve for T_1,

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

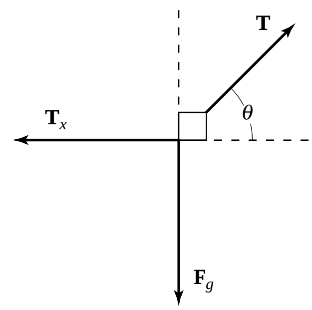
$$T_3 = F_g = \boxed{325\ \text{N}}$$

$$T_1 = F_g \frac{\cos 25.0°}{\sin 85.0°} = \boxed{296\ \text{N}}$$

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

5.25 See the solution for T_1 in Problem 5.24.

***5.26** (a) An explanation proceeding from fundamental physical principles will be best for the parents and for you. Consider forces on the bit of string touching the weight hanger as shown in the free-body diagram:



Horizontal Forces: $\sum F_x = ma_x \Rightarrow -T_x + T\cos\theta = 0$

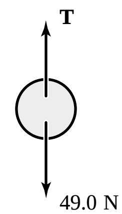
Vertical Forces: $\sum F_y = ma_y \Rightarrow -F_g + T\sin\theta = 0$

You need only the equation for the vertical forces to find that the tension in the string is given by $T = \boxed{\dfrac{F_g}{\sin\theta}}$. The force the child feels gets smaller, changing from T to $T\cos\theta$, while the counterweight hangs on the string. On the other hand, the kite does not notice what you are doing and the tension in the main part of the string stays constant. You do not need a level, since you learned in physics lab to sight to a horizontal line in a building. Share with the parents your estimate of the experimental uncertainty, which you make by thinking critically about the measurement, by repeating trials, practicing in advance and looking for variations and improvements in technique, including using other observers. You will then be glad to have the parents themselves repeat your measurements.

(b) $$T = \frac{F_g}{\sin\theta} = \frac{(0.132\ \text{kg})(9.80\ \text{m/s}^2)}{\sin 46.3°} = \boxed{1.79\ \text{N}}$$

5.27 (a) Isolate either mass

$$T + mg = ma = 0$$



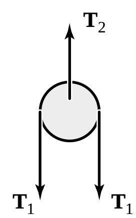
$$|T| = |mg|$$

The scale reads the tension T, so

$$T = mg = 5.00\text{ kg} \times 9.80\text{ m/s}^2$$

$$= \boxed{49.0\text{ N}}$$

(b) Isolate each mass

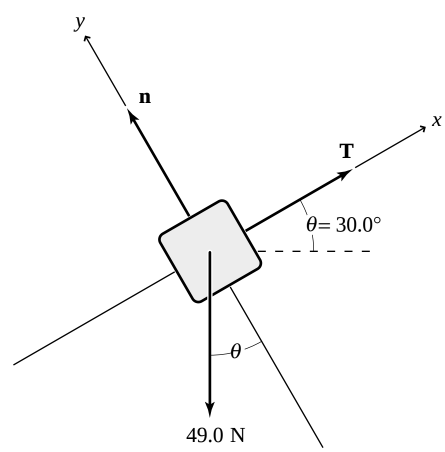


$$\mathbf{T}_2 + 2\mathbf{T}_1 = 0$$

$$T_2 = 2|T_1| = 2mg$$

$$= \boxed{98.0\text{ N}}$$

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



Take the component along the incline

$$\mathbf{n}_x + \mathbf{T}_x + m\mathbf{g}_x = 0$$

or $\quad 0 + T - mg\sin 30.0° = 0$

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

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

5.28 Let R represent the horizontal force of air resistance.

(a) $\sum \mathbf{F}_x = ma_x$ becomes $T\sin 40.0° - R = 0$

$\sum \mathbf{F}_y = ma_y$ reads $T\cos 40.0° - F_g = 0$

Then $T = \dfrac{mg}{\cos 40.0°} = \dfrac{6.08 \times 10^3\text{ N}}{\cos 40.0°} = 7.93 \times 10^3\text{ N}$

$$R = 7.93 \times 10^3\text{ N}\sin 40 = \boxed{5.10 \times 10^3\text{ N}}$$

(b) The value of R will be the same. Now

$$T \sin 7.00° - R = 0 \qquad T = \frac{5.10 \times 10^3 \text{ N}}{\sin 7.00°} = 4.18 \times 10^4 \text{ N}$$

$$T \cos 7.00° - mg = 0$$

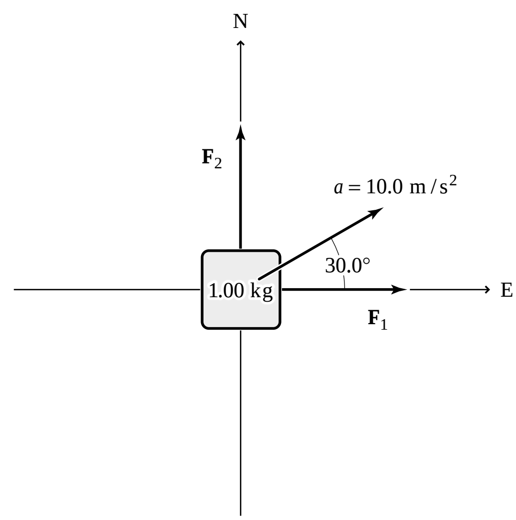
$$m = \frac{(4.18 \times 10^4 \text{ N}) \cos 7.00°}{9.80 \text{ m/s}^2} = 4.24 \times 10^3 \text{ kg}$$

$$m_{\text{water}} = 4.24 \times 10^3 \text{ kg} - 620 \text{ kg} = \boxed{3.62 \times 10^3 \text{ kg}}$$

5.29 Choosing a coordinate system with **i** East and **j** North.

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

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



Goal Solution

G: The net force acting on the mass is $\sum F = ma = (1 \text{ kg})(10 \text{ m/s}^2) = 10$ N, so if we examine a diagram of the forces drawn to scale, we see that $F_1 \approx 9$ N directed to the east.

O: We can find a more precise result by examining the forces in terms of vector components. For convenience, we choose directions east and north along **i** and **j**, respectively.

A: $\mathbf{a} = [(10.0 \cos 30.0°)\mathbf{i} + (10.0 \sin 30.0°)\mathbf{j}] \text{ m/s}^2 = (8.66\mathbf{i} + 5.00\mathbf{j}) \text{ m/s}^2$

From Newton's second law, $\sum \mathbf{F} = m\mathbf{a} = (1.00 \text{ kg})[(8.66\mathbf{i} + 5.00\mathbf{j}) \text{ m/s}^2] = (8.66\mathbf{i} + 5.00\mathbf{j})$ N

And $\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$.

so $\mathbf{F}_1 = \sum \mathbf{F} - \mathbf{F}_2 = (8.66\mathbf{i} + 5.00\mathbf{j} - 5.00\mathbf{j})$ N $= 8.66\mathbf{i}$ N $= 8.66$ N to the east

L: Our calculated answer agrees with the prediction from the force diagram.

5.30 (a) The cart and mass accelerate horizontally.

$$\sum F_y = ma_y \quad +T\cos\theta - mg = 0$$

$$\sum F_x = ma_x \quad +T\sin\theta = ma$$

Substitute $T = \dfrac{mg}{\cos\theta}$

$$\frac{mg\sin\theta}{\cos\theta} = mg\tan\theta = ma$$

$$\boxed{a = g\tan\theta}$$

(b) $a = (9.80 \text{ m/s}^2)\tan 23.0° = \boxed{4.16 \text{ m/s}^2}$

***5.31** Let us call the forces exerted by each person F_1 and F_2. Thus, for pulling in the same direction, Newton's second law becomes

$$F_1 + F_2 = (200 \text{ kg})(1.52 \text{ m/s}^2)$$

or $\quad F_1 + F_2 = 304 \text{ N} \quad (1)$

When pulling in opposite directions,

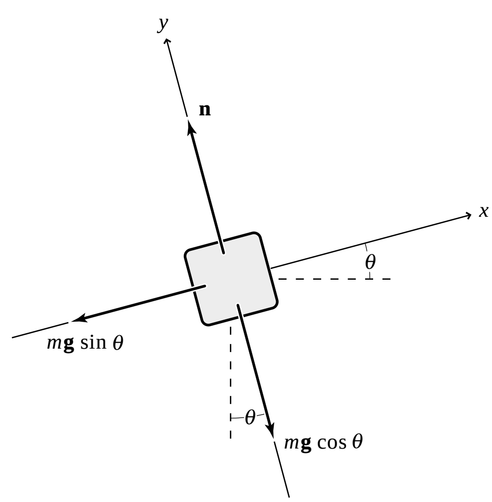
$$F_1 - F_2 = (200 \text{ kg})(-0.518 \text{ m/s}^2)$$

or $\quad F_1 - F_2 = -104 \text{ N} \quad (2)$

Solving simultaneously, we find

$$F_1 = \boxed{100 \text{ N}}, \text{ and } F_2 = \boxed{204 \text{ N}}$$

5.32 The two forces acting on the block are the normal force, n, and the weight, mg. If the block is considered to be a point mass and the x-axis is chosen to be parallel to the plane then the free body diagram will be as shown in the figure to the right. The angle θ is the angle of inclination of the plane. Applying Newton's second law for the accelerating system (and taking the direction of motion as the positive direction) we have



$$\sum F_y = n - mg\cos\theta = 0; \; n = mg\cos\theta$$

$$\sum F_x = -mg\sin\theta = ma; \; a = -g\sin\theta$$

(a) When $\theta = 15.0°$ $\qquad a = \boxed{-2.54 \text{ m/s}^2}$

(b) Starting from rest

$$v_f^2 = v_i^2 + 2ax$$

$$v_f = \sqrt{2ax} = \sqrt{(2)(-2.54\ \text{m/s}^2)(-2.00\ \text{m})} = \boxed{3.18\ \text{m/s}}$$

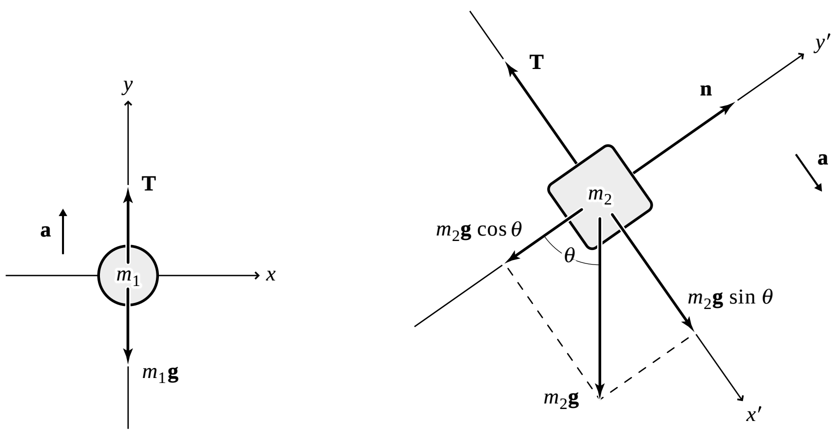
***5.33** $v_f^2 = v_i^2 + 2ax$

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

$$0 = (5.00)^2 - 2(9.80)\sin(20.0°)x$$

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

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



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

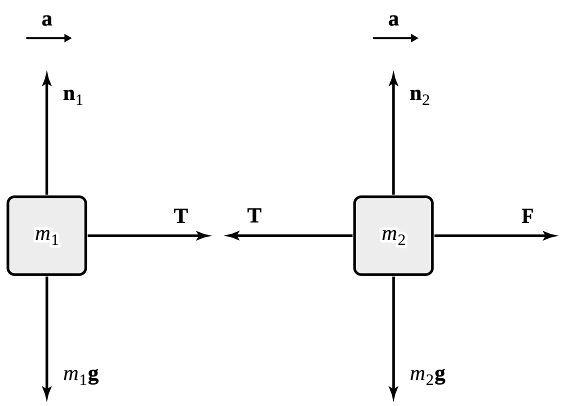
5.35 Applying Newton's second law to each block (motion along the x-axis).

For m_2: $\sum F_x = F - T = m_2 a$

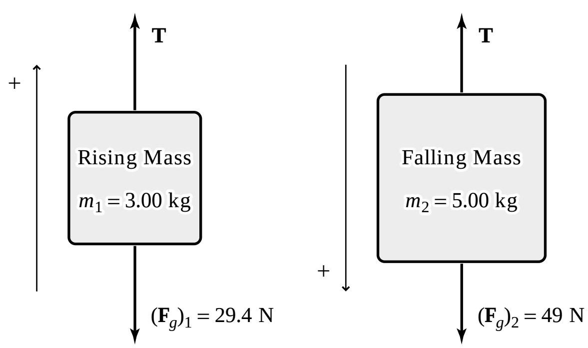
For m_1: $\sum F_x = T = m_1 a$

Solving these equations for a and T, we find

$$\boxed{a = \frac{F}{m_1 + m_2}} \quad \text{and} \quad \boxed{T = \frac{F m_1}{m_1 + m_2}}$$



***5.36** First, consider the 3.00 kg rising mass. The forces on it are the tension, T, and its weight, 29.4 N. With the upward direction as positive, the second law becomes



$$\sum F_y = ma_y$$

$$T - 29.4 \text{ N} = (3.00 \text{ kg})a \qquad (1)$$

The forces on the falling 5.00 kg mass are its weight and T, and its acceleration is the same as that of the rising mass. Calling the positive direction down for this mass, we have

$$\sum F_y = ma_y$$

$$49 \text{ N} - T = (5.00 \text{ kg})a \qquad (2)$$

Equations (1) and (2) can be solved simultaneously to give

(a) the tension as $T = \boxed{36.8 \text{ N}}$

(b) and the acceleration as $a = \boxed{2.45 \text{ m/s}^2}$

(c) Consider the 3.00 kg mass. We have

$$y = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(2.45\ \mathrm{m/s^2})(1.00\ \mathrm{s})^2 = \boxed{1.23\ \mathrm{m}}$$

5.37 $T - m_1 g = m_1 a$ (1) Forces acting on 2.00 kg block

$F_x - T = m_2 a$ (2) Forces acting on 8.00 kg block

(a) Eliminate T and solve for a.

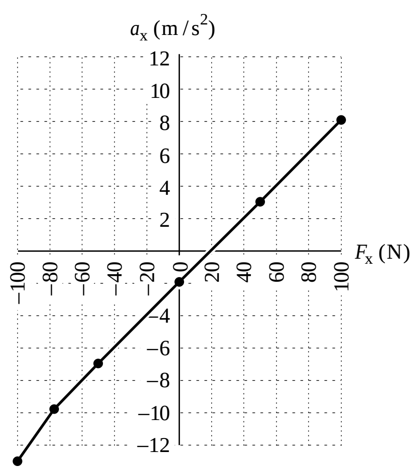
$$a = \frac{F_x - m_1 g}{m_1 + m_2} \qquad \boxed{a > 0 \text{ for } F_x > m_1 g = 19.6\ \mathrm{N}}$$

(b) Eliminate a and solve for T.

$$T = \frac{m_1}{m_1 + m_2}(F_x + m_2 g) \qquad \boxed{T = 0 \text{ for } F_x \le -m_2 g = -78.4\ \mathrm{N}}$$

(c)

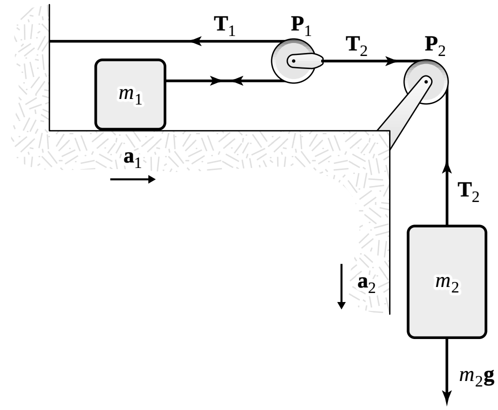
F_x, N	–100	–78.4	–50.0	0	50.0	100
a_x, m/s^2	–12.5	–9.80	–6.96	–1.96	3.04	8.04



5.38 (a) Pulley P_1 has acceleration a_2.

Since m_1 moves *twice* the distance P_1 moves in the same time, m_1 has twice the acceleration of P_1. i.e., $\boxed{a_1 = 2a_2}$

(b) From the figure, and using $F = ma$:



$$m_2 g - T_2 = m_2 a_2 \qquad (1)$$

$$T_1 = m_1 a_1 = 2m_1 a_2 \qquad (2)$$

$$T_2 - 2T_1 = 0 \qquad (3)$$

Equation (1) becomes $m_2 g - 2T_1 = m_2 a_2$

This equation combined with Equation (2) yields

$$\frac{2T_1}{m_1}\left(m_1 + \frac{m_2}{2}\right) = m_2 g$$

$$\boxed{T_1 = \frac{m_1 m_2}{2m_1 + \frac{1}{2}m_2} g} \quad \text{and} \quad \boxed{T_2 = \frac{m_1 m_2}{m_1 + \frac{1}{4}m_2} g}$$

(c) From the values of T_1 and T_2 we find that

$$a_1 = \frac{T_1}{m_1} = \boxed{\frac{m_2 g}{2m_1 + \frac{1}{2}m_2}}$$

$$a_2 = \frac{1}{2}a_1 = \boxed{\frac{m_2 g}{4m_1 + m_2}}$$

5.39 First, we will compute the needed accelerations:

(1) Before it starts to move: $a_y = 0$.

(2) During the first 0.800 s: $a_y = \dfrac{v_y - v_{iy}}{t} = \dfrac{1.20 \text{ m/s} - 0}{0.800 \text{ s}} = 1.50 \text{ m/s}^2$.

(3) While moving at constant velocity: $a_y = 0$.

(4) During the last 1.50 s: $a_y = \dfrac{v_y - v_{iy}}{t} = \dfrac{0 - 1.20 \text{ m/s}}{1.50 \text{ s}} = -0.800 \text{ m/s}^2$.

Newton's second law is: $T = 706 \text{ N} + (72.0 \text{ kg})a_y$.

(a) When $a_y = 0$, $T = \boxed{706 \text{ N}}$

(b) When $a_y = 1.50 \text{ m/s}^2$, $T = \boxed{814 \text{ N}}$

(c) When $a_y = 0$, $T = \boxed{706 \text{ N}}$

(d) When $a_y = -0.800 \text{ m/s}^2$, $T = \boxed{648 \text{ N}}$

Goal Solution

G: Based on sensations experienced riding in an elevator, we expect that the man should feel slightly heavier when the elevator first starts to ascend, lighter when it comes to a stop, and his normal weight when the elevator is not accelerating. His apparent weight is registered by the spring scale beneath his feet, so the scale force should correspond to the force he feels through his legs (Newton's third law).

O: We should draw free body diagrams for each part of the elevator trip and apply Newton's second law to find the scale force. The acceleration can be found from the change in speed divided by the elapsed time.

A: Consider the free-body diagram of the man shown below. The force F is the upward force exerted on the man by the scale, and his weight is

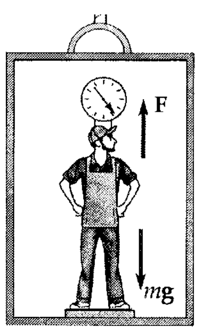
$$F_g = mg = (72.0\text{ kg})(9.80\text{ m/s}^2) = 706\text{ N}$$

With $+y$ defined to be up, Newton's second law gives

$$\sum F_y = +F_s - F_g = ma$$

So the upward scale force is $F_s = 706\text{ N} + (72.0\text{ kg})$ **[Equation 1]**

Where a is the acceleration the man experiences as the elevator changes speed.



(a) Before the elevator starts moving, the acceleration of the elevator is zero ($a = 0$) so Equation 1 gives the force exerted by the scale on the man as 706 N (upward). Thus, the man exerts a downward force of 706 N on the scale.

(b) During the first 0.800 s of motion, the man's acceleration is

$$a = \frac{\Delta v}{\Delta t} = \frac{(+1.20\text{ m/s} - 0)}{0.800\text{ s}} = 1.50\text{ m/s}^2$$

Substituting a into Equation 1 then gives:

$$F_s = 706\text{ N} + (72.0\text{ kg})(+1.50\text{ m/s}^2) = 814\text{ N}$$

(c) While the elevator is traveling upward at constant speed, the acceleration is zero and Equation 1 again gives a scale force $F_s = 706\text{ N}$

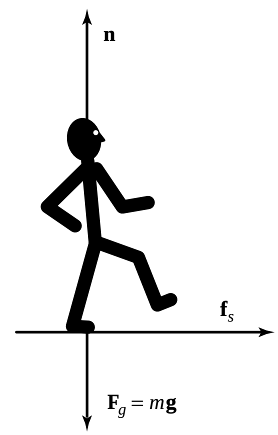
(d) During the last 1.50 s, the elevator starts with an upward velocity of 1.20 m/s, and comes to rest with an acceleration

$$a = \frac{\Delta v}{\Delta t} = \frac{0 - (+1.20 \text{ m/s})}{1.50 \text{ s}} = -0.800 \text{ m/s}^2$$

$$F_s = 706 \text{ N} + (72.0 \text{ kg})(-0.800 \text{ m/s}^2) = 648 \text{ N}$$

L: The calculated scale forces are consistent with our predictions. This problem could be extended to a couple of extreme cases. If the acceleration of the elevator were $+9.8 \text{ m/s}^2$, then the man would feel twice as heavy, and if $a = -9.8 \text{ m/s}^2$ (free fall), then he would feel "weightless", even though his true weight ($Fg = mg$) would remain the same.

***5.40** From Newton's third law, the forward force of the ground on the sprinter equals the magnitude of the friction force the sprinter exerts on the ground. If the sprinter's shoe is not to slip on the ground, this is a static friction force and its maximum magnitude is $f_{s,\,\max} = \mu_s mg$.

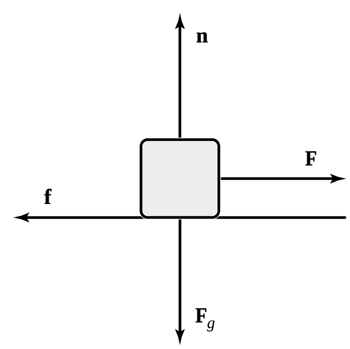


From Newton's second law applied to the sprinter, $f_{s,\,\max} = \mu_s mg = ma_{max}$ where $a_{\max}$ is the maximum forward acceleration the sprinter can achieve. From this, the acceleration is seen to be $a_{\max} = \mu_s g$. Note that the mass has canceled out.

If $\mu_s = 0.800$,

$$a_{\max} = 0.800(9.80 \text{ m/s}^2) = \boxed{7.84 \text{ m/s}^2 \text{ independent of the mass}}$$

5.41 For equilibrium: $f = F$ and $n = F_g$



Also, $f = \mu n$

i.e., $\mu = \frac{f}{n} = \frac{F}{F_g}$

$$\mu_s = \frac{75.0 \text{ N}}{(25.0)(9.80) \text{ N}} \quad \text{and} \quad \mu_k = \frac{60.0 \text{ N}}{(25.0)(9.80) \text{ N}}$$

$$\mu_s = \boxed{0.306} \quad \mu_k = \boxed{0.245}$$

***5.42** $F = \mu n = ma$ and in this case the normal force $n = mg$; therefore,

$$F = \mu mg = ma \quad \text{or} \quad \mu = \frac{a}{g}$$

The acceleration is found from

$$a = \frac{(v_f - v_i)}{t} = \frac{(80.0 \text{ mi/h})(0.447 \text{ (m/s)/(mi/h)})}{8.00 \text{ s}} = 4.47 \text{ m/s}^2$$

Substituting this value into the expression for μ we find

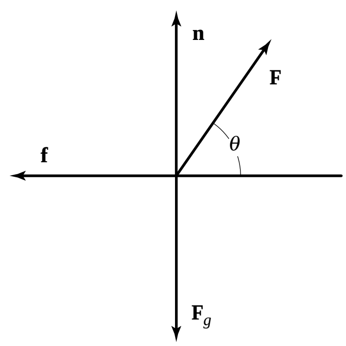
$$\mu = \frac{4.47 \text{ m/s}^2}{9.80 \text{ m/s}^2} = \boxed{0.456}$$

5.43 $v_i = 50.0 \text{ mi/h} = 22.4 \text{ m/s}$

(a) $x = \dfrac{v_i^2}{2\mu g} = \dfrac{(22.4 \text{ m/s})^2}{2(0.100)(9.80 \text{ m/s}^2)} = \boxed{256 \text{ m}}$

(b) $x = \dfrac{v_i^2}{2\mu g} = \dfrac{(22.4 \text{ m/s})^2}{2(0.600)(9.80 \text{ m/s}^2)} = \boxed{42.7 \text{ m}}$

5.44 $m_{\text{suitcase}} = 20.0 \text{ kg}$, $F = 35.0 \text{ N}$



(a) $F \cos\theta = 20.0 \text{ N}$

$$\cos\theta = \frac{20.0}{35.0} = 0.571, \quad \boxed{\theta = 55.2°}$$

(b) $n = F_g - F \sin\theta = [196 - 35.0(0.821)] \text{ N}$

$$\boxed{n = 167 \text{ N}}$$

5.45 $m = 3.00 \text{ kg}$, $\theta = 30.0°$, $x = 2.00 \text{ m}$, $t = 1.50 \text{ s}$

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

$$2.00 \text{ m} = \frac{1}{2} a(1.50 \text{ s})^2 \rightarrow a = \frac{4.00}{(1.50)^2} = \boxed{1.78 \text{ m/s}^2}$$

$$\Sigma\mathbf{F} = \mathbf{n} + \mathbf{f} + m\mathbf{g} = m\mathbf{a}$$

Along x: $0 - f + mg \sin 30.0° = ma \rightarrow f = m(g \sin 30.0° - a)$

Along y: $n + 0 - mg \sin 30.0° = 0 \rightarrow n = mg \cos 30.0°$

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

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

(d) $v_f^2 = v_i^2 + 2a(x_f - x_i)$ where $x_f - x_i = 2.00$ m

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

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

***5.46** $-f + mg \sin\theta = 0$

and $+n - mg \cos\theta = 0$

with $f = \mu n$ yield

$\mu_s = \tan\theta_c = \tan(36.0°) = \boxed{0.727}$

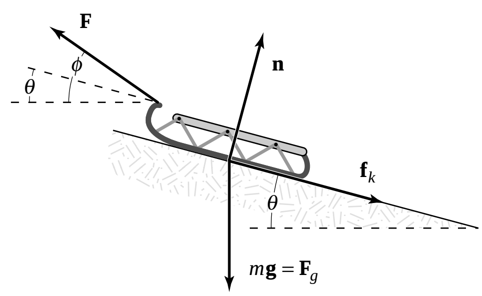
$\mu_k = \tan\theta_c = \tan(30.0°) = \boxed{0.577}$

5.47 $F_g = 60.0$ N

$\theta = 15.0°$

$\phi = 35.0°$

$F = 25.0$ N



(a) The sled is in equilibrium on the plane.

Resolving along the plane: $F\cos(\phi - \theta) = mg \sin\theta + f_k$.

Resolving ⊥ plane: $n + F\sin(\phi - \theta) = mg\cos\theta$.

Also, $f_k = \mu_k n$

$F\cos(\phi - \theta) - mg\sin\theta = \mu_k\,[mg\cos\theta - F\sin(\phi - \theta)]$

$25.0 \cos 20.0° - 60.0 \sin 15.0° = \mu_k (60.0 \cos 15.0° - 25.0 \sin 20.0°)$

$\mu_k = \boxed{0.161}$

(b) Resolving ⊥ to the plane: $n = mg\cos\theta$.

Along the plane we have $\Sigma F = ma$.

$mg\sin\theta - f_k = ma$

Also, $f_k = \mu_k n = \mu_k mg\cos\theta$.

So along the plane we have $mg\sin\theta - \mu_k mg\cos\theta = ma$

$$a = g(\sin\theta - \mu_k\cos\theta) = (9.80\text{ m/s}^2)(\sin 15.0° - 0.161\cos 15.0°)$$

$$= \boxed{1.01\text{ m/s}^2}$$

***5.48** $mg\sin 5.00° - f = ma_x$ and $f = \mu mg\cos 5.00°$

$\therefore\ g\sin 5.00° - \mu g\cos 5.00° = a_x$

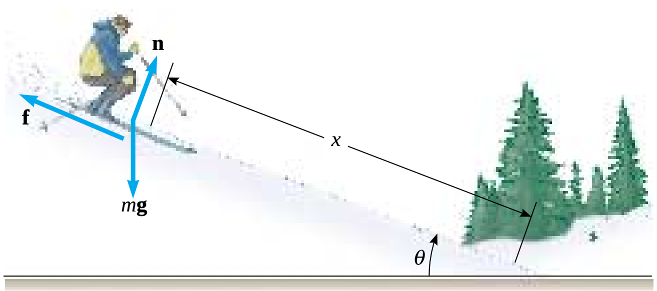
$a_x = g(\sin 5.00° - \mu\cos 5.00°) = -0.903\text{ m/s}^2$

From Equation 2.12,

$$v_f^2 - v_i^2 = 2ax$$

$$-(20.0)^2 = -2(0.903)x$$

$$\boxed{x = 221\text{ m}}$$



5.49 $T - f_f = 5.00a$ (for 5.00 kg mass)

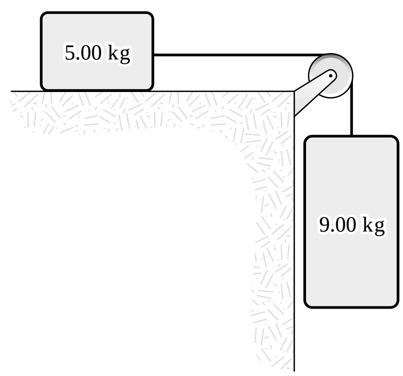
$9.00g - T = 9.00a$ (for 9.00 kg mass)

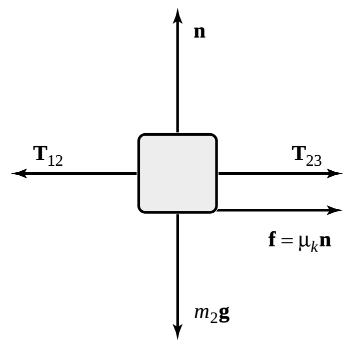
Adding these two equations gives:

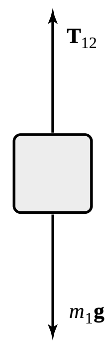
$$9.00(9.80) - 0.200(5.00)(9.80) = 14.0a$$

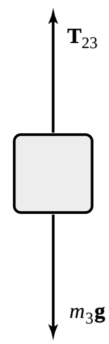
$$a = 5.60\text{ m/s}^2$$

$$\therefore\ T = 5.00(5.60) + 0.200(5.00)(9.80) = \boxed{37.8\text{ N}}$$









5.50 Let a represent the positive magnitude of the acceleration $-a\mathbf{j}$ of m_1, of the acceleration $-a\mathbf{i}$ of m_2, and of the acceleration $+a\mathbf{j}$ 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, $\Sigma F_y = ma_y$ $+T_{12} - m_1 g = -m_1 a$

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

and $\Sigma F_y = ma_y$ $n - m_2 g = 0$

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

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:

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

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

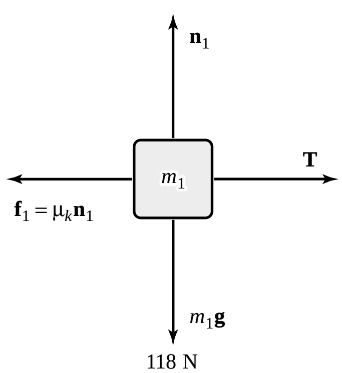
(b) Now $-T_{12} + 39.2\text{ N} = 4.00\text{ kg}(2.31\text{ m/s}^2)$

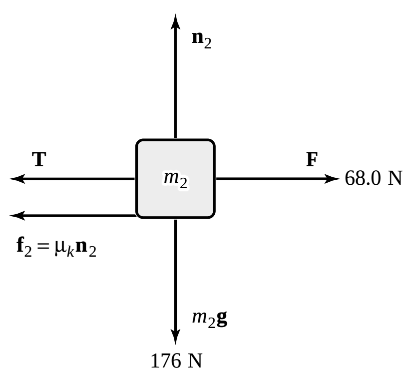
$$\boxed{T_{12} = 30.0\text{ N}}$$

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

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

5.51 (a)





(b) $68.0 - T - \mu m_2 g = m_2 a$ (Block #2)

$T - \mu m_1 g = m_1 a$ (Block #1)

Adding, $68.0 - \mu(m_1 + m_2)g = (m_1 + m_2)a$

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

$$T = m_1 a + \mu m_1 g = \boxed{27.2\ \text{N}}$$

5.52 (a) The rope makes angle $\text{Arctan}\left(\frac{10.0\ \text{cm}}{40.0\ \text{cm}}\right) = 14.0°$

$\Sigma F_y = ma_y$ $+10.0\ \text{N} \sin 14.0° + n - 2.20\ \text{kg}(9.80\ \text{m/s}^2) = 0$

$n = 19.1\ \text{N}$

$f_k = \mu_k n = 0.400(19.1\ \text{N}) = 7.65\ \text{N}$

$\Sigma F_x = ma_x$ $+10.0\ \text{N} \cos 14.0° - 7.65\ \text{N} = (2.20\ \text{kg})a$

$a = \boxed{0.931\ \text{m/s}^2}$

(b) $\Sigma F_x = ma_x$

$10.0\ \text{N} \cos\theta - f_k = 0$

$10.0\ \text{N} \cos\theta = f_k = \mu_k n = 0.400[2.20\ \text{kg}(9.80\ \text{m/s}^2) - 10.0\ \text{N} \sin\theta]$

$10.0\ \text{N} \sqrt{1 - \sin^2\theta} = 8.62\ \text{N} - 4.00\ \text{N} \sin\theta$

$100 - 100 \sin^2\theta = 74.4 - 69.0 \sin\theta + 16.0 \sin^2\theta$

$-116 \sin^2\theta + 69.0 \sin\theta + 25.6 = 0$

$$\sin\theta = \frac{-69.0 \pm \sqrt{(69.0)^2 - 4(25.6)(-116)}}{2(-116)}$$

$\sin\theta = -0.259$ or 0.854

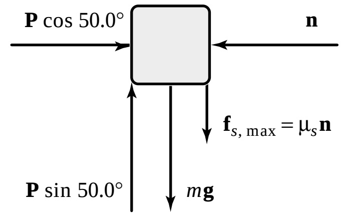
$\theta = -15.0°$ or $58.6°$

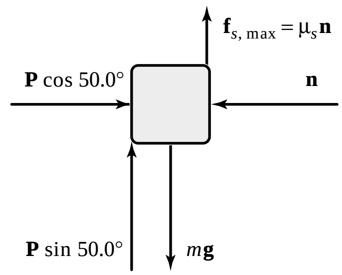
The negative root would refer to the pulley below the block.

We choose $\tan 58.6° = \frac{10.0\ \text{cm}}{x}$

$x = \boxed{6.10\ \text{cm}}$

***5.53** (Case 1, impending upward motion)





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

$$f_{s,\,\max} = \mu_s n = \mu_s P\cos 50.0°$$

$$= 0.250(0.643)P = 0.161P$$

Setting $\sum F_y = 0$:

$$P\sin 50.0° - 0.161P - (3.00)(9.80) = 0$$

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

(Case 2, impending downward motion)

$f_{s,\,\max} = 0.161P$ as in Case 1.

Setting $\sum F_y = 0$:

$$P\sin 50.0° + 0.161P - (3.00)(9.80) = 0$$

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

5.54 $\sum \mathbf{F} = m\mathbf{a}$ gives the object's acceleration

$$\mathbf{a} = \frac{\sum F}{m} = \frac{(8.00\mathbf{i} - 4.00t\,\mathbf{j})\text{ N}}{2.00\text{ kg}}$$

$$\mathbf{a} = (4.00\text{ m/s}^2)\mathbf{i} - (2.00\text{ m/s}^3)t\,\mathbf{j} = \frac{d\mathbf{v}}{dt}$$

Its velocity is

$$\int_{v_i}^{v} d\mathbf{v} = \mathbf{v} - \mathbf{v}_i = \mathbf{v} - 0 = \int_0^t \mathbf{a}\,dt$$

$$\mathbf{v} = \int_0^t [(4.00\text{ m/s}^2)\mathbf{i} - (2.00\text{ m/s}^3)t\,\mathbf{j}]\,dt$$

$$\mathbf{v} = (4.00t\text{ m/s}^2)\mathbf{i} - (1.00t^2\text{ m/s}^3)\mathbf{j}$$

(a) We require $|\mathbf{v}| = 15.0\text{ m/s}$ $|\mathbf{v}|^2 = 225\text{ m}^2/\text{s}^2$

$$16.0t^2\text{ m}^2/\text{s}^4 + 1.00t^4\text{ m}^2/\text{s}^6 = 225\text{ m}^2/\text{s}^2$$

$$1.00t^4 + 16.0\text{ s}^2t^2 - 225\text{ s}^4 = 0$$

$$t^2 = \frac{-16.0 \pm \sqrt{(16.0)^2 - 4(-225)}}{2.00} = 9.00\text{ s}^2$$

$$t = \boxed{3.00\text{ s}}$$

Take $\mathbf{r}_i = 0$ at $t = 0$. The position is

$$\mathbf{r} = \int_0^t \mathbf{v}\, dt = \int_0^t [(4.00t \text{ m/s}^2)\mathbf{i} - (1.00t^2 \text{ m/s}^3)\mathbf{j}]dt$$

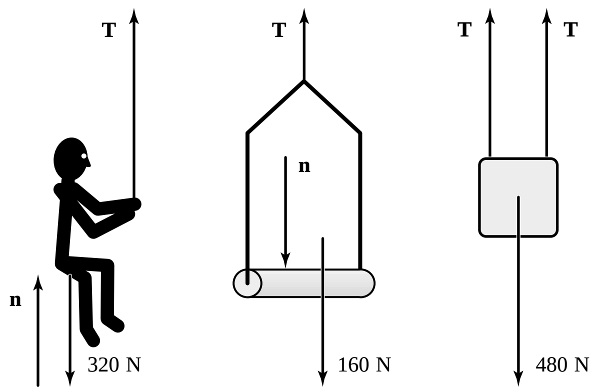
$$\mathbf{r} = (4.00 \text{ m/s}^2)\frac{t^2}{2}\,\mathbf{i} - (1.00 \text{ m/s}^3)\frac{t^3}{3}\,\mathbf{j}$$

at $t = 3$ s we evaluate

(c) $\mathbf{r} = \boxed{(18.0\mathbf{i} - 9.00\mathbf{j}) \text{ m}}$

(b) So $|\mathbf{r}| = \sqrt{(18.0)^2 + (9.00)^2}$ m $= \boxed{20.1 \text{ m}}$

5.55 (a)



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

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

Solving for a gives $a = \dfrac{(500 - 480)}{49.0} = \boxed{0.408 \text{ m/s}^2}$

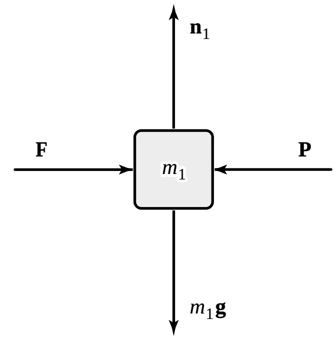
(c) $\Sigma F\,(\text{on Pat}) = n + T - 320 = ma \quad \text{where} \quad m = \dfrac{320}{9.80} = 32.7 \text{ kg}$

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

***5.56** (a) $F = ma$

$18.0 = (2.00 + 3.00 + 4.00)a$

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

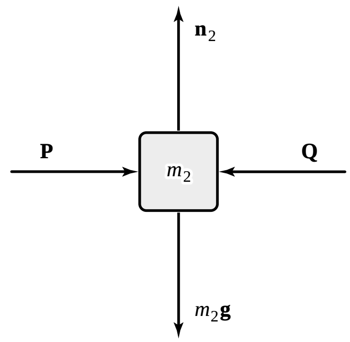


(b) The force on each block can be found by knowing mass and acceleration:

$\Sigma F_1 = m_1 a = 2.00(2.00) = \boxed{4.00\ \text{N}}$

$\Sigma F_2 = m_2 a = 3.00(2.00) = \boxed{6.00\ \text{N}}$

$\Sigma F_3 = m_3 a = 4.00(2.00) = \boxed{8.00\ \text{N}}$

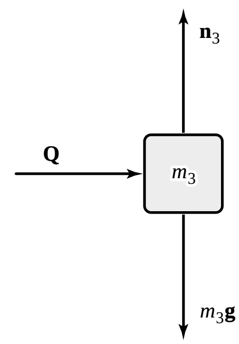


(c) Therefore, $\Sigma F_1 = 4.00\ \text{N} = F - P$

$P = \boxed{14.0\ \text{N}}$

$\Sigma F_2 = 6.00\ \text{N} = P - Q$

$Q = \boxed{800\ \text{N}}$



***5.57** We find the diver's impact speed by anaylzing his free-fall motion:

$v_f^2 = v_i^2 + 2ax = 0^2 + 2(-9.80\ \text{m/s}^2)(-10.0\ \text{m})$

$v_f = -14.0\ \text{m/s}$

Now for the 2.00 s of stopping, we have

$v_f = v_i + at$

$0 = -14.0\ \text{m/s} + a(2.00\ \text{s}),\ a = +7.00\ \text{m/s}^2$

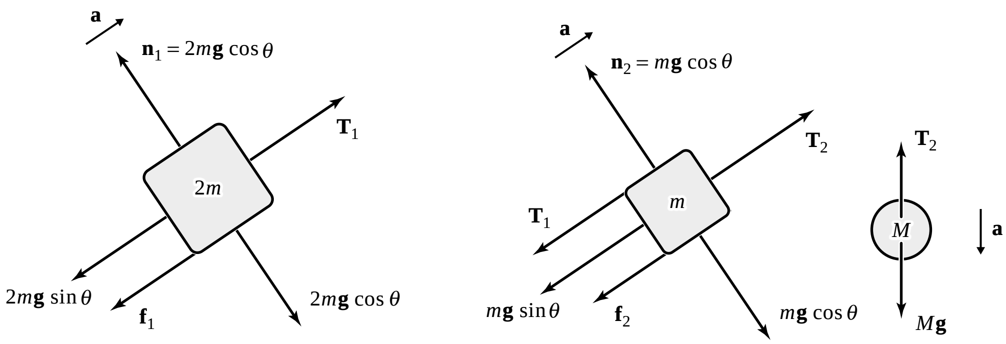
$\Sigma F_y = ma$

Call the force exerted by the water on the driver R.

$+R - (70.0\ \text{kg})(9.80\ \text{m/s}^2) = (70.0\ \text{kg})(7.00\ \text{m/s}^2)$

$R = \boxed{1.18\ \text{kN}}$

5.58



Applying Newton's second law to each object gives:

(1) $T_1 = f_1 + 2m(g \sin\theta + a)$ (2) $T_2 - T_1 = f_2 + m(g \sin\theta + a)$

and (3) $T_2 = M(g - a)$

Parts (a) and (b): Equilibrium ($\Rightarrow a = 0$) and frictionless incline ($\Rightarrow f_1 = f_2 = 0$) Under these conditions, the equations reduce to

(1) $\boxed{T_1 = 2mg \sin\theta}$ (2) $T_2 - T_1 = mg \sin\theta$ and (3') $T_2 = Mg$

Substituting (1') and (3') into equation (2') then gives $\boxed{M = 3m \sin\theta}$, so equation (3') becomes $\boxed{T_2 = 3mg \sin\theta}$.

Parts (c) and (d): $M = 6m \sin\theta$(double the value found above), and $f_1 = f_2 = 0$. With these conditions present, the equations become

$T_1 = 2m(g \sin\theta + a)$ $T_2 - T_1 = m(g \sin\theta + a)$ and $T_2 = 6m \sin\theta(g - a)$

Solved simultaneously, these yield $\boxed{a = \dfrac{g \sin\theta}{1 + 2\sin\theta}}$,

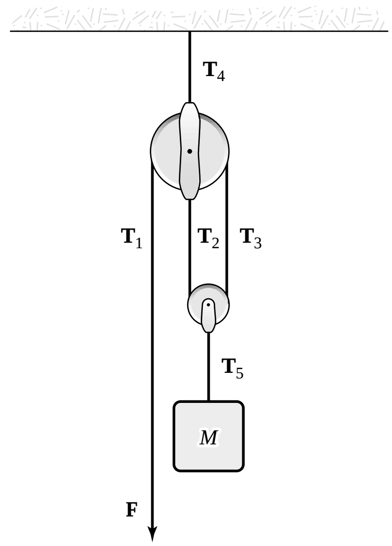
$\boxed{T_1 = 4mg \sin\theta\left(\dfrac{1 + \sin\theta}{1 + 2\sin\theta}\right)}$ and $\boxed{T_2 = 6mg \sin\theta\left(\dfrac{1 + \sin\theta}{1 + 2\sin\theta}\right)}$

Part (e): Equilibrium ($\Rightarrow a = 0$) and impending motion up the incline so $M = M_{\text{max}}$ while $f_1 = 2\mu_s\, mg \cos\theta$ and $f_2 = \mu_s\, mg \cos\theta$, both directed down the incline. Under these conditions, the equations become $T_1 = 2mg(\sin\theta + \mu_s \cos\theta)$, $T_2 - T_1 = mg(\sin\theta + \mu_s \cos\theta)$, and $T_2 = M_{\text{max}}\, g$ which yield $\boxed{M_{\text{max}} = 3m(\sin\theta + \mu_s \cos\theta)}$.

Part (f): Equilibrium ($\Rightarrow a = 0$) and impending motion **down** the incline so $M = M_{\text{min}}$ while $f_1 = 2\mu_s\, mg \cos\theta$ and $f_2 = \mu_s\, mg \cos\theta$, both directed **up** the incline. Under these conditions, the equations are $T_1 = 2mg(\sin\theta - \mu_s \cos\theta)$, $T_2 - T_1 = mg(\sin\theta - \mu_s \cos\theta)$, and $T_2 = M_{\text{min}}\, g$ which yield $\boxed{M_{\text{min}} = 3m(\sin\theta - \mu_s \cos\theta)}$.

Part (g): $\boxed{T_{2,\,\max} - T_{2,\,\min} = M_{\max}g - M_{\min}g = 6mg\mu_s \cos\theta}$

5.59 (a) First, we note that $F = T_1$. Next, we focus on the mass M and write $T_5 = Mg$. Next, we focus on the bottom pulley and write $T_5 = T_2 + T_3$. Finally, we focus on the top pulley and write $T_4 = T_1 + T_2 + T_3$.



Since the pulleys are massless and frictionless, $T_1 = T_3$, and $T_2 = T_3$. From this information, we have $T_5 = 2\,T_2$, so $T_2 = \dfrac{Mg}{2}$.

Then $\boxed{T_1 = T_2 = T_3 = \dfrac{Mg}{2}}$, and $\boxed{T_4 = \dfrac{3\,Mg}{2}}$, and $\boxed{T_5 = Mg}$

(b) Since $F = T_1$, we have $\boxed{F = \dfrac{Mg}{2}}$

5.60 (a) $\Sigma\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = (-9.00\mathbf{i} + 3.00\mathbf{j})\text{ N}$

Acceleration $\mathbf{a} = a_x\mathbf{i} + a_y\mathbf{j} = \dfrac{\Sigma\mathbf{F}}{m} = \dfrac{(-9.00\mathbf{i} + 3.00\mathbf{j})\text{ N}}{2.00\text{ kg}} = (-4.50\mathbf{i} + 1.50\mathbf{j})\text{ m/s}^2$

Velocity $\mathbf{v} = v_x\mathbf{i} + v_y\mathbf{j} = \mathbf{v}_\text{i} + \mathbf{a}t = \mathbf{a}t$

$$\mathbf{v} = (-4.50\mathbf{i} + 1.50\mathbf{j})(\text{m/s}^2)(10\text{ s}) = \boxed{(-45.0\mathbf{i} + 15.0\mathbf{j})\text{ m/s}}$$

(b) The direction of motion makes angle θ with the x-direction.

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(-\frac{15.0\text{ m/s}}{45.0\text{ m/s}}\right)$$

$$\theta = -18.4° + 180° = \boxed{162° \text{ from } +x\text{-axis}}$$

(c) Displacement:

$$x\text{-displacement} = x - x_i = v_{xi}t + \frac{1}{2}a_xt^2 = \left(\frac{1}{2}\right)(-4.50\text{ m/s}^2)(10.0\text{ s})^2 = -225\text{ m}$$

$$y\text{-displacement} = y - y_i = v_{yi}t + \frac{1}{2}a_yt^2 = \left(\frac{1}{2}\right)(+1.50\text{ m/s}^2)(10.0\text{ s})^2 = +75.0\text{ m}$$

$$\Delta\mathbf{r} = \boxed{(-225\mathbf{i} + 75.0\mathbf{j})\text{ m}}$$

(d) Position: $\equiv \mathbf{r} = \mathbf{r}_1 + \Delta\mathbf{r}$

$$\mathbf{r} = (-2.00\mathbf{i} + 4.00\mathbf{j}) + (-225\mathbf{i} + 75.0\mathbf{j}) = \boxed{(-227\mathbf{i} + 79.0\mathbf{j})\text{ m}}$$

5.61 (a) The crate is in equilibrium.

Let the normal force acting on it be n and the friction force, f_s.

Resolving vertically: $n = F_g + P \sin\theta$

Horizontally: $P \cos\theta = f_s$

But $f_s \le \mu_s n$

i.e., $P\cos\theta \le \mu_s (F_g + P\sin\theta)$

or $P(\cos\theta - \mu_s \sin\theta) \le \mu_s F_g$

Divide by $\cos\theta$: $P(1 - \mu_s \tan\theta) \le \mu_s F_g \sec\theta$

Then $\boxed{P_{\text{minimum}} = \dfrac{\mu_s F_g \sec\theta}{1 - \mu_s \tan\theta}}$

(b) $P = \dfrac{0.400(100\text{ N})\sec\theta}{1 - 0.400\tan\theta}$

θ (deg)	0.00	15.0	30.0	45.0	60.0
P (N)	40.0	46.4	60.1	94.3	260

5.62 (a) Following Example 5.6 $a = g\sin\theta = (9.80\text{ m/s}^2)\sin 30.0°$

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

(b) The block slides distance x on the incline, with $\sin 30.0° = 0.500\text{ m}/x$ $x = 1.00$ m

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

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

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

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

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

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

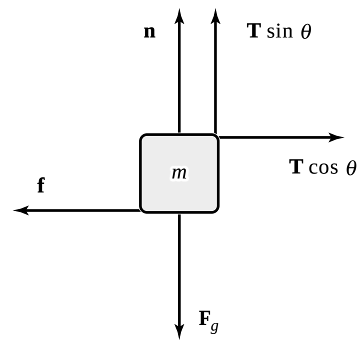
$t = 0.499$ s, the other root being unphysical.

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

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

(e) The mass of the block makes no difference.

***5.63** With motion impending, $n + T\sin\theta - mg = 0$



$$f = \mu_s(mg - T\sin\theta)$$

and $T\cos\theta - \mu_s mg + \mu_s T\sin\theta = 0$

so $$T = \frac{\mu_s mg}{\cos\theta + \mu_s \sin\theta}$$

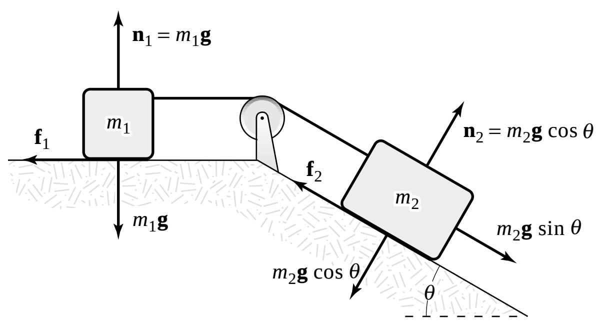
To minimize T, we maximize $\cos\theta + \mu_s\sin\theta$

$$\frac{d}{d\theta}(\cos\theta + \mu_s\sin\theta) = 0 = -\sin\theta + \mu_s\cos\theta$$

(a) $\theta = \text{Arctan}\,\mu_s = \text{Arctan}\,0.350 = \boxed{19.3°}$

(b) $$T = \frac{(0.350)(1.30\text{ kg})(9.80\text{ m/s}^2)}{\cos 19.3° + 0.350\sin 19.3°} = \boxed{4.21\text{ N}}$$

5.64



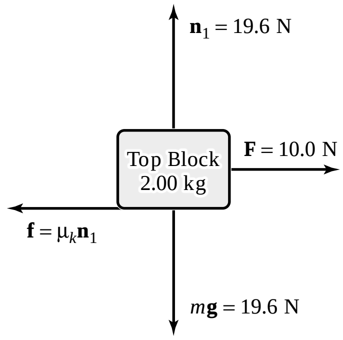
For the system to start to move when released, the force tending to move m_2 down the incline, $m_2 g\sin\theta$, must exceed the maximum friction force which can retard the motion:

$$f_{\text{max}} = f_{1,\,\text{max}} + f_{2,\,\text{max}} = \mu_{s,\,1}n_1 + \mu_{s,\,2}n_2 = \mu_{s,\,1}m_1 g + \mu_{s,\,2}m_2 g\cos\theta$$

From Table 5.2, $\mu_{s,\,1} = 0.610$ (aluminum on steel) and $\mu_{s,\,2} = 0.530$ (copper on steel). With $m_1 = 2.00$ kg, $m_2 = 6.00$ kg, $\theta = 30.0°$, the maximum friction force is found to be $f_{\text{max}} = 38.9$ N. This exceeds the force tending to cause the system to move, $m_2 g\sin\theta = (6.00)(9.80)\sin 30.0° = 29.4$ N. Hence, $\boxed{\text{the system will not start to move when released}}$.

The friction forces increase in magnitudes until the total friction force retarding the motion, $f = f_1 + f_2$, equals the force tending to set the system in motion. That is until $\boxed{f = m_2 g\sin\theta = 29.4\text{ N}}$.

5.65 (a) First, draw a free-body diagram, (Fig. 1) of the top block.



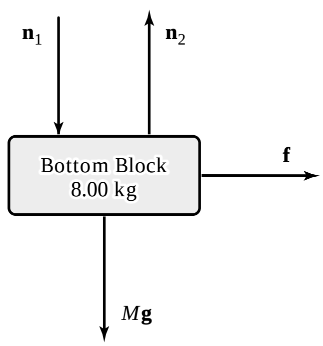
Since $a_y = 0$, $n_1 = 19.6$ N and $f_k = \mu_k n_1 = (0.300)(19.6) = 5.88$ N

$$\Sigma F_x = ma_T$$

gives $10.0\text{ N} - 5.88\text{ N} = (2.00\text{ kg})a_T$, or

$$a_T = 2.06\text{ m/s}^2 \text{ (for top block)}$$

Now draw a free-body diagram (Fig. 2) of the bottom block and observe that



$$\Sigma F_x = Ma_B$$

gives $f = 5.88\text{ N} = (8.00\text{ kg})a_B$, or

$$a_B = 0.753\text{ m/s}^2 \text{ (for the bottom block)}$$

In time t, the distance each block moves (starting from rest) is

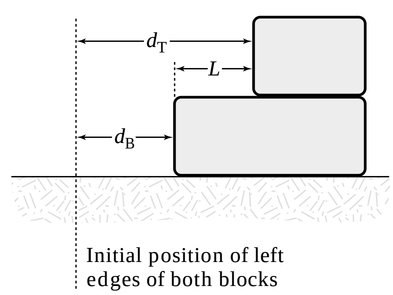
$$d_T = \frac{1}{2}a_T t^2 \quad \text{and} \quad d_B = \frac{1}{2}a_B t^2$$

For the top block to reach the right edge of the bottom block, it is necessary that

$$d_\text{T} = d_\text{B} + L \quad \text{or} \quad \text{(See Figure 3)}$$

$$\frac{1}{2}(2.06\text{ m/s}^2)\,t^2 = \frac{1}{2}(0.735\text{ m/s}^2)\,t^2 + 3.00\text{ m}$$

which gives: $t = \boxed{2.13\text{ s}}$

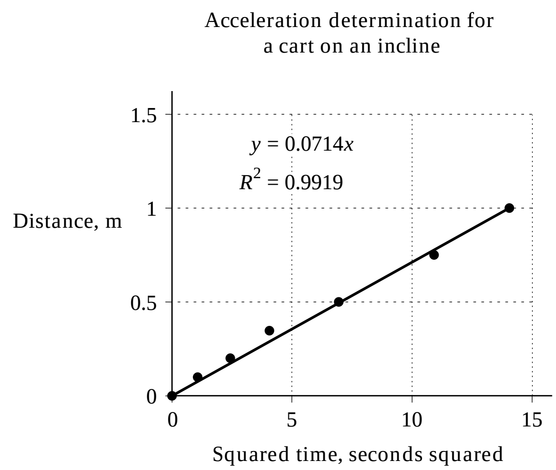


(b) From above,

$$d_B = \frac{1}{2}(0.735 \text{ m/s}^2)(2.13 \text{ s})^2 = \boxed{1.67 \text{ m}}$$

5.66

t(s)	t^2(s^2)	x(m)
0	0	0
1.02	1.040	0.100
1.53	2.341	0.200
2.01	4.040	0.350
2.64	6.970	0.500
3.30	10.89	0.750
3.75	14.06	1.00



From $x = \frac{1}{2}at^2$

the slope of a graph of x versus t^2 is $\frac{1}{2}a$,

and $a = 2 \times \text{slope} = 2(0.0714 \text{ m/s}^2) = \boxed{0.143 \text{ m/s}^2}$

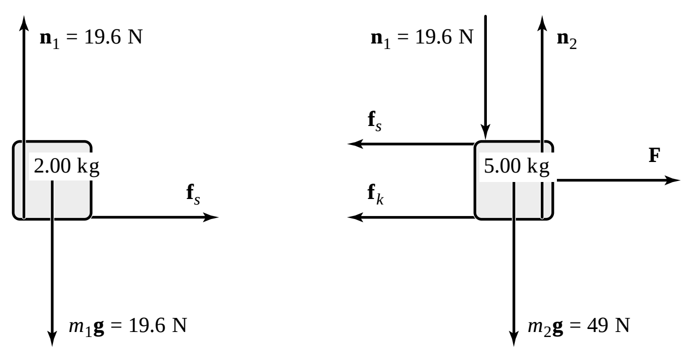
From $a' = g \sin\theta$, we obtain

$$a' = (9.80 \text{ m/s}^2)\left(\frac{1.774}{127.1}\right) = 0.137 \text{ m/s}^2, \text{ different by } 4\%$$

The difference is accounted for by the uncertainty in the data, which we may estimate from the third point as

$$\frac{0.350 - (0.0714)(4.04)}{0.350} = 18\%$$

5.67 (a)



The force of static friction between the blocks accelerates the 2.00 kg block.

(b) $\Sigma F = ma$, for both blocks together

$F - \mu n_2 = ma$,

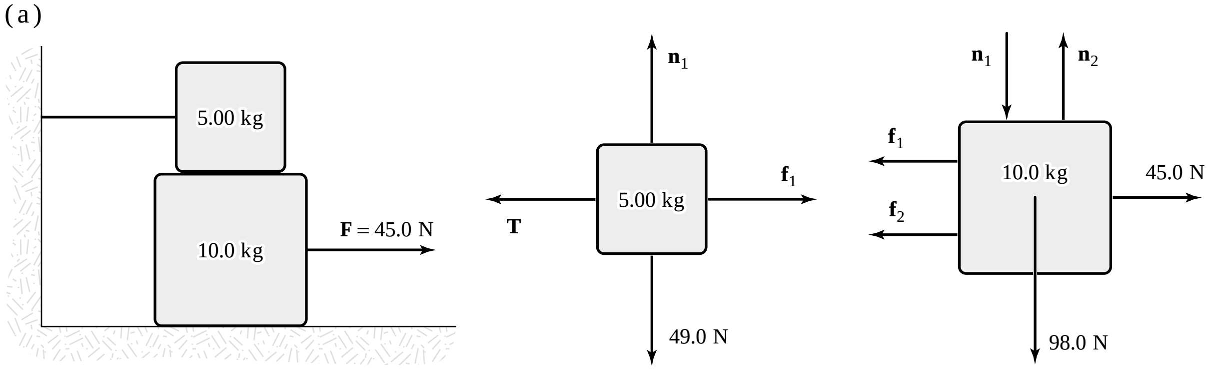
$F - (0.200)[(5.00 + 2.00)(9.80)] = (5.00 + 2.00)3.00$

Therefore $F = \boxed{34.7\ \text{N}}$

(c) $f = \mu_1(2.00)(9.80) = m_1 a = 2.00(3.00)$

Therefore $\mu = \boxed{0.306}$

5.68 (a)



f_1 and n_1 appear in both diagrams as action-reaction pairs

(b) 5.00 kg: $\Sigma F_x = ma$ $n_1 = m_1 g = (5.00)(9.80) = 49.0$ N $\qquad f_1 - T = 0$

$T = f_1 = \mu mg = (0.200)(5.00)(9.80) = \boxed{9.80\ \text{N}}$

10.0 kg: $\Sigma F_x = ma \quad \Sigma F_y = 0$

$45.0 - f_1 - f_2 = 10.0a \qquad n_2 - n_1 - 98.0 = 0$

$f_2 = \mu n_2 = \mu(n_1 + 98.0) = (0.20)(49.0 + 98.0) = 29.4$ N

$45 - 9.80 - 29.4 = 10.0a$

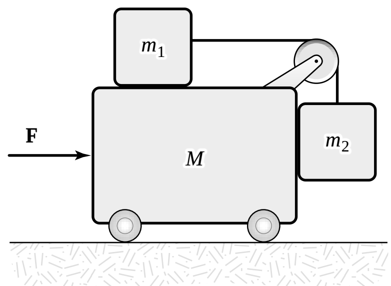
$a = \boxed{0.580\ \text{m/s}^2}$

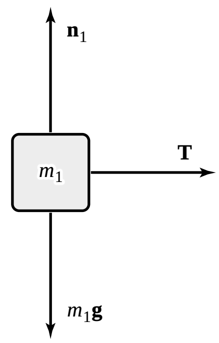
5.69 $\Sigma F = ma$

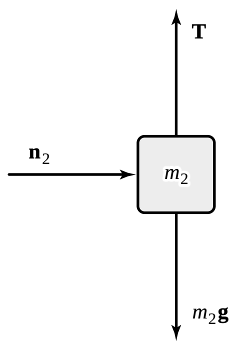
For m_1: $T = m_1 a \quad a = \dfrac{m_2 g}{m_1}$

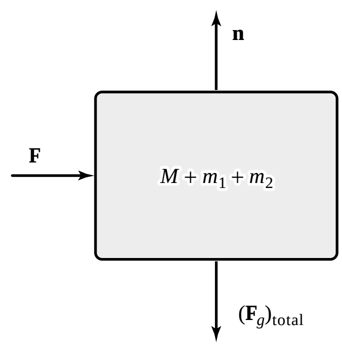
For m_2: $T - m_2 g = 0$

For all 3 blocks: $F = (M + m_1 + m_2)a = \boxed{(M + m_1 + m_2)\left(\dfrac{m_2 g}{m_1}\right)}$









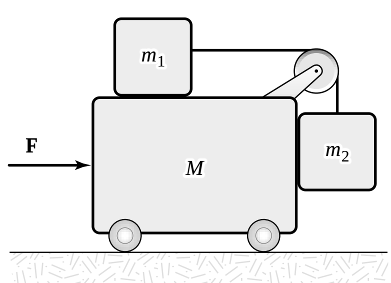
Goal Solution

Draw separate free-body diagrams for blocks m_1 and m_2.

Remembering that normal forces are always perpendicular to the contacting surface, and always **push** on a body, draw n_1 and n_2 as shown. Note that m_2 should be in **contact** with the cart, and therefore does have a normal force from the cart.

Remembering that ropes always **pull** on bodies in the direction of the rope, draw the tension force **T**.

Finally, draw the gravitational force on each block, which always points downwards.



G: What can keep m_2 from falling? Only tension in the cord connecting it with m_1 . This tension pulls forward on m_1 to accelerate that mass. This acceleration should be proportional to m_2 and to g and inversely proportional to m_1, so perhaps $a = (m_2/m_1)g$ We should also expect the applied force to be proportional to the total mass of the system.

O: Use $\Sigma F = ma$ and the free-body diagrams above.

A: For m_2, $T - m_2 g = 0$ or $T = m_2 g$

For m_1, $T = m_1 a$ or $a = \dfrac{T}{m_1}$

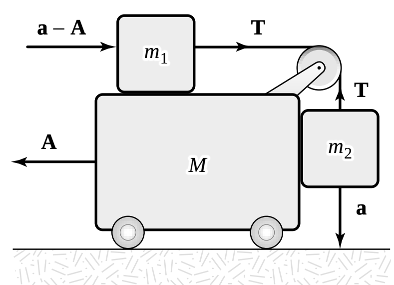
Substituting for T, we have $a = \dfrac{m_2 g}{m_1}$

For all 3 blocks, $F = (M + m_1 + m_2)a$.

Therefore, $F = (M + m_1 + m_2)\left(\dfrac{m_2 g}{m_1}\right)$

L: Even though this problem did not have a numerical solution, we were still able to rationalize the algebraic form of the solution. This technique does not always work, especially for complex situations, but often we can think through a problem to see if an equation for the solution makes sense based on the physical principles we know.

5.70 (1) $m_1(a - A) = T \Rightarrow a = T/m_1 + A$



(2) $MA = R_x = T \Rightarrow A = T/M$

(3) $m_2 a = m_2 g - T \Rightarrow T = m_2(g - a)$

(a) Substitute the value for a from (1) into (3) and solve for T ;

$$T = m_2[g - (T/m_1 + A)]$$

Substitute for A from (2);

$$T = m_2\left[g - \left(\frac{T}{m_1} + \frac{T}{M}\right)\right] = \boxed{m_2 g\left[\frac{m_1 M}{m_1 M + m_2(m_1 + M)}\right]}$$

(b) Solve (3) for a and substitute value of T

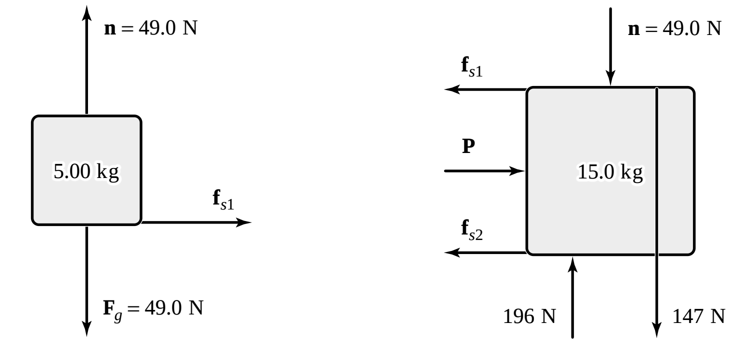
$$\boxed{a = \frac{m_2 g(M + m_1)}{m_1 M + m_2(M + m_1)}}$$

(c) From (2), $A = T/M$; Substitute the value of T

$$\boxed{A = \frac{m_1 m_2 g}{m_1 M + m_2(m_1 + M)}}$$

(d) $$\boxed{a - A = \frac{M m_2 g}{m_1 M + m_2(m_1 + M)}}$$

***5.71** (a) Motion impending



$f_{s1} = \mu n = 14.7$ N $f_{s2} = 0.500(196\text{ N}) = 98.0$ N

(b) $P = f_{s1} + f_{s2} = 14.7\text{ N} + 98.0\text{ N} = \boxed{113\text{ N}}$

(c) Once motion starts, kinetic friction acts.

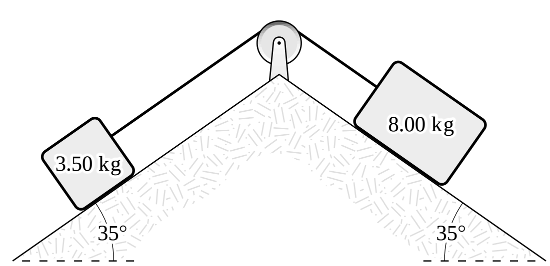
$$112.7\text{ N} - 0.100(49.0\text{ N}) - 0.400(196\text{ N}) = 15.0\text{ kg } a_2$$

$$a_2 = \boxed{1.96\text{ m/s}^2}$$

$$0.100(49.0\text{ N}) = 5.00\text{ kg } a_1$$

$$a_1 = \boxed{0.980\text{ m/s}^2}$$

5.72 Since it has a larger mass, we expect the 8.00 kg block to move down the plane. The acceleration for both blocks should have the same magnitude since they are joined together by a non-stretching string.



$\Sigma F_1 = m_1 a_1$: $-m_1 g \sin 35.0° + T = m_1 a$

$\Sigma F_2 = m_2 a_2$: $-m_2 g \sin 35.0° + T = -m_2 a$

and $-(3.50)(9.80)\sin 35.0° + T = 3.50a$

$-(8.00)(9.80)\sin 35.0° + T = -8.00a$

$T = \boxed{27.4\text{ N}}$ $a = \boxed{2.20\text{ m/s}^2}$

5.73 $\sum F_1 = m_1 a$: $-m_1 g \sin 35.0° - f_{k,1} + T = m_1 a$

(1) $-(3.50)(9.80)\sin 35.0° - \mu_k(3.50)(9.80)\cos 35.0° + T = (3.50)(1.50)$

$\sum F_2 = m_2 a$: $+m_2 g \sin 35.0° - f_{k,2} - T = m_2 a$

(2) $+(8.00)(9.80)\sin 35.0° - \mu_k(8.00)(9.80)\cos 35.0° - T = (8.00)(1.50)$

Solving equations (1) and (2) simultaneously gives

(a) $\boxed{\mu_k = 0.0871}$

(b) $\boxed{T = 27.4 \text{ N}}$

5.74 The forces acting on the sled are

(a) $T - F_f = ma$

$T - 500 \text{ N} = (100 \text{ kg})(1.00 \text{ m/s}^2)$

$T = \boxed{600 \text{ N}}$

(b) Frictional force pushes the horse forward.

$f - T = m_{\text{horse}} a$

$f - 600 \text{ N} = (500 \text{ kg})(1.00 \text{ m/s}^2)$

$f = \boxed{1100 \text{ N}}$

(c) $f - F_f = 600 \text{ N}$

$\Sigma m = 100 \text{ kg} + 500 \text{ kg}$

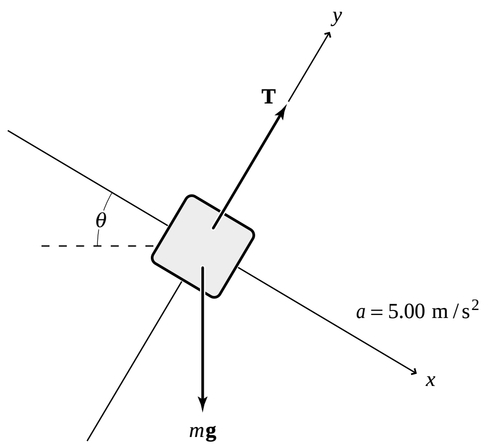
$$a = \frac{\Sigma F}{\Sigma m} = \frac{600 \text{ N}}{600 \text{ kg}} = \boxed{1.00 \text{ m/s}^2}$$

5.75 $mg \sin \theta = m(5.00 \text{ m/s}^2)$

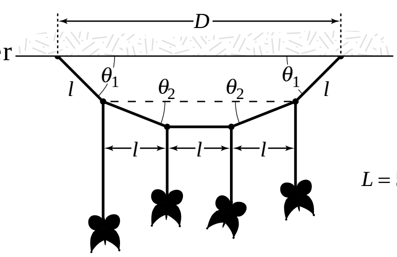
$\theta = \boxed{30.7°}$

$T = mg \cos \theta = (0.100)(9.80) \cos 30.7°$

$T = \boxed{0.843 \text{ N}}$



5.76 (a) Apply Newton's 2nd law to two points where butterflies are attached on either half of mobile (other half the same, by symmetry)



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

(2) $T_1 \sin \theta_1 - T_2 \sin \theta_2 - mg = 0$

(3) $T_2 \cos \theta_2 - T_3 = 0$

(4) $T_2 \sin \theta_2 - mg = 0$

Substituting (3) into (1) for $T_2 \sin \theta_2$ $\quad T_1 \sin \theta_1 - mg - mg = 0$

Then $\boxed{T_1 = \dfrac{2mg}{\sin \theta_1}}$

Substitute (3) into (1) for $T_2 \cos \theta_2$ $\quad T_3 - T_1 \cos \theta_1 = 0, \quad T_3 = T_1 \cos \theta_1$

Substitute value of T_1; $\quad T_3 = 2mg \dfrac{\cos \theta_1}{\sin \theta_1} = \dfrac{2mg}{\tan \theta_1}$

From Eq. (4), $\quad \boxed{T_2 = \dfrac{mg}{\sin \theta_2}}$

(b) We must find θ_2 and substitute for θ_2: $T_2 = \dfrac{mg}{\sin\left[\tan^{-1}\left(\frac{1}{2}\tan\,\theta_1\right)\right]}$

divide (4) by (3);

$$\frac{T_2 \sin\,\theta_2}{T_2 \cos\,\theta_2} = \frac{mg}{T_3} \;\Rightarrow \tan\,\theta_2 = \frac{mg}{T_3}$$

Substitute value of $T_3 \Rightarrow \tan\,\theta_2 = \dfrac{mg \tan\,\theta_1}{2mg}$

$$\boxed{\theta_2 = \tan^{-1}\left(\frac{\tan\,\theta_1}{2}\right)}$$

(c) D is the total horizontal displacement of each string

$$D = 2\,l\,\cos\theta_1 + 2\,l\,\cos\theta_2 + l \quad \text{and} \quad L = 5\,l$$

$$D = \frac{L}{5}\left\{2\cos\,\theta_1 + 2\cos\left[\tan^{-1}\left(\frac{1}{2}\,\tan\,\theta_1\right)\right] + 1\right\}$$

5.77 If all the weight is on the rear wheels,

(a) $F = ma \quad mg\mu_s = ma$

But $\Delta x = \dfrac{at^2}{2} = \dfrac{g\mu_s t^2}{2}$, so $\mu_s = \dfrac{2\Delta x}{gt^2}$

$$\mu_s = \frac{2(0.250\text{ mi})(1609\text{ m/mi})}{(9.80\text{ m/s}^2)(4.96\text{ s})^2} = \boxed{3.34}$$

(b) Time would increase, as the wheels would skid and only kinetic friction would act; or perhaps the car would flip over.

5.78 $\sum F_y = ma_y$: $n - mg\cos\theta = 0$, or

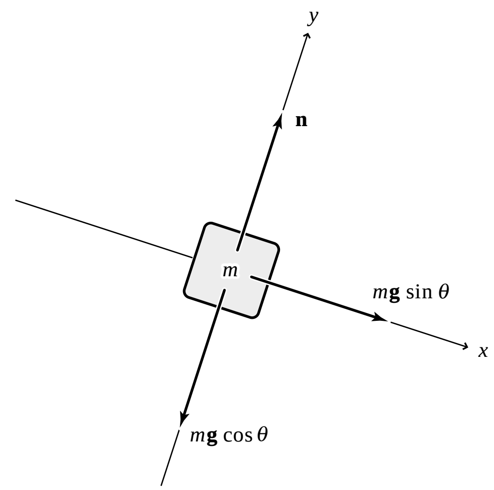
$$n = (8.40)(9.80)\cos\theta$$

$$n = (82.3\text{ N})\cos\theta$$

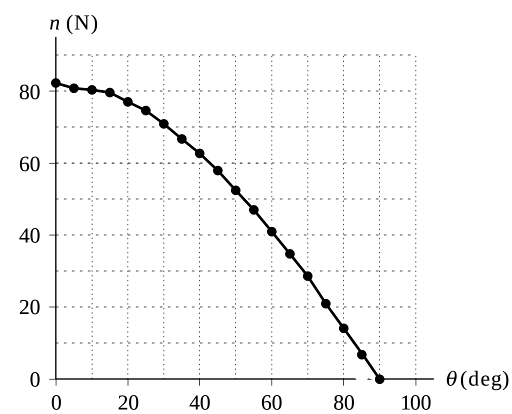
$\sum F_x = ma_x$: $mg\sin\theta = ma$, or

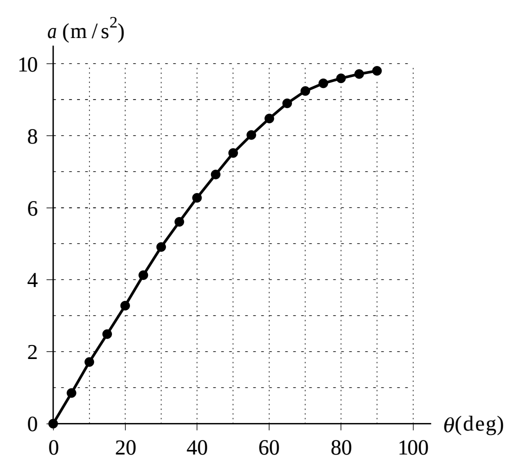
$$a = g\sin\theta$$

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



θ (deg)	n (N)	a (m/s^2)
0.00	82.3	0.00
5.00	82.0	0.854
10.0	81.1	1.70
15.0	79.5	2.54
20.0	77.4	3.35
25.0	74.6	4.14
30.0	71.3	4.90
35.0	67.4	5.62
40.0	63.1	6.30
45.0	58.2	6.93
50.0	52.9	7.51
55.0	47.2	8.03
60.0	41.2	8.49
65.0	34.8	8.88
70.0	28.2	9.21
75.0	21.3	9.47
80.0	14.3	9.65
85.0	7.17	9.76
90.0	0.00	9.80





At 0°, the normal force is the full weight and the acceleration is zero. At 90°, the mass is in free fall next to the vertical incline.