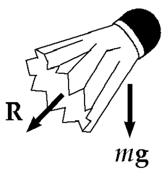
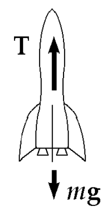
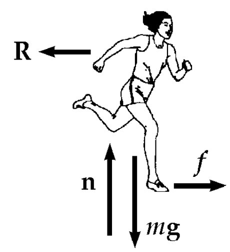
CHAPTER 4

ANSWERS TO QUESTIONS

Q4.1 (a) $m\mathbf{a} = \mathbf{R} + m\mathbf{g}$ (b) $ma = T - mg$ (c) $ma = f - R$







Q4.2 When the bus starts moving, the mass of Claudette is accelerated by the force of the back of the seat on her body. Clark is standing, however, and the only force on him is the friction between his shoes and the floor of the bus. Thus, when the bus starts moving, his feet start accelerating forward, but the rest of his body experiences almost no accelerating force (only that due to his being attached to his accelerating feet!). As a consequence, his body tends to stay almost at rest, according to Newton's first law, relative to the ground. Relative to Claudette, however, he is moving toward her and falls into her lap. (Both performers won Academy Awards.)

Q4.3 First ask, "Was the bus moving forward or backing up?" If it was moving forward, the passenger is lying. A fast stop would make the suitcase fly toward the front relative to the bus, not toward the rear. Fine him for malicious litigiousness.

Q4.4 No. The reaction to your weight is an upward force you exert on the Earth.

Q4.5 Push gently. It is easier on your toe, on the specimen, and on the back wall of the storage compartment.

Q4.6 Because "gravity" is changed inside the elevator. $"g" = g \pm a$

Q4.7 As a man takes a step, the action is the force his foot exerts on the Earth; the reaction is the force of the Earth on his foot. In the second case, the action is the force exerted on the girl's back by the snowball; the reaction is the force exerted on the snowball by the girl's back. The third action is the force of the glove on the ball; the reaction is the force of the ball on the glove. The fourth action is the force exerted on the window by the air molecules; the reaction is the force on the air molecules exerted by the window.

Q4.8 Air friction and gravity. Foot kicking ball and ball pushing back on foot. Ball accelerates from kick because nothing is holding it in place. During flight, the Earth pulls down on the ball and the ball pulls up on the Earth. Air pushes back on the ball and the ball pushes forward on the air.

Q4.9 The molecules of the floor resist the ball on impact and push the ball back, upward. The actual force acting is due to the forces between molecules that allow the floor to keep its integrity and to prevent the ball from passing through. Notice that for a ball passing through a window, the molecular forces weren't strong enough.

Q4.10 Mistake one: The car might be momentarily at rest, in the process of reversing forward into backward motion. In this case, the forces on it add to a large backward resultant.
Mistake two: There are no cars in interstellar space. If the car is remaining at rest, there are some large forces on it, including its weight and some force or forces of support.
Mistake three: The statement reverses cause and effect, like a politician who thinks that his getting elected was the reason for people to vote for him.

Q4.11 A particular nugget weighs less in Denver, at greater distance from the center of the earth, so you will pay less for it there, if it is sold by weight. If it is sold by mass, you can buy gold in either place equally well.

Q4.12 As the barbell goes through the bottom of a cycle, the lifter exerts an upward force on it, and the scale reads the larger upward force that the floor exerts on them together. Around the top of the weight's motion, the scale reads less than average. If the iron is moving upward, the lifter can declare that she has thrown it, just by letting go of it for a moment. Thus this case is included in our previous answer.

Q4.13 Some physics teachers do this by asking a beefy student to pull on the ends of a cord supporting a can of soup at its center. Some get two burly young men pulling on opposite ends of a strong rope, while the smallest person in class gleefully mashes the center of the rope down to the table. Point out the beauty of sagging suspension-bridge cables. With a laser and optical lever, demonstrate that the mayor makes the table sag when he sits on it, and the judge bends the bench. Give them "I make the floor sag" buttons. Estimate the cost of an infinitely strong cable, and the truth will always win.

Q4.14 Suppose the rope is horizontal and has negligible weight. Its tension is 200 N. Along with a vertical force equal to his weight, each person must exert a 200 N horizontal force on the ground.

Q4.15 The acceleration increases, slowly at first, and then more rapidly, according to $a = (0.5\ \mathrm{m/s^2})M_0/(M_0 - Rt)$ where M_0 is the original mass and R is the rate of mass loss.

Q4.16 An object cannot exert a net force on itself. One force is always exerted by one object on a second object. A stretched string in a harp pulls down on the frame, but up on the soundboard, while the frame and the soundboard pull up and down on the string. The tuned harp exerts zero total force on itself.

PROBLEM SOLUTIONS

4.1 For the same force F, acting on different masses

$$F = m_1 a_1$$

and $$F = m_2 a_2$$

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

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

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

4.2 Since the car is moving with constant speed and in a straight line, the resultant force on it must be $\boxed{\text{zero}}$ regardless of whether it is moving toward the right or the left.

4.3 $m = 3.00\ \text{kg}$

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

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

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

4.4 $v_f = 880\ \text{m/s}$, $m = 25.8\ \text{kg}$, $x_f = 6\ \text{m}$.

$v_f^2 = 2ax_f = 2x_f\left(\dfrac{F}{m}\right)$

$F = \dfrac{mv_f^2}{2x_f} = \boxed{1.66 \times 10^6\ \text{N forward}}$

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

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

Velocity $\quad \mathbf{v}_f = v_x\mathbf{i} + v_y\mathbf{j} = \mathbf{v}_i + \mathbf{a}t = \mathbf{a}t$

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

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

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

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

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

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

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

(d) Position: $\quad \mathbf{r}_f = \mathbf{r}_i + \Delta\mathbf{r}$

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

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

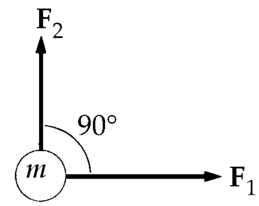
or $\quad F_1 + F_2 = 304\text{ N} \quad (1)$

When pulling in opposite directions, $\quad F_1 - F_2 = 200\text{ kg}\left(-0.518\text{ m/s}^2\right)$

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

Solving simultaneously, we find $\quad F_1 = \boxed{100\text{ N}}$, and $F_2 = \boxed{204\text{ N}}$

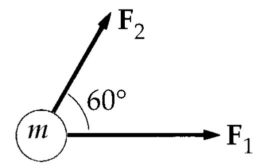
4.7 (a) $\Sigma\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = (20.0\mathbf{i} + 15.0\mathbf{j})\text{ N}$



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

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

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



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

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

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

$\Sigma\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = (27.5\mathbf{i} + 13.0\mathbf{j})\text{ N} = m\mathbf{a} = 5.00\mathbf{a}$

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

4.8 $\Sigma\mathbf{F} = m\mathbf{a}$ reads $\quad (-2.00\mathbf{i} + 2.00\mathbf{j} + 5.00\mathbf{i} - 3.00\mathbf{j} - 45.0\mathbf{i})\text{ N} = m(3.75\text{ m/s}^2)\,\hat{\mathbf{a}}$

where $\hat{\mathbf{a}}$ represents the direction of $\mathbf{a}$ $\quad (-42.0\mathbf{i} - 1.00\mathbf{j})\text{ N} = m(3.75\text{ m/s}^2)\,\hat{\mathbf{a}}$

$$\Sigma\mathbf{F} = \sqrt{(42.0)^2 + (1.00)^2}\text{ N at } \tan^{-1}\left(\frac{1.00}{42.0}\right) \text{ below the } -x\text{-axis}$$

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

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) $\mathbf{v}_f = \mathbf{v}_i + \mathbf{a}t = 0 + (3.75\text{ m/s}^2 \text{ at } 181°)10.0\text{ s}$ so $\mathbf{v}_f = 37.5\text{ m/s at } 181°$

$\mathbf{v}_f = 37.5\text{ m/s}\cos 181°\mathbf{i} + 37.5\text{ m/s}\sin 181°\mathbf{j}$ so $\mathbf{v}_f = \boxed{(-37.5\mathbf{i} - 0.893\mathbf{j})\text{ m/s}}$

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

4.9 $v_x = \dfrac{dx}{dt} = 10t,$ $v_y = \dfrac{dy}{dt} = 9t^2$

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

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

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

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

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

4.10 (a) $F_g = mg = 120\ \text{lb} = (4.448\ \text{N/lb})(120\ \text{lb}) = \boxed{534\ \text{N}}$

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

4.11 $F_g = mg = 900\ \text{N}$ $m = \dfrac{900\ \text{N}}{9.80\ \text{m/s}^2} = 91.8\ \text{kg}$

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

4.12 $F_g = \text{weight of ball} = mg$

$v_{\text{release}} = v$ and time to accelerate $= t$: $\mathbf{a} = \dfrac{\Delta v}{\Delta t} = \dfrac{v}{t} = \dfrac{v}{t}\mathbf{i}$

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

(b) $\mathbf{F}_p - F_g\mathbf{j} = \dfrac{F_g v}{gt}\mathbf{i}$ $\mathbf{F}_p = \boxed{\dfrac{F_g v}{gt}\mathbf{i} + F_g\mathbf{j}}$

4.13 (a) $\Sigma F = ma$ and $v_f^2 = v_i^2 + 2ax_f$ or $a = \dfrac{v_f^2 - v_i^2}{2x_f}$

Therefore, $\Sigma F = m\dfrac{\left(v_f^2 - v_i^2\right)}{2x_f}$

$$\Sigma F = 9.11\times10^{-31}\ \text{kg}\frac{[(7.00\times10^5\ \text{m/s}^2)^2 - (3.00\times10^5\ \text{m/s}^2)^2]}{2(0.0500\ \text{m})} = \boxed{3.64\times10^{-18}\ \text{N}}$$

(b) The weight of the electron is

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

The accelerating force is $\boxed{4.08\times10^{11}\ \text{times the weight of the electron.}}$

***4.14** $F_g = mg$

$$1\ \text{pound} = (0.453\ 592\ 37\ \text{kg})(32.174\ 0\ \text{ft/s}^2)\left(\frac{12\ \text{in.}}{1\ \text{ft}}\right)\left(\frac{0.025\ 4\ \text{m}}{1\ \text{in.}}\right) = \boxed{4.448\ 21\ \text{N}}$$

***4.15** 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

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

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.

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

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

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

Now $\Sigma\mathbf{F} = m\mathbf{a}$ becomes $\mathbf{F}_g + \mathbf{F}_2 = m\mathbf{a}$

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

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

4.17 (a) You and the earth exert equal forces on each other: $m_y g = M_e a_e$

If your mass is 70.0 kg, $a_e = \dfrac{70.0\text{ kg}\left(9.80\text{ m/s}^2\right)}{5.98\times10^{24}\text{ kg}} = \boxed{\sim10^{-22}\text{ m/s}^2}$

(b) You and the planet move for equal times intervals according to $x = \frac{1}{2}at^2$

If the seat is 50.0 cm high, $\sqrt{\dfrac{2x_y}{a_y}} = \sqrt{\dfrac{2x_e}{a_e}}$

$$x_e = \frac{a_e}{a_y}x_y = \frac{m_y}{m_e}x_y = \frac{70.0\text{ kg}(0.500\text{ m})}{5.98\times10^{24}\text{ kg}}\boxed{\sim10^{-23}\text{ m}}$$

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

$v_f = v_i + at$: $\quad -670\text{ m/s} = 670\text{ m/s} + a\left(3.00\times10^{-13}\text{ s}\right)$

$$a = \boxed{-4.47\times10^{15}\text{ m/s}^2}$$

(b) For the molecule, $\Sigma\mathbf{F} = m\mathbf{a}$. Its weight is negligible.

$$\mathbf{F}_{\text{wall on molecule}} = 4.68\times10^{-26}\text{ kg}\left(-4.47\times10^{15}\text{ m/s}^2\right) = -2.09\times10^{-10}\text{ N}$$

$$\overline{\mathbf{F}}_{\text{molecule on wall}} = \boxed{+2.09\times10^{-10}\text{ N}}$$

4.19 (a) $\boxed{15.0\text{ lb up}}$

(b) $\boxed{5.00\text{ lb up}}$

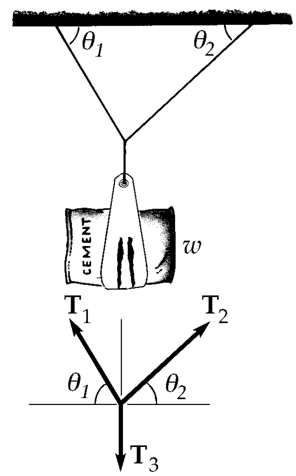
(c) $\boxed{0}$

4.20

$$T_3 = F_g \qquad (1)$$

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

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



Eliminate T_2 and solve for T_1,

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

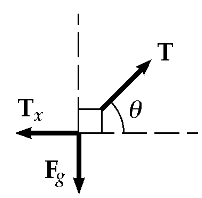
$$T_3 = F_g = \boxed{325 \text{ N}}$$

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

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

4.21 See the solution for T_1 in Problem 4.20.

***4.22** (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:



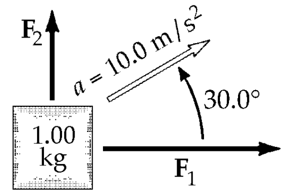
Horizontal Forces: $\Sigma F_x = ma_x \qquad -T_x + T\cos\theta = 0$

Vertical Forces: $\Sigma F_y = ma_y: \qquad -F_g + T\sin\theta = 0$

You need only the equation for the vertical forces to find that the tension in the string is given by $T = \boxed{F_g/\sin\theta}$. 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) $$T = \frac{F_g}{\sin\theta} = \frac{0.132 \text{ kg}(9.80 \text{ m/s}^2)}{\sin 46.3°} = \boxed{1.79 \text{ N}}$$

4.23 Choose a coordinate system with **i** East and **j** North.

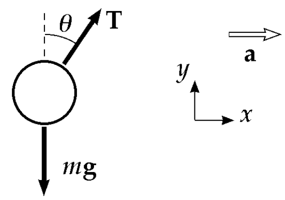


$$\Sigma\mathbf{F} = m\mathbf{a} = 1.00\ \mathrm{kg}\left(10.0\ \mathrm{m/s^2}\right)\ \text{at } 30.0°$$

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

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

4.24 (a) Assume the car and mass accelerate horizontally. We consider the forces on the suspended object.



$\Sigma F_y = ma_y$: $\qquad +T\cos\theta - mg = 0$

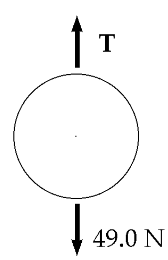
$\Sigma F_x = ma_x$: $\qquad +T\sin\theta = ma$

Substitute $T = \dfrac{mg}{\cos\theta}$: $\qquad \dfrac{mg\sin\theta}{\cos\theta} = mg\tan\theta = ma$

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

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

4.25 (a) Isolate either mass $\quad T + mg = ma = 0$

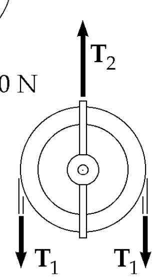


$$|T| = |mg|$$

The scale reads the tension T,

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

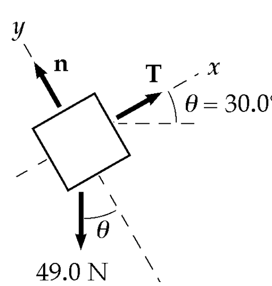
(b) Isolate the pulley $\qquad \mathbf{T}_2 + 2\mathbf{T}_1 = 0$



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

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

Take the component along the incline

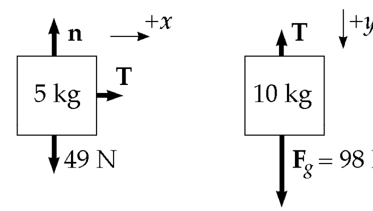


$$\mathbf{n}_x + \mathbf{T}_x + m\mathbf{g}_x = 0$$

or $\qquad 0 + T - mg\sin 30.0° = 0$

$$T = mg\sin 30.0° = \frac{mg}{2} = \frac{5.00(9.80)}{2} = \boxed{24.5\ \mathrm{N}}$$

4.26 First, consider the block moving along the horizontal. The only force in the direction of movement is T. Thus,



$$\Sigma F_x = ma$$

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

Next consider the block that moves vertically. The forces on it are the tension T and its weight, 98 N.

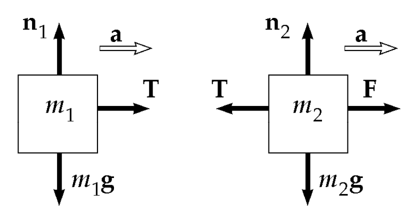
We have $\Sigma F_y = ma$

$$98\text{ N} - T = (10\text{ kg})a \qquad (2)$$

Note that both blocks must have the same magnitude of acceleration. Equations (1) and (2) can be solved simultaneously to give

$$\boxed{a = 6.53\ \text{m/s}^2 \text{ and } T = 32.7\text{ N}}$$

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



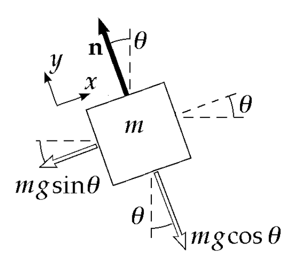
For m_2: $\Sigma F_x = F - T = m_2 a$

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

Solving these equations for a and T, we find

$$\boxed{a = \frac{F}{m_1 + m_2}} \quad \text{and} \quad \boxed{T = \frac{Fm_1}{m_1 + m_2}}$$

4.28 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 up the plane as the positive x direction) we have



$\Sigma F_y = n - mg\cos\theta = 0$: $\quad n = mg\cos\theta$

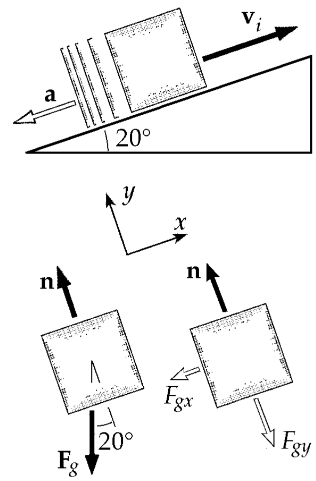
$\Sigma F_x = -mg\sin\theta = ma$: $\quad a = -g\sin\theta$

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

(b) Starting from rest $\quad v_f^2 = v_i^2 + 2a(x_f - x_i) = 2ax_f$

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

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



$\Sigma F_x = ma_x \qquad -mg\sin 20.0° = ma$

$$v_f^2 = v_i^2 + 2a(x_f - x_1)$$

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

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

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

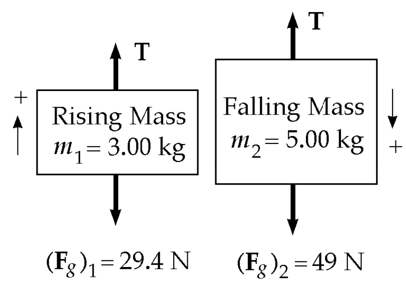
4.30 Take the x-axis down the slope: $\Sigma F_x = ma_x$: $\qquad mg\sin 30° = ma_x$

$$a_x = \left(9.80\text{ m/s}^2\right)\sin 30° = 4.90\text{ m/s}^2$$

The snow will reach you after the time t. Using kinematics, we find time using $x_f - x_i = v_i t + \frac{1}{2}at^2$:

$400\text{ m} = 0 + \frac{1}{2}\left(4.90\text{ m/s}^2\right)t^2 \qquad \boxed{t = 12.8\text{ s}}$

4.31 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



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

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

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

Equations (1) and (2) can be solved simultaneously by adding them:

$$T - 29.4\text{ N} + 49.0\text{ N} - T = (3.00\text{ kg})a + (5.00\text{ kg})a$$

(b) This gives the acceleration as $\qquad a = \dfrac{19.6\text{ N}}{8.00\text{ kg}} = \boxed{2.45\text{ m/s}^2}$

(a) Then $\qquad T - 29.4\text{ N} = (3.00\text{ kg})\left(2.45\text{ m/s}^2\right) = 7.35\text{ N}$

The tension is $\qquad T = \boxed{36.8\text{ N}}$

(c) Consider either mass. We have $\qquad y = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}\left(2.45\text{ m/s}^2\right)(1.00\text{ s})^2 = \boxed{1.23\text{ m}}$

***4.32** Both blocks move with acceleration $a=\left(\frac{m_2-m_1}{m_2+m_1}\right)g$: $a=\left(\frac{7\text{ kg}-2\text{ kg}}{7\text{ kg}+2\text{ kg}}\right)9.8\text{ m/s}^2=5.44\text{ m/s}^2$

(a) Take the upward direction as positive for m_1.

$v_{xf}^2=v_{xi}^2+2a_x\left(x_f-x_i\right)$: $0=(-2.4\text{ m/s})^2+2\left(5.44\text{ m/s}^2\right)\left(x_f-0\right)$

$$x_f=-\frac{5.76\text{ m}^2/\text{s}^2}{2\left(5.44\text{ m/s}^2\right)}=-0.529\text{ m}$$

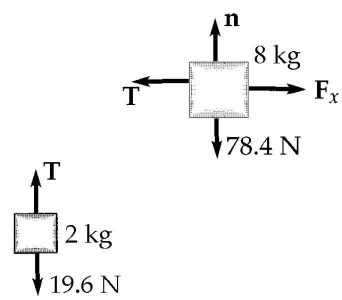
$x_f=$ $\boxed{\text{0.529 m below its initial level}}$

(b) $v_{xf}=v_{xi}+a_xt$: $v_{xf}=-2.40\text{ m/s}+\left(5.44\text{ m/s}^2\right)(1.80\text{ s})$

$v_{xf}=$ $\boxed{\text{7.40 m/s upward}}$

***4.33** Forces acting on 2.00 kg block: $T-m_1g=m_1a$ (1)

Forces acting on 8.00 kg block: $F_x-T=m_2a$ (2)



(a) Eliminate T and solve for a: $a=\frac{F_x-m_1g}{m_1+m_2}$

$$\boxed{a>0\ \text{ for }\ F_x>m_1g=19.6\text{ N}}$$

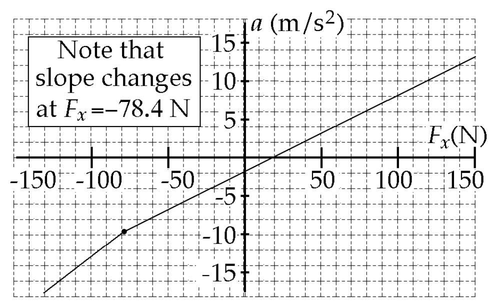
(b) Eliminate a and solve for T:

$$T=\frac{m_1}{m_1+m_2}\left(F_x+m_2g\right)$$

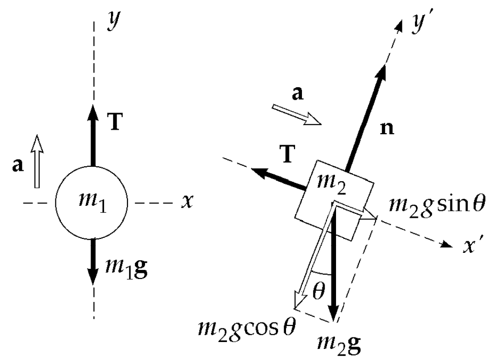
$$\boxed{T=0\ \text{ for }\ F_x\le -m_2g=-78.4\text{ N}}$$

(c)

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



4.34 $m_1 = 2.00 \text{ kg},\ m_2 = 6.00 \text{ kg},\ \theta = 55.0°,$



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

and $T - m_1 g = m_1 a$

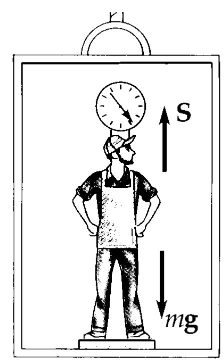
$$a = \frac{m_2 g \sin\theta - m_1 g}{m_1 + m_2} = \boxed{3.57 \text{ m/s}^2}$$

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

(c) Since

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

4.35 First, we will compute the needed accelerations:



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

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

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

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

Newton's second law is: $\Sigma F_y = m a_y$

$+S - (72.0 \text{ kg})(9.80 \text{ m/s}^2) = (72.0 \text{ kg}) a_y$

$S = 706 \text{ N} + (72.0 \text{ kg}) a_y$

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

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

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

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

***4.36** (a) For force components along the incline, with the upward direction taken as positive,

$\Sigma F_x = ma_x$: $\quad -mg\sin\theta = ma_x$

$$a_x = -g\sin\theta = -\left(9.8\ \text{m/s}^2\right)\sin 35° = -5.62\ \text{m/s}^2$$

For the upward motion, $\quad v_{xf}^{\,2} = v_{xi}^{\,2} + 2a_x\left(x_f - x_i\right)$

$$0 = (5\ \text{m/s})^2 + 2\left(-5.62\ \text{m/s}^2\right)\left(x_f - 0\right)$$

$$x_f = \frac{25\ \text{m}^2/\text{s}^2}{2\left(5.62\ \text{m/s}^2\right)} = \boxed{2.22\ \text{m}}$$

(b) The time to slide down is given by $\quad x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$

$$0 = 2.22\ \text{m} + 0 + \tfrac{1}{2}\left(-5.62\ \text{m/s}^2\right)t^2$$

$$t = \sqrt{\frac{2(2.22\ \text{m})}{5.62\ \text{m/s}^2}} = 0.890\ \text{s}$$

For the second particle, $\quad x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$

$$0 = 10\ \text{m} + v_{xi}(0.890\ \text{s}) + \left(-5.62\ \text{m/s}^2\right)(0.890\ \text{s})^2$$

$$v_{xi} = \frac{-10\ \text{m} + 2.22\ \text{m}}{0.890\ \text{s}} = -8.74\ \text{m/s}$$

$$\text{speed} = \boxed{8.74\ \text{m/s}}$$

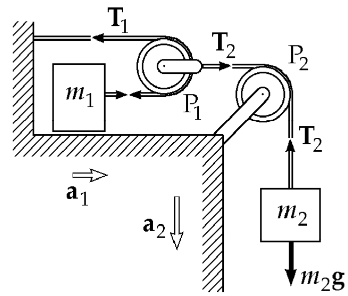
4.37 $m = 4.00\ \text{kg},\ \mathbf{v}_i = 3.00\mathbf{i}\ \text{m/s},\ \mathbf{v}_8 = \left(8.00\mathbf{i} + 10.0\mathbf{j}\right)\ \text{m/s},\ t = 8.00\ \text{s}$

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

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

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

4.38 (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

$\Sigma F = ma$: $\quad m_2 g - T_2 = m_2 a_2 \quad (1)$

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

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

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

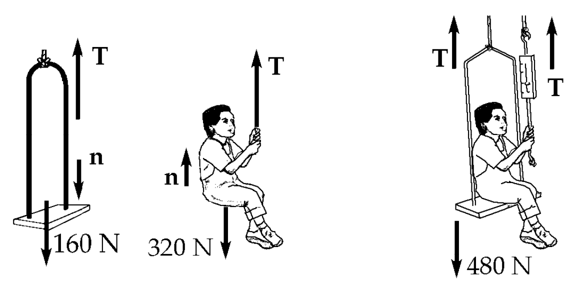
This equation combined with Equation (2) yields $\quad \dfrac{T_1}{m_1}\left(2m_1 + \dfrac{m_2}{2}\right) = m_2 g$

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

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

$$a_1 = \frac{T_1}{m_1} = \boxed{\frac{m_2 g}{2m_1 + \frac{1}{2}m_2}} \quad \text{and} \quad a_2 = \frac{1}{2}a_1 = \boxed{\frac{m_2 g}{4m_1 + m_2}}$$

4.39 (a) see Figure to the right



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

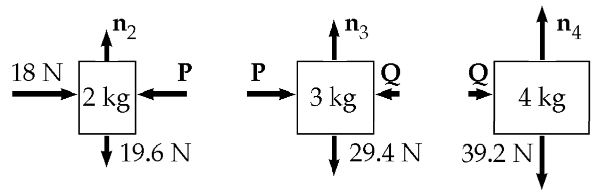
$$2T - 480 = ma, \text{ where } m = \frac{480}{9.80} = 49.0\text{ kg}$$

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

(c) $\Sigma F = ma$ on Pat: $\quad \Sigma F = n + T - 320 = ma$

where $m = \dfrac{320}{9.80} = 32.7\text{ kg}$ $\quad n = ma + 320 - T = 32.7(0.408) + 320 - 250 = \boxed{83.3\text{ N}}$

***4.40** (a) $18\text{ N} - P = (2\text{ kg})a$



$P - Q = (3\text{ kg})a$

$Q = (4\text{ kg})a$

Adding gives $18\text{ N} = (9\text{ kg})a$ so $a = \boxed{2.00\text{ m/s}^2}$

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

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

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

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

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

4.41 We find the diver's impact speed by analyzing his free-fall motion:

$v_f^2 = v_i^2 + 2ax = 0 + 2(-9.80\text{ m/s}^2)(-10.0\text{ m})$ so $v_f = -14.0\text{ m/s}$

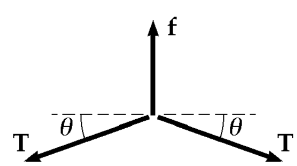
Now for the 2.00 s of stopping, we have $v_f = v_i + at$: $0 = -14.0\text{ m/s} + a(2.00\text{ s})$,

$a = +7.00\text{ m/s}^2$

Call the force exerted by the water on the diver R. Using $\Sigma F_y = ma$,

$+R - 70.0\text{ kg}(9.80\text{ m/s}^2) = 70.0\text{ kg}(7.00\text{ m/s}^2)$ $R = \boxed{1.18\text{ kN}}$

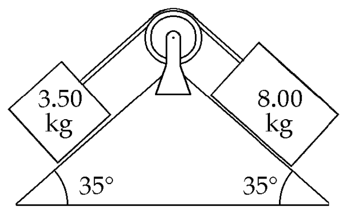
***4.42** (a) Consider forces on the midpoint of the rope. It is nearly in equilibrium just before the car begins to move. Take the y-axis in the direction of the force you exert:



$\Sigma F_y = ma_y$: $-T\sin\theta + f - T\sin\theta = 0$ $\boxed{T = \dfrac{f}{2\sin\theta}}$

(b) $T = \dfrac{100\text{ N}}{2\sin 7°} = \boxed{410\text{ N}}$

***4.43** 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. Define up the left hand plane as positive for the 3.50-kg object and down the right hand plane as positive for the 8.00-kg object.



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

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

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

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

Adding, we obtain $\quad +45.0 \text{ N} - 19.7 \text{ N} = (11.5 \text{ kg})a$

(b) Thus the acceleration is $\boxed{a = 2.20 \text{ m/s}^2}$

By substitution, $\quad -19.7 \text{ N} + T = (3.50 \text{ kg})(2.20 \text{ m/s}^2) = 7.70 \text{ N}$

(a) The tension is $\boxed{T = 27.4 \text{ N}}$

***4.44** Take the x-axis vertically upward. Your impact speed is given by

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i) = 0 + 2(-9.8 \text{ m/s}^2)(-1.00 \text{ m})$$

$$v_{xf} = -\sqrt{19.6 \text{ m}^2/\text{s}^2} = -4.43 \text{ m/s}$$

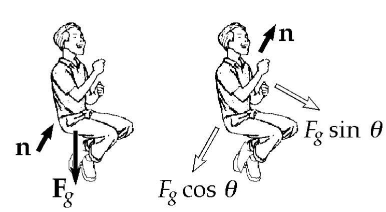
In stopping, $\Sigma F_x = ma_x$: $\quad +5.12\times 10^4 \text{ N} - 60 \text{ kg}(9.8 \text{ m/s}^2) = (60 \text{ kg})a_x$

$$a_x = \frac{5.06\times 10^4 \text{ N}}{60 \text{ kg}} = 844 \text{ m/s}^2$$

$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$ $\quad 0 = (-4.43 \text{ m/s})^2 + 2(844 \text{ m/s}^2)(-d)$

$$d = \frac{19.6 \text{ m}^2/\text{s}^2}{2(844 \text{ m/s}^2)} = \boxed{0.0116 \text{ m}}$$

***4.45** The scale reads the normal force exerted by the student on the seat and by the seat on the student. Take the student as object and the y-direction perpendicular to the track:



$\Sigma F_y = ma_y$: $\quad +n - F_g \cos\theta = 0$

$$n = (200 \text{ lb})\cos 30° = \boxed{173 \text{ lb}}$$

4.46 $\Sigma F_y = ma_y$: $\quad n - mg\cos\theta = 0$

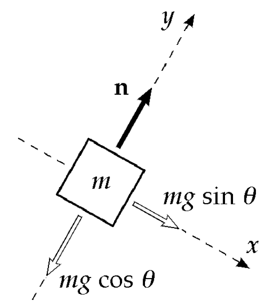
or $\quad n = 8.40(9.80)\cos\theta$

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

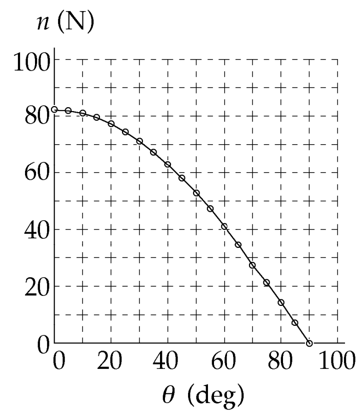
$\Sigma F_x = ma_x$: $\quad mg\sin\theta = ma$

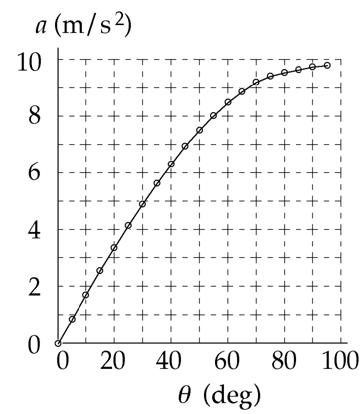
or $\quad a = g\sin\theta$

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



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





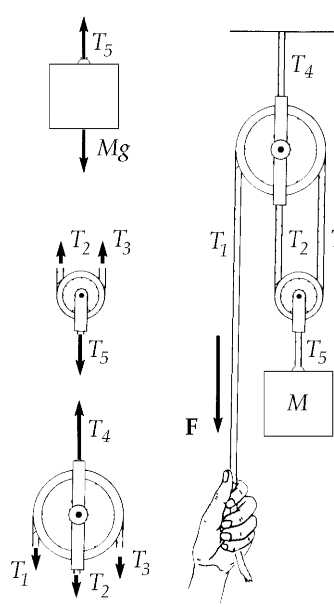
At 0°, the normal force is the full weight and the acceleration is zero. At 90°, the mass is in free fall next to the vertical incline.

4.47 (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 $T_4 = T_1 + T_2 + T_3$.

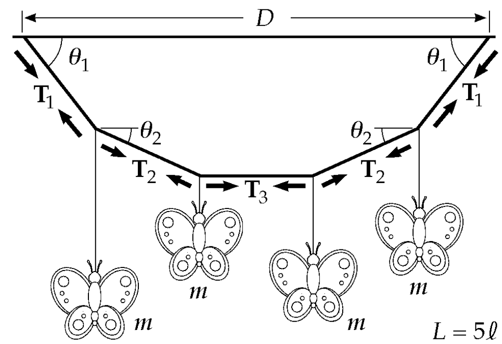
Since the pulleys are not starting to rotate and are frictionless, $T_1 = T_3$, and $T_2 = T_3$. From this information, we have $T_5 = 2T_2$, so $T_2 = \dfrac{Mg}{2}$.

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

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



***4.48** (a) Apply Newton's second 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 (4) into (2) for $T_2 \sin\theta_2$, $T_1 \sin\theta_1 - mg - mg = 0$

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

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

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

From Equation (4), $T_2 = \dfrac{mg}{\sin\theta_2}$

(b) Divide (4) by (3): $\dfrac{T_2 \sin\theta_2}{T_2 \cos\theta_2} = \dfrac{mg}{T_3}$

Substitute value of T_3: $\tan\theta_2 = \dfrac{mg \tan\theta_1}{2mg}$ $\boxed{\theta_2 = \tan^{-1}\left(\dfrac{\tan\theta_1}{2}\right)}$

Then we can finish answering part (a): $\boxed{T_2 = \dfrac{mg}{\sin\left[\tan^{-1}\left(\frac{1}{2}\tan\theta_1\right)\right]}}$

(c) D is the horizontal distance between the points at which the two ends of the string are attached to the ceiling.

$D = 2\ell \cos\theta_1 + 2\ell \cos\theta_2 + \ell$ and $L = 5\ell$

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

***4.49** (a) Following Example 4.3 $a = g\sin\theta = (9.80\text{ m/s}^2)\sin 30.0°$ $\boxed{a = 4.90\text{ m/s}^2}$

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

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

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

(c) Now in free fall $y_f - y_i = v_{yi}t + \frac{1}{2}a_y t^2$: $-2.00 = (-3.13\text{ m/s})\sin 30.0° t - \frac{1}{2}(9.80\text{ m/s}^2)t^2$

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

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

Only one root is physical $t = 0.499\text{ s}$

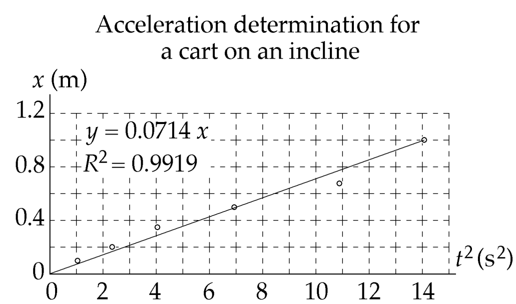
$$x_f = v_x t = [(3.13\text{ m/s})\cos 30.0°](0.499\text{ s}) = \boxed{1.35\text{ m}}$$

(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.

4.50

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 $\frac{1}{2}a$,

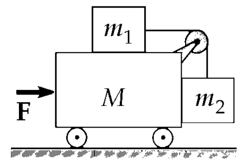
and $a = 2 \times \text{slope} = 2(0.0714\text{ m/s}^2) = \boxed{0.143\text{ m/s}^2}$

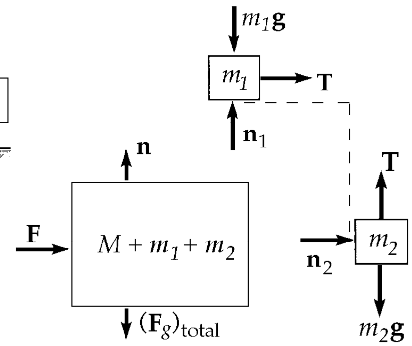
From $a' = g\sin\theta$, $a' = 9.80\text{ m/s}^2\left(\dfrac{1.774}{127.1}\right) = 0.137\text{ m/s}^2$, different by 4%

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

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

4.51 $\Sigma F = ma$





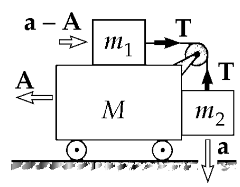
For m_1: $T = m_1 a$

For m_2: $T - m_2 g = 0$

Eliminating T, $a = \dfrac{m_2 g}{m_1}$

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

***4.52** (1) $m_1(a - A) = T \quad \Rightarrow \quad a = \dfrac{T}{m_1} + A$



(2) $MA = R_x = T \quad \Rightarrow \quad A = \dfrac{T}{M}$

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

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

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

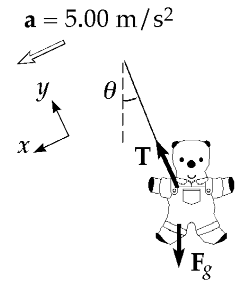
Substitute for A from (2): $T = m_2\left[g - \left(\dfrac{T}{m_1} + \dfrac{T}{M}\right)\right] = \boxed{m_2 g\left[\dfrac{m_1 M}{m_1 M + m_2(m_1 + M)}\right]}$

(b) Solve (3) for a and substitute value of T: $\boxed{a = \dfrac{m_2 g(m_1 + M)}{m_1 M + m_2(M + m_1)}}$

(c) From (2), $A = T / M$, Substitute the value of T: $\boxed{A = \dfrac{m_1 m_2 g}{m_1 M + m_2(m_1 + M)}}$

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

4.53 Choose the x-axis pointing down the slope.



$v_f = v_i + at$: $\quad 30.0 \text{ m/s} = 0 + a(6.00 \text{ s})$

$$a = 5.00 \text{ m/s}^2$$

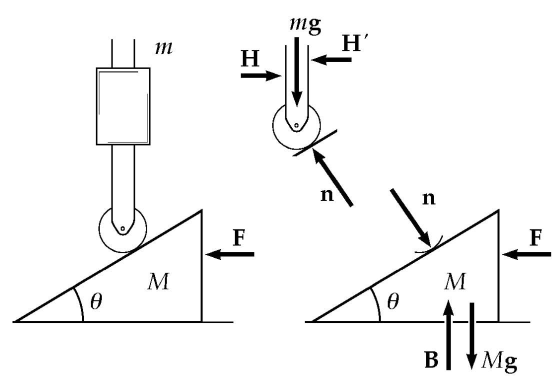
Consider forces on the toy.

$\Sigma F_x = ma_x$: $\quad mg\sin\theta = m\left(5.00 \text{ m/s}^2\right) \qquad \theta = \boxed{30.7°}$

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

$$T = mg\cos\theta = (0.100)(9.80)\cos 30.7° \qquad T = \boxed{0.843 \text{ N}}$$

***4.54** The upward acceleration of the rod is described by



$$y_f = y_i + v_{yi}t + \tfrac{1}{2}a_y t^2$$

$$1\times10^{-3} \text{ m} = 0 + 0 + \tfrac{1}{2}a_y\left(8\times10^{-3} \text{ s}\right)^2$$

$$a_y = 31.2 \text{ m/s}^2$$

The distance y moved by the rod and the distance x moved by the wedge in the same time are related by $\tan 15° = y/x \Rightarrow x = y/\tan 15°$. Then their speeds and accelerations are related by

$$\frac{dx}{dt} = \frac{1}{\tan 15°}\frac{dy}{dt} \quad \text{and} \quad \frac{d^2x}{dt^2} = \frac{1}{\tan 15°}\frac{d^2y}{dt^2} = \left(\frac{1}{\tan 15°}\right)31.2 \text{ m/s}^2 = 117 \text{ m/s}^2$$

The free body diagram for the rod is shown. Here H and H' are forces exerted by the guide.

$\Sigma F_y = ma_y$: $\quad n\cos 15° - mg = ma_y$

$$n\cos 15° - 0.250 \text{ kg}\left(9.8 \text{ m/s}^2\right) = 0.250 \text{ kg}\left(31.2 \text{ m/s}^2\right)$$

$$n = \frac{10.3 \text{ N}}{\cos 15°} = 10.6 \text{ N}$$

For the wedge,

$\Sigma F_x = Ma_x$: $\quad -n\sin 15° + F = 0.5 \text{ kg}\left(117 \text{ m/s}^2\right)$

$$F = (10.6 \text{ N})\sin 15° + 58.3 \text{ N} = \boxed{61.1 \text{ N}}$$

***4.55** (a) $y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$: $\quad 0 = 1.30\text{ m} + 0 + \frac{1}{2}\left(-9.8\text{ m/s}^2\right)t^2$

$$t = \sqrt{\frac{2(-1.30\text{ m})}{-9.8\text{ m/s}^2}} = \boxed{0.515\text{ s}}$$

$$v_{yf}^2 = v_{yi}^2 + 2a_y\left(y_f - y_i\right) = 0 + 2\left(-9.8\text{ m/s}^2\right)(0 - 1.30\text{ m}) = 25.5\text{ m/s}^2$$

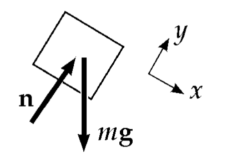
$$v_{yf} = -5.05\text{ m/s} \qquad \left|v_{yf}\right| = \boxed{5.05\text{ m/s}}$$

(b) Similarly, $\quad 0 = 1.30\text{ m} + \frac{1}{2}\left(8\times10^{-6}\right)\left(-9.8\text{ m/s}^2\right)t^2$

$$t = \boxed{182\text{ s}}$$

$$\left|v_{yf}\right| = \sqrt{2\left(8\times10^{-6}\right)\left(-9.8\text{ m/s}^2\right)(-1.30\text{ m})} = \boxed{14.3\text{ mm/s}}$$

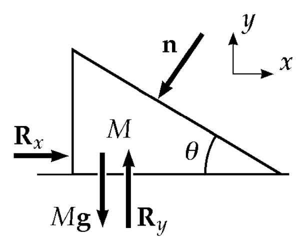
***4.56** Throughout its up and down motion after release the block has



$\Sigma F_y = ma_y$: $\quad +n - mg\cos\theta = 0$

$$n = mg\cos\theta$$

Let $\mathbf{R} = R_x\mathbf{i} + R_y\mathbf{j}$ represent the force of table on incline. We have



$\Sigma F_x = ma_x$: $\quad +R_x - n\sin\theta = 0$

$$R_x = mg\cos\theta\sin\theta$$

$\Sigma F_y = ma_y$: $\quad -Mg - n\cos\theta + R_y = 0$

$$R_y = Mg + mg\cos^2\theta$$

$$\boxed{\mathbf{R} = mg\cos\theta\sin\theta \text{ to the right } + \left(M + m\cos^2\theta\right)g \text{ upward}}$$

ANSWERS TO EVEN NUMBERED PROBLEMS

2. (a) zero (b) zero

4. 1.66 MN forward

6. 100 N and 204 N

8. (a) 181° counterclockwise from x-axis (b) 11.2 kg
(c) 37.5 m/s (d) $(-37.5\mathbf{i} - 0.893\mathbf{j})$ m/s

10. (a) 534 N (b) 54.5 kg

12. (a) $x = vt/2$ (b) $\left(F_g v / gt\right)\mathbf{i} + F_g\,\mathbf{j}$

14. 4.448 21 N

16. $(16.3\mathbf{i} + 14.6\mathbf{j})$ N

18. (a) -4.47×10^{15} m/s^2 (b) $+2.09 \times 10^{-10}$ N

20. $T_1 = 296$ N, $T_2 = 163$ N, $T_3 = 325$ N

22. (a) See the solution. $T = F_g / \sin\theta$ (b) 1.79 N

24. (a) $a = g \tan \theta$ (b) 4.16 m/s^2

26. See the solution. $a = 6.53$ m/s^2, $T = 32.7$ N

28. See the solution. (a) 2.54 m/s^2 down the incline (b) 3.18 m/s

30. 12.8 s

32. (a) 0.529 m (b) 7.40 m/s upward

34. (a) 3.57 m/s^2 (b) 26.7 N
(c) 7.14 m/s (See the solution.)

36. (a) 2.22 m (b) 8.74 m/s

38. (a) $a_1 = 2a_2$ (b) $T_1 = \dfrac{m_1 m_2}{2m_1 + \frac{1}{2}m_2} g,\ T_2 = \dfrac{m_1 m_2}{m_1 + \frac{1}{4}m_2} g$

(c) $a_1 = \dfrac{m_2 g}{2m_1 + \frac{1}{2}m_2},\ a_2 = \dfrac{m_2 g}{4m_1 + m_2}$

40. See the solution.
(a) 2.00 m/s^2
(b) 4.00 N on m_1, 6.00 N on m_2, 8.00 N on m_3
(c) 14.0 N between m_1 and m_2, 8.00 N between m_2 and m_3
(d) See the solution.

42. (a) $T = f/(2 \sin\theta)$ (b) 410 N

44. 1.16 cm

46. $n = (82.3 \text{ N}) \cos\theta,\ a = \left(9.80 \text{ m/s}^2\right)\sin\theta$. See the solution. Yes.

48. (a) $T_1 = \dfrac{2mg}{\sin\theta_1},\ T_2 = \dfrac{mg}{\sin\theta_2} = \dfrac{mg}{\sin\left[\tan^{-1}\left(\frac{1}{2}\tan\theta_1\right)\right]},\ T_3 = \dfrac{2mg}{\tan\theta_1}$ (b) $\theta_2 = \tan^{-1}\left(\dfrac{\tan\theta_1}{2}\right)$

50. See the solution. $a = 0.143 \text{ m/s}^2$, approximately 4% high

52. (a) $m_2 g\left[\dfrac{m_1 M}{m_1 M + m_2(m_1 + M)}\right]$ (b) $\dfrac{m_2 g(M + m_1)}{m_1 M + m_2(m_1 + M)}$

(c) $\dfrac{m_1 m_2 g}{m_1 M + m_2(m_1 + M)}$ (d) $\dfrac{M m_2 g}{m_1 M + m_2(m_1 + M)}$

54. 61.1 N

56. $mg\sin\theta\cos\theta\,\mathbf{i} + \left(M + m\cos^2\theta\right)g\,\mathbf{j}$