Solutions to Homework #4
(Chapter 4)

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.

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

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.

Q4.10 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.

Q4.13 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.

\[ m = 3.00 \text{ kg} \]
\[ \mathbf{a} = (2.00 \mathbf{i} + 5.00 \mathbf{j}) \text{ m/s}^2 \]
\[ \Sigma F = ma = [6.00 \mathbf{i} + 15.0 \mathbf{j}] \text{ N} \]
\[ |\Sigma F| = \sqrt{(6.00)^2 + (15.0)^2} \text{ N} = 16.2 \text{ N} \]
4.8 \( \Sigma F = ma \) reads \((-2.00 \hat{i} + 2.00 \hat{j} + 3.00 \hat{i} - 3.00 \hat{j} - 45.0 \hat{i}) \ N = m(3.75 \text{ m/s}^2) \ \hat{a} \)

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

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

\[ \Sigma F = 42.0 \ N \text{ at } 181^\circ = m(3.75 \text{ m/s}^2) \ \hat{a} \]

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

(a) \( \therefore \ [ \hat{a} \text{ is at } 181^\circ ] \) counter-clockwise from the x-axis

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

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

so \( \vec{v}_f = 37.5 \text{ m/s at } 181^\circ \)

\( \vec{v}_f = 37.5 \text{ m/s} \cos 181^\circ \hat{i} + 37.5 \text{ m/s} \sin 181^\circ \hat{j} \)

so \( \vec{v}_f = (-37.5 \hat{i} - 0.893 \hat{j}) \text{ m/s} \)

(c) \( \vec{v}_f = \sqrt{37.5^2 + 0.893^2} \text{ m/s} = 37.5 \text{ m/s} \)

4.19

(a) \( 15.0 \text{ lb up} \)

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

(c) \( 0 \)

4.25

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

\[ \frac{T}{2} = mg \]

The scale reads the tension \( T \),

so \( T = mg = 5.00 \text{ kg}(9.80 \text{ m/s}^2) = 49.0 \text{ N} \)

(b) Isolate the pulley \( T_2 + 2T_1 = 0 \)

\( T_2 = 2T_1 = 2mg = 98.0 \text{ N} \)

(c) \( \Sigma F = n + T + mg = 0 \)

Take the component along the incline

\( n_x + T_x + mg_x = 0 \)

or \( 0 + T - mg \sin 30.0^\circ = 0 \)

\( T = mg \sin 30.0^\circ = \frac{mg}{2} = 5.00(9.80) \frac{90}{2} = 24.5 \text{ N} \)
First, consider the block moving along the horizontal. The only force in the direction of movement is $T$. Thus,

$$\Sigma F_x = ma$$

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

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

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

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

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

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

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

and $P = 14 \text{ N}$

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

(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 particles, 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.

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

$$v_f^2 = v_i^2 + 2a_i(x_f - x_i) = 0 + 2(-9.8 \text{ m/s}^2)(-1.00 \text{ m})$$

$$v_f = \sqrt{196 \text{ m}^2/\text{s}^2} = 4.43 \text{ m/s}$$

In stopping, $\Sigma F_i = ma$:

$$-5.12 \times 10^4 \text{ N} - 60 \text{ kg} \left(9.8 \text{ m/s}^2\right) = (60 \text{ kg})a_i$$

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

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

$$0 = (-4.43 \text{ m/s})^2 + 2(844 \text{ m/s}^2)(-d)$$

$$d = \frac{19.6 \text{ m}^2/\text{s}^2}{2(844 \text{ m/s}^2)} = 0.0116 \text{ m}$$
(a) Following Example 4.3\[ a = g \sin \theta = \left( 9.80 \text{ m/s}^2 \right) \sin 30.0^\circ \quad a = 4.90 \text{ m/s}^2 \]

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

\[ x = 1.00 \text{ m} \quad v_f^2 = v_i^2 + 2a(x_f - x_i) = 0 + 2(4.90 \text{ m/s}^2)(1.00 \text{ m}) \quad v_f = 3.13 \text{ m/s} \]

after time

\[ t_x = \frac{2v_f}{v_f} = \frac{2(1.00 \text{ m})}{3.13 \text{ m/s}} = 0.639 \text{ s} \]

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

\[ -2.00 = (-3.13 \text{ m/s}) \sin 30.0^\circ t - \frac{1}{2}(9.80 \text{ m/s}^2) t^2 \\
(4.90 \text{ m/s}^2)^2 + (1.56 \text{ m/s})t - 2.00 = 0 \]

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

Only one root is physical

\[ t = 0.499 \text{ s} \]

\[ x_f = v_i t + ((3.13 \text{ m/s}) \cos 30.0^\circ)(0.499 \text{ s}) = 1.35 \text{ m} \]

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

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