Pearson Physics Level 20
Unit II Dynamics: Unit II Review
Solutions

Student Book pages 234–237

Vocabulary

1. **action-at-a-distance force:** a force that acts on objects whether or not the objects are touching
   action force: a force initiated by object A on object B
   apparent weight: the negative of the normal force acting on an object
   coefficient of friction: proportionality constant relating the magnitude of the force of friction to the magnitude of the normal force
   field: a three-dimensional region of influence surrounding an object
   free-body diagram: a vector diagram of an object in isolation showing all the forces acting on it
   free fall: a situation in which the only force acting on an object that has mass is the gravitational force
   gravitational field strength: gravitational force per unit mass at a specific location
   gravitational force: attractive force between any two objects due to their masses
   gravitational mass: mass measurement based on comparing the known weight of one object to the unknown weight of another
   inertia: property of an object that resists acceleration
   inertial mass: mass measurement based on the ratio of a known net force on an object to the acceleration of the object
   kinetic friction: force exerted on an object in motion that opposes its motion as it slides on another object
   net force: vector sum of two or more forces acting simultaneously on an object
   Newton's first law: an object will continue either being at rest or moving at constant velocity unless acted upon by an external non-zero net force
   Newton's law of gravitation: any two objects, A and B, in the universe exert gravitational forces of equal magnitude but opposite direction on each other; the forces are directed along the line joining the centres of both objects.
   Newton's second law: when an external non-zero net force acts on an object, the object accelerates in the direction of the net force; the magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the object
   Newton's third law: if object A exerts a force on object B, then B exerts a force on A that is equal in magnitude and opposite in direction
   normal force: a force on an object that is perpendicular to a common contact surface
   reaction force: force exerted by object B on object A
   static friction: force exerted on an object at rest that prevents the object from sliding on another object
   tension: magnitude of a force $\vec{F}_T$ exerted by a rope or string on an object at the point where the rope or string is attached to the object

true weight: gravitational force acting on an object that has mass

Knowledge

Chapter 3

2. ***Given***

$\vec{F}_1 = 60$ N [22.0°]

$\vec{F}_2 = 36$ N [110°]

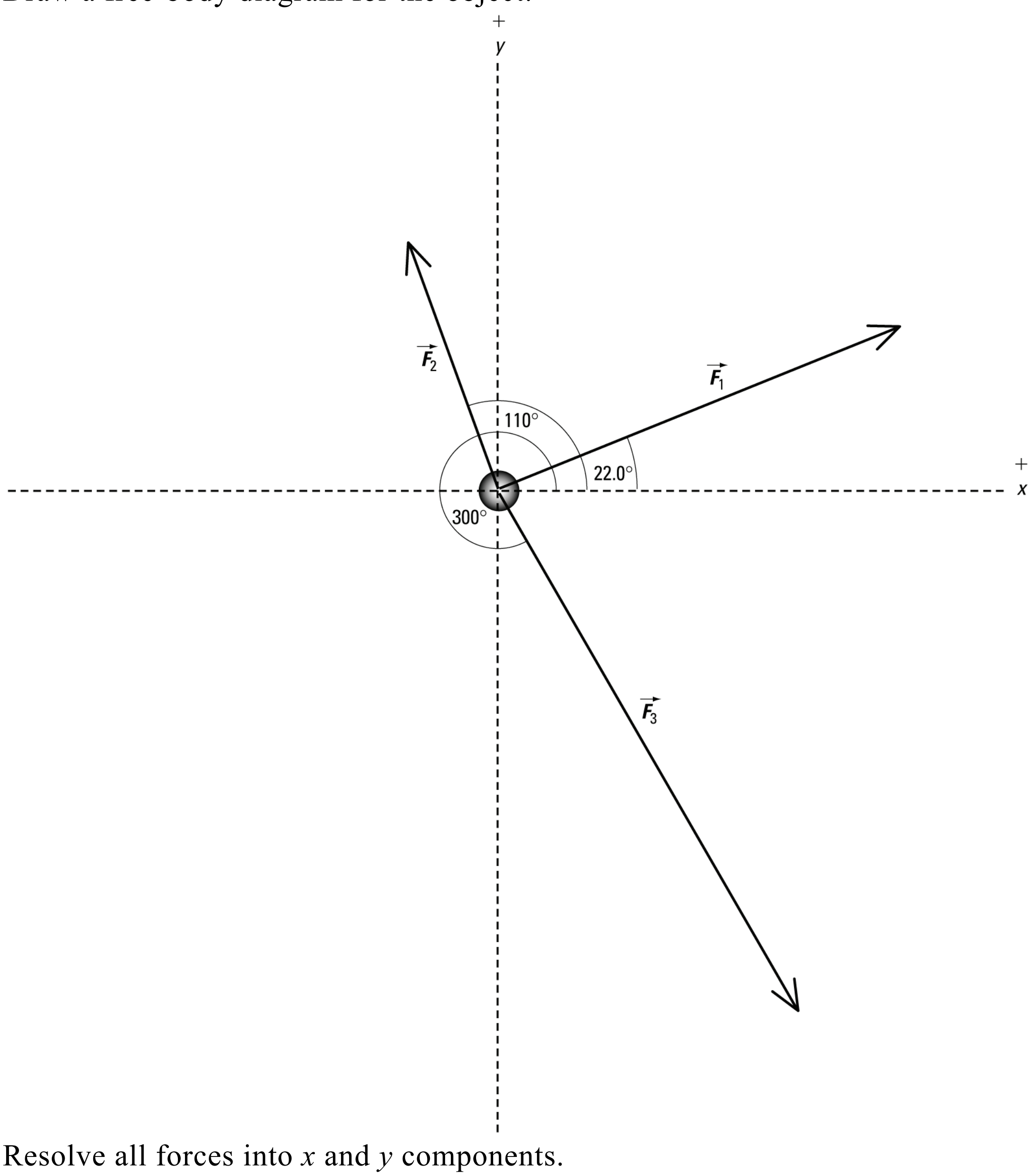
$\vec{F}_3 = 83$ N [300°]

Required

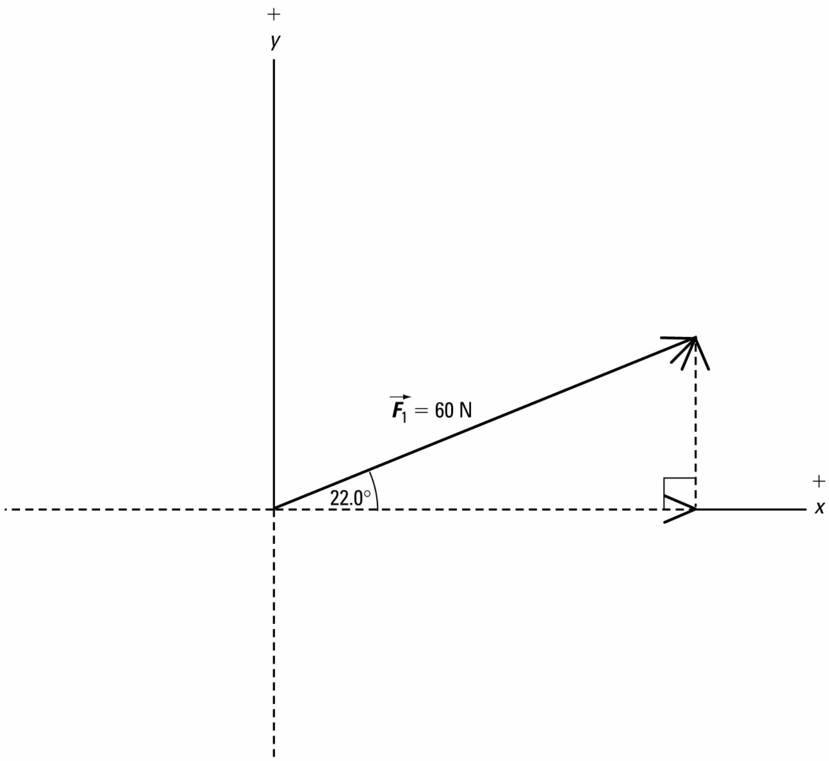
net force on object ($\vec{F}_{\text{net}}$)

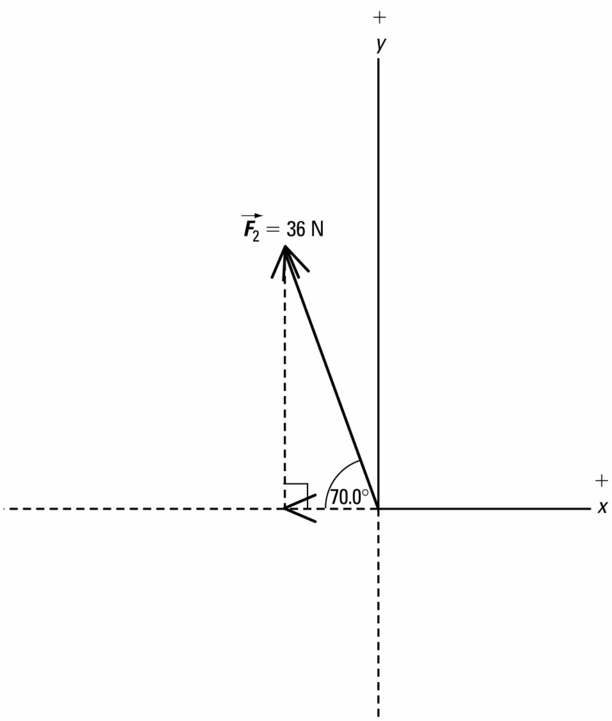
Analysis and Solution

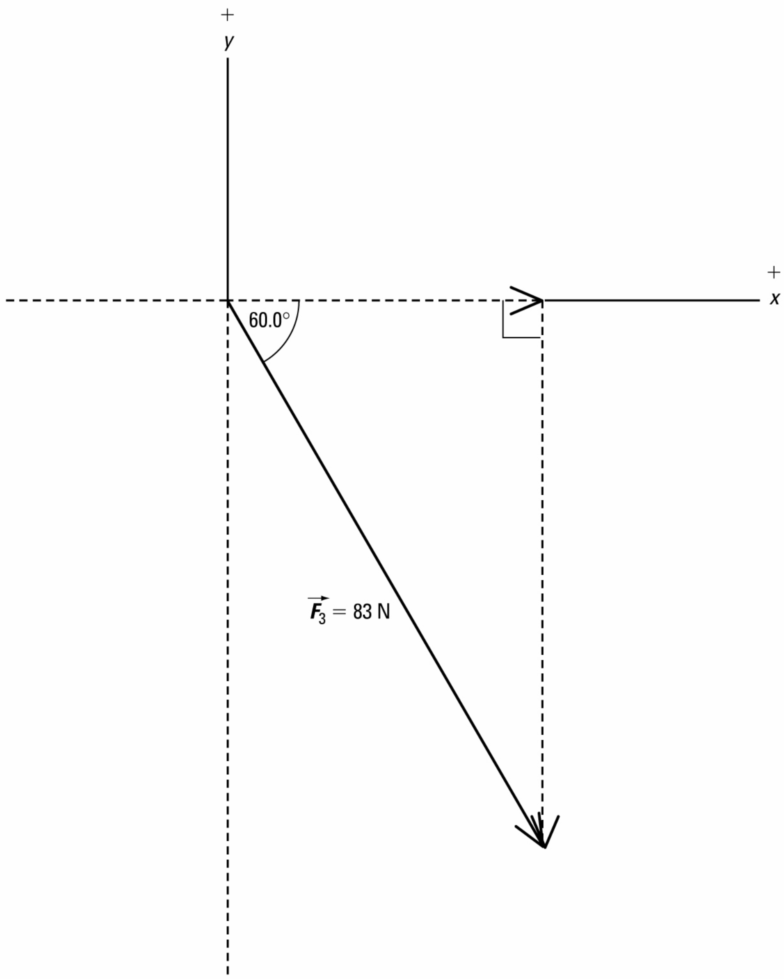
Draw a free-body diagram for the object.



Resolve all forces into *x* and *y* components.

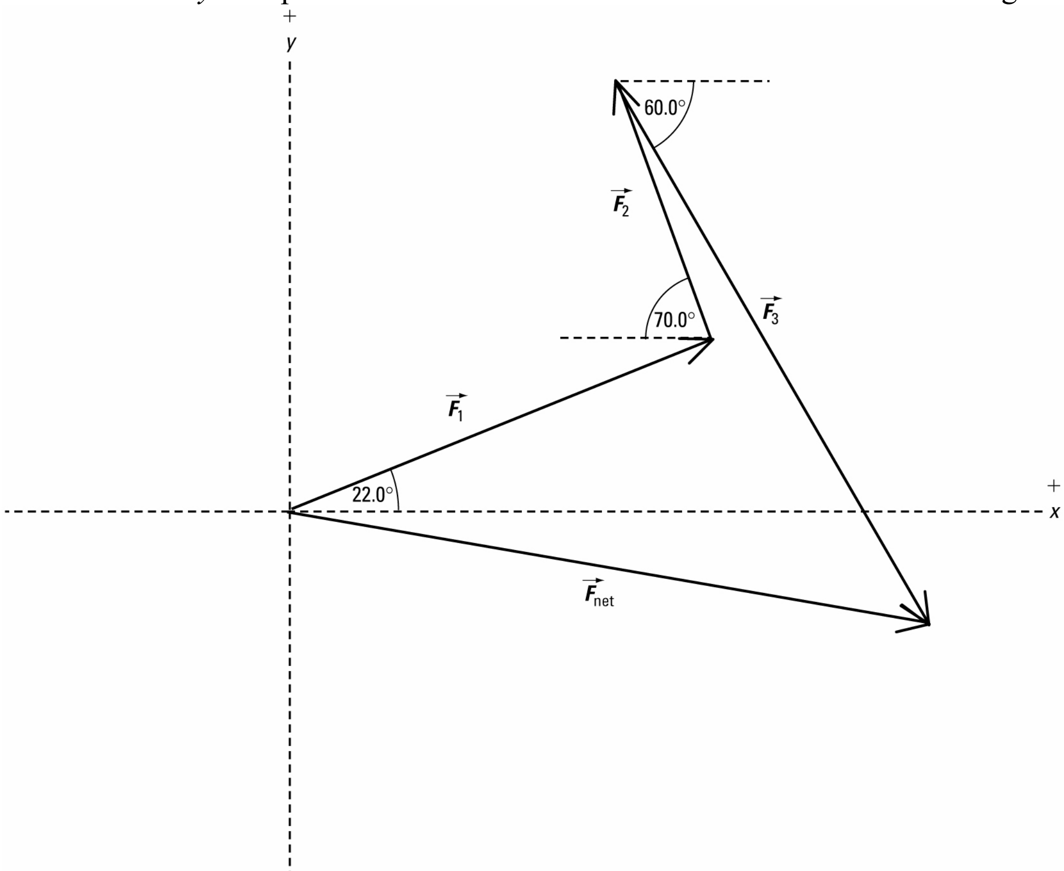

+
y
$\vec{F}_1 = 60$ N
22.0°
+
x


+
y
$\vec{F}_2 = 36$ N
70.0°
+
x



Vector	*x* component	*y* component
$\vec{F}_1$	(60 N)(cos 22.0°)	(60 N)(sin 22.0°)
$\vec{F}_2$	–(36 N)(cos 70.0°)	(36 N)(sin 70.0°)
$\vec{F}_3$	(83 N)(cos 60.0°)	–(83 N)(sin 60.0°)

Add the x and y components of all force vectors in the vector addition diagram.



x direction

$$\vec{F}_{\text{net}_x} = \vec{F}_{1_x} + \vec{F}_{2_x} + \vec{F}_{3_x}$$

$$\begin{aligned} F_{\text{net}_x} &= F_{1_x} + F_{2_x} + F_{3_x} \\ &= (60\text{ N})(\cos 22.0°) + \{-(36\text{ N})(\cos 70.0°)\} + (83\text{ N})(\cos 60.0°) \\ &= 84.8\text{ N} \end{aligned}$$

y direction

$$\vec{F}_{\text{net}_y} = \vec{F}_{1_y} + \vec{F}_{2_y} + \vec{F}_{3_y}$$

$$\begin{aligned} F_{\text{net}_y} &= F_{1_y} + F_{2_y} + F_{3_y} \\ &= (60\text{ N})(\sin 22.0°) + (36\text{ N})(\sin 70.0°) + \{-(83\text{ N})(\sin 60.0°)\} \\ &= -15.6\text{ N} \end{aligned}$$

Use the Pythagorean theorem to find the magnitude of $\vec{F}_{\text{net}}$.

$$\begin{aligned} F_{\text{net}} &= \sqrt{\left(F_{\text{net}_x}\right)^2 + \left(F_{\text{net}_y}\right)^2} \\ &= \sqrt{(84.8\text{ N})^2 + (-15.6\text{ N})^2} \\ &= 86\text{ N} \end{aligned}$$

Use the tangent function to find the direction of $\vec{F}_{net}$.

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{15.6\ \cancel{\text{N}}}{84.8\ \cancel{\text{N}}}$$
$$= 0.1836$$
$$\theta = \tan^{-1}(0.1836)$$
$$= 10.4°$$

From the vector addition diagram, this angle is between $\vec{F}_{net}$ and the positive x-axis. So the direction of $\vec{F}_{net}$ measured *counterclockwise* from the positive x-axis is 360° – 10.4° = 350°.

$$\vec{F}_{net} = 86 \text{ N } [350°]$$

Paraphrase

The net force on the object is 86 N [350°].

3. If an object experiences zero net force, it may be either stationary or moving at constant velocity.

4. A person with a plaster cast on an arm or leg experiences extra fatigue because the cast adds mass to the arm or leg. Every time the person moves the limb with the cast, the limb accelerates. Since the limb with the cast has greater mass, it requires a greater net force to cause the same acceleration than without the cast. This additional net force is supplied by the muscles which become fatigued.

5. During the spin cycle, the drum of a washing machine exerts a net force inward on the wet clothes to change their direction of motion. The result is the clothes move in a circle at high speed while excess water continues to move in a straight line through the small holes in the drum. The motion of the water out of the drum is tangent to the drum. Since the extracted water is drained while the drum is spinning, the water cannot come in contact with the clothes again when the machine stops spinning.

6. ***Given***

$m_c = 1.5$ kg

$\vec{F}_{app} = 6.0$ N [left]

$\vec{a} = 3.0$ m/s^2 [left]

Required

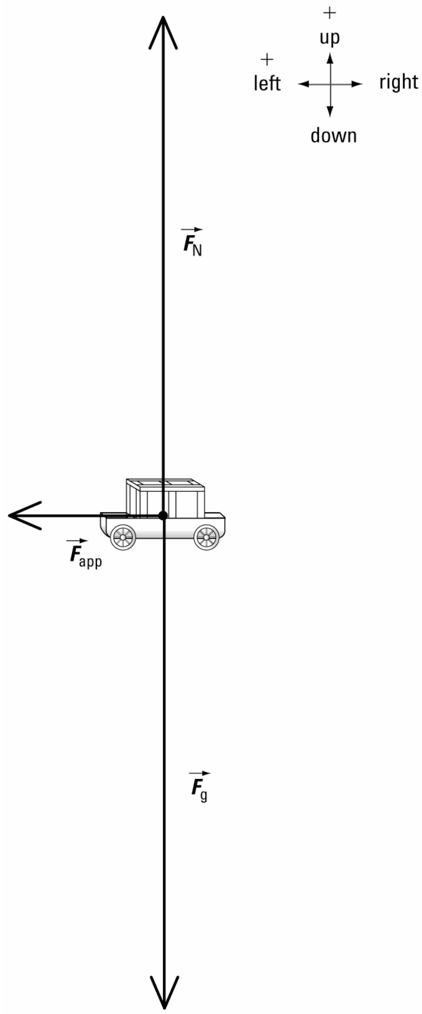
mass of load (m_l)

Analysis and Solution

The load and cart are a system because they move together as a unit. Find the total mass of the system.

$$m_T = m_l + m_c$$
$$= m_l + 1.5 \text{ kg}$$

Draw a free-body diagram for the system.



The system is not accelerating up or down.
So in the vertical direction, $F_{net_v} = 0$ N.

Write equations to find the net force on the system in both the horizontal and vertical directions.

horizontal direction

$$\vec{F}_{net_h} = \vec{F}_{app}$$

$$F_{net_h} = F_{app}$$

Apply Newton's second law.

$$m_T a = F_{app}$$

$$m_T = \frac{F_{app}}{a}$$

$$m_1 + 1.5\text{ kg} = \frac{F_{app}}{a}$$

vertical direction

$$\vec{F}_{net_v} = \vec{F}_N + \vec{F}_g$$

$$F_{net_v} = 0$$

Calculations in the vertical direction are not required in this problem.

$$m_1 = \frac{6.0\text{ N}}{3.0\text{ m/s}^2} - 1.5\text{ kg}$$

$$= \frac{6.0\text{ kg}\bullet \cancel{\frac{\text{m}}{\text{s}^2}}}{3.0\ \cancel{\frac{\text{m}}{\text{s}^2}}} - 1.5\text{ kg}$$

$$= 0.50\text{ kg}$$

Paraphrase

The load has a mass of 0.50 kg.

7. (a) If the mass is constant and the net force quadruples, the magnitude of the acceleration will quadruple.

$$a = \frac{F_{\text{net}}}{m}$$

$$= \frac{4F_{\text{net}}}{m}$$

$$= 4\left(\frac{F_{\text{net}}}{m}\right)$$

(b) If the mass is constant and the net force is divided by 4, the acceleration will be $\frac{1}{4}$ of its original magnitude.

$$a = \frac{F_{\text{net}}}{m}$$

$$= \frac{\left(\frac{1}{4}\right)F_{\text{net}}}{m}$$

$$= \left(\frac{1}{4}\right)\left(\frac{F_{\text{net}}}{m}\right)$$

(c) If the mass is constant and the net force becomes zero, the acceleration will be zero.

$$a = \frac{F_{\text{net}}}{m}$$

$$= \frac{0}{m}$$

$$= 0$$

8. ***Given***

$\vec{F}_A$ [along rope]

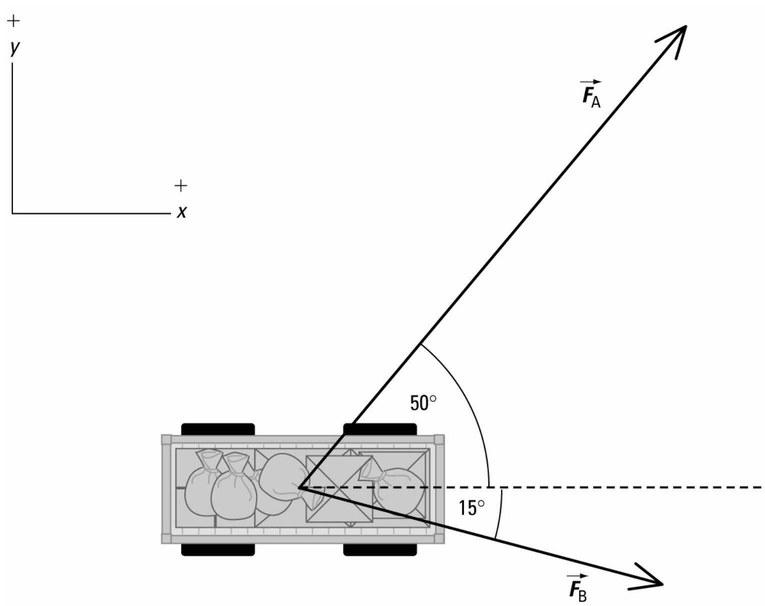
$\vec{F}_B = 25.0$ N [along rope]

$\theta_1 = 50°$

$\theta_2 = 345°$

$\vec{F}_{\text{net}} = 55.4$ N [26°]

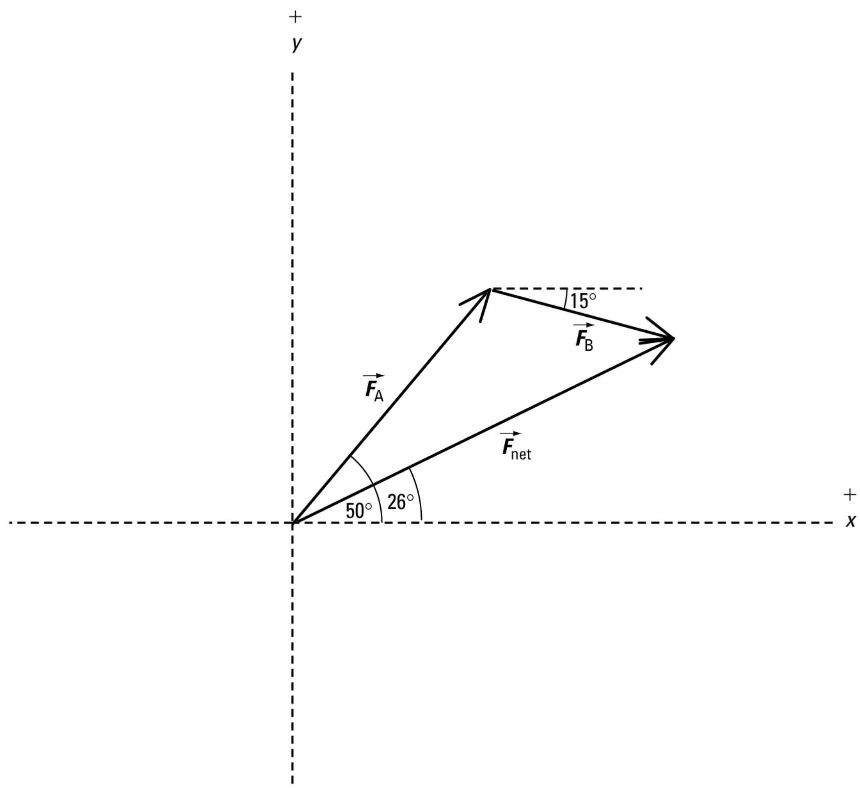
Required
magnitude of person A's applied force (F_A)
Analysis and Solution
Draw a free-body diagram for the wagon.



Resolve all forces into *x* and *y* components.

Vector	***x* component**	***y* component**
$\vec{F}_A$	$F_A(\cos 50°)$	$F_A(\sin 50°)$
$\vec{F}_B$	(25.0 N)(cos 15°)	–(25.0 N)(sin 15°)
$\vec{F}_{net}$	(55.4 N)(cos 26°)	(55.4 N)(sin 26°)

Add the *x* components of all force vectors in the vector addition diagram.



x direction

$$\vec{F}_{\text{net}_x} = \vec{F}_{\text{A}_x} + \vec{F}_{\text{B}_x}$$
$$F_{\text{net}_x} = F_{\text{A}_x} + F_{\text{B}_x}$$
$$(55.4\text{ N})(\cos 26°) = F_{\text{A}}(\cos 50°) + (25.0\text{ N})(\cos 15°)$$
$$F_{\text{A}} = \left(\frac{1}{\cos 50°}\right)\{(55.4\text{ N})(\cos 26°) - (25.0\text{ N})(\cos 15°)\}$$
$$= 39.9\text{ N}$$

Paraphrase

Person A is applying a force of magnitude 39.9 N on the wagon.

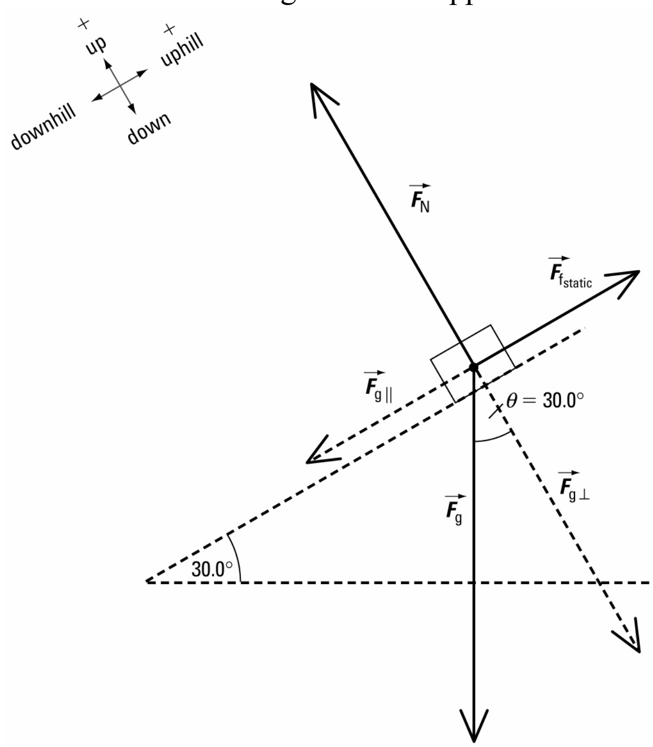
9. This example illustrates Newton's third law which states that if the table exerts a force on the book, the book exerts a force on the table of equal magnitude and opposite direction. The action-reaction forces act on two different objects.

10. The reaction force is the force exerted by the book on the pencil, which is 15 N [up].

11. The coefficients of static and kinetic friction are numerals without units because they are ratios of two physical quantities that have the same units. Both quantities are forces with units of newtons. These units cancel out, leaving just a numeral.

$$\mu_{\text{s}} = \frac{F_{\text{f}_{\text{static}}}\ [\cancel{\text{N}}]}{F_{\text{N}}\ [\cancel{\text{N}}]} \text{ and } \mu_{\text{k}} = \frac{F_{\text{f}_{\text{kinetic}}}\ [\cancel{\text{N}}]}{F_{\text{N}}\ [\cancel{\text{N}}]}$$

12. (a) From the free-body diagram below, the block is stationary because $\vec{F}_{f_{static}}$ and $\vec{F}_{g\parallel}$ have the same magnitude but opposite directions.



(b) A free-body diagram helps you visualize the situation of the problem. All the forces acting on the block are included, so it is easy to see why no motion occurs in this situation.

13. Since μ_s for wet concrete is greater than that for wet asphalt, the car will be able to slow down more quickly on wet concrete, assuming the car is not skidding. So the stopping distance and stopping time will be shorter.

If the car is skidding, the car will slide with equal ease on both surfaces because μ_k is the same for wet concrete and wet asphalt.

Chapter 4

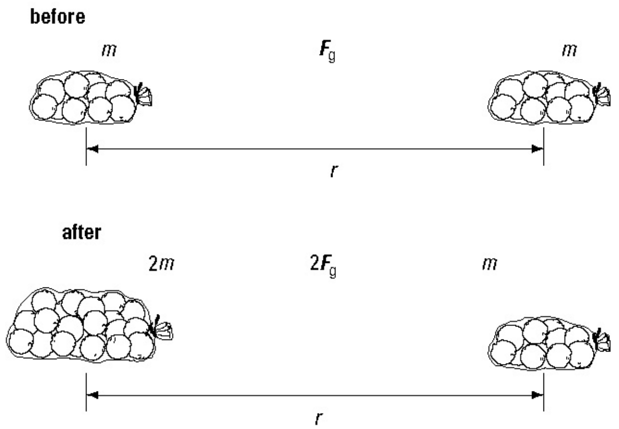
14. Since gravitational field strength is equivalent to the acceleration due to gravity, both values will be the same at the top of a tall skyscraper.

15. The inertia of an object is directly proportional to its mass. The greater the mass, the greater the inertia. Since both gravitational force and gravitational field strength vary with mass, mass is the fundamental quantity that affects the inertia of an object.

16. Since the magnitude of the gravitational field strength is slightly less at the top of a mountain, an athlete would weigh slightly less at the top than at the base. A ski jumper may be able to jump higher at top of the mountain than at the base. Also, the density of air decreases as you go up in altitude. So the air resistance acting on an athlete would be slightly less at the top of a mountain than at the base, resulting in slightly faster bobsled times.

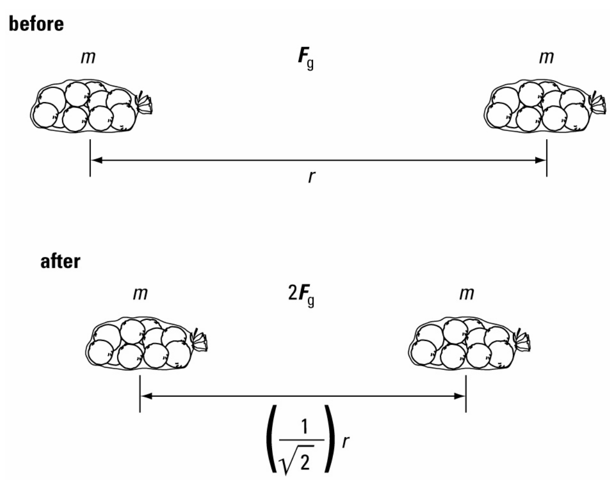
17. From Newton's law of gravitation, $F_g \propto m_A m_B$ and $F_g \propto \frac{1}{r^2}$. To double the gravitational force, you could double the mass of one of the bags. The figure below represents this situation.

$$\begin{aligned} F_g &\propto (2m)(m) \\ &\propto 2m^2 \end{aligned}$$



Another way to double the gravitational force is to reduce the separation distance. The figure below represents this situation.

$$\begin{aligned} F_g &\propto \frac{1}{\left(\frac{1}{\sqrt{2}}r\right)^2} \\ &\propto (\sqrt{2})^2\left(\frac{1}{r^2}\right) \\ &\propto 2\left(\frac{1}{r^2}\right) \end{aligned}$$



18. Substitute the definition $1\text{ N} = 1\ \dfrac{\text{kg}\bullet\text{m}}{\text{s}^2}$ into the student's answer. Then simplify.

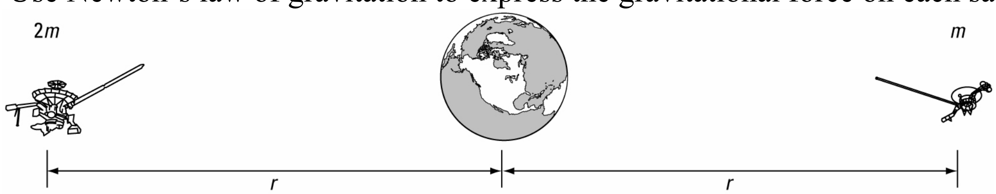
$$57.3\ \frac{\text{N}\bullet\text{s}^2}{\text{m}} = 57.3\left(\frac{\text{kg}\bullet\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)\left(\frac{\cancel{\text{s}^2}}{\cancel{\text{m}}}\right)$$
$$= 57.3\text{ kg}$$

The student was solving for mass.

19. If you express the statement as an equation, you get $F_g \propto \dfrac{1}{r^2}$. If the probe is twice as far away from Mars, the gravitational force would be $\dfrac{1}{2^2} = \dfrac{1}{4}$ of its original magnitude. If the probe is $\dfrac{1}{3}$ of its original distance from Mars, the gravitational force would be $\dfrac{1}{\left(\dfrac{1}{3^2}\right)} = 9$ times its original magnitude.

20. An object is weightless only if there is no gravitational force acting on it. An object in free fall is experiencing the gravitational force of a celestial body. So an object in free fall is not weightless, unless it is in deep space where the gravitational force is not measurable.

21. Use Newton's law of gravitation to express the gravitational force on each satellite.



The gravitational force on satellite m is $(F_g)_m = \dfrac{GmM}{r^2}$.

The gravitational force on satellite $2m$ is $(F_g)_{2m} = \dfrac{G(2m)M}{r^2}$ or $2\left(\dfrac{GmM}{r^2}\right)$.

So the gravitational force on satellite $2m$ is twice that on satellite m, for the same separation distance, because it has twice the mass.

22. From Figure 4.34 on page 221, the magnitude of Earth's gravitational field strength is greater at the North Pole than at the equator. So an object in free fall will experience a slightly greater acceleration due to gravity at the North Pole.

23. (a) The mass of an object has no effect on the acceleration due to gravity, provided that air resistance is negligible. For an object in free fall, the net force on the object is given by

$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{F}_{\text{air}}$$
$$F_{\text{net}} = F_g + F_{\text{air}}$$
$$-ma = -mg + F_{\text{air}}$$

If $F_{\text{air}} = 0$, $a = g$, so the acceleration is independent of mass.

(b) Gravitational field strength is the force per unit mass at a specific location. Gravitational field strength can be calculated using $g = \frac{GM_{\text{source}}}{r^2}$, which is independent of the mass of the object.

Applications

24. ***Given***

$\vec{F}_1 = 150\text{ N [40.0°]}$

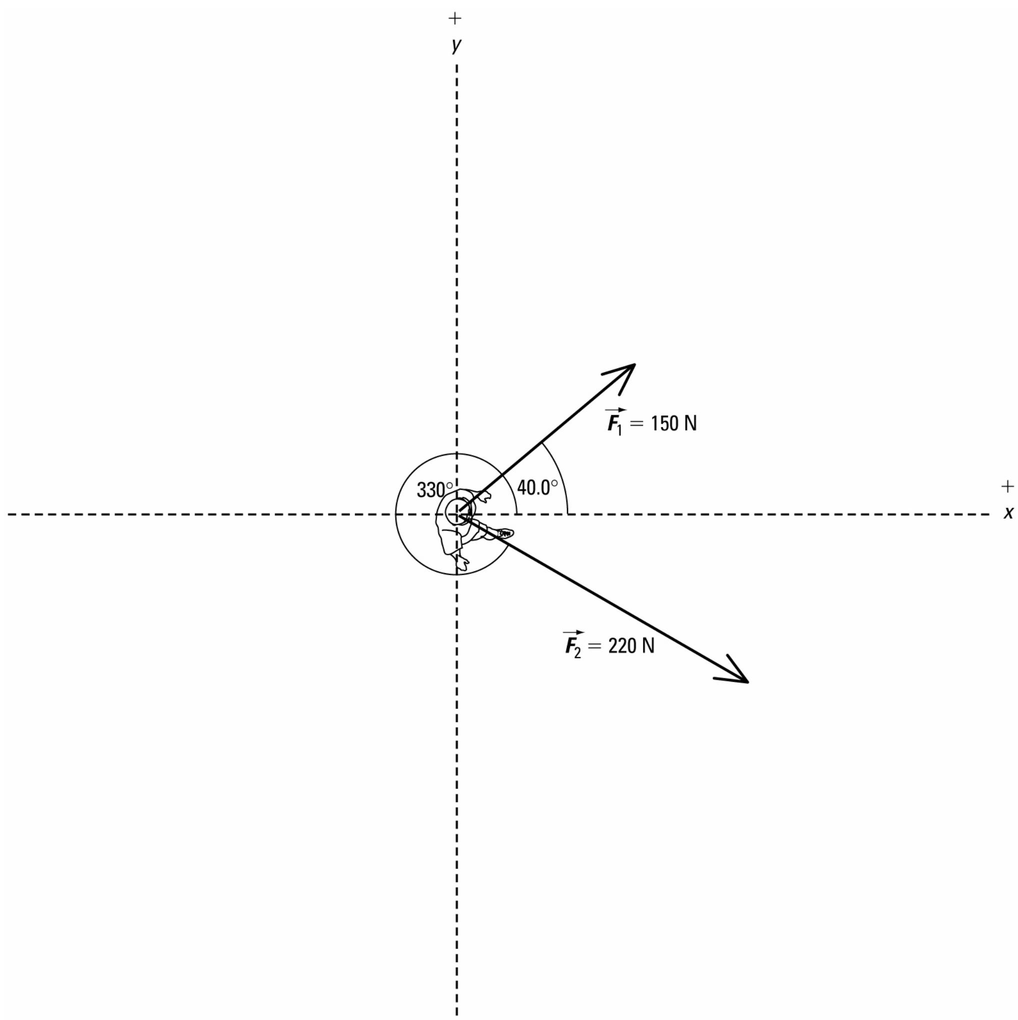
$\vec{F}_2 = 220\text{ N [330°]}$

Required

net force on the soccer player ($\vec{F}_{\text{net}}$)

Analysis and Solution

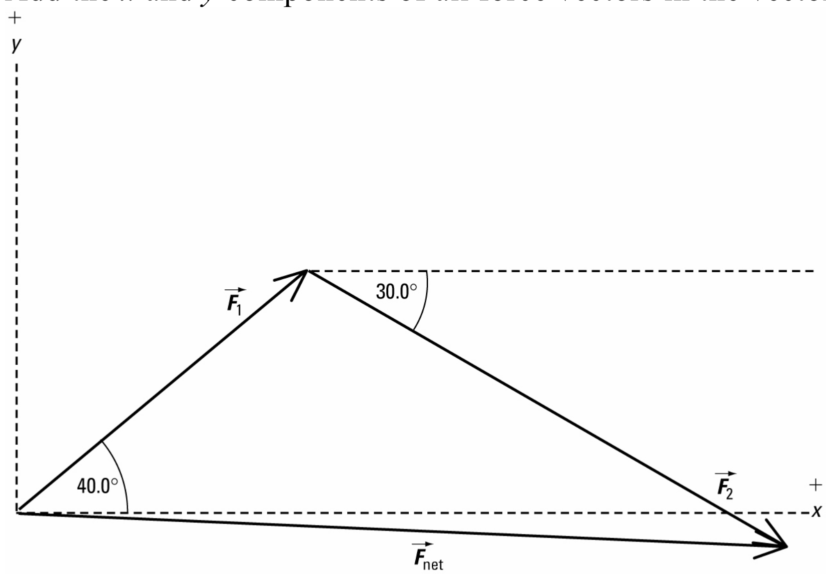
Draw a free-body diagram for the soccer player.



Resolve all forces into x and y components.

Vector	x **component**	y **component**
$\vec{F}_1$	(150 N)(cos 40.0°)	(150 N)(sin 40.0°)
$\vec{F}_2$	(220 N)(cos 30.0°)	–(220 N)(sin 30.0°)

Add the x and y components of all force vectors in the vector addition diagram.



x direction

$$\vec{F}_{\text{net}_x} = \vec{F}_{1_x} + \vec{F}_{2_x}$$

$$\begin{aligned} F_{\text{net}_x} &= F_{1_x} + F_{2_x} \\ &= (150 \text{ N})(\cos 40.0°) + (220 \text{ N})(\cos 30.0°) \\ &= 305.4 \text{ N} \end{aligned}$$

y direction

$$\vec{F}_{\text{net}_y} = \vec{F}_{1_y} + \vec{F}_{2_y}$$

$$\begin{aligned} F_{\text{net}_y} &= F_{1_y} + F_{2_y} \\ &= (150 \text{ N})(\sin 40.0°) + \{-(220 \text{ N})(\sin 30.0°)\} \\ &= (150 \text{ N})(\sin 40.0°) - (220 \text{ N})(\sin 30.0°) \\ &= -13.58 \text{ N} \end{aligned}$$

Use the Pythagorean theorem to find the magnitude of $\vec{F}_{\text{net}}$.

$$\begin{aligned} F_{\text{net}} &= \sqrt{\left(F_{\text{net}_x}\right)^2 + \left(F_{\text{net}_y}\right)^2} \\ &= \sqrt{(305.4 \text{ N})^2 + (-13.58 \text{ N})^2} \\ &= 306 \text{ N} \end{aligned}$$

Use the tangent function to find the direction of $\vec{F}_{\text{net}}$.

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$= \frac{13.58\ \cancel{\text{N}}}{305.4\ \cancel{\text{N}}}$$

$$= 0.0445$$

$$\theta = \tan^{-1}(0.0445)$$

$$= 2.5°$$

From the vector addition diagram, this angle is between $\vec{F}_{\text{net}}$ and the positive x-axis. So the direction of $\vec{F}_{\text{net}}$ measured *counterclockwise* from the positive x-axis is 360° – 2.5° = 357°.

$$\vec{F}_{\text{net}} = 306 \text{ N } [357°]$$

Paraphrase
The net force on the soccer player is 306 N [357°].

25. ***Given***
m = 1478 kg
$\vec{F}_{\text{net}}$ = 3100 N [W]

Required
acceleration of car ($\vec{a}$)

Analysis and Solution
The car is not accelerating up or down.
So in the vertical direction, F_{net_v} = 0 N.

In the horizontal direction, the acceleration of the car is in the direction of the net force. So use the scalar form of Newton's second law.

$$F_{\text{net}_\text{h}} = ma$$

$$a = \frac{F_{\text{net}_\text{h}}}{m}$$

$$= \frac{3100 \text{ N}}{1478 \text{ kg}}$$

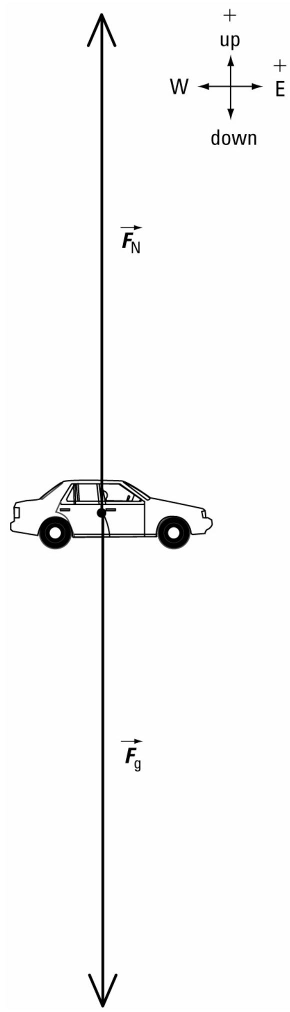
$$= \frac{3100\ \cancel{\text{kg}} \bullet \frac{\text{m}}{\text{s}^2}}{1478\ \cancel{\text{kg}}}$$

$$= 2.097 \text{ m/s}^2$$

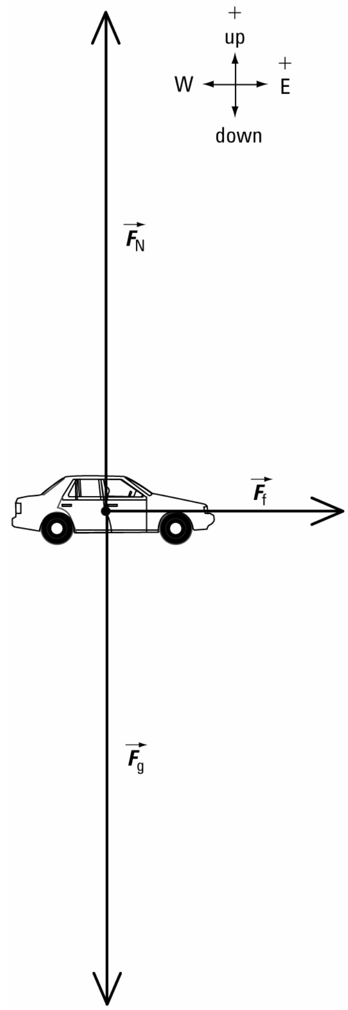
$$\vec{a} = 2.097 \text{ m/s}^2 \text{ [W]}$$

Paraphrase
The car will have an acceleration of 2.097 m/s^2 [W].

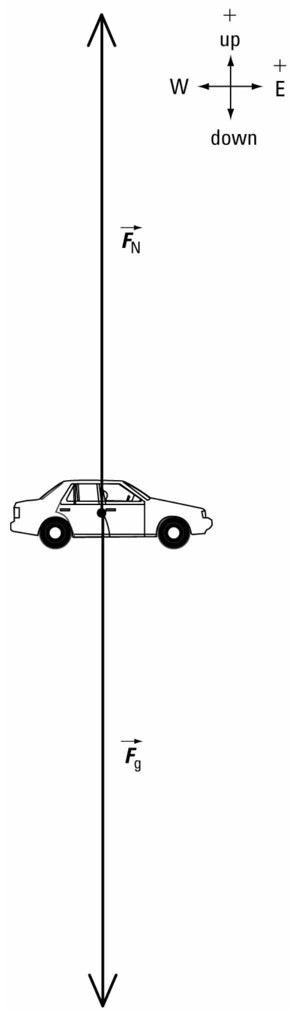
26. Car stopped



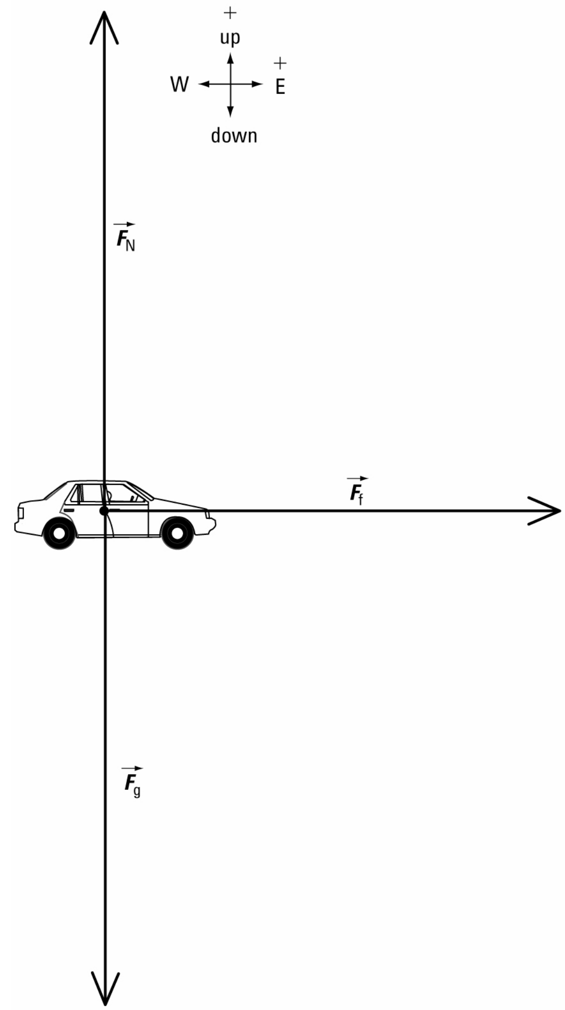
Car speeding up from stoplight



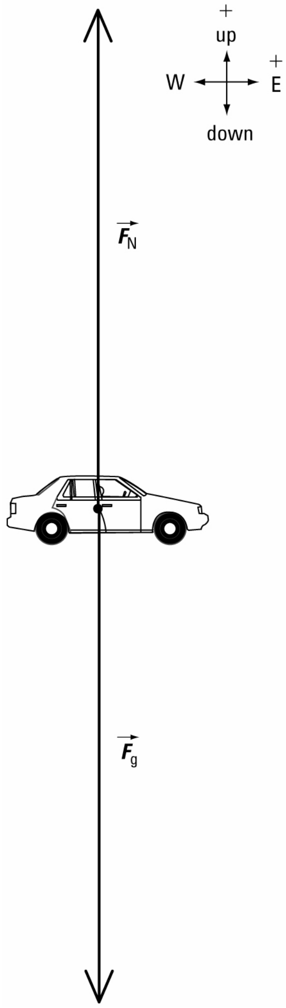
Car cruising at city speed limit



Car going on highway ramp



Car cruising at highway speed limit



27. ***Given***

magnitude of $\vec{F}_{net}$ = 8.0 N $\quad$ m = 4.0 kg

$\vec{v}_i$ = 10 m/s [right] $\quad$ $\vec{v}_f$ = 18 m/s [right]

Required

time interval during which net force acts (Δt)

Analysis and Solution

The acceleration of the object is in the direction of the net force. So use the scalar form of Newton's second law.

$$F_{net} = ma$$

$$a = \frac{F_{\text{net}}}{m}$$

$$= \frac{8.0 \text{ N}}{4.0 \text{ kg}}$$

$$= \frac{8.0 \cancel{\text{kg}} \bullet \frac{\text{m}}{\text{s}^2}}{4.0 \cancel{\text{kg}}}$$

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

$$\vec{a} = 2.00 \text{ m/s}^2 \text{ [right]}$$

Calculate the time interval.

$$a = \frac{\Delta v}{\Delta t}$$

$$\Delta t = \frac{\Delta v}{a}$$

$$= \frac{v_{\text{f}} - v_{\text{i}}}{a}$$

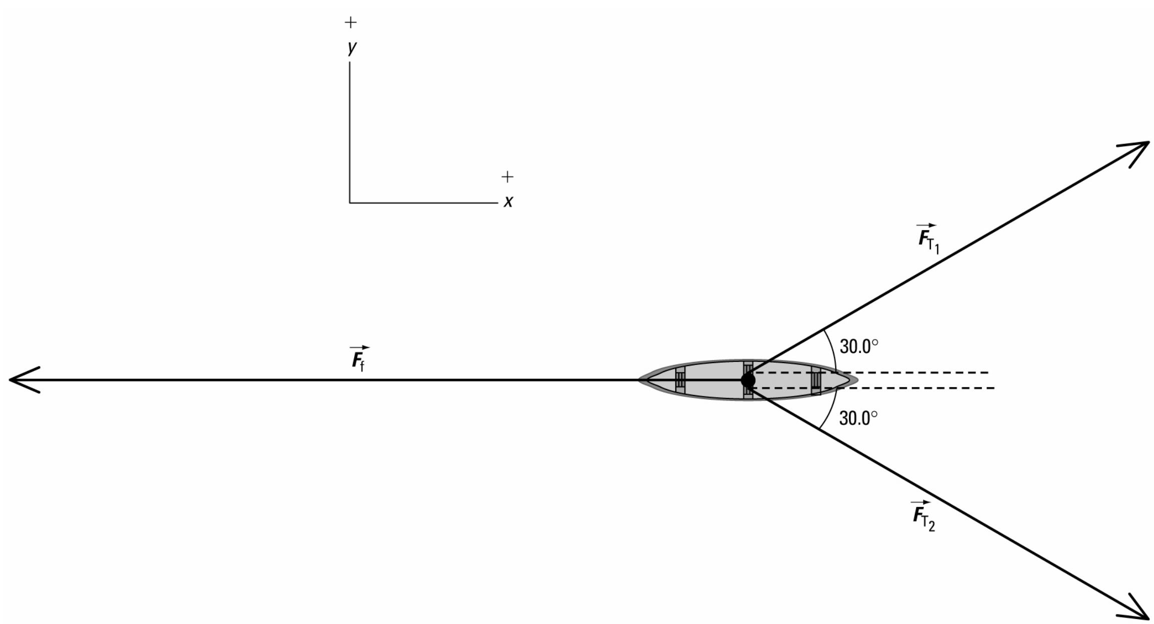
$$= \frac{18 \text{ m/s} - 10 \text{ m/s}}{2.00 \text{ m/s}^2}$$

$$= 4.0 \text{ s}$$

Paraphrase

The net force is applied for 4.0 s.

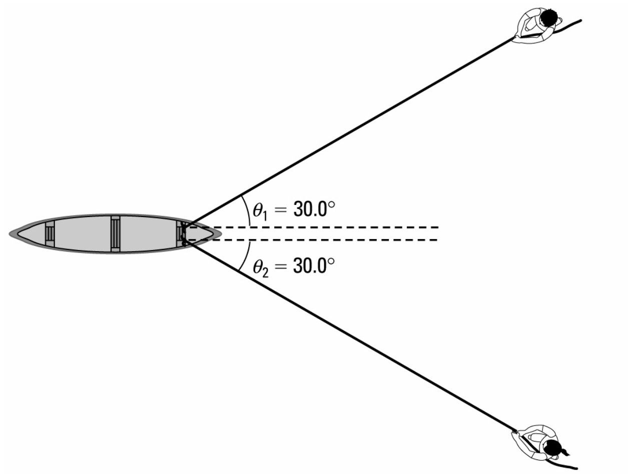
28. (a)



(b) ***Given***

$\vec{F}_{T_1}$ = 65.0 N [along rope] $\vec{F}_{T_2}$ = 65.0 N [along rope]

$\theta_1 = \theta_2 = 30.0°$ magnitude of $\vec{F}_f$ = 104 N



Required

net force on boat ($\vec{F}_{net}$)

Analysis and Solution

Resolve all forces into *x* and *y* components.

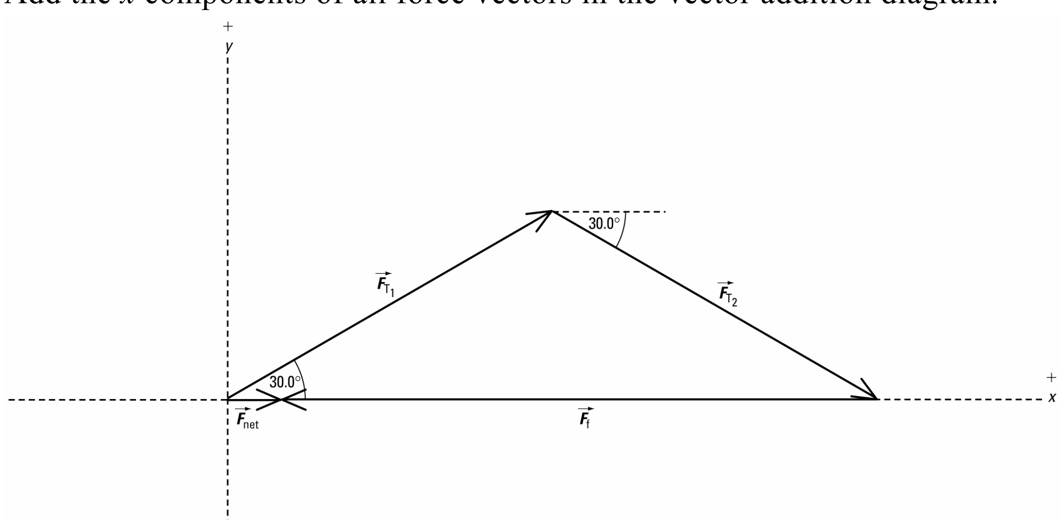
Vector	***x* component**	***y* component**
$\vec{F}_{T_1}$	(65.0 N)(cos 30.0°)	(65.0 N)(sin 30.0°)
$\vec{F}_{T_2}$	(65.0 N)(cos 30.0°)	–(65.0 N)(sin 30.0°)

From the chart, $F_{T_{1y}} = -F_{T_{2y}}$.

So $\vec{F}_{net_y} = \vec{F}_{T_{1y}} + \vec{F}_{T_{2y}}$

$F_{net_y} = F_{T_{1y}} + F_{T_{2y}} = 0$

Add the *x* components of all force vectors in the vector addition diagram.



x direction

$$\vec{F}_{\text{net}_x} = \vec{F}_{\text{T}_{1x}} + \vec{F}_{\text{T}_{2x}} + \vec{F}_{\text{f}}$$

$$\begin{aligned} F_{\text{net}_x} &= F_{\text{T}_{1x}} + F_{\text{T}_{2x}} + F_{\text{f}} \\ &= (65.0\text{ N})(\cos 30.0°) + (65.0\text{ N})(\cos 30.0°) + (-104\text{ N}) \\ &= (65.0\text{ N})(\cos 30.0°) + (65.0\text{ N})(\cos 30.0°) - 104\text{ N} \\ &= 8.58\text{ N} \end{aligned}$$

From the vector addition diagram, $\vec{F}_{\text{net}}$ is along the positive x-axis.

$$\vec{F}_{\text{net}} = 8.58\text{ N [0°]}$$

Paraphrase

The net force on the boat is 8.58 N [0°].

29. ***Given***

magnitude of $\vec{a}_{\text{A}} = 0.40\text{ m/s}^2$

$m_{\text{c}_\text{A}} = 3.0 \times 10^5\text{ kg}$ $\quad$ $m_{\text{c}_\text{B}} = 2.0 \times 10^5\text{ kg}$

$m_{\text{l}_\text{A}} = 5.0 \times 10^4\text{ kg}$ $\quad$ $m_{\text{l}_\text{B}} = 5.0 \times 10^4\text{ kg}$

Required

acceleration of train B ($\vec{a}_{\text{B}}$)

Analysis and Solution

The locomotive and cars of each train are a system because they move together as a unit. Find the total mass of each train.

$$\begin{aligned} m_{\text{T}_\text{A}} &= m_{\text{l}_\text{A}} + m_{\text{c}_\text{A}} \\ &= 5.0 \times 10^4\text{ kg} + 3.0 \times 10^5\text{ kg} \\ &= 3.5 \times 10^5\text{ kg} \end{aligned}$$

$$\begin{aligned} m_{\text{T}_\text{B}} &= m_{\text{l}_\text{B}} + m_{\text{c}_\text{B}} \\ &= 5.0 \times 10^4\text{ kg} + 2.0 \times 10^5\text{ kg} \\ &= 2.5 \times 10^5\text{ kg} \end{aligned}$$

Train A is not accelerating up or down.

So in the vertical direction, $F_{\text{net}_\text{v}} = 0$ N.

In the horizontal direction, the net force on train A is in the direction of its acceleration. So use the scalar form of Newton's second law.

$$\begin{aligned} F_{\text{net}_\text{h}} &= m_{\text{T}_\text{A}} a_{\text{A}} \\ &= (3.5 \times 10^5\text{ kg})(0.40\text{ m/s}^2) \\ &= 1.40 \times 10^5\text{ N} \end{aligned}$$

Train B is not accelerating up or down.

So in the vertical direction, $F_{\text{net}_\text{v}} = 0$ N.

In the horizontal direction, the acceleration of train B is in the direction of the net force. So use the scalar form of Newton's second law.

$$F_{\text{net}_\text{h}} = m_{\text{T}_\text{B}} a_{\text{B}}$$

$$a_B = \frac{F_{net_h}}{m_{T_B}}$$
$$= \frac{1.40 \times 10^5 \text{ N}}{2.5 \times 10^5 \text{ kg}}$$
$$= \frac{1.40\times10^5 \ \cancel{\text{kg}}\bullet\frac{\text{m}}{\text{s}^2}}{2.5\times10^5 \ \cancel{\text{kg}}}$$
$$= 0.56 \text{ m/s}^2$$
$$\vec{a}_B = 0.56 \text{ m/s}^2 \text{ [in same direction as train A]}$$

Paraphrase

Train B will have an acceleration of 0.56 m/s^2 [in same direction as train A].

30. ***Given***

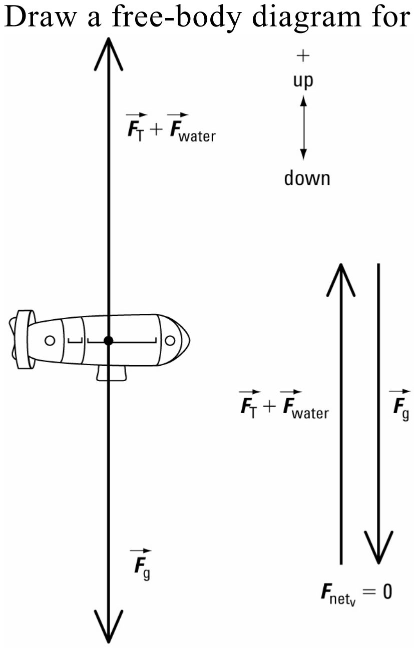
$m = 8.2$ t or 8.2×10^3 kg
$g = 9.81 \text{ m/s}^2$
$\vec{v} = 10$ cm/s [down]

Required

force exerted by water and cable on chamber ($\vec{F}_T + \vec{F}_{water}$)

Analysis and Solution

Draw a free-body diagram for the chamber.



Since the chamber is not accelerating, $\vec{F}_{net} = 0$ N in both the horizontal and vertical directions.

For the vertical direction, write an equation to find the net force on the chamber.

$$\vec{F}_{net_v} = \vec{F}_T + \vec{F}_{water} + \vec{F}_g$$
$$0 = F_T + F_{water} + F_g$$

$$F_T + F_{water} = -F_g$$
$$= -mg$$
$$= -\{-(8.2 \times 10^3 \text{ kg})(9.81 \text{ m/s}^2)\}$$
$$= 8.0 \times 10^4 \text{ N}$$
$$\vec{F}_T + \vec{F}_{water} = 8.0 \times 10^4 \text{ N [up]}$$

Paraphrase

The water and cable exert a force of 8.0×10^4 N [up] on the chamber.

31. ***Given***

m_b = 240 kg

m_r = 70 kg

$\vec{F}_{air}$ = 1280 N [backward]

$\vec{F}_{f_{static}}$ = 1950 N [forward]

Required

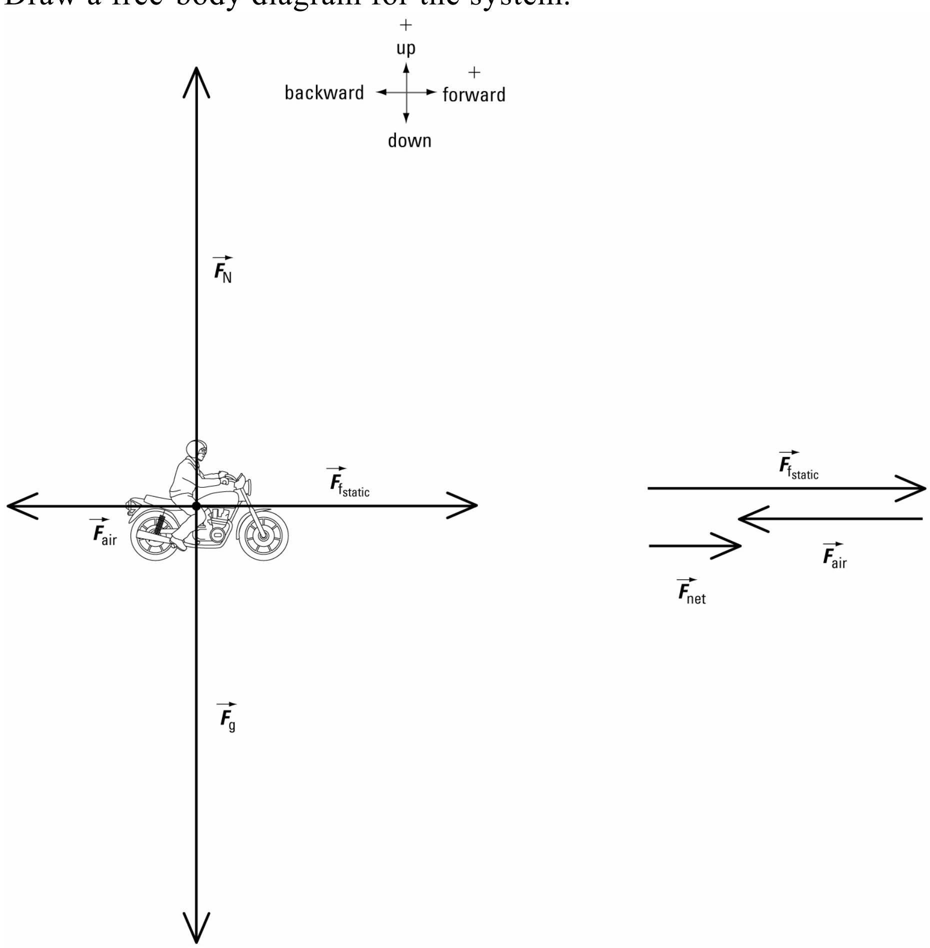
acceleration of system ($\vec{a}$)

Analysis and Solution

The motorcycle and rider are a system because they move together as a unit.
Find the total mass of the system.

$$m_T = m_b + m_r$$
$$= 240 \text{ kg} + 70 \text{ kg}$$
$$= 310 \text{ kg}$$

Draw a free-body diagram for the system.



The system is not accelerating up or down.
So in the vertical direction, $F_{\text{net}_v} = 0$ N.

Write equations to find the net force on the system in both the horizontal and vertical directions.

horizontal direction

$$\vec{F}_{\text{net}_h} = \vec{F}_{f_{\text{static}}} + \vec{F}_{\text{air}}$$

$$\begin{aligned} F_{\text{net}_h} &= F_{f_{\text{static}}} + F_{\text{air}} \\ &= 1950 \text{ N} + (-1280 \text{ N}) \\ &= 1950 \text{ N} - 1280 \text{ N} \\ &= 670 \text{ N} \end{aligned}$$

vertical direction

$$\vec{F}_{\text{net}_v} = \vec{F}_{\text{N}} + \vec{F}_{\text{g}}$$

$$F_{\text{net}_v} = 0$$

Calculations in the vertical direction are not required in this problem.

Apply Newton's second law to the horizontal direction.

$$\begin{aligned} F_{\text{net}_h} &= m_{\text{T}}\, a \\ a &= \frac{F_{\text{net}_h}}{m_{\text{T}}} \\ &= \frac{670 \text{ N}}{310 \text{ kg}} \\ &= \frac{670 \dfrac{\cancel{\text{kg}} \cdot \text{m}}{\text{s}^2}}{310 \ \cancel{\text{kg}}} \\ &= 2.2 \text{ m/s}^2 \\ \vec{a} &= 2.2 \text{ m/s}^2 \text{ [forward]} \end{aligned}$$

Paraphrase

The system will have an acceleration of 2.2 m/s^2 [forward].

32. ***Given***

$m = 0.25$ kg

$\Delta t = 0.60$ s

$\vec{v}_{\text{i}} = 15$ m/s [up]

$\vec{v}_{\text{f}} = 40$ m/s [up]

Required

force exerted by escaping gas ($\vec{F}_{\text{net}}$)

Analysis and Solution

Calculate the acceleration of the rocket.

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} \\ &= \frac{v_{\text{f}} - v_{\text{i}}}{\Delta t} \\ &= \frac{40 \text{ m/s} - 15 \text{ m/s}}{0.60 \text{ s}} \\ &= 41.7 \text{ m/s}^2 \end{aligned}$$

$\vec{a} = 41.7 \text{ m/s}^2$ [up]

The acceleration of the rocket is in the direction of the net force. So use the scalar form of Newton's second law.

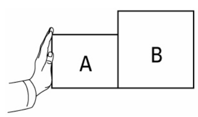
$$\begin{aligned} F_{\text{net}} &= ma \\ &= (0.25 \text{ kg})(41.7 \text{ m/s}^2) \\ &= 10 \text{ N} \\ \vec{F}_{\text{net}} &= 10 \text{ N [up]} \end{aligned}$$

Paraphrase

The escaping gas exerts a force of 10 N [up] on the rocket.

33. (a) ***Given***

$m_A = 60$ kg $m_B = 90$ kg $\vec{F}_{\text{app}} = 800$ N [right]



Required

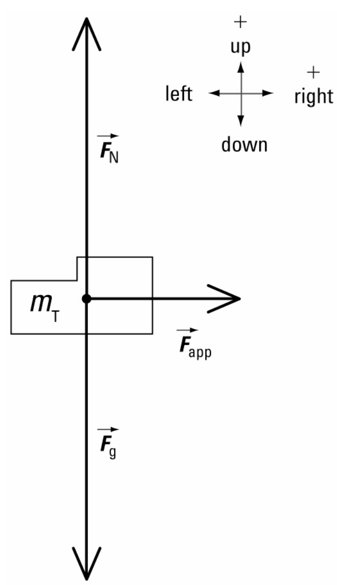
acceleration of both boxes ($\vec{a}$)

Analysis and Solution

Both boxes are a system because they move together as a unit. Find the total mass of the system.

$$\begin{aligned} m_T &= m_A + m_B \\ &= 60 \text{ kg} + 90 \text{ kg} \\ &= 150 \text{ kg} \end{aligned}$$

Draw a free-body diagram for the system.



The system is not accelerating up or down.
So in the vertical direction, $F_{\text{net}_v} = 0$ N.

Write equations to find the net force on the system in both the horizontal and vertical directions.

horizontal direction

$\vec{F}_{\text{net}_h} = \vec{F}_{\text{app}}$

$F_{\text{net}_h} = F_{\text{app}}$

$= 800 \text{ N}$

Apply Newton's second law to the horizontal direction.

$F_{\text{net}_h} = m_T a$

$a = \dfrac{F_{\text{net h}}}{m_T}$

$= \dfrac{800 \text{ N}}{150 \text{ kg}}$

$= \dfrac{800 \dfrac{\cancel{\text{kg}} \cdot \text{m}}{\text{s}^2}}{150 \ \cancel{\text{kg}}}$

$= 5.3 \text{ m/s}^2$

$\vec{a} = 5.3 \text{ m/s}^2 \text{ [right]}$

vertical direction

$\vec{F}_{\text{net}_v} = \vec{F}_N + \vec{F}_g$

$F_{\text{net}_v} = 0$

Calculations in the vertical direction are not required in this problem.

Paraphrase

The acceleration of both boxes is 5.3 m/s^2 [right].

(b) ***Given***

$m_A = 60 \text{ kg}$ $m_B = 90 \text{ kg}$

$\vec{F}_{\text{app}} = 800 \text{ N [right]}$

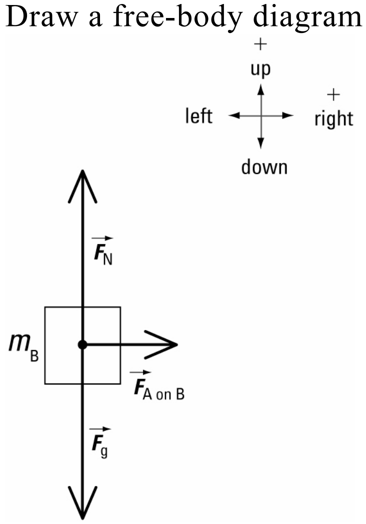
$\vec{a} = 5.33 \text{ m/s}^2$ [right] from part (a)

Required

magnitude of action-reaction forces between the boxes ($F_{\text{A on B}}$)

Analysis and Solution

Draw a free-body diagram for box B.



Box B is not accelerating up or down.

So in the vertical direction, $F_{\text{net}_v} = 0$ N.

Write equations to find the net force on box B in both the horizontal and vertical directions.

horizontal direction

$$\vec{F}_{\text{net}_h} = \vec{F}_{\text{A on B}}$$
$$F_{\text{net}_h} = F_{\text{A on B}}$$

Apply Newton's second law.

$$m_B a = F_{\text{A on B}}$$
$$F_{\text{A on B}} = (90 \text{ kg})(5.33 \text{ m/s}^2)$$
$$= 4.8 \times 10^2 \text{ N}$$

vertical direction

$$\vec{F}_{\text{net}_v} = \vec{F}_N + \vec{F}_g$$
$$F_{\text{net}_v} = 0$$

Calculations in the vertical direction are not required in this problem.

Paraphrase

The magnitude of the action-reaction forces between the boxes is 4.8×10^2 N.

34. ***Given***

$\vec{F}_{\text{app}} = 1.5$ N [right]

$m = 2.0$ kg

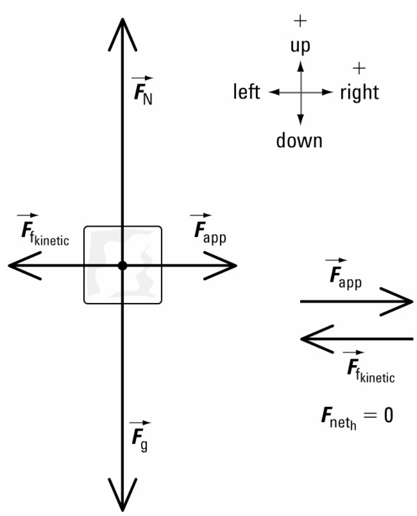
$g_{\text{Moon}} = 1.62 \text{ m/s}^2$

Required

coefficient of kinetic friction (μ_k)

Analysis and Solution

Draw a free-body diagram for the glass block.



Since the block is not accelerating, $\vec{F}_{\text{net}} = 0$ N in both the horizontal and vertical directions.

Write equations to find the net force on the block in both directions.

horizontal direction

$$\vec{F}_{\text{net}_h} = \vec{F}_{\text{app}} + \vec{F}_{f_{\text{kinetic}}}$$
$$F_{\text{net}_h} = F_{\text{app}} + F_{f_{\text{kinetic}}}$$

vertical direction

$$\vec{F}_{\text{net}_v} = \vec{F}_N + \vec{F}_g$$
$$F_{\text{net}_v} = F_N + F_g$$

$$\begin{aligned} 0 &= 1.5\ \text{N} + (-\mu_k F_N) \\ &= 1.5\ \text{N} - \mu_k F_N \\ \mu_k F_N &= 1.5\ \text{N} \end{aligned} \qquad \begin{aligned} 0 &= F_N + (-mg_{\text{Moon}}) \\ &= F_N - mg_{\text{Moon}} \\ F_N &= mg_{\text{Moon}} \end{aligned}$$

Substitute $F_N = mg_{\text{Moon}}$ into the last equation for the horizontal direction.

$$\begin{aligned} \mu_k mg_{\text{Moon}} &= 1.5\ \text{N} \\ \mu_s &= \frac{1.5\ \text{N}}{mg_{\text{Moon}}} \\ &= \frac{1.5\ \text{N}}{(2.0\ \text{kg})\left(1.62\ \dfrac{\text{m}}{\text{s}^2}\right)} \\ &= \frac{1.5\ \cancel{\text{kg}} \bullet \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}}{\left(2.0\ \cancel{\text{kg}}\right)\left(1.62\ \dfrac{\cancel{\text{m}}}{\cancel{\text{s}^2}}\right)} \\ &= 0.46 \end{aligned}$$

Paraphrase

The coefficient of kinetic friction for the glass block on the surface is 0.46.

35. (a) ***Given***

$m_A = 4.0$ kg $\qquad m_B = 6.0$ kg $\qquad m_C = 3.0$ kg

$g = 9.81\ \text{m/s}^2$

$\vec{a} = 1.4\ \text{m/s}^2$ [forward]

$\mu_s = 0.5$ from Table 3.4 (dry oak on dry oak)

Required

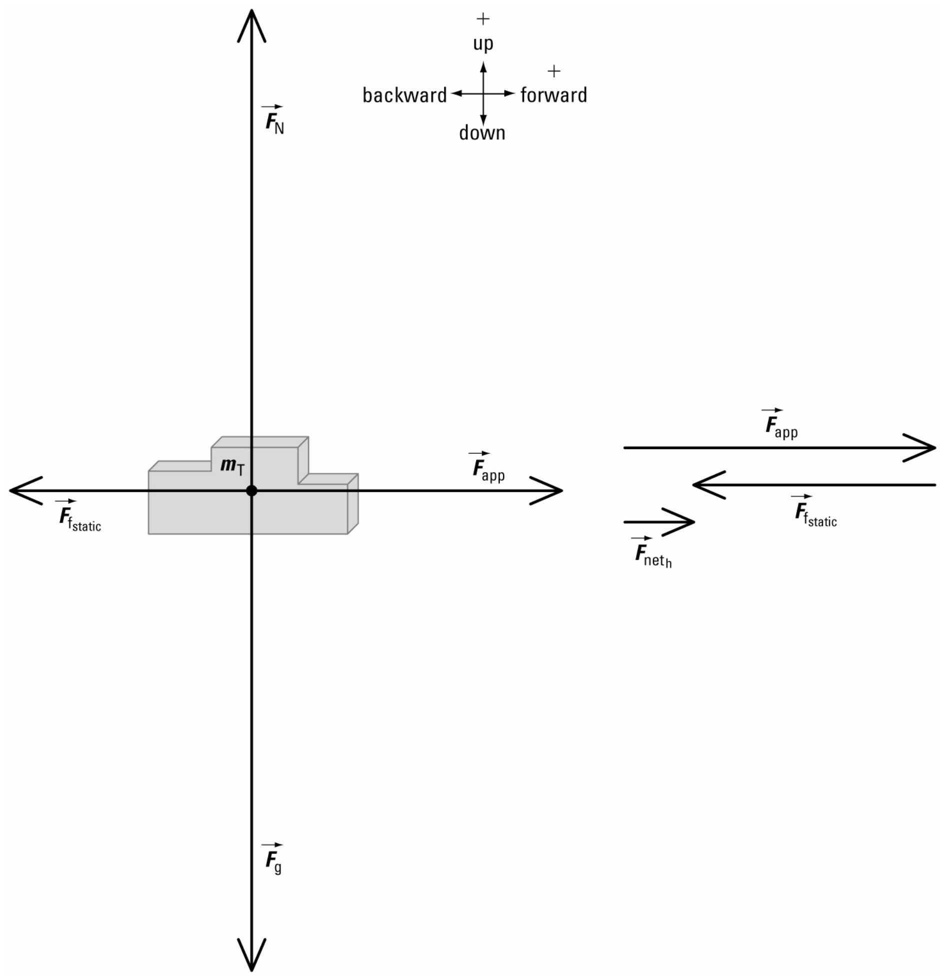
applied force on blocks ($\vec{F}_{\text{app}}$)

Analysis and Solution

The three blocks are a system because they move together as a unit. Find the total mass of the system.

$$\begin{aligned} m_T &= m_A + m_B + m_C \\ &= 4.0\ \text{kg} + 6.0\ \text{kg} + 3.0\ \text{kg} \\ &= 13.0\ \text{kg} \end{aligned}$$

Draw a free-body diagram for the system.



Since the system is not accelerating in the vertical direction, $F_{net_h} = 0$ N.

Write equations to find the net force on the system in both the horizontal and vertical directions.

horizontal direction

$$\begin{aligned}
\vec{F}_{net_h} &= \vec{F}_{app} + \vec{F}_{f_{static}} \\
F_{net_h} &= F_{app} + F_{f_{static}} \\
m_T a &= F_{app} + F_{f_{static}} \\
&= F_{app} + (-\mu_s F_N) \\
&= F_{app} - \mu_s F_N \\
F_{app} &= m_T a + \mu_s F_N
\end{aligned}$$

vertical direction

$$\begin{aligned}
\vec{F}_{net_v} &= \vec{F}_N + \vec{F}_g \\
F_{net_v} &= F_N + F_g \\
0 &= F_N + (-m_T g) \\
&= F_N - m_T g \\
F_N &= m_T g
\end{aligned}$$

Substitute $F_N = m_T g$ into the last equation for the horizontal direction.

$$\begin{aligned}
F_{app} &= m_T a + \mu_s m_T g \\
&= m_T(a + \mu_s g) \\
&= (13.0 \text{ kg})\{1.4 \text{ m/s}^2 + (0.5)(9.81 \text{ m/s}^2)\} \\
&= 8 \times 10^1 \text{ N}
\end{aligned}$$

$\vec{F}_{app} = 8 \times 10^1$ N [forward]

Paraphrase
An applied force of 8×10^1 N [forward] will cause the blocks to accelerate at 1.4 m/s^2 [forward].

(b) ***Given***

$m_A = 4.0$ kg $\quad m_B = 6.0$ kg $\quad m_C = 3.0$ kg

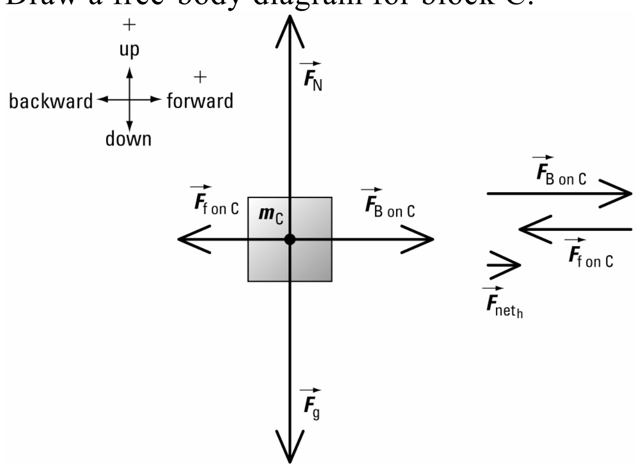
$g = 9.81$ m/s^2

$\vec{a} = 1.4$ m/s^2 [forward]

$\mu_s = 0.5$ from Table 3.4 (dry oak on dry oak)

Required
force exerted by block B on block C ($\vec{F}_{\text{B on C}}$)

Analysis and Solution
Draw a free-body diagram for block C.



Block C is not accelerating up or down.
So in the vertical direction, $F_{\text{net}_v} = 0$ N.

Write equations to find the net force on block C in both the horizontal and vertical directions.

horizontal direction

$$\begin{aligned}
\vec{F}_{\text{net}_h} &= \vec{F}_{\text{B on C}} + \vec{F}_{\text{f on C}} \\
F_{\text{net}_h} &= F_{\text{B on C}} + F_{\text{f on C}} \\
m_C a &= F_{\text{B on C}} + (-\mu_s F_N) \\
&= F_{\text{B on C}} - \mu_s F_N \\
F_{\text{B on C}} &= m_C a + \mu_s F_N
\end{aligned}$$

vertical direction

$$\begin{aligned}
\vec{F}_{\text{net}_v} &= \vec{F}_N + \vec{F}_g \\
F_{\text{net}_v} &= F_N + F_g \\
0 &= F_N + (-m_C g) \\
&= F_N - m_C g \\
F_N &= m_C g
\end{aligned}$$

Substitute $F_N = m_C g$ into the last equation for the horizontal direction.

$$\begin{aligned}
F_{\text{B on C}} &= m_C a + \mu_s m_C g \\
&= m_C(a + \mu_s g) \\
&= (3.0 \text{ kg})\{1.4 \text{ m/s}^2 + (0.5)(9.81 \text{ m/s}^2)\} \\
&= 2 \times 10^1 \text{ N} \\
\vec{F}_{\text{B on C}} &= 2 \times 10^1 \text{ N [forward]}
\end{aligned}$$

Paraphrase
Block B exerts a force of 2×10^1 N [forward] on block C.

(c) ***Given***

$m_A = 4.0$ kg $\quad m_B = 6.0$ kg $\quad m_C = 3.0$ kg

$g = 9.81 \text{ m/s}^2$

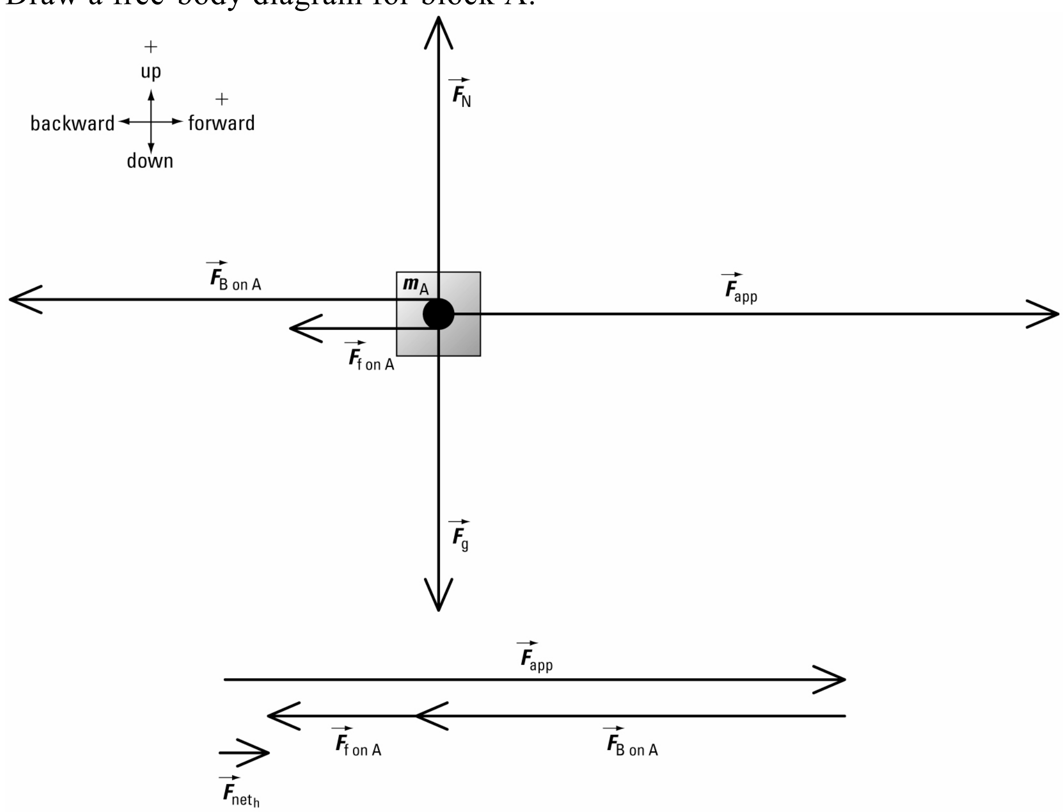
$\vec{a} = 1.4 \text{ m/s}^2$ [forward]

$\mu_s = 0.5$ from Table 3.4 (dry oak on dry oak)

$\vec{F}_{app} = 8.2 \times 10^1$ N [forward] from part (a)

Required
force exerted by block B on block A ($\vec{F}_{\text{B on A}}$)

Analysis and Solution
Draw a free-body diagram for block A.



Block A is not accelerating up or down.
So in the vertical direction, $F_{net_v} = 0$ N.

Write equations to find the net force on block A in both the horizontal and vertical directions.

horizontal direction

$$\begin{aligned}
\vec{F}_{net_h} &= \vec{F}_{app} + \vec{F}_{\text{B on A}} + \vec{F}_{\text{f on A}} \\
F_{net_h} &= F_{app} + F_{\text{B on A}} + F_{\text{f on A}} \\
m_A a &= F_{app} + F_{\text{B on A}} + (-\mu_s F_N) \\
&= F_{app} + F_{\text{B on A}} - \mu_s F_N
\end{aligned}$$

vertical direction

$$\begin{aligned}
\vec{F}_{net_v} &= \vec{F}_N + \vec{F}_g \\
F_{net_v} &= F_N + F_g \\
0 &= F_N + (-m_A g) \\
&= F_N - m_A g
\end{aligned}$$

$F_{\text{B on A}} = m_A a + \mu_s F_N - F_{\text{app}}$ $\qquad F_N = m_A g$

Substitute $F_N = m_A g$ into the last equation for the horizontal direction.

$$\begin{aligned} F_{\text{B on A}} &= m_A a + \mu_s m_A g - F_{\text{app}} \\ &= m_A(a + \mu_s g) - F_{\text{app}} \\ &= (4.0 \text{ kg})\{1.4 \text{ m/s}^2 + (0.5)(9.81 \text{ m/s}^2)\} - 8.2 \times 10^1 \text{ N} \\ &= -6 \times 10^1 \text{ N} \\ \vec{F}_{\text{B on A}} &= 6 \times 10^1 \text{ N [backward]} \end{aligned}$$

Paraphrase

Block B exerts a force of 6×10^1 N [backward] on block A.

36. ***Given***

$m = 10.0$ kg $\qquad \theta = 30.0°$

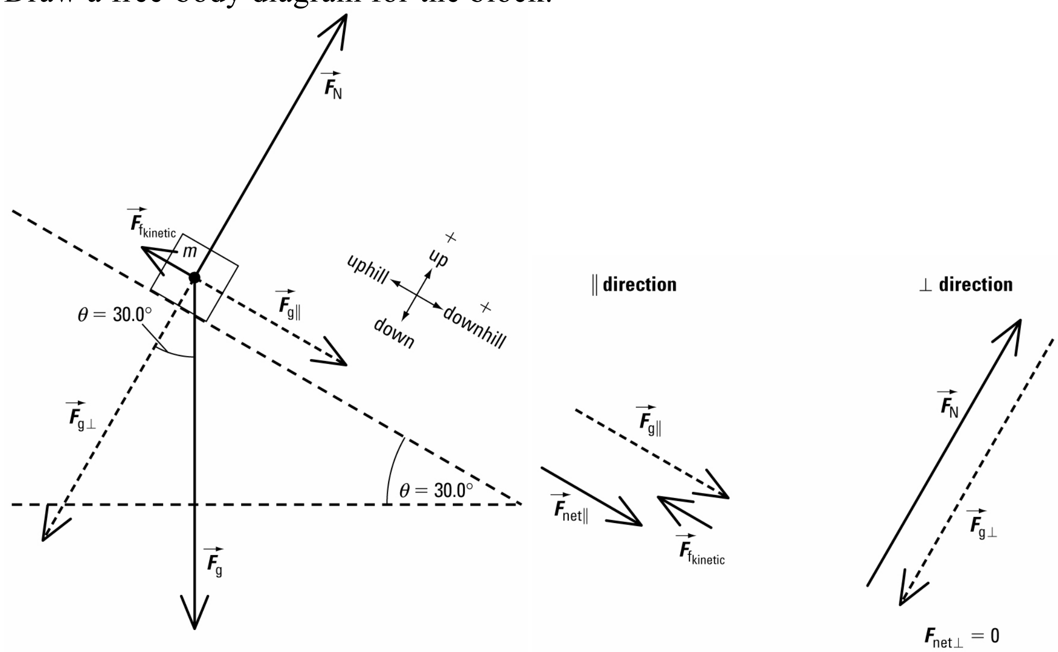
$\mu_k = 0.20$ $\qquad g = 9.81 \text{ m/s}^2$

Required

acceleration of block ($\vec{a}$)

Analysis and Solution

Draw a free-body diagram for the block.



Since the block is accelerating downhill, $\vec{F}_{\text{net}} \neq 0$ N parallel to the incline, but $\vec{F}_{\text{net}} = 0$ N perpendicular to the incline.

Write equations to find the net force on the block in both directions.

$\perp$ direction	$\parallel$ direction
$\vec{F}_{\text{net}\perp} = \vec{F}_N + \vec{F}_{g\perp}$	$\vec{F}_{\text{net}\parallel} = \vec{F}_{g\parallel} + \vec{F}_{f_{\text{kinetic}}}$
$F_{\text{net}\perp} = F_N + F_{g\perp}$	$F_{\text{net}\parallel} = F_{g\parallel} + F_{f_{\text{kinetic}}}$

$$0 = F_N + F_{g\perp} \qquad ma = F_{g\parallel} + F_{f_{kinetic}}$$

$$F_N = -F_{g\perp}$$

Now, $F_{g\perp} = -mg\cos\theta$ $\qquad$ $F_{g\parallel} = mg\sin\theta$ and $F_{f_{kinetic}} = -\mu_k F_N$

So, $F_N = -(-mg\cos\theta)$ $\qquad$ $ma = mg\sin\theta + (-\mu_k F_N)$

$= mg\cos\theta$ $\qquad$ $= mg\sin\theta - \mu_k F_N$

Substitute $F_N = mg\cos\theta$ into the last equation for the || direction.

$$\cancel{m}a = \cancel{m}g\sin\theta - \mu_k \cancel{m}g\cos\theta$$

$$\begin{aligned} a &= g(\sin\theta - \mu_k\cos\theta) \\ &= (9.81\ \text{m/s}^2)\{\sin 30.0° - (0.20)(\cos 30.0°)\} \\ &= 3.2\ \text{m/s}^2 \\ \vec{a} &= 3.2\ \text{m/s}^2\ [\text{downhill}] \end{aligned}$$

Paraphrase

The acceleration of the block is 3.2 m/s^2 [downhill].

37. ***Given***

$m_A = 15$ kg $\qquad$ $m_B = 20$ kg

$\vec{g} = 9.81$ m/s^2 [down]

magnitude of $\vec{F}_{app} = 416$ N $\qquad$ magnitude of $\vec{F}_f = 20$ N

Required

acceleration of each object ($\vec{a}_A$ and $\vec{a}_B$)

Analysis and Solution

Since the person is pulling the rope, objects A and B will accelerate up.

The rope has a negligible mass.

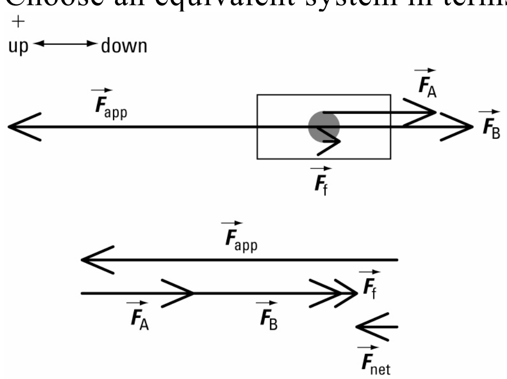
So the tension in the rope is the same on both sides of the pulley.

The magnitude of $\vec{a}_A$ is equal to the magnitude of $\vec{a}_B$.

Find the total mass of both objects.

$$\begin{aligned} m_T &= m_A + m_B \\ &= 15\ \text{kg} + 20\ \text{kg} \\ &= 35\ \text{kg} \end{aligned}$$

Choose an equivalent system in terms of m_T to analyze the motion.



$\vec{F}_A$ is equal to the gravitational force acting on m_A, and $\vec{F}_B$ is equal to the gravitational force acting on m_B.

Apply Newton's second law to find the net force acting on m_T.

$$\vec{F}_{net} = \vec{F}_{app} + \vec{F}_{A} + \vec{F}_{B} + \vec{F}_{f}$$

$$\begin{aligned}
F_{net} &= F_{app} + F_A + F_B + F_f \\
&= 416\text{ N} - m_A g - m_B g - 20\text{ N} \\
&= 416\text{ N} - (m_A + m_B)g - 20\text{ N} \\
&= 416\text{ N} - m_T g - 20\text{ N} \\
&= 416\text{ N} - (35\text{ kg})(9.81\text{ m/s}^2) - 20\text{ N} \\
&= 52.7\ \frac{\text{kg•m}}{\text{s}^2} \\
&= 52.7\text{ N}
\end{aligned}$$

Use the scalar form of Newton's second law to calculate the magnitude of the acceleration.

$$\begin{aligned}
F_{net} &= m_T a \\
a &= \frac{F_{net}}{m_T} \\
&= \frac{52.7\text{ N}}{35\text{ kg}} \\
&= \frac{52.7\ \frac{\cancel{\text{kg}}\text{•m}}{\text{s}^2}}{35\ \cancel{\text{kg}}} \\
&= 1.5\text{ m/s}^2 \\
\vec{a}_A &= \vec{a}_B = 1.5\text{ m/s}^2\text{ [up]}
\end{aligned}$$

Paraphrase

Objects A and B will have an acceleration of 1.5 m/s^2 [up].

38. (a) ***Given***

$m_A = 6.0$ kg $\quad m_B = 2.0$ kg $\quad m_C = 4.0$ kg

$\mu_k = 0.200$

$g = 9.81$ m/s^2

Required

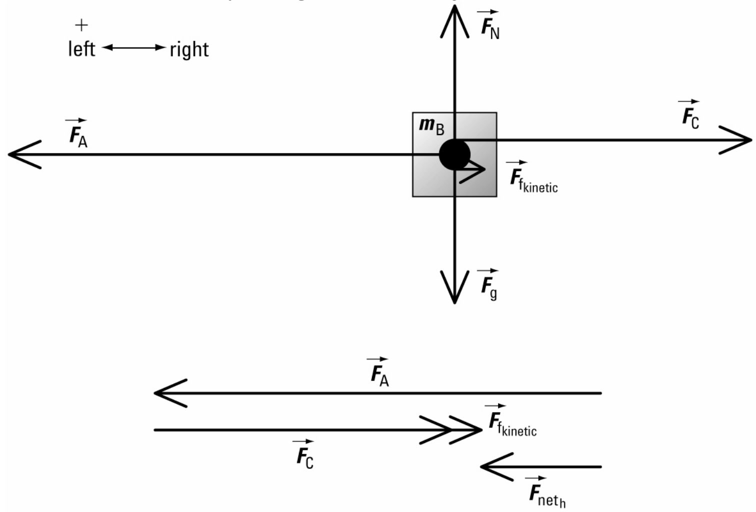
acceleration of object B ($\vec{a}_B$)

Analysis and Solution

Since $m_A > m_C$, you would expect m_A to accelerate down while m_C accelerates up. Since object B will accelerate left, choose left to be positive.
The strings have negligible mass and do not stretch.
So the magnitude of $\vec{a}_A$ is equal to the magnitude of $\vec{a}_B$, which is also equal to the magnitude of $\vec{a}_C$.
Find the total mass of the system.

$$\begin{aligned}
m_T &= m_A + m_B + m_C \\
&= 6.0\text{ kg} + 2.0\text{ kg} + 4.0\text{ kg} \\
&= 12.0\text{ kg}
\end{aligned}$$

Draw a free-body diagram for object B.



$\vec{F}_A$ is equal to the gravitational force acting on m_A, and $\vec{F}_C$ is equal to the gravitational force acting on m_C. Apply Newton's second law to find the acceleration of m_B.

horizontal direction

$$\vec{F}_{net_h} = \vec{F}_A + \vec{F}_C + \vec{F}_{f_{kinetic}}$$
$$F_{net_h} = F_A + F_C + F_{f_{kinetic}}$$
$$\begin{aligned} m_T a_B &= F_A + F_C + F_{f_{kinetic}} \\ &= m_A g + (-m_C g) + (-\mu_k F_N) \\ &= m_A g - m_C g - \mu_k F_N \\ &= g(m_A - m_C) - \mu_k F_N \end{aligned}$$

vertical direction

$$\vec{F}_{net_v} = \vec{F}_N + \vec{F}_g$$
$$F_{net_v} = F_N + F_g$$
$$\begin{aligned} 0 &= F_N + (-m_B g) \\ &= F_N - m_B g \\ F_N &= m_B g \end{aligned}$$

Substitute $F_N = m_B g$ into the last equation for the horizontal direction.

$$\begin{aligned} m_T a_B &= g(m_A - m_C) - \mu_k m_B g \\ a_B &= \left(\frac{m_A - m_C}{m_T}\right) g - \left(\frac{m_B}{m_T}\right) \mu_k g \\ &= \left(\frac{6.0\text{ kg} - 4.0\text{ kg}}{12.0\text{ kg}}\right)(9.81\text{ m/s}^2) - \left(\frac{2.0\ \cancel{\text{kg}}}{12.0\ \cancel{\text{kg}}}\right)(0.200)(9.81\text{ m/s}^2) \\ &= \left(\frac{2.0\ \cancel{\text{kg}}}{12.0\ \cancel{\text{kg}}}\right)(9.81\text{ m/s}^2) - \left(\frac{2.0}{12.0}\right)(0.200)(9.81\text{ m/s}^2) \\ &= 1.3\text{ m/s}^2 \\ \vec{a}_B &= 1.3\text{ m/s}^2\ [\text{left}] \end{aligned}$$

Paraphrase

Object B will have an acceleration of 1.3 m/s^2 [toward object A].

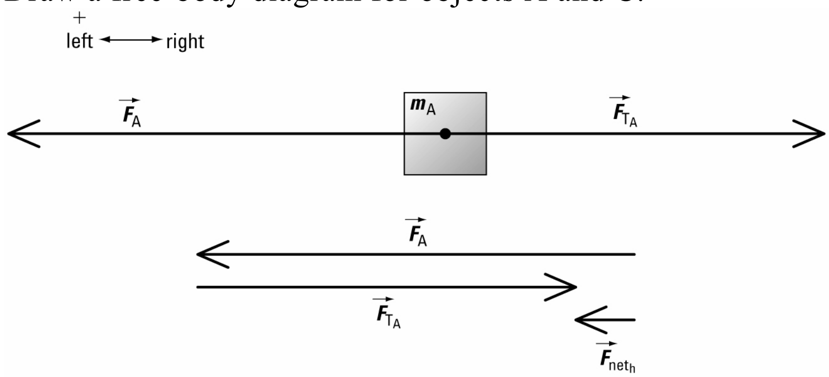
(b) ***Given***

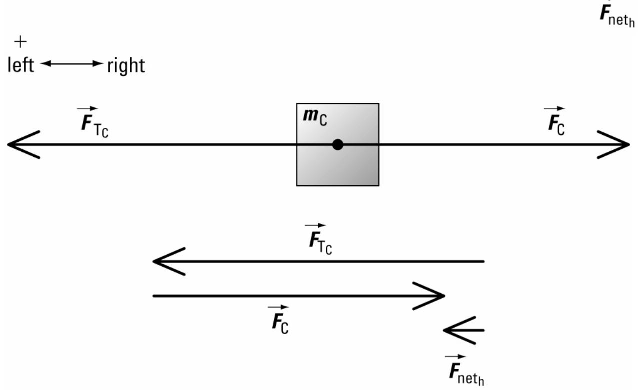
$m_A = 6.0$ kg $\quad m_B = 2.0$ kg $\quad m_C = 4.0$ kg

$\mu_k = 0.200 \quad g = 9.81$ m/s^2

$\vec{a}_B = 1.31$ m/s^2 [left] from part (a)

Required
tension in each string
Analysis and Solution
Draw a free-body diagram for objects A and C.





Apply Newton's second law to find the tension in the string between objects A and B.

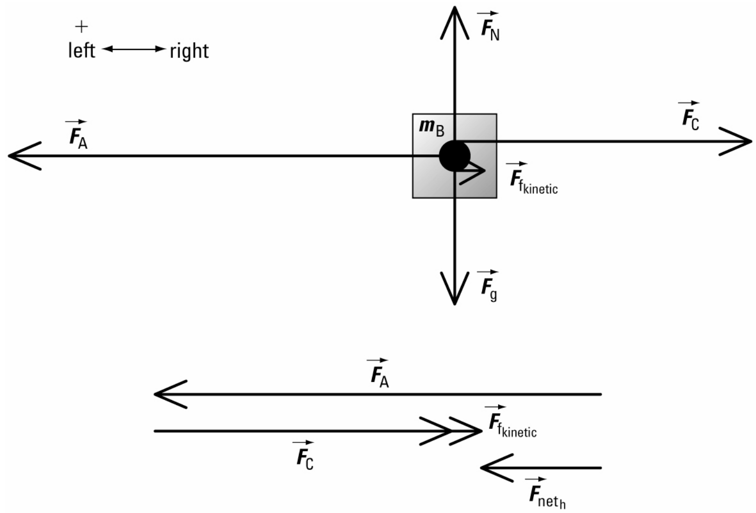
$$\begin{aligned}
\vec{F}_{net} &= \vec{F}_A + \vec{F}_{T_A} \\
F_{net} &= F_A + F_{T_A} \\
m_A a_A &= m_A g + F_{T_A} \\
F_{T_A} &= m_A a_A - m_A g \\
&= m_A(a_A - g) \\
&= (6.0\text{ kg})(1.31\text{ m/s}^2 - 9.81\text{ m/s}^2) \\
&= -51\text{ N}
\end{aligned}$$

Apply Newton's second law to find the tension in the string between objects B and C.

$$\begin{aligned}
\vec{F}_{net} &= \vec{F}_C + \vec{F}_{T_C} \\
F_{net} &= F_C + F_{T_C} \\
m_C a_C &= -m_C g + F_{T_C} \\
F_{T_C} &= m_C a_C + m_C g \\
&= m_C(a_C + g) \\
&= (4.0\text{ kg})(1.31\text{ m/s}^2 + 9.81\text{ m/s}^2) \\
&= 44\text{ N}
\end{aligned}$$

Paraphrase and Verify
The tension in the string between objects A and B is 51 N, and the tension in the string between objects B and C is 44 N. Both tensions are different because objects A and C have different masses. Also in the case of object A, the tension force opposes the gravitational force on object A, but in the case of object C, the tension force must overcome the gravitational force on object C and also accelerate it.

(c)



(d) Four action-reaction pairs associated with object B are

- normal force exerted by the table on object B directed up (action)
- force exerted by object B on the table directed down (reaction)

- force exerted by string attached to object A on object B directed left (action)
- force exerted by object B on string attached to object A directed right (reaction)

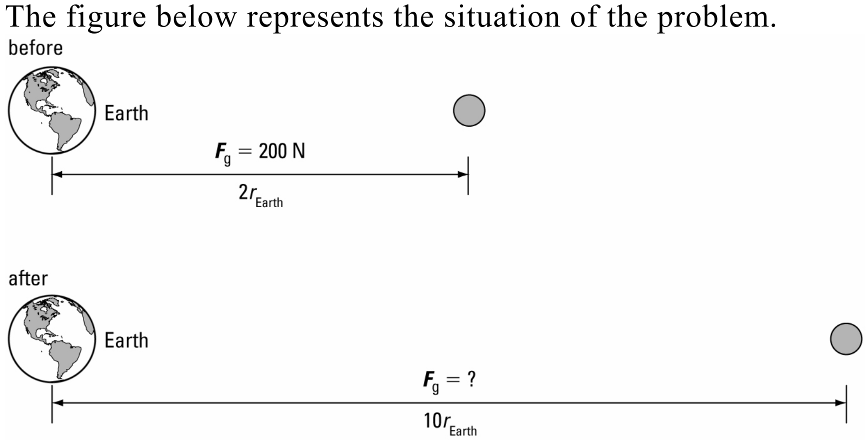
- force exerted by string attached to object C on object B directed right (action)
- force exerted by object B on string attached to object C directed left (reaction)

- gravitational force exerted by Earth on object B directed down (action)
- force exerted by object B on Earth directed up (reaction)

39. ***Analysis and Solution***

From Newton's law of gravitation, $F_g \propto \frac{1}{r^2}$.

The figure below represents the situation of the problem.



before

$$F_g \propto \frac{1}{(2r)^2}$$
$$\propto \left(\frac{1}{2^2}\right)\left(\frac{1}{r^2}\right)$$
$$\propto \left(\frac{1}{4}\right)\left(\frac{1}{r^2}\right)$$

after

$$F_g \propto \frac{1}{(10r)^2}$$
$$\propto \left(\frac{1}{10^2}\right)\left(\frac{1}{r^2}\right)$$
$$\propto \left(\frac{1}{100}\right)\left(\frac{1}{r^2}\right)$$

Calculate the factor change of F_g.

$$\frac{\left(\frac{1}{100}\right)}{\left(\frac{1}{4}\right)} = \frac{4}{100} = \frac{1}{25}$$

Calculate F_g.

$$\frac{1}{25}F_g = \frac{1}{25} \times (200\text{ N}) = 8.00\text{ N}$$

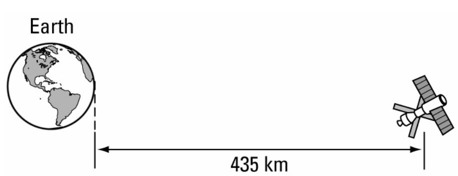
The new gravitational force will be 8.00 N [toward Earth's centre].

40. When each diver steps off the diving tower, they will be in free fall and the only force acting on the divers will be the gravitational force. Since the problem assumes negligible air resistance, both divers will experience the same gravitational acceleration. So the time it takes to reach the water will be the same for both divers.

41. ***Given***

m_s = 68 t or 6.8×10^4 kg r_s = 435 km or 4.35×10^5 m

$m_{Earth} = 5.97 \times 10^{24}$ kg $r_{Earth} = 6.38 \times 10^6$ m



Required

gravitational field strength at the location of Skylab 1 ($\vec{g}$)

Analysis and Solution

Find the separation distance between Skylab 1 and Earth.

$$\begin{aligned} r &= r_s + r_{Earth} \\ &= 4.35 \times 10^5\text{ m} + 6.38 \times 10^6\text{ m} \\ &= 6.82 \times 10^6\text{ m} \end{aligned}$$

Use the equation $g = \frac{GM_{source}}{r^2}$ to calculate the magnitude of the gravitational field strength.

$$g = \frac{Gm_{\text{Earth}}}{r^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^{\cancel{2}}}\right)(5.97\times10^{24}\ \cancel{\text{kg}})}{\left(6.82\times10^{6}\ \text{m}\right)^2}$$

$$= 8.6\ \text{N/kg}$$

$$\vec{g} = 8.6\ \text{N/kg [toward Earth's centre]}$$

Paraphrase

The gravitational field strength at the location of Skylab 1 is 8.6 N/kg [toward Earth's centre].

42. ***Given***

$m_b = 4.00$ kg

$m_{\text{Earth}} = 5.97 \times 10^{24}$ kg $r_{\text{Earth}} = 6.38 \times 10^6$ m

$m_{\text{Mars}} = 6.42 \times 10^{23}$ kg $r_{\text{Mars}} = 3.40 \times 10^6$ m

Required

difference in reading on spring scale (ΔF_g)

Analysis and Solution

Use the equation $g = \frac{GM_{\text{source}}}{r^2}$ to calculate the magnitude of the gravitational field strength on Earth and on Mars.

Earth

$$g_{\text{Earth}} = \frac{Gm_{\text{Earth}}}{(r_{\text{Earth}})^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^{\cancel{2}}}\right)(5.97\times10^{24}\ \cancel{\text{kg}})}{\left(6.38\times10^{6}\ \text{m}\right)^2}$$

$$= 9.783\ \text{N/kg}$$

Mars

$$g_{\text{Mars}} = \frac{Gm_{\text{Mars}}}{(r_{\text{Mars}})^2}$$

$$= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\cdot\text{m}^2}{\text{kg}^{\cancel{2}}}\right)(6.42\times10^{23}\ \cancel{\text{kg}})}{\left(3.40\times10^{6}\ \text{m}\right)^2}$$

$$= 3.704\ \text{N/kg}$$

$$\begin{aligned}\Delta F_g &= F_{g_{Earth}} - F_{g_{Mars}} \\ &= m_b g_{Earth} - m_b g_{Mars} \\ &= m_b(g_{Earth} - g_{Mars}) \\ &= (4.00 \text{ kg})(9.783 \text{ N/kg} - 3.704 \text{ N/kg}) \\ &= 24.3 \text{ N}\end{aligned}$$

Paraphrase

The reading on the spring scale will be 24.3 N less on Mars than on Earth.

43. (a) and (b) ***Given***

	$m = 60$ kg	$\vec{g} = 9.81$ m/s^2 [down]
(i)	$\vec{a} = 0$ m/s^2	$\vec{v}$ = constant
(ii)	$\vec{a} = 0$ m/s^2	$\vec{v} = 0$ m/s
(iii)	$\vec{a} = 4.9$ m/s^2 [up]	
(iv)	$\vec{a} = 3.3$ m/s^2 [down]	

Required

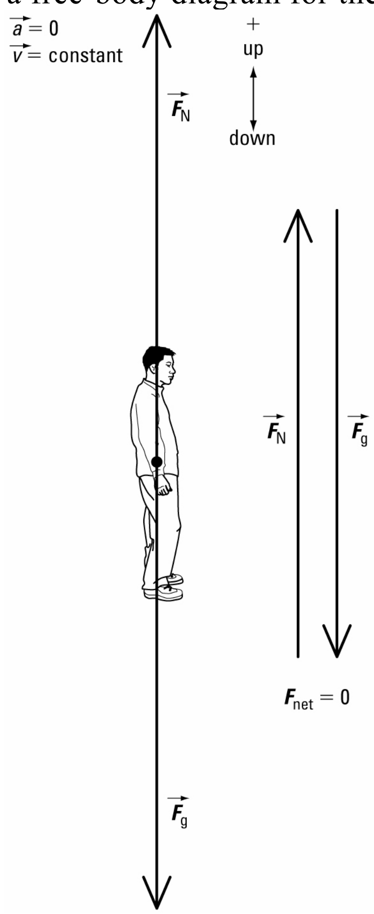
(a) reading on the scale (F_N)

(b) true weight and apparent weight ($\vec{F}_g$ and $\vec{w}$)

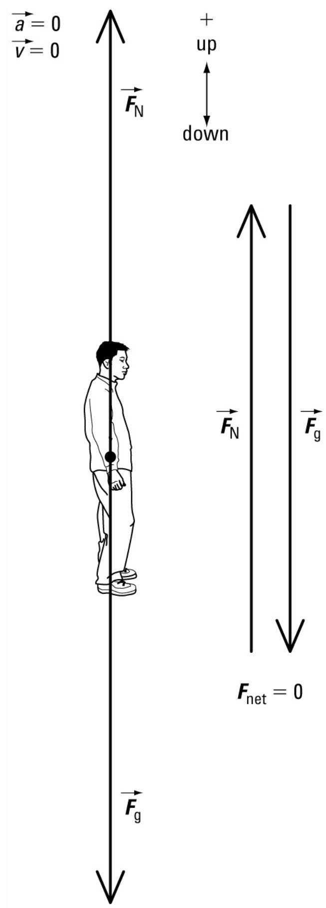
Analysis and Solution

Draw a free-body diagram for the student in each situation.

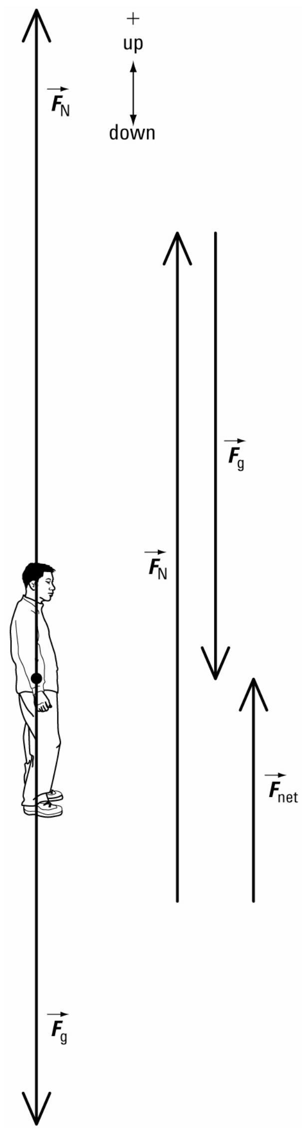
(i)



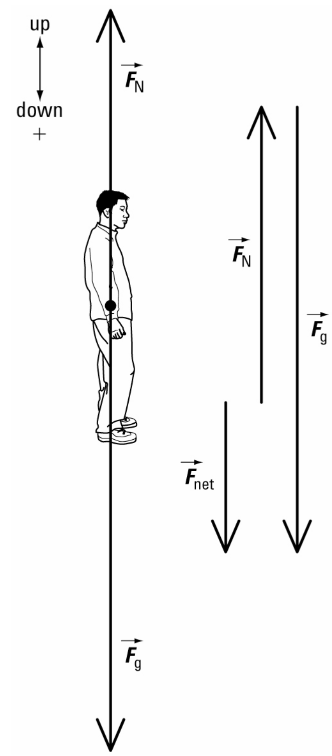
(ii)



(iii)



(iv)



Use the equation $\vec{F}_g = m\vec{g}$ to find the student's true weight.

$$\begin{aligned}
\vec{F}_g &= m\vec{g} \\
F_g &= (60 \text{ kg})(-9.81 \text{ m/s}^2) \\
&= -5.9 \times 10^2 \text{ N} \\
\vec{F}_g &= 5.9 \times 10^2 \text{ N [down]}
\end{aligned}$$

The student is not accelerating left or right.
So in the horizontal direction, $\vec{F}_{net} = 0$ N.
For the vertical direction, write an equation to find the net force on the student.

(i) and (ii) $\vec{F}_{net} = \vec{F}_g + \vec{F}_N$

$$0 = F_g + F_N$$

$$F_N = -F_g$$
$$= -(-5.9 \times 10^2 \text{ N})$$
$$= 5.9 \times 10^2 \text{ N}$$
$$\vec{F}_N = 5.9 \times 10^2 \text{ N [up]}$$

Use the equation $\vec{w} = -\vec{F}_N$ to find the student's apparent weight.

$$\vec{w} = -\vec{F}_N$$
$$= 5.9 \times 10^2 \text{ N [down]}$$

(iii) $\vec{F}_{net} = \vec{F}_g + \vec{F}_N$

$$F_{net} = F_g + F_N$$

Apply Newton's second law.

$$ma = F_g + F_N$$
$$F_N = ma - F_g$$
$$= (60 \text{ kg})(4.9 \text{ m/s}^2) - (-5.89 \times 10^2 \text{ N})$$
$$= (60 \text{ kg})(4.9 \text{ m/s}^2) + 5.89 \times 10^2 \text{ N}$$
$$= 8.8 \times 10^2 \text{ N}$$
$$\vec{F}_N = 8.8 \times 10^2 \text{ N [up]}$$

Use the equation $\vec{w} = -\vec{F}_N$ to find the student's apparent weight.

$$\vec{w} = -\vec{F}_N$$
$$= 8.8 \times 10^2 \text{ N [down]}$$

(iv) $\vec{F}_{net} = \vec{F}_g + \vec{F}_N$

$$F_{net} = F_g + F_N$$

Apply Newton's second law.

$$ma = F_g + F_N$$
$$F_N = ma - F_g$$
$$= (60 \text{ kg})(3.3 \text{ m/s}^2) - 5.89 \times 10^2 \text{ N}$$
$$= -3.9 \times 10^2 \text{ N}$$
$$\vec{F}_N = 3.9 \times 10^2 \text{ N [up]}$$

Use the equation $\vec{w} = -\vec{F}_N$ to find the student's apparent weight.

$$\vec{w} = -\vec{F}_N$$
$$= 3.9 \times 10^2 \text{ N [down]}$$

Paraphrase

(a) The reading on the scale will be 5.9×10^2 N for situations (i) and (ii), 8.8×10^2 N for situation (iii), and 3.9×10^2 N for situation (iv).

(b) The true weight of the student in all situations is 5.9×10^2 N [down]. The apparent weight is 5.9×10^2 N [down] for situations (i) and (ii),

8.8×10^2 N [down] for situation (iii), and 3.9×10^2 N [down] for situation (iv).

44. ***Given***

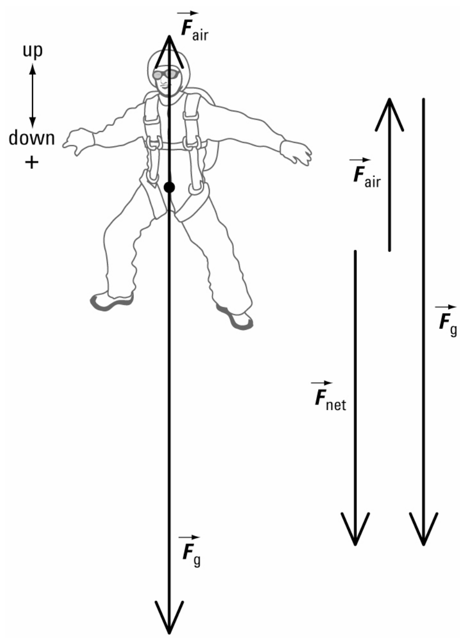
m = 60 kg $\vec{F}_{\text{air}}$ = 200 N [up] $\vec{g}$ = 9.81 m/s^2 [down]

Required

true weight and acceleration of skydiver ($\vec{F}_{\text{g}}$ and $\vec{a}$)

Analysis and Solution

Draw a free-body diagram for the skydiver.



Use the equation $\vec{F}_{\text{g}} = m\vec{g}$ to find the skydiver's true weight.

$$\begin{aligned}\vec{F}_{\text{g}} &= m\vec{g} \\ F_{\text{g}} &= (60\text{ kg})(9.81\text{ m/s}^2) \\ &= 5.9 \times 10^2\text{ N} \\ \vec{F}_{\text{g}} &= 5.9 \times 10^2\text{ N [down]}\end{aligned}$$

The skydiver is not accelerating left or right.
So in the horizontal direction, $\vec{F}_{\text{net}}$ = 0 N.
For the vertical direction, write an equation to find the net force on the skydiver.

$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_{\text{g}} + \vec{F}_{\text{air}} \\ F_{\text{net}} &= F_{\text{g}} + F_{\text{air}}\end{aligned}$$

Apply Newton's second law.

$$\begin{aligned}ma &= F_{\text{g}} + F_{\text{air}} \\ &= mg + F_{\text{air}}\end{aligned}$$

$$a = g + \left(\frac{-200\text{ N}}{m}\right)$$

$$= 9.81\text{ m/s}^2 - \frac{200\ \cancel{\text{kg}} \bullet \frac{\text{m}}{\text{s}^2}}{60\ \cancel{\text{kg}}}$$

$$= 6.5\text{ m/s}^2$$

$$\vec{a} = 6.5\text{ m/s}^2\text{ [down]}$$

Paraphrase
The skydiver has a true weight of 5.9×10^2 N [down] and an acceleration of 6.5 m/s^2 [down].

45. (a) ***Given***

$m = 25$ kg $\Delta t = 8.0$ s $d = 300$ m $\vec{g} = 9.81$ m/s^2 [down]

Required
acceleration of boulder ($\vec{a}$)

Analysis and Solution
Calculate the magnitude of the acceleration of the boulder.

$$d = \left(\frac{1}{2}\right)a(\Delta t)^2$$

$$a = \frac{2d}{(\Delta t)^2}$$

$$= \frac{2(300\text{ m})}{(8.0\text{ s})^2}$$

$$= 9.38\text{ m/s}^2$$

$$\vec{a} = 9.4\text{ m/s}^2\text{ [down]}$$

Paraphrase
While falling, the boulder has an acceleration of 9.4 m/s^2 [down].

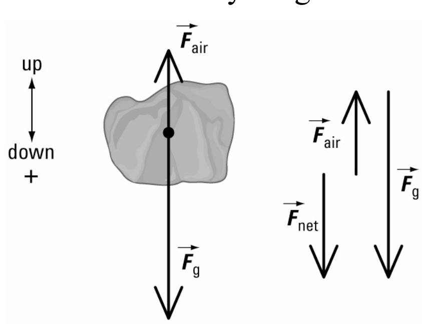
(b) ***Given***

$m = 25$ kg $\Delta t = 8.0$ s $d = 300$ m $\vec{g} = 9.81$ m/s^2 [down]

$\vec{a} = 9.38$ m/s^2 [down] from part (a)

Required
air resistance on boulder ($\vec{F}_{\text{air}}$)

Analysis and Solution
Draw a free-body diagram for the boulder.



The boulder is not accelerating left or right.
So in the horizontal direction, $\vec{F}_{\text{net}} = 0$ N.
For the vertical direction, write an equation to find the net force on the boulder.

$$\vec{F}_{\text{net}} = \vec{F}_{\text{g}} + \vec{F}_{\text{air}}$$
$$F_{\text{net}} = F_{\text{g}} + F_{\text{air}}$$

Apply Newton's second law.

$$\begin{aligned} ma &= mg + F_{\text{air}} \\ F_{\text{air}} &= ma - mg \\ &= m(a - g) \\ &= (25\text{ kg})(9.38\text{ m/s}^2 - 9.81\text{ m/s}^2) \\ &= 11\text{ N} \\ \vec{F}_{\text{air}} &= 11\text{ N [up]} \end{aligned}$$

Paraphrase
The air resistance on the boulder is 11 N [up].

(c) ***Given***
$m = 25$ kg $\Delta t = 8.0$ s $d = 300$ m $\vec{g} = 9.81\text{ m/s}^2$ [down]
$\vec{a} = 9.38\text{ m/s}^2$ [down] from part (a)
$\vec{F}_{\text{air}} = 10.9$ N [up] from part (b)

Required
apparent weight of boulder ($\vec{w}$)

Analysis and Solution
The air resistance on the boulder is equivalent to the normal force.

$$\vec{F}_{\text{N}} = 10.9\text{ N [up]}$$

Use the equation $\vec{w} = -\vec{F}_{\text{N}}$ to find the apparent weight of the boulder.

$$\begin{aligned} \vec{w} &= -\vec{F}_{\text{N}} \\ &= 11\text{ N [down]} \end{aligned}$$

Paraphrase
The boulder has an apparent weight of 11 N [down].

Extensions

46. ***Given***
$l = 36$ cm or 0.36 m
$m_{\text{Earth}} = 5.97 \times 10^{24}$ kg $r_{\text{Earth}} = 6.38 \times 10^{6}$ m
$m_{\text{Moon}} = 7.35 \times 10^{22}$ kg $r_{\text{Moon}} = 1.74 \times 10^{6}$ m

Required
period of pendulum on Earth and the Moon (T_{Earth} and T_{Moon})

Analysis and Solution

Use the equation $g = \frac{GM_{\text{source}}}{r^2}$ to calculate the magnitude of the gravitational acceleration on Earth and on the Moon.

Earth

$$
\begin{aligned}
g_{\text{Earth}} &= \frac{Gm_{\text{Earth}}}{(r_{\text{Earth}})^2} \\
&= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\text{kg}^{\cancel{2}}}\right)(5.97\times10^{24}\ \cancel{\text{kg}})}{\left(6.38\times10^{6}\ \text{m}\right)^2} \\
&= 9.783\ \text{m/s}^2
\end{aligned}
$$

$$
\begin{aligned}
T_{\text{Earth}} &= 2\pi\sqrt{\frac{l}{g_{\text{Earth}}}} \\
&= 2\pi\sqrt{\frac{0.36\ \cancel{\text{m}}}{9.783\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\
&= 1.2\ \text{s}
\end{aligned}
$$

Moon

$$
\begin{aligned}
g_{\text{Moon}} &= \frac{Gm_{\text{Moon}}}{(r_{\text{Moon}})^2} \\
&= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\text{kg}^{\cancel{2}}}\right)(7.35\times10^{22}\ \cancel{\text{kg}})}{\left(1.74\times10^{6}\ \text{m}\right)^2} \\
&= 1.619\ \text{m/s}^2
\end{aligned}
$$

$$
\begin{aligned}
T_{\text{Moon}} &= 2\pi\sqrt{\frac{l}{g_{\text{Moon}}}} \\
&= 2\pi\sqrt{\frac{0.36\ \cancel{\text{m}}}{1.619\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\
&= 3.0\ \text{s}
\end{aligned}
$$

Paraphrase

The pendulum will have a period of 1.2 s on Earth and 3.0 s on the Moon.

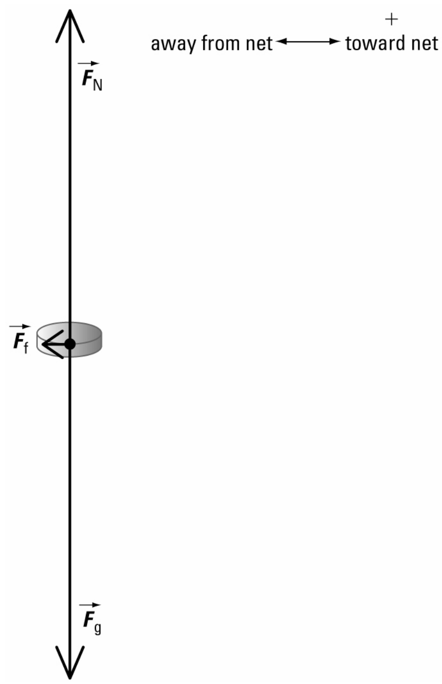
47. (a) ***Given***

m = 150 g or 0.150 kg $\qquad$ $\vec{v}_{\text{i}}$ = 7.0 m/s [toward net]

d = 32 m $\qquad$ μ_{k} = 0.08 $\qquad$ g = 9.81 m/s^2

Required
force of kinetic friction on puck ($\vec{F}_{\text{f kinetic}}$)

Analysis and Solution
Draw a free-body diagram for the puck.



Since the puck is accelerating, $\vec{F}_{\text{net}} \neq 0$ N in the horizontal direction, but $\vec{F}_{\text{net}} = 0$ N in the vertical direction.

Calculate $F_{\text{f}_{\text{kinetic}}}$.

$$\begin{aligned} F_{\text{f}_{\text{kinetic}}} &= \mu_k F_N \\ &= \mu_k mg \\ &= (0.08)(0.150 \text{ kg})(9.81 \text{ m/s}^2) \\ &= 0.12 \text{ N} \end{aligned}$$

$$\vec{F}_{\text{f}_{\text{kinetic}}} = 0.12 \text{ N [away from net]}$$

Paraphrase
The force of kinetic friction on the hockey puck is 0.12 N [away from net].

(b) ***Given***

$m = 150$ g or 0.150 kg $\qquad \vec{v}_i = 7.0$ m/s [toward net]

$d = 32$ m $\qquad \mu_k = 0.08 \qquad g = 9.81$ m/s^2

$\vec{F}_{\text{f}_{\text{kinetic}}} = 0.118$ N [away from net] from part (a)

Required
acceleration of puck ($\vec{a}$)

Analysis and Solution

Write equations to find the net force on the puck in both the horizontal and vertical directions.

horizontal direction

$$\vec{F}_{\text{net}_\text{h}} = \vec{F}_{\text{f}_\text{kinetic}}$$

$$F_{\text{net}_\text{h}} = F_{\text{f}_\text{kinetic}}$$

$$ma = F_{\text{f}_\text{kinetic}}$$

$$\begin{aligned} a &= \frac{F_{\text{f}_\text{kinetic}}}{m} \\ &= \frac{-0.118\text{ N}}{0.150\text{ kg}} \\ &= \frac{-0.118\ \cancel{\text{kg}}\bullet\frac{\text{m}}{\text{s}^2}}{0.150\ \cancel{\text{kg}}} \\ &= -0.78\text{ m/s}^2 \end{aligned}$$

$$\vec{a} = -0.78\text{ m/s}^2\text{ [toward net]}$$

vertical direction

$$\vec{F}_{\text{net}_\text{v}} = \vec{F}_\text{N} + \vec{F}_\text{g}$$

$$F_{\text{net}_\text{v}} = 0$$

Calculations in the vertical direction are not required in this problem.

Paraphrase

The acceleration of the puck is –0.78 m/s^2 [toward net].

(c) ***Given***

m = 150 g or 0.150 kg

$\vec{v}_\text{i}$ = 7.0 m/s [toward net]

d = 32 m

μ_k = 0.08

g = 9.81 m/s^2

$\vec{F}_{\text{f}_\text{kinetic}}$ = 0.118 N [away from net] from part (a)

$\vec{a}$ = –0.785 m/s^2 [toward net] from part (b)

Required

time for puck to stop (Δt)

Analysis and Solution

Calculate the time for the puck to stop.

$$a = \frac{\Delta v}{\Delta t}$$

$$\begin{aligned} \Delta t &= \frac{\Delta v}{a} \\ &= \frac{v_\text{f} - v_\text{i}}{a} \\ &= \frac{0\text{ m/s} - 7.0\text{ m/s}}{-0.785\text{ m/s}^2} \\ &= 8.9\text{ s} \end{aligned}$$

Paraphrase

It will take 8.9 s for the puck to stop.

(d) ***Given***

m = 150 g or 0.150 kg $\vec{v}_i$ = 7.0 m/s [toward net]

d = 32 m μ_k = 0.08 g = 9.81 m/s^2

$\vec{F}_{f_{kinetic}}$ = 0.118 N [away from net] from part (a)

$\vec{a}$ = –0.785 m/s^2 [toward net] from part (b)

Required

determine if puck will reach the net

Analysis and Solution

Calculate the distance the puck travels before it stops.

$$\begin{aligned}(v_f)^2 &= (v_i)^2 + 2ad \\ 0 &= (v_i)^2 + 2ad \\ d &= \frac{(v_i)^2}{-2a} \\ &= \frac{(7.0\text{ m/s})^2}{-2(-0.785\text{ m/s}^2)} \\ &= 31\text{ m}\end{aligned}$$

Paraphrase

Since the puck will only travel 31 m, it will not reach the net.

48.

Criteria	Newton's 1st Law	Newton's 2nd Law	Newton's 3rd Law
Inertia			
Objects	one object in isolation	one object experiencing an external non-zero net force	two objects interacting with each other
Velocity	zero or constant	changing	zero, constant, or changing
Equation	$\vec{F}_{net} = 0$ when $\Delta\vec{v} = 0$	$\vec{F}_{net} = m\vec{a}$	$\vec{F}_{A\text{ on }B} = -\vec{F}_{B\text{ on }A}$
Example	gliding while skating	accelerating while riding a bicycle	satellite orbiting Earth
Application	seat belts and airbags	parachute	aircraft propeller

49. Although the effectiveness of these swimsuits is still a matter of debate, those in favour of some standardization might argue that less developed countries cannot afford to keep up with innovations in equipment and would be disadvantaged. Even within any particular country, athletes with less financial means might not be able to afford the best equipment, so the best athletes might not get to represent their country. Standardization would also make the comparison of Olympic records more meaningful.

Those opposed to standardization of equipment might suggest that faster times, higher jumps, etc., would not be possible and the Olympics may not be as exciting as they could be. Another argument might be that advances in Olympic equipment might become available for the general population to use in everyday activities.

50. Stakeholders and their perspectives can be identified through class discussion. Have students identify those totally in favour of airbags, those in favour with reservation, and those totally against airbags. Stakeholders include the general public, consumer activist groups, medical practitioners, insurance companies, automobile manufacturers, accident investigators, and others.

51. (a) ***Given***

$m = 3.8 \times 10^6$ kg

$\vec{F}_{\text{thrust}} = 5.0 \times 10^7$ N [forward] $\qquad \vec{g} = 9.81$ m/s^2 [down]

Required

true weight of rocket ($\vec{F}_{\text{g}}$)

Analysis and Solution

Use the equation $\vec{F}_{\text{g}} = m\vec{g}$ to find the true weight of the rocket.

$$\begin{aligned} \vec{F}_{\text{g}} &= m\vec{g} \\ F_{\text{g}} &= (3.8 \times 10^6 \text{ kg})(-9.81 \text{ m/s}^2) \\ &= -3.7 \times 10^7 \text{ N} \\ \vec{F}_{\text{g}} &= 3.7 \times 10^7 \text{ N [down]} \end{aligned}$$

Paraphrase

The rocket has a true weight of 3.7×10^7 N [down].

(b) ***Given***

$m = 3.8 \times 10^6$ kg

$\vec{F}_{\text{thrust}} = 5.0 \times 10^7$ N [forward] $\qquad \vec{g} = 9.81$ m/s^2 [down]

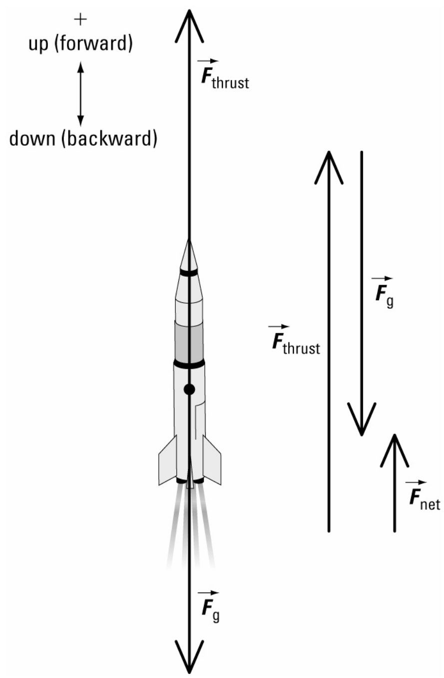
$\vec{F}_{\text{g}} = 3.73 \times 10^7$ N [down] from part (a)

Required

net force on rocket at liftoff ($\vec{F}_{\text{net}}$)

Analysis and Solution

Draw a free-body diagram for the rocket.



The rocket is not accelerating left or right.
So in the horizontal direction, $\vec{F}_{net} = 0$ N.
For the vertical direction, write an equation to find the net force on the rocket.

$$\vec{F}_{net} = \vec{F}_{thrust} + \vec{F}_g$$

$$\begin{aligned}
F_{net} &= F_{thrust} + F_g \\
&= 5.0 \times 10^7 \text{ N} + (-3.73 \times 10^7 \text{ N}) \\
&= 5.0 \times 10^7 \text{ N} - 3.73 \times 10^7 \text{ N} \\
&= 1.3 \times 10^7 \text{ N}
\end{aligned}$$

$$\vec{F}_{net} = 1.3 \times 10^7 \text{ N [forward]}$$

Paraphrase
The net force on the rocket at liftoff is 1.3×10^7 N [forward].

(c) ***Given***
$m = 3.8 \times 10^6$ kg
$\vec{F}_{thrust} = 5.0 \times 10^7$ N [forward] $\qquad \vec{g} = 9.81$ m/s^2 [down]
$\vec{F}_g = 3.73 \times 10^7$ N [down] from part (a)
$\vec{F}_{net} = 1.27 \times 10^7$ N [forward] from part (b)

Required
initial acceleration of rocket ($\vec{a}$)

Analysis and Solution
The acceleration of the rocket is in the direction of the net force. So use the scalar form of Newton's second law.

$$F_{net} = ma$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{1.27 \times 10^7 \text{ N}}{3.8 \times 10^6 \text{ kg}}$$
$$= \frac{1.27 \times 10^7 \ \frac{\cancel{\text{kg}} \bullet \text{m}}{\text{s}^2}}{3.8 \times 10^6 \ \cancel{\text{kg}}}$$
$$= 3.3 \text{ m/s}^2$$
$$\vec{a} = 3.3 \text{ m/s}^2 \text{ [forward]}$$

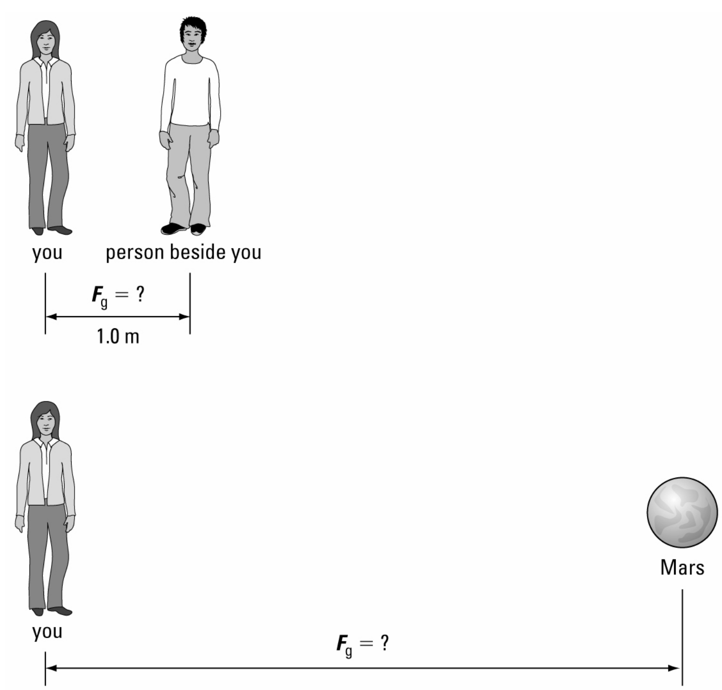
Paraphrase
The rocket has an acceleration of 3.3 m/s^2 [forward] at liftoff.

(d) If the force exerted by the engines remains constant as the fuel burns, the magnitude of the acceleration will increase because the mass of the rocket is decreasing.

(e) The first-stage engines are jettisoned after the fuel is consumed to minimize the mass of the rocket. This results in the maximum possible acceleration.

52. (a) ***Given***

$m_p = 70$ kg
$m_{Mars} = 6.42 \times 10^{23}$ kg
$r_{Earth} = 6.38 \times 10^6$ m
$r_{p\text{ to }y} = 1.0$ m
$r_{M\text{ to }E} = 2.3 \times 10^{11}$ m



Required
ratio of $(F_g)_p$ to $(F_g)_M$

Analysis and Solution

Suppose your mass is 55 kg.

Calculate the separation distance between you and Mars.

$$\begin{aligned} r_{\text{M to y}} &= r_{\text{M to E}} - r_{\text{Earth}} \\ &= 2.3 \times 10^{11}\ \text{m} - 6.38 \times 10^{6}\ \text{m} \\ &= 2.30 \times 10^{11}\ \text{m} \end{aligned}$$

Calculate F_g exerted by Mars on you using Newton's law of gravitation.

$$\begin{aligned} (F_g)_M &= \frac{Gm_{\text{Mars}}m_y}{\left(r_{\text{M to y}}\right)^2} \\ &= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\cancel{\text{kg}^2}}\right)(6.42\times10^{23}\ \cancel{\text{kg}})(55\ \cancel{\text{kg}})}{(2.30\times10^{11}\ \text{m})^2} \\ &= 4.452 \times 10^{-8}\ \text{N} \end{aligned}$$

Calculate F_g exerted by the person next to you using Newton's law of gravitation.

$$\begin{aligned} (F_g)_p &= \frac{Gm_p m_y}{\left(r_{\text{p to y}}\right)^2} \\ &= \frac{\left(6.67\times10^{-11}\ \frac{\text{N}\bullet\text{m}^2}{\cancel{\text{kg}^2}}\right)(70\ \cancel{\text{kg}})(55\ \cancel{\text{kg}})}{(1.0\ \text{m})^2} \\ &= 2.568 \times 10^{-7}\ \text{N} \end{aligned}$$

Calculate the ratio of $(F_g)_p$ to $(F_g)_M$.

$$\begin{aligned} \frac{(F_g)_p}{(F_g)_M} &= \frac{2.568\times10^{-7}\ \cancel{\text{N}}}{4.452\times10^{-8}\ \cancel{\text{N}}} \\ &= 5.8 \end{aligned}$$

Paraphrase

The person next to you exerts a gravitational force that is 5.8 times greater than Mars does on you.

(b) Since the person next to you exerts a much greater gravitational force on you than Mars does on you, the claim made by astrologers is not valid.

53. This research question will be of particular interest to students interested in medicine or engineering. An artificial hip consists of a stem attached to the femur, a ball (or head) fitted onto the stem, and a cup attached to the acetabulum which provides a smooth gliding surface for the ball. Early materials for artificial joints included glass, Pyrex™, ivory, Bakelite™, and other plastics but these were discarded because of breakage, wear, bio-incompatibility among other problems. Currently, stems are typically made of alloys of titanium or cobalt-chromium which are considered to be the stongest. Most biocompatible heads are usually made of ceramic or a cobalt-chromium alloy. Some acetabular cups consist of a metal shell securely attached to a polyethylene liner. Various types of cement are used to anchor the prosthesis components to bone. Cementless versions have a textured surface to allow for bone cell ingrowth. Some cementless acetabular cups are reinforced with screws. The surfaces of all moving parts are very smooth and strong, and the human body constantly lubricates the joint surfaces.

54. This investigation will involve both science and technology. It nurtures many scientific processes including experimental design and the control of variables. It could also serve as an excellent cross-country skiing field-trip to a local park. Some of the variables involved are temperature, type of snow, snow packing, mass of person, mass of skis, normal force, static and kinetic friction, ski length, ski width, ski base design, and ski waxes. Students could also investigate the advertising and communication strategies used to sell waxes for skis.

55. Gait analysis is the study of how humans walk. In order to start walking, a person leans forward to shift the centre of mass forward slightly. The person exerts an action force backward (static friction) on the ground, one foot at a time. According to Newton's third law, the ground then exerts a reaction force forward on each foot. The reaction force causes the person to experience a non-zero net force and the person accelerates forward. From Newton's second law, the magnitude of the net force is directly proportional to the person's mass and the acceleration desired.

In order for a person to stop walking, the process is similar except that the directions are reversed. The person must shift the centre of mass backward slightly. The person exerts an action force forward on the ground, one foot at a time. According to Newton's third law, the ground then exerts a reaction force backward on each foot. The reaction force causes the person to slow down to a stop.

The process is similar when a person changes direction. Walking is even more involved than just involving Newton's laws. The chemical energy stored in food is converted to gravitational potential and kinetic energy as the body moves slightly up and down. Also, the legs change the person's velocity.

For interesting websites on the topic of gait analysis, follow the links at www.pearsoned.ca/school/physicssource.

