Solutions for College Physics 5th Edition by Giambattista

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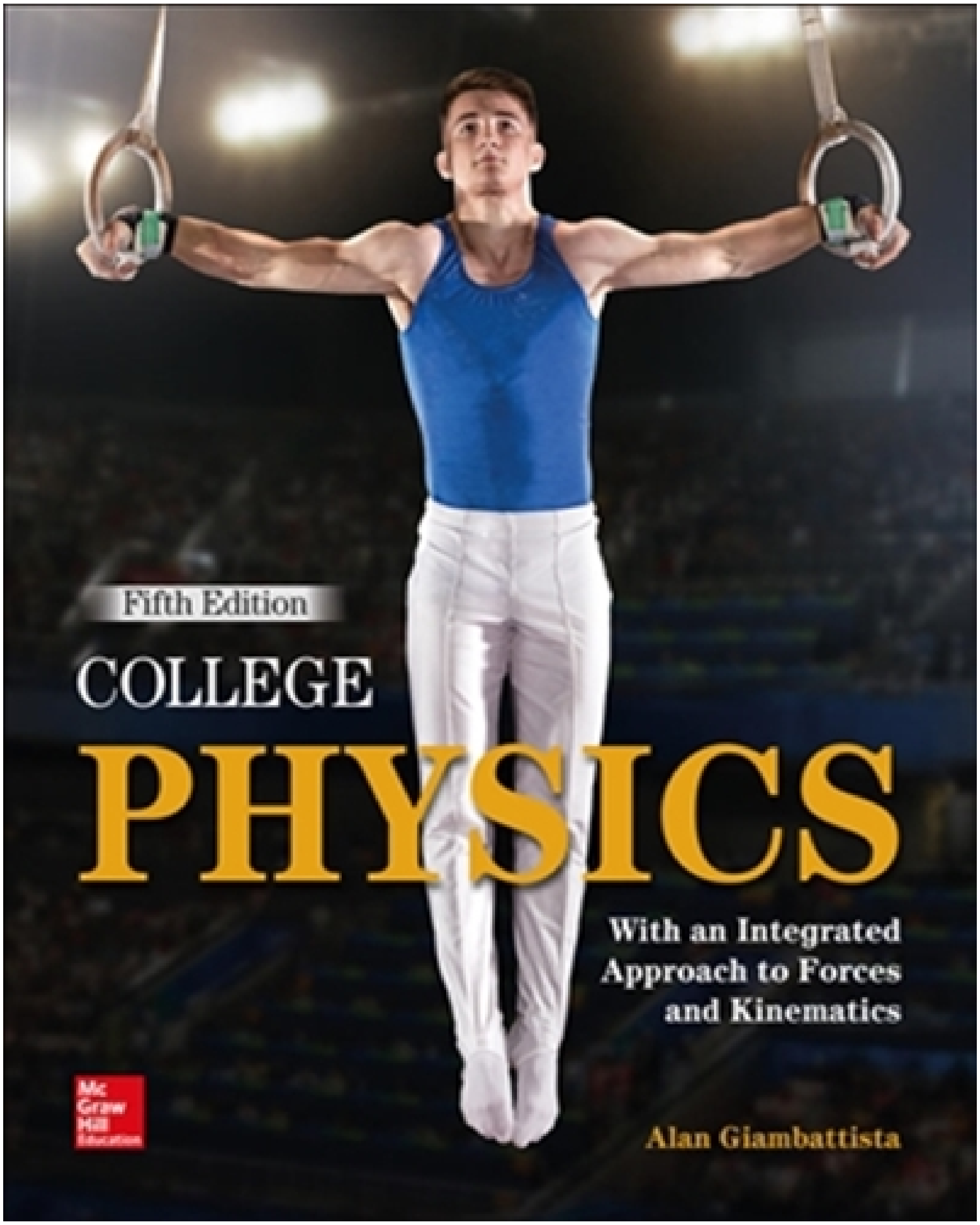


Solutions

Chapter 2
FORCE

Conceptual Questions

1. We are to determine the force(s), if any, *not* acting on the scale. Most of the listed forces do act on the scale: The scale is in contact with the floor, so a contact force due to the floor is exerted on the scale. The scale is in contact with the person's feet, so a contact force due to the person's feet is exerted on the scale. The scale is in the vicinity of a very large mass (Earth), so the weight of the scale is a force exerted on the scale. *The weight of the person* is a force exerted on the person due to the very large mass, so it is not a force exerted on the scale.

2. We are to distinguish between the vector and scalar quantities. Volume, speed, length, and time are directionless. Therefore, they are scalar quantities. *Force* has both direction and magnitude; therefore, it is a vector quantity.

3. We are to distinguish between the vector and scalar quantities. Temperature, test score, stock value, humidity, and mass are directionless quantities; therefore, they are scalar quantities. *Velocity* has both direction and magnitude; therefore, it is a vector quantity, and not a scalar.

4. In an automobile accident the force due to the collision changes the motion of the car, but the driver and passengers continue to move as described by Newton's first law. Seat belts supply the force necessary to change their motion and slow them down. Without seat belts people would collide with the steering wheel or windshield, for example, and stand a greater risk of injury.

5. When the person strikes the rug with the carpet beater, the rug begins to move forward. Some of the dust is not contacted by the beater and is left behind, to fall away from the rug. Once the rug and the dust still stuck to it are moving, the carpet frame supplies a force to overcome the inertia of the rug and bring it back to rest, while the inertia of the dust causes it to continue moving forward. Similarly, when someone throws a baseball the inertia of the ball causes it to continue moving after it has left the person's hand.

6. When the dog shakes, his wet fur changes velocity back and forth. The water will only remain on the fur if it has the same velocity as the fur. For this to happen, there must be a sufficiently large force holding it on as the dog shakes. When the force is not sufficient, drops of water lose contact with the fur and experience no more force from the dog's motion. From the principle of inertia (Newton's first law) these drops resist changes in velocity, so they fly off the dog's body with whatever velocity they had when they lost contact. The drops in the air will then fall to the ground due to the force of gravity. As the dog continues shaking himself, more drops are shaken loose.

7. When the handle hits the board and stops abruptly, Newton's first law says that the steel head will continue to move for a short distance, resisting changes in velocity, until the force of friction between the head and the handle has brought it to rest. It will have then moved down somewhat, to where the handle is a little thicker, resulting in a tightening of the head onto the handle.

8. The road pushes on the tires causing the car to move forward. The engine initiates this process by rotating the wheels so they push backwards on the road. In accordance with Newton's third law the road exerts an equal and opposite external force on the tires.

9. Because of the principle of inertia, the cars continue moving until a sufficient force has caused them to stop. The contact force between the cars at the moment of collision starts to slow them down. Before this force has stopped the cars completely they will have moved several decimeters, crumpling the front ends. The rear end of the car continues to move while the front end is being crumpled, until it too comes to rest.

10. **(a)** Yes, since the direction matters. See Fig. 2.3c.

(b) No. The largest possible magnitude occurs when the two vectors point in the same direction. Then the magnitude of the sum equals the sum of the magnitudes.

11. (a) The reading of the scale is the magnitude of the normal force pushing up on you. This equals your weight as long as the normal force and the force of gravity are the only forces acting on you, and you are at rest or moving with a constant velocity.

(b) If you were standing on the scale in a swimming pool for example, there would be a buoyant force from the water pushing up on you, and the scale would read a smaller apparent weight. Also, the scale would not read your weight if you were accelerating—for example standing on the scale in an elevator as it was moving upward with increasing speed.

12. (a) False. Moving at constant speed, the engine must be pulling with a force equal to the force of friction, which under ordinary conditions is much less than the train's weight.

(b) False. By Newton's third law, the engine's pull on the first car and that car's pull on the engine must always be equal in magnitude and opposite in direction.

(c) False. Its inertia would cause it to keep coasting at a constant speed. The force of friction would cause the train to slow down and eventually stop.

13. The weight of a person is the force of gravitational attraction on that person due to the Earth. This force is inversely proportional to the square of the distance between the person and the center of the Earth.

(a) The rotation of the Earth causes a flattening of the planet such that the radius along the equator is greater than the radius from center to either pole. The man would therefore weigh more at the North Pole where his distance to the center of the Earth is less.

(b) The man would weigh more at the base of the mountain because, once again, this location is closer to the center of the Earth, thus increasing the force of gravitational attraction.

14. A vector is a quantity that has both a magnitude and a direction associated with it. Velocity and displacement are both examples of vector quantities. A scalar is a quantity that is only defined by a magnitude—it has no direction associated with it. Scalar quantities include speed and distance traveled.

15. The key is that the equal and opposite forces of Newton's third law are acting on two different objects—one on the wagon and the other on you. The wagon can therefore experience a non-zero net force, which causes it to accelerate forward. You pull the wagon forward more strongly than anything else pulls the wagon backward.

16. No single component of a vector can ever be greater than the magnitude of the vector. This is equivalent to the statement that each side of a right triangle must be shorter than its hypotenuse—a statement that can be verified using the Pythagorean Theorem.

17. The top string would be the first to break, since the tension it experiences is larger by an amount equal to the weight of the ball it is holding up.

18. The forces are equal in magnitude, in accordance with Newton's third law. The resulting changes in velocity will not be equal though, because the masses are different.

19. Newton's third law tells us that if the person on the raft walks away from the pier, the raft will in turn move toward the pier. Thus, after walking the length of the raft, it should be possible for the person with the hook on the pier to grab the raft and reel it in. Without the person on the pier to hold the raft, this technique would be of no use, as the raft would move back away from the pier on the return walk.

20. No; to be equal they must also have the same direction. If the magnitudes are different, they cannot be equal.

21. The primary benefit of graphical vector addition is its use in providing a visual understanding of the problem—a feature that is often obscured in algebraic vector addition. Despite this benefit, adding vectors graphically is a cumbersome and imprecise process whereas the algebraic method is relatively easy to perform and provides much greater accuracy. These benefits make the algebraic method the favored choice in most situations.

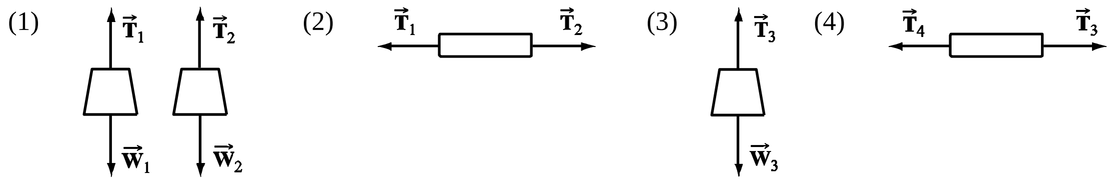
22. A simple pulley allows one to change the direction of an applied force. For example one may lift a heavy box up by attaching it to a rope with a pulley. One then pulls down on the rope to produce an upward force on the box. A more complex system of pulleys can reduce the force that must be applied in order to lift the object or pull on it. An inclined plane can also be used to reduce the force necessary to move an object up. In pushing a heavy box up a low-friction inclined plane, the force required is less than the box's weight.

23. Yes, as long as the *y*-axis is perpendicular to the chosen *x*-axis. This will often simplify a problem.

24. The tension is the same everywhere along the line.

25. No; the concept of contact force is valid only for the macroscopic scale. The idea of contact breaks down at the atomic scale, since there is no way to define contact between atoms. Atoms are mostly empty space, and the electrons never 'touch' one another, but exert electrical forces on one another across empty space.

26. (a) Below are two diagrams for each of the two cases.



Sum the forces in (1):
Left weight: $\sum F_y = T_1 - W_1 = 0,$ so $T_1 = W_1 = 550$ N.
Right weight: $\sum F_y = T_2 - W_2 = 0,$ so $T_2 = W_2 = 550$ N.
Since $W_1 = W_2,$ $T_1 = T_2 = 550$ N; the tensions are the same, and the scale in (2) has forces exerted on it of magnitude 550 N, which are opposite in direction.
Sum the forces in (3):
Single weight: $\sum F_y = T_3 - W_3 = 0,$ so $T_3 = W_3 = 550$ N. The scale in (4) is in equilibrium, so $T_4 = T_3 = 550$ N.
Both scales are in equilibrium and each has two forces which are equal in magnitude and opposite in direction exerted on it. The magnitudes of the forces are equal, so in each case, the two ropes pull on the scale with forces of 550 N in opposite directions, so the scales give the same reading.

(b) The reading on each scale is equal to the tension in the rope, 550 N.

27. The *gravitational force* is the fundamental force that governs the motion of planets in the solar system. Gravity is by far the weakest of the fundamental forces, though it dominates interactions at large scales primarily because planets and larger bodies are extremely massive. The electromagnetic force is ineffective for such bodies because they are electrically neutral. The final two fundamental forces, the weak and strong nuclear forces, dominate interactions at very small distance scales, but have no effect on the large distance scales associated with the motion of large bodies.

28. The range of the strong force is about 10^{-15} m, so it certainly does not have unlimited range. Contact forces are not unlimited, as well, since they are limited to the contact region between objects (and there are no known objects of unlimited size). Both *electromagnetic and gravitational forces* have unlimited ranges.

29. The strong force holds protons and neutrons together in the atomic nucleus, and its range is much smaller than the radius of an atom; thus, it is not the force that binds electrons to nuclei to form atoms. When atoms on the surfaces of two objects come very close together, they interact via the electromagnetic force. These are contact forces. So, contact force is an interaction *between* atoms, not *within* atoms; thus, it is not the force that binds electrons to nuclei. Nuclei and electrons have masses so small that the gravitational forces between them are vanishingly small; so, gravitational force is not the force that binds electrons to nuclei. So, we are left with *electromagnetism* as the force that is the fundamental interaction that binds electrons to nuclei to form atoms.

30. Of all of the fundamental forces, *the weak force* has the shortest range (about 10^{-17} m). In the Sun, the weak interaction enables thermonuclear reactions to occur, without which there would be no sunlight.

31. Of the fundamental forces, *the strong force* is the strongest, hence its name. It is strong, but has a very short range. But the range is just the right size (about 10^{-15} m) to be the fundamental interaction that binds quarks together to form protons, neutrons, and many exotic subatomic particles.

32. We consider only the horizontal forces on the horse and the sleigh. The horse decides to speed up. She pushes backward, say 20% harder, on the ground. The ground exerts a 20% larger forward force on the horse, and the horse's body speeds up in forward motion. Then the horse pulls harder on her harness, say by 13%, so that the sleigh feels a larger forward force and also speeds up. The sleigh does pull backward 13% harder than before on the horse, but the net force on the horse is still forward, in the direction of the large horizontal component of the contact force exerted by the ground. Suppose the sleigh has twice the mass of the horse. Then as the motion of both speeds up, the *net* force on the sleigh is twice as large as the *net* force acting on the horse. This is true even as the force of horse on sleigh is equal in magnitude to the force of sleigh on horse.

Multiple-Choice Questions

1. (b) **2.** (b) **3.** (a) **4.** (b) **5.** (d) **6.** (b) **7.** (c) **8.** (c) **9.** (d) **10.** (b) **11.** (c) **12.** (b) **13.** (a) **14.** We interpret the problem to refer to the total frictional force on the woman, including any air resistance and the average static friction force exerted by the moving conveyor belt. The answer is (a). **15.** (a) **16.** (c) **17.** (b) **18.** (d)

Problems

1. **Strategy** There are 0.2248 pounds per newton.

Solution Find the weight of the sack of flour in pounds.

$$19.8 \text{ N} \times \frac{0.2248 \text{ lb}}{1 \text{ N}} = \boxed{4.45 \text{ lb}}$$

Discussion To state the result more formally, the force that Earth exerts on the sack is gravitational, 4.45 lb down.

2. **Strategy** There are 0.2248 pounds per newton.

Solution Find the weight of the astronaut in newtons.

$$175 \text{ lb} \times \frac{1 \text{ N}}{0.2248 \text{ lb}} = \boxed{778 \text{ N}}$$

3. **Strategy** Look at how long each arrow is.

Solution Disregarding whether they point up or down, left or right, and how far vertically they go in comparison to how far horizontally, looking only at the length in the scale picture, we see that B and C have equal lengths and A is longer. In order of increasing magnitude, we have $\boxed{B = C, A}$. For confirmation we can use the theorem of Pythagoras to find the magnitude of each vector.

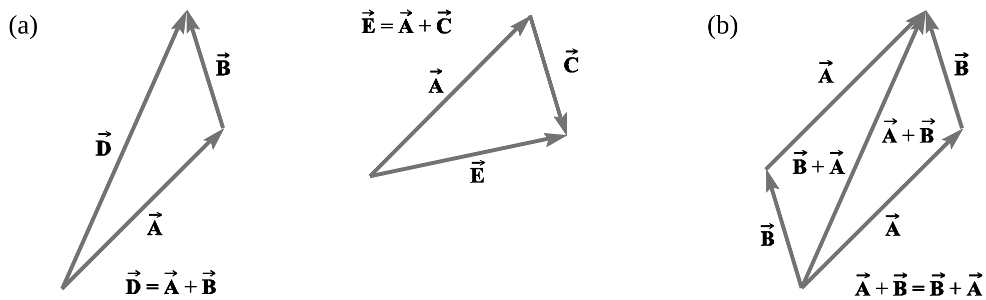
$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{4^2 + 4^2} = \sqrt{16+16} = \sqrt{32}$$

$$B = \sqrt{B_x^2 + B_y^2} = \sqrt{(-1)^2 + 3^2} = \sqrt{1+9} = \sqrt{10}$$ We see numerically the order $B = C, A$.

$$C = \sqrt{C_x^2 + C_y^2} = \sqrt{1^2 + (-3)^2} = \sqrt{1+9} = \sqrt{10}$$

4. Strategy Find graphically the vectors $\vec{\mathbf{D}} = \vec{\mathbf{A}} + \vec{\mathbf{B}}$ and $\vec{\mathbf{E}} = \vec{\mathbf{A}} + \vec{\mathbf{C}}$. Then, show graphically that $\vec{\mathbf{A}} + \vec{\mathbf{B}} = \vec{\mathbf{B}} + \vec{\mathbf{A}}$.

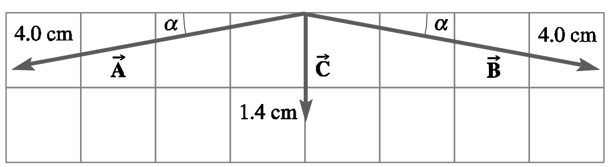
Solution Use graph paper, ruler, and protractor to find the magnitude and direction of the vector sum of the two forces in each case.



Vector **D** goes three spaces to the right and seven spaces up. Vector **E** goes five spaces to the right and one space up.

5. Strategy Sketch the addition to find $\vec{\mathbf{C}}$. Use the fact that $|\vec{\mathbf{A}}| = |\vec{\mathbf{B}}|$ and symmetry to determine the direction of $\vec{\mathbf{C}}$.

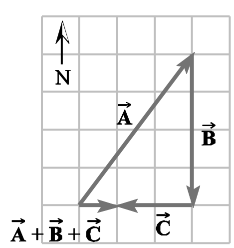
Solution By symmetry, the horizontal components cancel when $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ are added, so $\vec{\mathbf{C}}$ points downward;. The downward components of each vector have the same magnitude, about 0.7 N. So, the magnitude of $\vec{\mathbf{C}}$ is about 1.4 N. The sketch is shown:



Discussion Mathematics is not just about numbers. You could call this geometry, or recognize it as having real direct application to the way forces behave (that's physics), or both.

6. Strategy Draw the vectors tail-to-head and their sum. Use the scale of the drawing to find the magnitude of the vector sum.

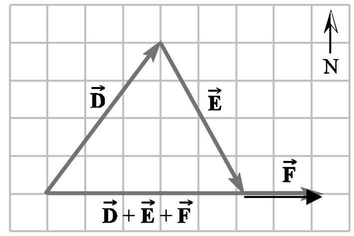
Solution The length of the vector sum is equal to one side of a grid square, so the magnitude is 2 N. The vector points east, so the vector sum of the forces is 2 N to the east.



Discussion The vector sum would not have to be straight in the *x* or *y* direction, so you still need a ruler and protractor to find the numerical answer if your instructor puts a problem like this on a quiz.

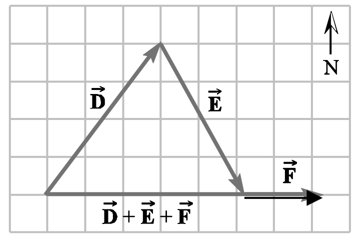
7. Strategy In the diagram pay attention only to the lengths of the three arrows.

Solution The arrows are drawn starting from different points in the diagram here, but with the right directions and lengths. Vector **F** is two boxes long, so it has the smallest magnitude. Vector **E** is next, and vector **D** is the longest. So the ranking is $\boxed{|\mathbf{F}| < |\mathbf{E}| < |\mathbf{D}|}$. If you think your eyes might deceive you when you compare **D** and **E**, notice that the length of **D** is $\sqrt{3^2+4^2}$ boxes and the length of **E** is $\sqrt{2^2+4^2}$ boxes.



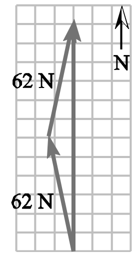
8. Strategy Graph the vectors and their sum. Use the scale of the graph to find the magnitude of the vector sum.

Solution The length of the vector sum is equal to seven sides of a grid square, so the magnitude is 14 N. The vector points east, so the vector sum of the forces is $\boxed{\text{14 N to the east}}$. (Note that $\vec{\mathbf{F}}$ and the vector sum overlap in the diagram.)



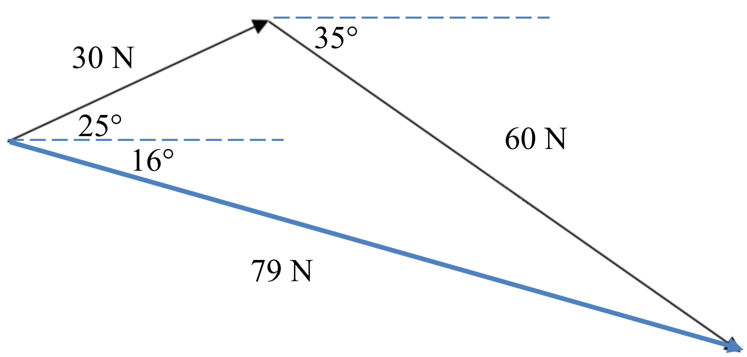
9.. **Strategy** Graph the vectors and their sum. Use the scale of the graph to find the magnitude of the vector sum. As a check and for precision, we can add with the component method. Take the *x* direction as east

Solution Use graph paper, ruler, and protractor to construct arrows, tail to head, representing the two forces separately. Then draw in a third arrow to represent the resultant. Measure the magnitude and direction of the vector sum of the two forces. The vector sum points due north. Each side of a grid square represents 10 N, so the magnitude of the net force on the sledge is about **120 N north**.

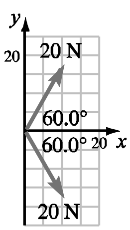


Discussion The *x* component of the sum is zero by symmetry. The *y* component is (62 N) sin78° + (62 N)sin 78° = 1.2×10^2 N, so the sum is 0.12 kN due north.

10. **Strategy** We make a scale drawing of the vector addition, choosing for example 1 cm of arrow length to represent 10 N. The two vectors being added are drawn using a protractor to establish the angles and a ruler to determine the lengths.
Solution The resultant vector arrow is measured to be 7.9 cm long, so the sum of the two forces has magnitude **79 N**. The angle is measured to be **16° below the horizontal**.



11. **Strategy** Use graph paper to draw a diagram. Then find the components of the vectors to add them.
Solution Find the vector sum of the vectors.



By symmetry, the *y*-components of the vectors cancel. This is described by $+20\text{ N}\sin 60° - 20\text{ N}\sin 60° = 0$

The *x*-components each look to be about 10 N, so the vector sum is $+20\text{ N}\cos 60° + 20\text{ N}\cos 60° =$ $10\text{ N} + 10\text{ N} = 20\text{ N}$. So the vector sum is **20 N in the positive *x*-direction.**

12. **Strategy** Look just at how far to the right the head of each arrow is relative to its tail. Going left ranks as less than zero.

Solution In order of increasing *x* component, the vectors are $\boxed{C_x, B_x, A_x}$. We can do the ranking numerically by reading the *x*-coordinate of each vector, keeping in mind that each square represents 2 N on a side.

$A_x = +6$ N; $B_x = 0$; $C_x = -4$ N So again the order of increasing *x*-component is $\boxed{C_x, B_x, A_x}$.

13. Strategy Look just at how far up the head of each arrow is relative to its tail. Going down ranks as less than zero.

Solution In order of increasing *y* component, the vectors are $\boxed{E_y, F_y, D_y}$. We can do the ranking numerically by reading the *y*-coordinate of the terminal point of each vector in box-widths, starting from the initial point. We count $D_y = 4; E_y = -4; F_y = 0$ So again the order of increasing *y*-component is $\boxed{E_y, F_y, D_y}$.

Discussion The idea of a vector can be considered a single new idea. But it involves various aspects that you can practice thinking about separately: horizontal component, vertical component, northward component, eastward component, magnitude, direction. Note also that it has a unit. In an engineering application we might deal with three-component vectors in three-dimensional space. Later in this course we will deal with subtraction and with two different ways to form products of vectors. But there is no way to divide vectors.

14. Strategy Add the corresponding *x*-components of each vector sum.

Solution Find the total *x*-components. $A_x + B_x = 4 + (-1) = 3;\quad B_x + C_x = -1 + 1 = 0;\quad A_x + C_x = 4 + 1 = 5$

In order of increasing *x*-component, we have $\boxed{B_x + C_x, A_x + B_x, A_x + C_x}$.

Discussion. You can add to the picture to sketch in the additions of $\vec{\mathbf{A}}$ to $\vec{\mathbf{B}}$, of $\vec{\mathbf{B}}$ to $\vec{\mathbf{C}}$, and of $\vec{\mathbf{A}}$ to $\vec{\mathbf{C}}$, using the boxes to guide your counts. And then just counting how far each sum carries its arrow to the right gives you the quantities that are to be ranked.

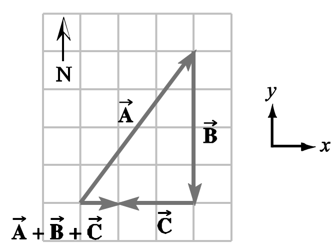
15. Strategy Draw the vectors and their sum. Use the drawing and the grid to read the components of the vectors. Then use the component method to find the vector sum.

Solution Find the vector sum.

x-comp: $A_x + B_x + C_x = 3(2\text{ N}) + 0(2\text{ N}) - 2(2\text{ N}) = 2\text{ N}$

y-comp: $A_y + B_y + C_y = 4(2\text{ N}) - 4(2\text{ N}) + 0(2\text{ N}) = 0$

The vector sum of the forces is 2 N in the positive *x*-direction or $\boxed{\text{2 N to the east}}$.

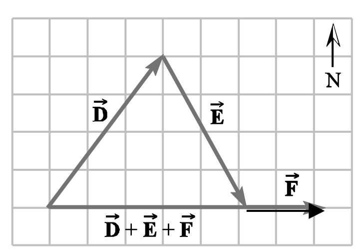


Discussion A common mistake is mixing up positive and negative signs when writing down components. Making a sketch, even if you do not make a measured drawing or count boxes, is a good way to guard against this mistake.

16. Strategy Make a sketch of the vectors and their sum. Use the scale of the graph to find the approximate magnitude of the vector sum and identify the direction.

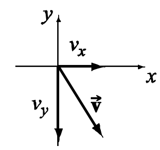
Solution The sketch is shown. Note that $\vec{\mathbf{F}}$ and the vector sum overlap. The *x* component of the sum is

3 spaces + 2 spaces + 2 spaces = 7 spaces = 7 spaces (2 N/space) = 14 N. The *y* component of the sum is +8 N – 8 N + 0 = 0. Then the resultant is $\boxed{\text{14 N to the east}}$



17. Strategy The components of $\vec{\mathbf{v}}$ are given. Since the *x*-component is positive and the *y*-component is negative, the vector lies in the fourth quadrant. Give the angle with respect to the axes.

Solution Find the magnitude and direction of $\vec{\mathbf{v}}$.



(a) $v=\sqrt{v_x{}^2+v_y{}^2}=\sqrt{(16.4\text{ m/s})^2+(-26.3\text{ m/s})^2}=\boxed{31.0\text{ m/s}}$

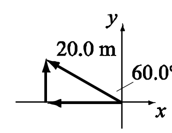
(b) The angle with the *x* axis is $\theta=\tan^{-1}(v_y/v_x)$

$\theta=\tan^{-1}\dfrac{-26.3}{16.4}=\boxed{-58.1°\text{ with the }+x\text{-axis and }31.9°\text{ with the }-y\text{-axis}}$ The negative angle with the *x* axis by convention means 58.1° clockwise rather than counterclockwise.

Discussion The sketch, whether drawn to scale or not, always helps avoid mistakes in identifying the physical direction of the vector and specifying the angle it makes with this or that axis.

18. Strategy The vector makes an angle of 60.0° counterclockwise from the *y*-axis. So, the angle clockwise from the negative *x*-axis is 90.0° – 60.0° = 30.0°.

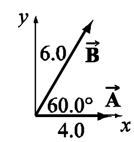
Solution Find the components of the vector.



x-comp = –(20.0 m) cos (30.0°) = $\boxed{-17.3\text{ m}}$ and *y*-comp = +(20.0 m) sin (30.0°) = $\boxed{10.0\text{ m}}$.

19. Strategy Let $\vec{\mathbf{A}}$ be directed along the +*x*-axis and let $\vec{\mathbf{B}}$ be 60.0° CCW from $\vec{\mathbf{A}}$.

Solution Find the magnitude of $\vec{\mathbf{A}}+\vec{\mathbf{B}}$.

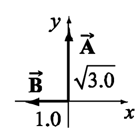


$(A+B)_x=A_x+B_x=4.0+6.0\cos 60.0°=7.0$ and $(A+B)_y=A_y+B_y=0+6.0\sin 60.0°=5.2,$ so

$\left|\vec{\mathbf{A}}+\vec{\mathbf{B}}\right|=\sqrt{7.0^2+5.2^2}=\boxed{8.7\text{ units}}$.

20. (a) Strategy Since each vector is directed along a different axis, each component of the vector sum is just equal to the vector that lies along that component's axis. Use the Pythagorean theorem.

Solution Find the magnitude of $\vec{\mathbf{A}}+\vec{\mathbf{B}}$.



$\left|\vec{\mathbf{A}}+\vec{\mathbf{B}}\right|=\sqrt{[(A+B)_x]^2+[(A+B)_y]^2}=\sqrt{(-1.0)^2+(\sqrt{3.0})^2}=2.0\text{ units}$

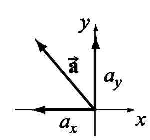
Find the direction of this vector in the second quadrant.

$\theta=\tan^{-1}\dfrac{\sqrt{3.0}}{1.0}=60°$ CW from the $-x$ axis, so

$\vec{\mathbf{A}}+\vec{\mathbf{B}}=\boxed{2.0\text{ units at }60°\text{ CW from the }-x\text{ axis}}$.

21. Strategy The components of $\vec{\mathbf{a}}$ are given. Since the *x*-component is negative and the *y*-component is positive, the vector lies in the second quadrant. Give the angle with respect to the axis to which it lies closest.

Solution Find the magnitude and direction of $\vec{\mathbf{a}}$.



(a) $a=\sqrt{a_x{}^2+a_y{}^2}=\sqrt{(-3.0\text{ m/s}^2)^2+(4.0\text{ m/s}^2)^2}=\boxed{5.0\text{ m/s}^2}$

(b) $\theta=\tan^{-1}\dfrac{4.0}{3.0}=53°$ CW from the $-x$ axis or $\boxed{37°\text{ CCW from the }+y\text{ axis}}$

Discussion. Some people like to reduce routine tasks to routine. An arbitrary choice is to state all angles counterclockwise from the +*x* axis. In this problem the direction angle would be 127°. With its angle θ in this standard form, the *x* component of a vector $\vec{\mathbf{A}}$ is always given by $A\cos\theta$ and the *y* component by $A\sin\theta$, with your calculator supplying just enough minus signs in the right places. If you do it like this, leave the signs with the components whenever you compute $\tan^{-1}(A_y/A_x)$. If the *x* component is negative, add 180° to the angle your calculator tells you. And remember that turning by 360° gets you back to your original direction, so –40° is the same as 320°.

22. Strategy We use sines and cosines to find the components of vectors from magnitude and direction.

Solution Find the components of each vector.

Vector $\vec{\mathbf{A}}$:

$A_x = (7.0\text{ m})\cos 20.0° = \boxed{6.6\text{ m}}$

$A_y = (7.0\text{ m})\sin 20.0° = \boxed{2.4\text{ m}}$

Vector $\vec{\mathbf{B}}$:

$B_x = (7.0\text{ N})\cos(-20.0°) = \boxed{6.6\text{ N}}$

$B_y = (7.0\text{ N})\sin(-20.0°) = \boxed{-2.4\text{ N}}$

Vector $\vec{\mathbf{C}}$:

$C_x = -(7.0\text{ m})\sin 20.0° = \boxed{-2.4\text{ m}}$

$C_y = (7.0\text{ m})\cos 20.0° = \boxed{6.6\text{ m}}$

Vector $\vec{\mathbf{D}}$:

$D_x = -(7.0\text{ N})\sin(20°) = \boxed{-2.4\text{ N}}$

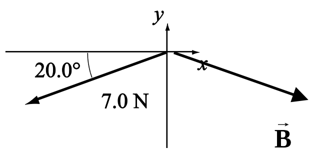
$D_y = -(7.0\text{ N})\cos(20°) = \boxed{-6.6\text{ N}}$

23. Strategy and Solution Multiplying a vector by a scalar is equivalent to multiplying the vector's components by that scalar value. Multiplying a vector by a positive scalar—other than 1—changes the magnitude of the vector and its components but not the direction. Therefore, doubling the magnitude of the vector $\boxed{\text{doubles both components, without changing their signs}}$.

Discussion With $\vec{\mathbf{B}} = B$ at $\theta = B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}}$ we can write $2\vec{\mathbf{B}} = (2B)$ at $\theta = 2(B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}}) = 2B_x\hat{\mathbf{x}} + 2B_y\hat{\mathbf{y}}$. The direction of the vector is unchanged while the arrow representing it gets twice as long.

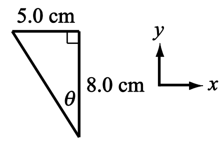
24. Strategy Take the vector $\vec{\mathbf{B}}$ in the textbook diagram for problems 22 through 24. It is in the fourth quadrant. Reversing the sign of the *x*-component results in both the *x*- and the *y*-component being negative. The resulting vector lies in the third quadrant, 20.0° below the negative *x*-axis.

Solution The sketch is shown.



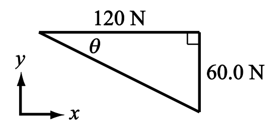
25. Strategy Use the Pythagorean theorem to find the magnitude of each vector. Sketch a right triangle to find the direction angle. Give the angle with respect to the axis to which it lies closest.

Solution Find the magnitude and direction of each vector.



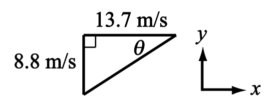
(a) $r=\sqrt{(-5.0\text{ cm})^2+(8.0\text{ cm})^2}=\boxed{9.4\text{ cm}}$ and

$\theta=\tan^{-1}\dfrac{5.0}{8.0}=\boxed{32°\text{ CCW from the }+y\text{-axis}}$.



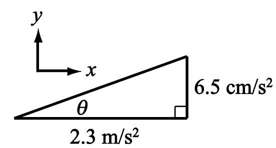
(b) $F=\sqrt{(120\text{ N})^2+(-60.0\text{ N})^2}=\boxed{130\text{ N}}$ and

$\theta=\tan^{-1}\dfrac{60.0}{120}=\boxed{27°\text{ CW from the }+x\text{-axis}}$.



(c) $v=\sqrt{(-13.7\text{ m/s})^2+(-8.8\text{ m/s})^2}=\boxed{16.3\text{ m/s}}$ and

$\theta=\tan^{-1}\dfrac{8.8}{13.7}=\boxed{33°\text{ CCW from the }-x\text{-axis}}$.



(d) $a=\sqrt{(2.3\text{ m/s}^2)^2+(6.5\times10^{-2}\text{ m/s}^2)^2}=\boxed{2.3\text{ m/s}^2}$ and

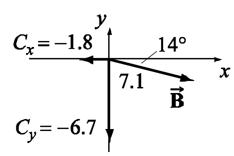
$\theta=\tan^{-1}\dfrac{0.065}{2.3}=\boxed{1.6°\text{ CCW from the }+x\text{-axis}}$.

Discussion These vectors are a displacement, a force, a velocity, and an acceleration. The same mathematical method works for all. We have given the directions by specifying a conveniently small angle clockwise or counterclockwise from one side of one axis, *x* or *y*. Alternatively, we could give directions as they appear on polar coordinate graph paper, with 0° to the right along the *x* axis, and all angles up to 359.99° measured counterclockwise from the *x* axis. Then 30° below the $-x$ axis, for example, is at 210°. Because it is used at one point later in the course, let us note that a vector in three-dimensional space has three components, *x*, *y*, and *z*. Its magnitude is given by $|\mathbf{A}| = A = (A_x^2 + A_y^2 + A_z^2)^{1/2}$, a perhaps remarkably simple generalization of the Pythagorean theorem.

26. (a) Strategy Since the angle is below the +*x*-axis, it is negative.

Solution Compute the components.

$b_x=7.1\cos(-14°)=\boxed{6.9}$ and $b_y=7.1\sin(-14°)=\boxed{-1.7}$.



(b) Strategy The components of $\vec{\mathbf{c}}$ are given. Use the Pythagorean theorem.

Solution Compute the magnitude and direction of $\vec{\mathbf{c}}$

$c=\sqrt{c_x{}^2+c_y{}^2}=\sqrt{(-1.8)^2+(-6.7)^2}=\boxed{6.9}$

$\tan^{-1}\dfrac{-6.7}{-1.8}=75°$ The *x* component is negative, so $\theta=75°$ below the $-x$ axis

(c) Strategy Add the components of the vectors to find the components of the vector sum. Use the Pythagorean theorem. Give the angle with respect to a specified axis.

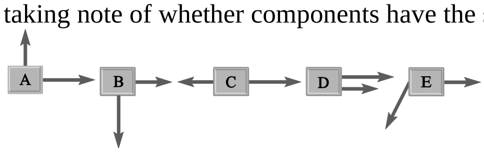
Solution Find the magnitude and direction of $\vec{\mathbf{c}}+\vec{\mathbf{b}}$.

$$|\vec{\mathbf{c}}+\vec{\mathbf{b}}| = \sqrt{(c_x+b_x)^2+(c_y+b_y)^2} = \sqrt{(-1.8+6.9)^2+(-6.7-1.7)^2} = \boxed{9.8} \text{ and}$$

$$\tan^{-1}\frac{-8.4}{5.1} = -59° = \boxed{59° \text{ CW from the } +x \text{ axis or } 31° \text{ CCW from the } -y\text{-axis}}.$$

27. Strategy The shorter vectors each have magnitude 2000 N and the longer vectors all have magnitude 3000 N. The ranking can be seen by eye. But we will confirm the rankings by finding the components of each vector and adding. Where necessary we use the Pythagorean theorem to find the net force, magnitude.

Solution The smaller the angle between the two forces, the greater the magnitude of their sum. Thus the net force is greatest in case D. Next come A and B together, then E, and then C. We thus have the ranking $\boxed{\text{C, E, A = B, D}}$. We can confirm the answer if we add the vertical and horizontal components of each vector, taking note of whether components have the same or opposite directions.



The net forces on objects C and D are the easiest to determine, since the vectors are horizontal.

$C = 3000\text{ N} - 2000\text{ N} = 1000\text{ N}; D = 3000\text{ N} + 2000\text{ N} = 5000\text{ N}$

To find the magnitude of the net force on objects A and B, we use the Pythagorean theorem.

$$A = \sqrt{(3000\text{ N})^2+(2000\text{ N})^2} = 3600\text{ N} = B$$

So far, we have C, A = B, D (from smallest magnitude to largest). We must estimate the net force on object E. The angle that the longer vector makes with the horizontal is approximately 60°.Using this estimate we find the magnitudes of the components.

$E_x = -(3000\text{ N})\cos 60° = -1500\text{ N}; \; E_y = -(3000\text{ N})\sin 60° = -2600\text{ N}$

We have a net horizontal component of 500 N. Use the Pythagorean theorem to find the magnitude of the net force on object E.

$$E = \sqrt{(500\text{ N})^2+(2600\text{ N})^2} = 2650\text{ N}$$

From smallest to largest, the magnitudes of the net forces are $\boxed{\text{C, E, A = B, D}}$.

28. Strategy All the forces are in the vertical direction. To make all the forces on the foot add to zero, the force of the tibia pushing down on the ankle joint must be equal in magnitude and opposite in direction to the tension in the Achilles tendon pulling up on the ankle joint plus the normal force due to the ground pushing up on the ball of the foot.

Solution Find the force exerted on the foot by the tibia.

$$(2230\text{ N} + 750\text{ N})\text{ down} = \boxed{2980\text{ N down}}$$

Discussion It is reasonable to neglect the weight of the foot. If it is only 5 N or less, it would not affect the answer given to three digits. In engineering mechanics, a framework of struts is a structure that supports loads much heavier than itself. Bicycle frames, stepladders, and dish drainers are examples.

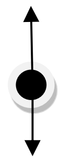
29. Strategy Since the man and mattress are neither starting to move upward nor downward, the net force must be zero in the vertical direction.

Solution So that the net force is zero, the upward force of the water must be equal to the combined weight of the man and the air mattress, or $\boxed{806\text{ N}}$.

Discussion You may think that a free body diagram is not necessary for the solution, but draw one anyway. It confirms our answer and makes it as easy as possible to compare one force problem with another. Having just two forces acting on the object, this situation is more complicated than for a meteoroid in outer space, but still ranks as a simple problem. In the diagram the forces are labeled with their magnitudes rather than with their vertical components.

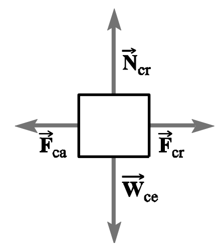
Buoyant force = 806 N

Gravitational Force = 806 N



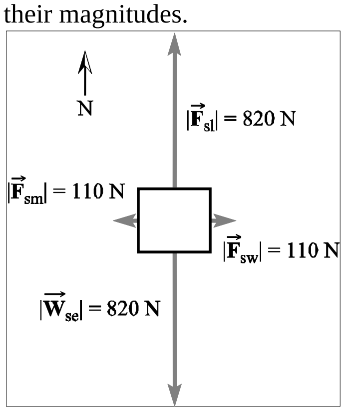
30. **Strategy** The car is moving straight with constant speed, so the horizontal pair of forces and the vertical pair of forces are equal in magnitude and opposite in direction. Let the subscripts be the following:
c = car   e = Earth   r = road   a = air

Solution Since the car is moving with constant velocity, the net force on the car is zero. The free-body diagram is shown.



Discussion Besides air resistance, also called drag, acting backwards, you could say there is rolling resistance against the tires, exerted by the road. The force we have drawn as the forward force of the road on the car is the combination of this rolling resistance and the very real static friction force of the road on the drive wheels, which keeps them rolling instead of skidding.

31. **Strategy** The force of the lake water on the boat must be equal in magnitude and opposite in direction to the weight of the boat. The force of the wind on the boat must be equal in magnitude and opposite in direction to that of the line. Let the subscripts be the following: s = sailboat e = Earth w = wind l = lake m = mooring line
Solution The free-body diagram is shown, representing a side view looking north. The forces are labeled with their magnitudes.

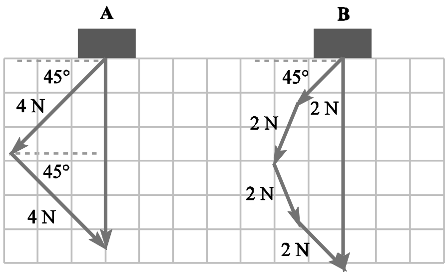


Discussion Everything touching the boat can exert a force on it. We know that the water in the lake exerts an upward force with no horizontal component because the water makes the boat float and the problem statement says that there is no current in the lake. For many students, choosing 'where to stand and which way to look' is a significant source of difficulty. Our choice to look horizontally north lets us draw all the forces in the plane of the picture. In our diagram, up is up. The upward orientation arrow should not really be labeled N. North is into the plane of the picture or away from you. There is a symbol for that: $\otimes$ **.**

32. **Strategy** Make a scale drawing to visualize which net force is greater.

CLICK HERE TO ACCESS THE COMPLETE Solutions

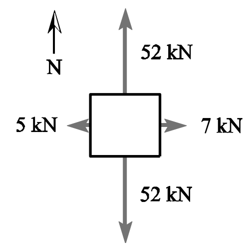
Solution The scale drawing is shown.



The net force magnitude on object *B* is greater than that on object *A* because two of the forces acting on *B* are directed at an angle greater than 45° with respect to the horizontal and contribute more to the downward directed net force.

33. Strategy Draw a free-body diagram and add the force to find the net force on the truck.

Solution In the FBD the forces are labeled with their magnitudes. The vertically directed forces balance, so the net force is due to the difference in the east-west forces.
7 kN east + 5 kN west = 7 kN east − 5 kN east = 2 kN east



Discussion The diagram is drawn from a standpoint looking horizontally toward the north. North is not really up in the picture, but instead away from you into the plane of the picture, which can be represented by the symbol ⊗. The problem is just about forces on the truck—in effect about the environment of the truck. But we can tell a bit about the motion of the truck. It is gaining speed in its motion toward the right in the picture. Perhaps the driver has just stepped on the gas. That action makes the engine exert a torque (twist) on the drive wheels, tending to make the bottom of the wheel slip backward over the road. Unless the road is coated with ice, the static friction force of the road resists the relative sliding motion by pushing forward on the truck through its tires.

34. Strategy For each object, add the forces to find the net force.

Solution

(a) 10 N left + 40 N right = −10 N right + 40 N right = 30 N to the right

(b) The forces balance, so the net force is 0.

(c) The horizontal forces balance, so the net force is due only to the downward force. The net force is 18 N downward.

Discussion A lot of information is contained in a free body diagram. In a sense it is not a diagram of the object at all, but rather of what the rest of the universe is doing to the object—an object can never exert a force on itself.

35. Strategy Use the properties of vectors to answer the questions.

Solution

(a) The only way for the sum to have a magnitude of 7.0 N is if the vectors are in the same direction.

(b) Recognizing from $5^2 = 3^2 + 4^2$ that the three vectors form a 3-4-5 right triangle, we know that the vectors are perpendicular.

(c) The smallest magnitude sum can only be obtained if the two vectors are in opposite directions; the magnitude of the smallest vector sum is 1.0 N.

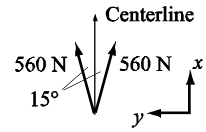
36. Strategy Let the *y*-direction be perpendicular to the canal and the +*x*-direction be parallel to the center line in the direction of motion.

Solution Find the net force on the barge.

$\sum F_y = T\sin 15° - T\sin 15° = 0$ and

$\sum F_x = T\cos 15° + T\cos 15° = 2T\cos 15° = 2(560\text{ N})\cos 15° = 1.1\text{ kN}.$

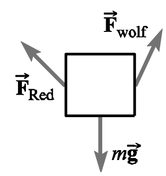
So, $\vec{\mathbf{F}}_{\text{net}} = \boxed{1.1\text{ kN forward (along the center line)}}$.



This sum is not the net force on the boat. The boat is moving forward (up in the diagram) so the water exerts a resistance or drag force on it, down in the diagram, that may be smaller than, larger than, or equal to 1.1 kN.

37. Strategy Draw a free-body diagram. Then, solve for the angle Red Riding Hood was pulling such that the net force on the basket is straight up.

Solution Since we don't know all quantities, the vectors in the diagram are not to scale. For the net force to be straight up, the net force component in the horizontal direction must be zero. Only the forces due to Red and the wolf have components in the horizontal direction, so these components must be equal in magnitude but opposite in direction. Set these components equal and solve for the angle. Since the angle is measured from the vertical, the horizontal component of the wolf's force is the magnitude times the sine of the angle (and similarly for Red's force).



$(12\text{ N})\sin\theta = (6.4\text{ N})\sin 25°$

$$\theta = \sin^{-1}\frac{(6.4\text{ N})\sin 25°}{12\text{ N}} = \boxed{13° \text{ from the vertical}}$$

Discussion Do not think you are learning a routine just for finding the sum of forces. The idea of the component method can be used to solve for a variety of unknowns. Some (pedantic) people might say that the algebra of our solution jumped in in the middle of the logical chain. A good starting point might be $\Sigma F_x = 0$, and then

$-12\text{ N}\sin\theta + 6.4\text{ N}\sin 25° = 0$. If the basket is momentarily still in contact with the ground, the surface might be exerting an upward force on it that is not shown in our diagram.

38. Strategy Read the problem twice to make sure it is asking just about an interaction pair of forces.

Solution It is irrelevant whether the bird is hovering, soaring, diving, changing velocity, or keeping constant velocity. The forces of air on bird and bird on air are two aspects of one interaction, so they have equal magnitudes and are in opposite directions. The force of bird on air is 0.30 N down.

39. Strategy and Solution The towline and glider exert forces on each other that are interaction partners; thus, as described by Newton's third law of motion, the forces they exert on each other are equal in magnitude and opposite in direction. Therefore, the force exerted by the glider on the towline is 850 N, horizontally due west.

Discussion If something seems too easy to you, you can think about what other more complicated questions you are getting ready to answer. If the car is speeding up, the friction force on its tires must be greater than 850 N and the drag force on the glider must be less than 850 N.

40. Strategy Consider forces acting on the rod.

Solution

One force acting on the rod is the downward force on the rod by the line; its interaction partner is the upward force on the line by the rod. Another force acting on the rod is the downward gravitational force on the rod by the Earth; its interaction partner is the upward gravitational force on the Earth by the rod. The third is the total upward force exerted by the fisherman on the rod. The rod in the same interaction exerts a total downward force on the fisherman's two hands.

Discussion In the picture or from experience it appears that the fisherman pushes down on the rod with his right hand in one place and pushes up on the rod with his left hand in another place. In our answer we could list these two forces separately, each with its third-law partner of the force the rod exerts on one hand.

41. Strategy Consider forces acting on the fish suspended by the line.

Solution

One force acting on the fish is an upward force on the fish by the line; its interaction partner is a downward force on the line by the fish. A second force acting on the fish is the downward gravitational force on the fish; its interaction partner is the upward gravitational force on Earth by the fish.

Discussion When the fish was in the water, the water exerted a relatively large upward buoyant force on it; but it is not touching the water any more. The fisherman does not touch the fish, and so exerts no force on it. The fish could be struggling and trying to leap, so that the line tension could be fluctuating widely, but our answer is still correct—instant by instant, the forces of fish on line and of line on fish get large and small together. The fish could be swinging like a pendulum, so that the force of the line could have a varying horizontal component, but our answer is still correct again.

42. Strategy Use Newton's first and third laws.

Solution

(a) Margie is in equilibrium, acted on by the downward force of 543 N and the upward normal force of the scale, which must have the same magnitude $\boxed{543\text{ N}}$ in order for the forces to add to zero.

(b) Refer to part (a). The interaction partner of the force exerted on Margie by the scale is the contact force of Margie's feet pushing downward on the scale.

(c) Choose as a system Margie and the scale together. The Earth pulls down on this system with a combined weight force of 543 N + 45 N = 588 N. For the system to be in equilibrium the ground must push up with a normal force of $\boxed{588\text{ N}}$.

(d) Refer to part (c). The interaction partner of the force exerted on the scale by the floor is the contact force on the floor due to the scale.

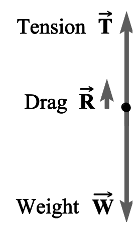
43. (a) Strategy Identify each force acting on the skydiver.

Solution

Gravitational force exerted on the skydiver by Earth; drag exerted on the skydiver by the air; tension exerted on the skydiver by the parachute.

(b) Strategy Draw an FBD using the force information in part (a).

Solution The FBD for the forces exerted on the skydiver is shown at right.



(c) Strategy Determine the magnitude of the force exerted by the air using the force of the parachute and the weight of the skydiver.

Solution Both the upward tension force exerted by the parachute and the upward drag force exerted by the air act to oppose the downward force due to gravity exerted on the skydiver (the weight). Since the skydiver is falling at constant speed, the net force on the skydiver is zero. Thus, the sum of the magnitudes of the upward forces must be equal to that of the skydiver's weight. So, $F_{\text{air}} + 620\text{ N} = 650\text{ N}$, or $F_{\text{air}} = \boxed{30\text{ N}}$.

(d) Strategy Use Newton's laws to identify the interaction partners of each force acting on the skydiver.

Solution

Gravitational force exerted on Earth by the skydiver, 650 N upward; drag exerted on the air by the skydiver, 30 N downward; tension exerted on the parachute by the skydiver, 620 N downward.

Discussion If it is hard for you to think of an ordinary-size object pulling up gravitationally on the Earth, just turn your bathroom scale upside down and stand on it. Then it measures the force you exert on the planet. Or think about a refrigerator magnet and a paper clip. The magnet can exert a force on the clip and can also exert a force on the refrigerator door. Each piece of ordinary steel exerts a force of attraction on the magnet. The way the magnet picks up a paper clip is evidence for both a force the magnet exerts on the clip and a force the clip exerts on the magnet. The way the magnet sticks to the refrigerator door is evidence for both a force the magnet exerts on the door and a force the door exerts on the magnet.

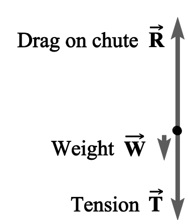
44. (a) Strategy Identify each force acting on the parachute.

Solution

Drag is exerted on the parachute by the air; tension is exerted on the parachute by the skydiver; gravity (weight) is exerted on the parachute by Earth.

(b) Strategy Draw an FBD using the force information in part (a).

Solution The FBD for the forces exerted on the parachute is shown at right.



(c) Strategy The force on the parachute due to the skydiver is equal in magnitude and opposite in direction to the force exerted on the skydiver due to the parachute. They are interaction partners described by Newton's third law.

Solution Since the force exerted on the skydiver due to the parachute is 620 N upward, the force exerted on the parachute due to the skydiver is $\boxed{620\text{ N downward}}$.

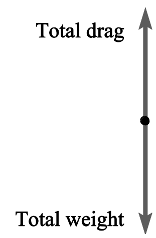
(d) Strategy Use Newton's laws to identify the interaction partners of each force acting on the parachute.

Solution

Tension is exerted on the skydiver by the parachute; drag is exerted on the air by the parachute; gravity is exerted on Earth by the parachute.

45. Strategy Treat the skydiver and parachute as a single system.

Solution The two external forces acting on the skydiver and parachute system are the upward directed drag force due to the air (total drag) and the downward directed force due to gravity (total weight). The magnitudes are equal. The FBD is shown at right.

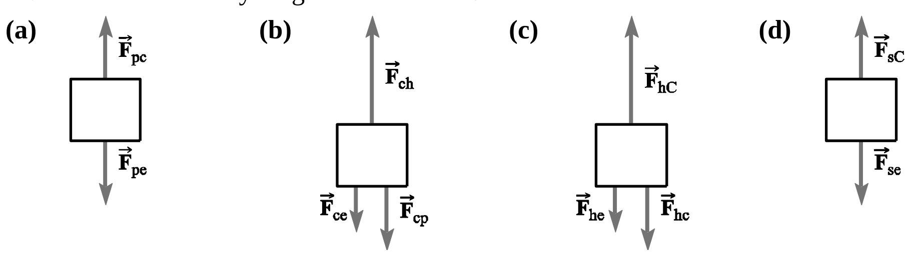


Discussion The FBD for the skydiver and parachute together as a system is simpler than the FBD's for the skydiver or the parachute separately. Newton's third law guarantees that internal forces, exerted by one part of the system on another part, will cancel out, adding to zero when the whole system is considered.

46. Strategy Draw vector arrows representing all of the forces acting on the object. Make sure that the directions of the arrows correctly illustrate the directions of the forces and that their lengths are proportional to the magnitudes of the forces. Let the subscripts be the following:

p = system of plant, soil, pot h = hook c = cord C = ceiling
e = Earth s = system of plant, soil, pot, cord, hook

Solution The free-body diagrams are shown.



pot and contents **cord** **hook** **system**

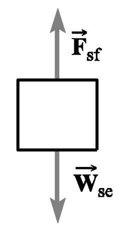
47. Strategy Analyze the forces due to and on the three interacting objects: the woman, the chair, and the floor.

Solution

(a) The weight of the woman is directed downward. The forces on the woman due to the seat and armrests are directed upward and total 25 N + 25 N + 500 N = 550 N. The chair and floor must together support her entire weight, and the rest of her weight to be supported is $600\text{ N} - 2(25\text{ N}) - 500\text{ N} = 50\text{ N}$. Thus, the floor exerts a force on the woman's feet of 50.0 N upward.

(b) The force exerted by the floor on the chair must be equal to the weight of the chair plus the weight of the woman supported by the chair, or 600 N + 100 N − 50 N = 650 N. Thus, the floor exerts a force on the chair of 650 N upward.

(c) The two forces acting on the woman and chair system are the upward force due to the floor and the downward gravitational force due to the Earth. Let the subscripts be the following: s = woman and chair system, e = Earth, f = floor.



48. Strategy Use the conversion factor for pounds to newtons, 1 lb = 4.448 N, and the Earth's average gravitational field strength, $g = 9.80\ \text{N/kg}$.

Solution

(a) Answers will vary. For a 150-lb person, $(150\ \text{lb})(4.448\ \text{N/lb}) = \boxed{670\ \text{N}}$.

(b) Weight of 250 g of cheese $= mg = (0.25\ \text{kg})(9.80\ \text{N/kg}) = \boxed{2.5\ \text{N}}$

(c) Answers will vary. A stick of butter weighs about 0.25 lb.
$(0.25\ \text{lb})(4.448\ \text{N/lb}) = 1.1\ \text{N}$
So, $\boxed{\text{a stick of butter with one pat removed}}$ weighs close to 1 N.

49. Strategy Use the conversion factor for pounds to newtons, $0.2248\ \text{lb} = 1\ \text{N}$.

Solution

(a) Find the weight of the girl in newtons.
$W = mg = (40.0\ \text{kg})(9.80\ \text{N/kg}) = \boxed{392\ \text{N}}$

(b) Find the weight of the girl in pounds.
$(392\ \text{N})(0.2248\ \text{lb/N}) = \boxed{88.1\ \text{lb}}$

Discussion The distinction between mass and weight was discovered experimentally by Jean Richer in 1671 when he transported pendulum clocks (recently invented) from Paris to French Guiana, where the measurably lower free-fall acceleration (9.78 N/kg versus 9.81 N/kg) caused them to run more slowly. Think of mass as a property of an object in itself, like a census of the elementary particles it contains. Think of weight as the measure of an interaction that the object has with Earth or with whatever other astronomical object is nearby.

50. Strategy Find the mass using the weight of the man and the Earth's average gravitational field strength, $g = 9.80\ \text{N/kg}$.

Solution Find the mass of the man.

$$m = \frac{W}{g} = \frac{0.80\times10^3\ \text{N}}{9.80\ \text{N/kg}} = \boxed{82\ \text{kg}}$$

51. Strategy Use Newton's universal law of gravitation. The *Voyager 1* spacecraft is approximately 17 billion kilometers from the Sun.

Solution Find the approximate magnitude of the gravitational force with which the Sun pulls on the spacecraft.

$$F = \frac{Gm_1m_2}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(722\ \text{kg})(1.987\times10^{30}\ \text{kg})}{(17\times10^{12}\ \text{m})^2} = \boxed{3.3\times10^{-4}\ \text{N}}$$

52. Strategy Gravitational field strength is given by $g = GM/R^2$, so let the new field strength be $g' = ng = GM/r^2$, where $n = 2/3$ for part (a) and $1/3$ for part (b).

Solution Determine *r* in terms of *R*. $\frac{g'}{g} = \frac{ng}{g} = n = \frac{\frac{GM}{r^2}}{\frac{GM}{R^2}} = \frac{R^2}{r^2}$, so $r = \frac{R}{\sqrt{n}}$.

Find an expression for the altitude, *h*. $h = r - R = \frac{R}{\sqrt{n}} - R = R\left(\frac{1}{\sqrt{n}} - 1\right)$

(a) $h = (6.371\times10^3\text{ km})\left(\frac{1}{\sqrt{2/3}} - 1\right) = \boxed{1432\text{ km}}$

(b) $h = (6.371\times10^3\text{ km})\left(\frac{1}{\sqrt{1/3}} - 1\right) = \boxed{4664\text{ km}}$

53. Strategy On Earth, $g = 9.80\text{ N/kg}$.

Solution Find the man's weight on Earth, Mars, Venus, and Earth's moon.
On Earth $mg = (65\text{ kg})(9.80\text{ N/kg}) = \boxed{640\text{ N}}$

(a) Find the man's weight on Mars. $mg = (65\text{ kg})(3.7\text{ N/kg}) = \boxed{240\text{ N}}$ $\boxed{\text{about 4/10 of its Earth value}}$

(b) Find the man's weight on Venus. $mg = (65\text{ kg})(8.9\text{ N/kg}) = \boxed{580\text{ N}}$ $\boxed{\text{about 9/10 of its value here}}$

(c) Find the man's weight on Earth's moon. $mg = (65\text{ kg})(1.6\text{ N/kg}) = \boxed{100\text{ N}}$ $\boxed{\text{about 1/6 of its value on Earth}}$

Discussion Earth is the largest object in the solar system with a solid surface, so Earth exerts a larger force on an object at its surface than other planets, satellites, asteroids, meteoroids, or comet nuclei do. Remember or look again at astronauts bounding from place to place on the Moon, where they had to learn a new means of progression.

54. Strategy This is the same as asking, "At what altitude is the gravitational field strength half of its value at the surface of the Earth?" $g = GM/R^2$, so let the new field strength be $g' = ng = GM/r^2$ where $n = 1/2$.

Solution Determine *r* in terms of *R*. $\frac{g'}{g} = \frac{ng}{g} = n = \frac{\frac{GM}{r^2}}{\frac{GM}{R^2}} = \frac{R^2}{r^2}$, so $r = \frac{R}{\sqrt{n}}$.

Find an expression for the altitude, *h*.

$h = r - R = \frac{R}{\sqrt{n}} - R = R\left(\frac{1}{\sqrt{n}} - 1\right)$, so $h = (6.371\times10^3\text{ km})\left(\frac{1}{\sqrt{1/2}} - 1\right) = \boxed{2639\text{ km}}$.

55. Strategy Gravitational field strength is given by $g = GM/R^2$. Find $H = R_2 - R_1$, where R_1 and R_2 are the distances from the center of the Earth to the surface of the Earth and the location of the balloon, respectively.

Solution Find the height above sea level of the balloon, H.

$$H = R_2 - R_1 = \sqrt{\frac{GM}{g_2}} - \sqrt{\frac{GM}{g_1}} = \sqrt{GM}\left(g_2^{-1/2} - g_1^{-1/2}\right)$$

$$= \sqrt{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})}\left[(9.792\ \text{N/kg})^{-1/2} - (9.803\ \text{N/kg})^{-1/2}\right] = \boxed{4\ \text{km}}$$

Discussion The dropping air pressure would be much easier to measure. A typical airplane's or skydiver's altimeter is a barometer with a different faceplate.

56. Strategy The gravitational field strength is given by $g = GM/R^2$. Use the mass of the Earth and the gravitational field strength of the Moon, which we take as 1.62 N/kg, and solve for R, which, in this case, is the distance from the center of the Earth. Then, subtract the radius of the Earth to find the height above the surface.

Solution Solving for R, we have

$$R = \sqrt{\frac{GM}{g}} = \sqrt{\frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})}{1.62\ \text{m/s}^2}} = 1.57\times10^4\ \text{km}.$$

So, the height above the Earth's surface is $1.57\times10^4\ \text{km} - 6.371\times10^3\ \text{km} = \boxed{9.3\times10^3\ \text{km}}$.

57. (a) Strategy Compare the strengths of the forces at the location of the rock.

Solution The gravitational force exerted on each of two bodies on the other is inversely proportional to the square of the distance between them. The Moon is much closer to the rock than is the Earth, so (even though the Earth is much more massive than the Moon) $\boxed{\text{the rock will fall toward the Moon's surface}}$.

(b) Strategy We can look up the Moon's surface gravitational field strength as $1.62\ \text{N/kg.}$, which could also be computed from GM/r^2 and data in Appendix B. The force of the Moon on the rock is by name the weight of the rock on the Moon.

Solution Find the weight of the rock, which is the gravitational force exerted by the Moon on it.

$F = W = mg = (1.0\ \text{kg})(1.62\ \text{N/kg}) = 1.6\ \text{N}$

The force on the rock due to the Moon is $\boxed{\text{1.6 N toward the Moon}}$.

(c) Strategy Use Newton's law of universal gravitation. The average Earth-Moon distance is 3.845×10^8 m. The mass of the Earth is 5.974×10^{24} kg.

Solution Find the gravitational force exerted by the Earth on the rock.

$$F = \frac{Gm_1m_2}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.0\ \text{kg})(5.974\times10^{24}\ \text{kg})}{(3.845\times10^8\ \text{m})^2} = 2.7\ \text{mN}$$

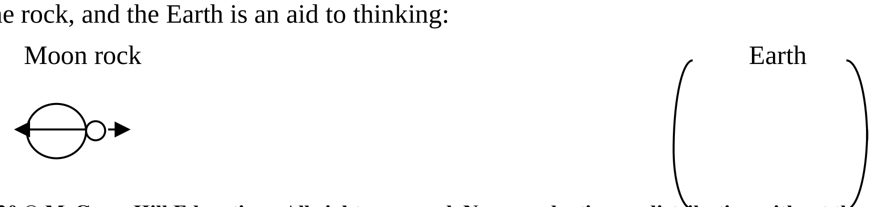
Since gravitational force is attractive, the force exerted by the Earth on the rock is $\boxed{\text{2.7 mN toward Earth}}$.

(d) Strategy Add up the forces.

Solution The total gravitational force on the rock is 1.6 N down toward the Moon + 0.0027 N up toward Earth =

= (1.6 – 0.0027) N down toward the Moon = $\boxed{\text{1.6 N down toward the Moon}}$

Discussion In a word, the gravitational force exerted by the Earth is negligible for the moon rock. This means that it does not affect the value to the precision to which we are working. For some people a diagram of the Moon, the rock, and the Earth is an aid to thinking:



CLICK HERE TO ACCESS THE COMPLETE Solutions

Force of Moon Force of Earth

But it is not easy to draw the diagram to scale, and the dominant factor in making the force of the Earth so small is the great comparative distance from the rock to the Earth, together with the squaring in the inverse square law.

58. (a) Strategy Use Newton's universal law of gravitation and $r = 3.845\times10^8$ m for the distance between Earth and the Moon.

Solution Find the magnitude of the gravitational force that Earth exerts on the Moon.

$$F = \frac{GM_E M_M}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})(7.35\times10^{22}\ \text{kg})}{(3.845\times10^8\ \text{m})^2} = \boxed{1.98\times10^{20}\ \text{N}}$$

(b) Strategy Use Newton's third law.

Solution According to Newton's third law, the magnitude of the gravitational force that the Moon exerts on Earth is [the same] as the force that Earth exerts on the moon.

Discussion It is right away tempting to find the acceleration of the Moon due to this force,

1.98×10^{20} N/7.35×10^{22} kg = 2.70×10^{-3} m/s^2. It was Newton's big idea under the apple tree to associate this acceleration with the orbital motion of the Moon, as we will see in an upcoming chapter.

59. Strategy Use Newton's universal law of gravitation.

Solution Find the ratio.

$$\frac{F_1}{F_2} = \frac{Gm_1m_2}{r_1^2} \div \frac{Gm_1m_2}{r_2^2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{r_1 + 3.20\times10^5\ \text{m}}{r_1}\right)^2 = \left(\frac{6.371\times10^6\ \text{m} + 0.32\times10^6\ \text{m}}{6.371\times10^6\ \text{m}}\right)^2 = \boxed{1.10}$$

Discussion The 320 km altitude for an artificial satellite is realistic. You probably live closer to outer space than to your State capital. Outer space is close enough that the Earth's gravitational field is only a few percent weaker there than at the surface.

60. (a) Strategy Use Newton's universal law of gravitation and 3.845×10^8 m for the distance between Earth and the Moon; and $1.50\times10^{11}\ \text{m} + 3.845\times10^8$ m for the distance between the Sun and the Moon. During a lunar eclipse, the gravitational forces due to the Sun and Earth on the Moon are in the same direction.

Solution Find the magnitude of the net gravitational force.

$$F = \frac{GM_S M_M}{r_{MS}^2} + \frac{GM_E M_M}{r_{ME}^2} = GM_M\left(\frac{M_S}{r_{MS}^2} + \frac{M_E}{r_{ME}^2}\right)$$

$$= (6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.349\times10^{22}\ \text{kg})\left[\frac{1.987\times10^{30}\ \text{kg}}{(1.50\times10^{11}\ \text{m} + 3.845\times10^8\ \text{m})^2} + \frac{5.974\times10^{24}\ \text{kg}}{(3.845\times10^8\ \text{m})^2}\right]$$

$$= \boxed{6.29\times10^{20}\ \text{N}}$$

(b) Strategy Use Newton's universal law of gravitation and 3.845×10^8 m for the distance between Earth and the Moon; and $1.50\times10^{11}\ \text{m} - 3.845\times10^8$ m for the distance between the Sun and the Moon. During a solar eclipse, the gravitational forces due to the Sun and Earth on the Moon are in opposite directions.

Solution Find the magnitude of the net gravitational force.

$$F = \frac{GM_S M_M}{r_{MS}^2} - \frac{GM_E M_M}{r_{ME}^2} = GM_M\left(\frac{M_S}{r_{MS}^2} - \frac{M_E}{r_{ME}^2}\right)$$
$$= (6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(7.349\times10^{22}\ \text{kg})\left[\frac{1.987\times10^{30}\ \text{kg}}{(1.50\times10^{11}\ \text{m} - 3.845\times10^{8}\ \text{m})^2} - \frac{5.974\times10^{24}\ \text{kg}}{(3.845\times10^{8}\ \text{m})^2}\right]$$
$$= \boxed{2.37\times10^{20}\ \text{N}}$$

Discussion The Sun exerts a larger force on the Moon than the Earth does. Why then do we think of the Moon as orbiting the Earth? Why doesn't the Sun capture the Moon away from the Earth? Think better of the Earth-Moon system as in orbit around the Sun. The Moon's path wobbles closer and farther away from the Sun, crossing the Earth's nearly circular orbit about 27 times a year, but the Moon's path is always concave toward the Sun.

61. **Strategy** The point at which the gravitational field is zero is somewhere along the line between the centers of the two stars. Use Newton's law of universal gravitation.

Solution The distance between the stars is $d = d_1 + d_2$, where d_1 is the distance to the $F = 0$ point from the star with mass M_1 and d_2 is the distance to the $F = 0$ point from the heavier star. The forces are equal in magnitude [2]and opposite in direction at the $F = 0$ point. Let m be a test mass at the $F = 0$ point.

$$\frac{GM_1 m}{{d_1}^2} = \frac{G(4.0M_1)m}{{d_2}^2},\ \text{so}\ d_2 = 2.0d_1.$$

$$d = d_1 + d_2 = d_1 + 2.0d_1 = 3.0d_1,\ \text{so}\ d_1 = \frac{d}{3.0} = 0.33d.$$

The net gravitational field is zero at one third of the distance between the stars, as measured from the star with mass M_1.

Discussion It would be a rare student who could work this problem out in their head, not having seen one like it before. But see if you can check the answer in your head, as follows. The zero-field point is twice as far from the more massive star than from the lighter one. The distance is squared in the inverse square law, so at the special point r^2 is four times larger for the heavier star. This value of r^2 just compensates for the four-times larger mass of the big star. Producing individually gravitational fields of equal magnitude in opposite directions, the stars can indeed create a net field of zero at the special point, and at no other point.

62. **Strategy** Identify convenient objects or systems to consider. Identify the forces acting on them. Use Newton's first law to relate the forces. Be alert for when Newton's third law can give you an answer.

Solution **(a)** Choose the table and Fernando together as the system. The two forces acting on this system are the table pushing up and Earth pulling down with a force of (54 kg)(9.8 N/kg) = 529 N. Then we have $\Sigma\mathbf{F} = 0$ implying $+N_{table\ on\ book} - 592\ \text{N} = 0$ so $N_{table\ on\ book} = \boxed{592\ \text{N up.}}$

(b) Choose Fernando alone as the system. He feels forces of the dictionary pushing up and Earth pulling down with force (52 kg)(9.8 N/kg) = 510 N. Then we have $\Sigma\mathbf{F} = 0$ implying $+N_{book\ onboy} - 510\ \text{N} = 0$ so $N_{book\ on\ boy} = \boxed{510\ \text{N up.}}$

(c) The table is not touching Fernando and so exerts $\boxed{\text{zero}}$ force on him.

(d) This is the interaction partner to the force in (a), so it is $\boxed{\text{592 N down by dictionary on table}}$.

(e) This is the interaction partner to the force in (b), so it is $\boxed{\text{510 N down by Fernando on dictionary}}$.

(f) Fernando is not touching the table and so exerts zero force on it.

63. Strategy Consider each of the four forces and any possible relationships between them.

Solution (a) (1) The force of Earth pulling on the hammer is gravitational: $mg = (0.94\text{ kg})(9.8\text{ N/kg}) =$

9.2 N down .

(2) The hammer is in equilibrium under two forces: 9.2 N down and the table pushing up. Then for zero net force, the force of the table on the hammer must be 9.2 N up .

(3) The force of hammer on table is the interaction partner to force (2). As described by Newton's third law, it must be 9.2 N down .

(4) The force of hammer on Earth is the interaction partner to force (1). As described by Newton's third law, it must be 9.2 N up .

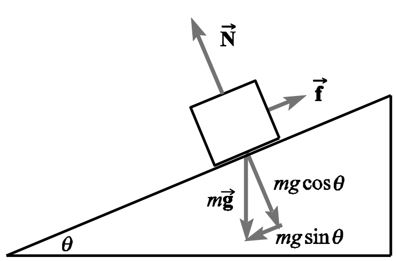
(b) As noted in part (a), forces (2) and (3) are interaction partners and forces (1) and (4) are interaction partners. On the other hand, forces (1) and (2) are equal-magnitude and opposite because of Newton's first law , and are not interaction partners. Forces (3) and (4) are also equal-magnitude and opposite without being an interaction pair, but we regard this as accidental, since these force act on entirely different, unconnected objects.

Discussion If we drew a free body diagram, it would show the hammer and only forces (1) and (2), the ones acting on the hammer. There is no standard way to diagram interaction pairs. They cannot appear in a free body diagram of a single object, because they always act on different objects. To emphasize the difference between "Newton's first law equality" and "Newton's third law equality," suppose that the table and hammer are put into an elevator that starts to move upward. Then the hammer is not in equilibrium. Force (2) would be greater than force (1) as long as the elevator is gaining speed. But forces (2) and (3) would still be equal-magnitude and opposite, and forces (1) and (4) would too.

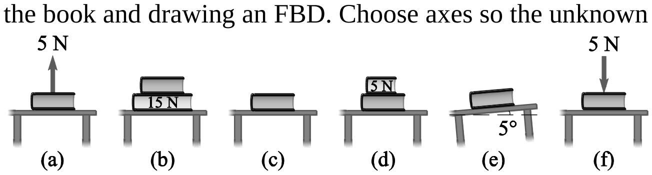
64. Strategy To just get the block to move, the magnitude of the component of gravitational force pulling the box down the plane must be equal to the magnitude of the maximum force of static friction. See the free-body diagram, where the force components are labeled with their magnitudes.

Solution Find the angle of the ramp. When motion is "impending"—when the block is just ready to move, we still say it is in equilibrium. From $\Sigma F_y = 0$ we have $N = mg\cos\theta$. And from $\Sigma F_x = 0$ we have

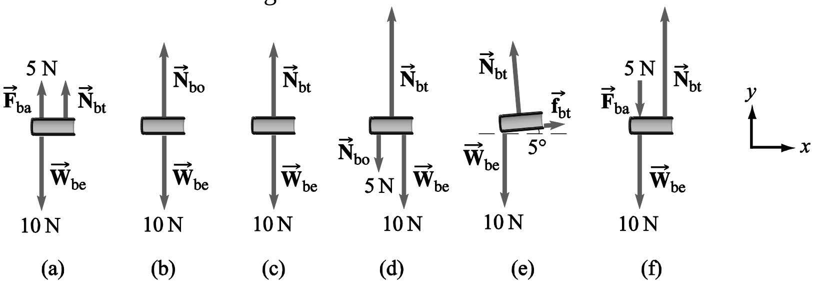
$$\begin{aligned} mg\sin\theta &= f_{\text{max}} \\ &= \mu_s N \\ &= \mu_s mg\cos\theta \\ \tan\theta &= \mu_s \\ \theta &= \tan^{-1}\mu_s = \tan^{-1}0.30 = \boxed{17°} \end{aligned}$$



65. Strategy To proceed step by step, we determine the magnitude of the normal force on the book due to the table in each case by setting the net force on the book equal to zero. In each case, start by identifying the forces acting on the book and drawing an FBD. Choose axes so the unknown normal force is in the +*y*-direction.



Solution Determine the magnitude of the normal force in each case, using the FBDs below, where some forces are labeled with their magnitudes.



Now find N_{bt} by setting the net force in the y-direction equal to zero.

(a) N_{bt} is smaller than the weight of the book (10 N) due to the applied force pulling up (N_{bt} = 5 N).

(b) N_{bt} = 0 because the table is not touching the book, so it can't exert a contact force on it. (There *is* a normal force due to the 15-N book.)

(c) N_{bt} is equal to the weight of the book (N_{bt} = 10 N).

(d) N_{bt} is larger than the weight of the book due to the contact force of the 5-N book pushing down. The 5-N book is also in equilibrium, so the contact force is 5 N and N_{bt} = 15 N.

(e) N_{bt} is equal to the y-component of the weight, so it is *slightly* less than 10 N, or $(10\text{ N})\cos 5°$.

(f) N_{bt} is the same as in (d)—it doesn't matter whether the applied force of 5 N downward is due to a book sitting on top of it or something else.

From smallest to greatest, $\boxed{\text{(b), (a), (e), (c), (d) = (f)}}$.

Discussion After some practice, you may be able to figure out the ranking without explicitly drawing free body diagrams or doing numerical calculations. The simplest case can be thought of as (c). Then the normal force is less in case (a) than it is in (c), and greater in (f). Case (d) is the same as (f) as far as the normal force on the book is concerned. Case (b) must be the smallest, with no normal force because of no contact between the book and the table. And case (e)'s normal force must be less than (c). But a thorough person would need to see a calculation to decide which of (a) and (e) has the smaller value of N – it depends on the gravitational force on the book as well as on the values of 5 N and 5°. Thus without calculation we have evidence that the ranking runs (b) < [(a) and (e) ? or (e) and (a) ?] < (c) < (d) = (f).

66. Strategy While the crate is remaining at rest, the force of static friction must be equal in magnitude and opposite in direction to the component of the crate's weight along and down the incline.

Solution Find the frictional force on the crate.

$\sum F_x = f_s - mg\sin\theta = 0,\ \text{so } f_s = mg\sin\theta = (18.0\text{ kg})(9.80\ \text{N/kg})\sin 30° = 88\text{ N}.$

The frictional force is $\boxed{\text{88 N up the ramp}}$.

Discussion The force of friction in this case is not given by $\mu_s N$. The force of friction has less than its maximum value. The maximum value would be $\mu_s N = \mu_s mg\cos\theta = 0.75 \times 153\text{ N} = 115\text{ N}$. So 88 N is an allowed answer.

67. Strategy While the crate is sliding down the ramp, the force of kinetic friction acts and is opposite in direction to the crate's motion down the incline.

Solution Find the frictional force on the crate.

$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta = (18.0\text{ kg})(9.80\text{ m/s}^2)\cos 30° = \boxed{150\text{ N}}$

$\sum F_x = f_k = \mu_k N = \mu_k mg\cos\theta = 0.40(18.0\text{ kg})(9.80\text{ N/kg})\cos 30° = 61\text{ N}$

The frictional force is $\boxed{\text{61 N up the ramp}}$.

Discussion Some students feel most secure if they identify numerical values for *m*, equal to 18.0 kg, then *mg* = 176 N, then *N* = *mg* cos*θ* = 153 N, and finally the friction force = 0.40 × 153 N = 61 N. This pattern of thinking, sometimes called 'plug and chug,' explicitly keeps track of what is known and what is unknown. If this appeals to you, you can accomplish the same thing ,while raising your thinking up one level of sophistication, by putting a little check mark above the symbol for each quantity that is known. Then you can write less and prepare yourself for solving derivation problems, also called 'show that' or all-symbolic problems.

68. Strategy While the crate is sliding up the ramp, the force of kinetic friction acts and is opposite in direction to the crate's motion up the incline.

Solution Find the frictional force on the crate.

$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta.$

$\sum F_x = f_k = \mu_k N = \mu_k mg\cos\theta = 0.40(18.0\text{ kg})(9.80\text{ N/kg})\cos 30° = 61\text{ N}$

The frictional force is $\boxed{\text{61 N down the ramp}}$.

Discussion Our model of sliding friction says that the speed of motion does not affect the kinetic friction force; neither does the gross area of contact or the action of any forces other than the normal force. When you hold your hand out of the window of a moving car, you feel a fluid friction force with quite different properties.

69. Strategy Without sliding, the crate is at rest relative to the conveyor belt, so static friction acts. Also, the crate is in equilibrium, so the force of static friction must be equal in magnitude and opposite in direction to the component of the crate's weight along and down the incline.

Solution The normal force is $N = mg\cos\theta = (18.0\text{ kg})(9.80\text{ N/kg})\cos 30° = \boxed{150\text{ N}}$. Find the frictional force on the crate.

$\sum F_x = f_s - mg\sin\theta = 0,$ so $f_s = mg\sin\theta = (18.0\text{ kg})(9.80\text{ N/kg})\sin 30° = 88\text{ N}.$

The frictional force is $\boxed{\text{88 N up the ramp}}$.

Discussion As far as forces are concerned, this problem is identical to problem 66, with the crate at rest on the incline. Equilibrium includes the case of an object remaining at rest and the case of an object moving with no change in velocity. The force of friction in this case is not given by $\mu_s N$. The force of friction has less than its maximum value. The maximum value would be $\mu_s N = \mu_s mg\cos\theta$ = 0.75 × 153 N = 115 N. So 88 N is an allowed answer.

70. Strategy The direction of the normal force is always perpendicular to the surface of the ramp. The friction force is in whatever direction is necessary to oppose the motion of the object.

Solution The results are shown in the table.

	$\vec{\mathbf{N}}$	$\vec{\mathbf{f}}$
(a)	perpendicular to and away from the ramp	along the ramp upward

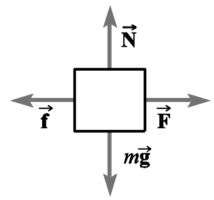
(b)	perpendicular to and away from the ramp	along the ramp downward
(c)	perpendicular to and away from the ramp	along the ramp upward

Discussion The text does a good job in explaining how a surface can exert normal forces of different sizes, always perpendicularly outward from the surface, and frictional forces of different sizes, always along the surface. Your instructor may show you a nice demonstration of a very solid object sagging just enough to exert just the normal force it must exert to support a load. If not, see if you can find such a demonstration on the internet.

71. (a) Strategy To just get the block to move, the force must be equal to the maximum force of static friction.

Solution Solve for μ_s.

$$F = f_{max} = \mu_s N = \mu_s mg, \text{ so } \mu_s = \frac{F}{mg} = \frac{12.0\text{ N}}{(3.0\text{ kg})(9.80\text{ N/kg})} = \boxed{0.41}.$$



(b) Strategy The maximum static frictional force is now proportional to the total mass of the two blocks. The free-body diagram is the same as before, except that it is drawn for the system consisting of both blocks together. The mass *m* is now the sum of the masses of both blocks.

Solution Find the magnitude *F* of the force required to make the two blocks start to move.

$$F = \mu_s mg = 0.41(3.0\text{ kg} + 7.0\text{ kg})(9.80\text{ N/kg}) = \boxed{40\text{ N}}$$

Discussion If you do a simple lab experiment to find the coefficient of friction between two surfaces, it may be similar to the situation considered here. In lab you are likely to observe that a block does a bit of speeding up and slowing down; or that different sections of the table surface give you noticeably different measurements for the friction force. Friction is caused by microscopic irregularities in the sliding surfaces, and can be associated with macroscopic scatter in experimental measurements for friction forces. We can say that the results have rather high uncertainty compared with, say, data from an air track. But that does not invalidate our theory, as long as we estimate the uncertainty from the measurements and state the uncertainty with the results.

72. (a) Strategy Use Newton's first law of motion.

Solution Since the sleigh is moving with constant speed in a straight line, the net force acting on the sleigh is $\boxed{\text{zero}}$.

(b) Strategy Since $F_{net} = 0$, the force of magnitude *T* must be equal to the force of kinetic friction.

Solution Find the coefficient of kinetic friction.

$$T = f_k = \mu_k mg, \text{ so } \mu_k = \boxed{\frac{T}{mg}}.$$

73. Strategy Since the block moves with constant speed, there is zero net force on the block. Draw the free-body diagram using this information. Let the subscripts be the following:
b = block B = Brenda w = wall e = Earth

Solution Find the coefficient of kinetic friction between the wall and the block.

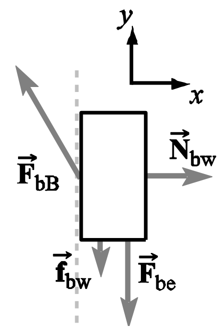
$\sum F_x = N_{bw} - F_{bB}\sin\theta = 0,$ so $N_{bw} = F_{bB}\sin\theta.$

$\sum F_y = F_{bB}\cos\theta - F_{be} - f_{bw} = 0,$ so $f_{bw} = F_{bB}\cos\theta - F_{be}.$

Since $f_{bw} = \mu_k N_{bw}$, we have

$$\mu_k = \frac{F_{bB}\cos\theta - F_{be}}{N_{bw}} = \frac{F_{bB}\cos\theta - F_{be}}{F_{bB}\sin\theta} = \frac{1}{\tan\theta} - \frac{F_{be}}{F_{bB}}\frac{1}{\sin\theta}$$

$$= \frac{1}{\tan 30.0°} - \frac{2.0\text{ N}}{3.0\text{ N}\sin 30.0°} = \boxed{0.4}$$



Discussion For many students this problem repays careful study. You might find it easier to keep track of 'knowns' versus 'unknowns' by showing in the FBD the Earth-force (weight) as 2.0 N down. Brenda's force has upward vertical component 3.0 N cos 30° = 2.60 N and horizontal component 3.0 N sin 30° = 1.50 N into the wall. Then from $\Sigma F_x = 0$ the normal force must be 1.50 N away from the wall. From $\Sigma F_y = 0$ the friction force must be 2.60 N – 2.0 N = 0.60 N. The answer follows from $\mu_k = f/N$. Note well that a vertical wall exerts a horizontal normal force. The FBD is the most essential part of the solution. It keeps track of which forces appear in the horizontal-force equation and which in the vertical-force equation. It lets you keep track of where the sine goes and where the cosine.

74. (a) Strategy Refer to Example 2.14. The maximum static friction force must be greater than the *x*-component of the weight. Use Newton's first law of motion.

Solution

$\sum F_x = f_s - mg\sin\theta \geq 0,$ so $f_{s\,max} \geq mg\sin\theta$ **and** $\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta.$

Compare the forces of friction and gravity. For the crate not to slide we must have

$$\begin{aligned} \mu_s N &\geq mg\sin\theta \\ \mu_s mg\cos\theta &\geq mg\sin\theta \\ \mu_s &\geq \tan\theta \\ 0.42 &\geq \tan 15° \\ 0.42 &\geq 0.27 \quad \text{True} \end{aligned}$$

$\boxed{\text{Yes}}$; the static friction force can hold the safe in place.

(b) Part (b) is unnecessary, since the answer to part (a) is yes.

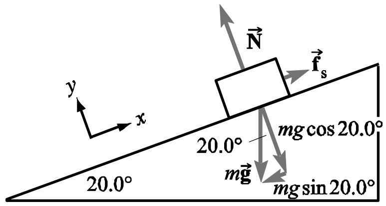
Discussion It is a kind of safety feature to choose an angle for the ramp that is not so steep as to make the heavy safe slide down when the movers take a break.

75. Strategy Use Newton's laws of motion.

Solution Without a ramp, the force is equal to the weight of the object *mg*. According to Newton's first law of motion and Fig. 2.33, with a frictionless plane the force is equal to $mg\sin\phi = mg\frac{h}{d}$. So, the mechanical advantage is $\frac{mg}{mg\frac{h}{d}} = \frac{d}{h}.$

76. Strategy Use Newton's first law of motion. Draw a free body diagram.

Solution



The components of the gravitational force are labeled with their magnitudes.

(a) Compute the magnitude of the normal force.

$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta = (80.0\text{ N})\cos 20.0° = 75.2\text{ N}.$

The normal force is [75.2 N perpendicular to and above the surface of the ramp].

(b) [The interaction partner is equal in magnitude to the component of the apple crate's weight perpendicular to the ramp, 75.2 N perpendicular to the ramp and opposite in direction to the normal force, 'drilling down into the ramp'; it is exerted by the crate on the ramp; it is a contact force.]

(c) Compute the magnitude of the force of static friction on the crate.

$\sum F_x = f_s - mg\sin\theta = 0,$ so $f_s = mg\sin\theta = (80.0\text{ N})\sin 20.0° = 27.4\text{ N}.$

The force of [static friction] exerted on the crate by the ramp is [27.4 N up the incline].

(d) The [minimum possible value of the coefficient of static friction] is the value that just makes the force of static friction oppose the component of the crate's weight that is directed down the incline.

$$f_s = \mu_{s,\,min}N = mg\sin\theta,\ \text{so}\ \mu_{s,\,min} = \frac{mg\sin\theta}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \tan 20.0° = \boxed{0.364}.$$

(e) Find the magnitude.

$$F = \sqrt{f_s^2 + N^2} = \sqrt{(27.4\text{ N})^2 + (75.2\text{ N})^2} = 80.0\text{ N}$$

Find the direction.

$$\theta = \tan^{-1}\frac{N}{f} = \tan^{-1}\frac{mg\cos\theta}{mg\sin\theta} = \tan^{-1}\frac{1}{\tan 20.0°} = 70.0°\text{ or upward}$$

So, $\vec{\mathbf{F}} = \boxed{80.0\text{ N upward}}$.

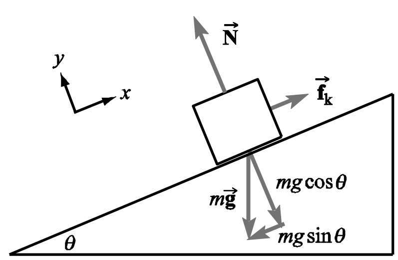
77. (a) Strategy Draw a diagram and use Newton's first law of motion.

Solution Component forces in the picture are labeled with their magnitudes. According to the first law, since the skier is moving with constant velocity, the net force on the skier is zero. Calculate the force of kinetic friction.

$\sum F_x = f_k - mg\sin\theta = 0,$ so

$f_k = mg\sin\theta = (85\text{ kg})(9.80\text{ N/kg})\sin 11° = 160\text{ N}.$

The force of kinetic friction is [160 N up the slope].



(b) Strategy Use the diagram and results from part (a).

Solution Find the normal force.

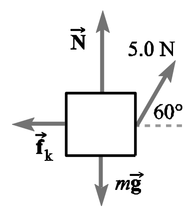
$\Sigma F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta.$ Since $f_k = \mu_k N,$

$$\mu_k = \frac{f_k}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \tan 11° = \boxed{0.19}.$$

Discussion If the angle were any different, the skier would be gaining or losing speed. The 11° angle of the slope is called the 'angle of uniform slip.' In the textbook the two components of the gravitational force would be labeled with minus signs, as $-mg\cos\theta$ and $-mg\sin\theta$. We quite arbitrarily omit the signs in the diagram, showing the magnitudes of the components. So we have to take extra care to include the signs in the ΣF equations, where we are guided by the arrowheads in the diagram. Notice that the given mass (85 kg) of the skier is unnecessary information. If you calculated numerically the gravitational force on her, its two components, the normal force, and the frictional force, all that calculator use would have been unnecessary. Our solution, working with symbols as far as possible, makes the solution as simple as it can be.

78. Strategy Since the suitcase is moving at a constant speed, the net force on it must be zero. The force of friction must oppose the force of the pull. So, the force of friction must be equal in magnitude and opposite in direction to the horizontal component of the force of the pull. Draw a free-body diagram to illustrate the situation.

Solution Find the force of friction.



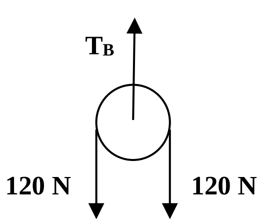
The horizontal component of the pull force is $(5.0\text{ N})\cos 60° = 2.5\text{ N}.$ Since the horizontal component of the pull force is equal and opposite to the friction force, the force of friction acting on the suitcase is $\boxed{\text{2.5 N, opposite the direction of motion}}$.

79. Strategy Recall that the tension in the rope is the same along its length.

Solution The tension in the cord passing around the pulley is equal to the weight at the end of the rope, 120 N. Therefore, $\boxed{\text{scale A reads 120 N}}$.

There are two forces pulling downward on the pulley due to the tension of 120 N in each part of the rope. Therefore, $\Sigma F_y = 0 = -T_A + T_B - T_A$ so $T_B = 2T_A = 240$ N. $\boxed{\text{Scale B reads 240 N}}$, since it supports the pulley.

Discussion You can think that the special skill you are developing through practice is choosing a good object to consider the forces on. Among the planet, load, scales, ropes, floor, and ceiling, the object to consider here is the pulley. If scale A had any reading other than 120 N the pulley would be starting to rotate, but it is not. A free body diagram of the pulley shows two 120 N forces pulling down and one force T_B pulling up.



80. Strategy Recall that the tension in the rope is the same along its length.

Solution The tension is equal to the weight at the end of the rope, 120 N. Therefore, $\boxed{\text{both scales read 120 N}}$.

Discussion The cord supporting the pulley must make a 45° angle with the horizontal, not quite as shown.

81. Strategy Use Newton's first law of motion.

Solution (a) The Earth exerts a force on the mass, which then exerts a force on the scale, which then exerts a force on the hook, which then exerts a force on the ceiling. All these forces are equal (assuming that the masses of the spring scale, cords, and hook are negligible). The scale reading is $\boxed{98\text{ N}}$. In addition, each body on which a force is exerted, exerts an equal-magnitude and opposite force on its neighbors. So, the ceiling exerts a force on the hook, the hook on the scale, etc.

(b) One person replaces the force on the mass due to the Earth, and the other person replaces the force on the scale due to the hook. So, each person must exert a force of $\boxed{98\text{ N}}$.

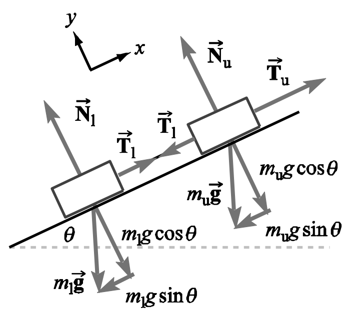
Discussion Some students are confused by this situation because they sympathize with the effort required of each of the people pulling on the ends of the horizontal compound cord. They do not think any 'effort' has to be put out by the ceiling. A nice demonstration can reveal that the ceiling sags temporarily under a load, without any damage or wear. The floor sags a bit where you are standing. Again, some students might observe that in the tug-of-war situation one person pulls the case of the spring balance to the left and the other person pulls the pointer to the right. Should each person then just exert force 49 N? No, because the spring balance reads the tension in the ropes and tension is automatically equal to the forces the ropes exert on objects at both ends.

82. Strategy Use Newton's laws of motion and analyze each scale separately.

Solution $\boxed{\text{Scale B reads 120 N}}$ due to the apples hanging from it. According to Newton's third law, $\boxed{\text{scale A also reads 120 N,}}$ since B is attached directly below it, which is attached to the weight.

83. Strategy Use Newton's first law of motion. The lower cord supports only the lower box, whereas the upper cord supports both boxes. Draw a diagram.

Solution Find the tension in each cord. The arrows in the diagram are labeled with force magnitudes.



Lower box

$\sum F_x = T_l - m_l g\sin\theta = 0,$ so

$T_l = m_l g\sin\theta = (2.0\text{ kg})(9.80\text{ N/kg})\sin 25° = \boxed{8.3\text{ N}}.$

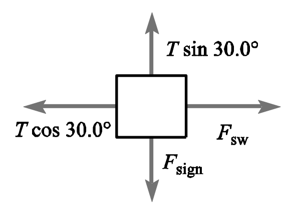
Upper box

$\sum F_x = T_u - m_u g\sin\theta - T_l = 0,$ so

$T_u = m_u g\sin\theta + T_l = (1.0\text{ kg})(9.80\text{ N/kg})\sin 25° + 8.3\text{ N} = \boxed{12.4\text{ N}}.$

84. Strategy Identify all forces acting on the strut. Decompose the tension into its *x*- and *y*-components.

Solution Use Newton's first law of motion. See the diagram, where forces are labeled with their magnitudes.



$\sum F_y = T\sin 30.0° - 200.0\text{ N} = 0,$ so

$T = \dfrac{200.0\text{ N}}{\sin 30.0°} = \boxed{400\text{ N}}.$

85. Strategy Use Newton's first law of motion. Let +*y* be down and +*x* to the right.

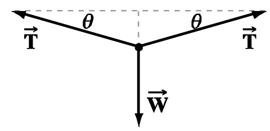
Solution To find the force $\vec{F}$ 'applied' to the front tooth by the wire, we can say we are finding the normal force the jawbone exerts on the roots of the front tooth to hold it at rest. This normal force is just in the opposite direction.

$\sum F_x = T\sin\theta - T\sin\theta = 0$ and $\sum F_y = T\cos\theta + T\cos\theta - N = 0.$ So, we have

$N = 2T\cos\theta = 2(12\text{ N})\cos 37.5° = 19\text{ N}.$ The normal force is toward the front of the mouth and by Newton's first law, the total force exerted by the wire is the same size and directed toward the back of the mouth. $\vec{\mathbf{F}} = \boxed{\text{19 N toward the back of the mouth}}$.

Discussion Orthodontists really do measure forces in newtons. To see whether to use a sine or a cosine to find an x or y component, look at whether the angle is with the y or the x axis.

86. Strategy Use Newton's laws of motion. Draw a diagram.

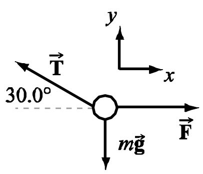


Solution Find the tension. We consider the forces on the bit of clothesline just below the bird.
$\sum F_x = T\cos\theta - T\cos\theta = 0$ so $T = T$ The tension on both sides of the rope is the same.

$\sum F_y = T\sin\theta + T\sin\theta - W = 0$. So, $2T\sin\theta = W$, or $T = \boxed{\dfrac{W}{2\sin\theta}}$.

87. Strategy Use Newton's first law of motion. Draw a free-body diagram.

Solution



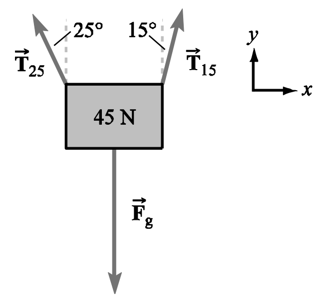
(a) $\sum F_x = F - T\cos\theta = 0$, so $F = T\cos\theta$. $\sum F_y = T\sin\theta - mg = 0$, so $T\sin\theta = mg$, or $T = \dfrac{mg}{\sin\theta}$.

Thus, $F = \dfrac{mg}{\sin\theta}\cos\theta = \dfrac{mg}{\tan\theta} = \dfrac{(2.0\text{ kg})(9.80\text{ N/kg})}{\tan 30.0°} = \boxed{34\text{ N}}$.

(b) $T = \dfrac{(2.0\text{ kg})(9.80\text{ N/kg})}{\sin 30.0°} = \boxed{39\text{ N}}$

Discussion The hard part is understanding that you can productively take components of a force that is unknown in strength, when it is known in direction.

88. Strategy Use Newton's first law of motion. Draw a free-body diagram.



Solution Find the tension in each wire.

$\sum F_x = -T_{25}\sin 25° + T_{15}\sin 15° = 0$, so $T_{25}\sin 25° = T_{15}\sin 15°$, or

$$T_{25} = \frac{\sin 15°}{\sin 25°}T_{15}.$$

$\sum F_y = T_{25}\cos 25° + T_{15}\cos 15° - F = 0$, so

$T_{15}\cos 15° + T_{25}\cos 25° = F.$

Substitute for T_{25}.

$$T_{15}\cos 15° + \left(\frac{\sin 15°}{\sin 25°}T_{15}\right)\cos 25° = F$$

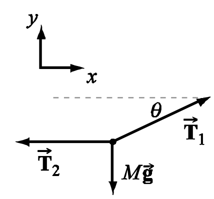
$$T_{15}\left(\cos 15° + \frac{\sin 15°}{\tan 25°}\right) = F$$

$$T_{15} = \frac{45\text{ N}}{\cos 15° + \frac{\sin 15°}{\tan 25°}} = \boxed{30\text{ N}}$$

$$T_{25} = \frac{\sin 15°}{\sin 25°}(30\text{ N}) = \boxed{18\text{ N}}$$

89. Strategy Use Newton's first law. Draw a free-body diagram.

Solution



(a) Find the tension in the rope from which the pulley hangs. Consider the pulley.

$\sum F_y = T_1\sin\theta - Mg = 0$ and $\sum F_x = T_1\cos\theta - T_2 = 0.$

The tension in the rope does not change when the rope goes over the frictionless pulley. The tension is due to the mass M, so $T_2 = Mg$.

Thus, $T_1\cos\theta = Mg$ and $T_1\sin\theta = Mg$.

According to these equations, $\cos\theta = \sin\theta$, which is true only if $\theta = 45°$ for $0° \le \theta \le 90°$.

Therefore, $T_1 = \dfrac{Mg}{\cos 45°} = \boxed{\sqrt{2}Mg}$.

(b) As found in part (a), $\theta = \boxed{45°}$.

Discussion With no numbers given in the problem, how can you tell when you arrive at an answer? The problem statement specifies a block of mass M, so when the quantities that the problem asks for are expressed in terms of M, constants such as g, and numerical factors, then we have an answer. How do we keep track of what is to be thought of as known and what is unknown in an equation? If you like, you can put little check marks over the symbols that stand for 'known' quantities. Many students are used to taking components of a known force in a known direction, writing things like 30 N cos45° and 30 N sin45°. A leap of faith is required to believe that you are making progress when you take components of an unknown force, as here we have $T_1\cos 45°$ and $T_1\sin 45°$. You only need to have faith for a little while, because the answers start to tumble out after a line or two of algebra.

90. Strategy We are concerned with the interactions of pairs of objects that exert forces on each other. Analyze the given forces in light of Newton's first and third laws.

Solution Forces (1) and (2) are third law partners. This is an interaction between two objects, the bike and the Earth. Each body exerts a gravitational force on the other body; and these forces are equal in magnitude and opposite in direction. They act not between the same pair of objects in reverse order, but on the same body. Their equality means that the bike is in equilibrium.

91. Strategy Use Newton's first and third laws of motion.

Solution

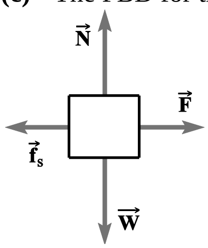
(a) The forces acting on the crate are the following:

The gravitational force exerted on the crate by Earth; the normal force exerted on the crate by the floor; the contact force exerted on the crate by Phineas; static friction exerted on the crate by the floor.

(b) The interaction partners of each force acting on the crate are the following:

The gravitational force exerted on Earth by the crate; the normal force exerted on the surface by the crate; the contact force exerted on Phineas by the crate; static friction exerted on the surface by the crate.

(c) The FBD for the crate:



Only external forces acting on an object are shown in a free-body diagram (FBD). So no, only the forces acting on the crate are shown in the FBD.

(d) The crate is not accelerating; therefore, the net force acting on the crate is zero. Because of this, the normal force exerted on the crate by the floor must be equal in magnitude to the weight of the crate; and the force of static friction exerted on the crate by the floor is equal in magnitude to the force exerted on the crate by Phineas. The magnitudes of the forces exerted on the crate are:

weight = normal force = 350 N; force exerted by Phineas = static friction = 150 N

(e) Only forces acting *on* the crate are shown in the FBD, not interaction partners which are forces due to the crate; so no; these forces are equal-magnitude and opposite because the net force on the crate is zero.

92. Strategy Analyze the forces for each situation. The tension must never exceed 12 N.

Solution Find the tension in each wire. Refer to the diagram.

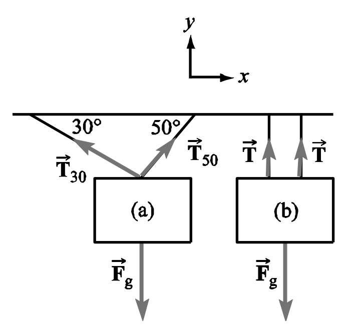


Figure (a)

$\sum F_x = T_{50}\cos 50° - T_{30}\cos 30° = 0$, so $T_{50}\cos 50° = T_{30}\cos 30°$, or

$$T_{30} = \frac{\cos 50°}{\cos 30°}T_{50}.$$

$\sum F_y = T_{30}\sin 30° + T_{50}\sin 50° - F_g = 0$, so

$T_{30}\sin 30° + T_{50}\sin 50° = F_g$.

Substitute for T_{30}.

$$\left(\frac{\cos 50°}{\cos 30°}T_{50}\right)\sin 30° + T_{50}\sin 50° = F_g$$

$$T_{50}\left(\cos 50° \tan 30° + \sin 50°\right) = F_g$$

$$T_{50} = \frac{15\text{ N}}{\cos 50° \tan 30° + \sin 50°} = 13\text{ N}$$

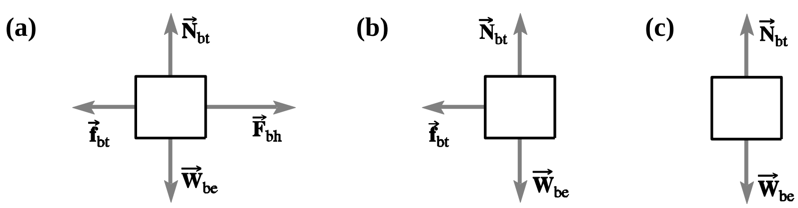
$$T_{30} = \frac{\cos 50°}{\cos 30°}(13.2\text{ N}) = 9.8\text{ N}$$

Figure (b) The cords are symmetrically placed so they exert tension forces of the same size. $\sum F_y = T + T - F_g = 0,$ so $2T = F_g,$ or $T = (15\text{ N})/2 = 7.5\text{ N}.$

Since 13 N > 12 N, the arrangement in Fig. (a) breaks the twine. Since 7.5 N < 12 N, the arrangement in Fig. (b) successfully hangs the picture.

93. Strategy Draw free-body diagrams of the book for each situation. Let the subscripts be the following:
b = book t = table e = Earth h = hand

Solution The diagrams are shown.



(d) Strategy and Solution In cases (a) and (b), the book is accelerating; so in these cases, the net force is not zero.

(e) Strategy and Solution The normal force on the book is equal to its weight, $(0.50\text{ kg})(9.80\text{ m/s}^2) = 4.9\text{ N}.$ The net force acting on the book in part (b) is equal to the force of kinetic friction. The force of kinetic friction is opposite the direction of motion. The magnitude is $\mu_k N = 0.40(4.9\text{ N}) = 2.0\text{ N}.$ Thus, the net force on the book is 2.0 N opposite the direction of motion.

(f) Strategy and Solution The free-body diagram would look just like the diagram for part (c) and the book would not slow down because there is no net force on the book (friction is zero).

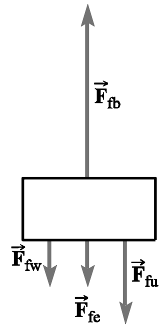
Discussion One can think of this as a simple problem. If you find difficulty, it may be because in (b) there is motion to the right and the FBD shows no force to the right. For a very long time in history, everyone thought that the book would carry with it some of the forward 'impetus' that the hand had given it. In the frictionless situation (f), the FBD (c) shows no forward force and there is continuous forward motion. The key to connecting force and motion is to recognize that the net force is not associated with the velocity but with how the velocity is changing. FBD (a), with the long forward arrow, shows the forces on a book speeding up in motion toward the right. FBD (b) shows forces that can make the book slow down in motion toward the right. FBD (c) is consistent with a book in equilibrium, whether it is keeping constant nonzero velocity or keeping constant zero velocity.

94. Strategy The forces on the forearm, in addition to that of the bicep, are gravity due to the Earth, a downward force due to the upper arm bone, and the downward force due to the 50-N load. Let the subscripts be the

following:
f = forearm e = Earth b = biceps w = load u = upper arm bone

Solution The free-body diagram is shown.

The force exerted by the biceps muscle must counterbalance three forces. And the force by the upper arm bone is large. Both it and the muscle force must be large because they are close together and act together to prevent the forearm from rotating about the elbow joint, as well as preventing it from moving up or down as a unit.



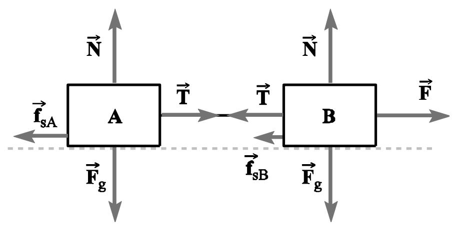
Discussion Moving through space as a unit is called translating. We will study the kind of motion called rotating in chapter 8, and see a second condition for equilibrium, besides Newton's first law, that relates the forces acting on the forearm and their locations. It is the condition that the total torque caused by all the forces must equal zero. Then we will see that the free body diagram should be drawn to better show the locations of the forces, as well as their names and directions.

95. Strategy Draw a diagram and use Newton's first law of motion.

Solution With equal masses and equal weights, the blocks feel equal normal forces. Consider the instant with 'motion impending,' with the blocks still in equilibrium but with motion ready to begin.

(a) The magnitude of the force of static friction on block A due to the floor must be equal to the magnitude of the tension in the cord, so $T = f_{sA} = \mu_A N = \mu_A mg.$
The magnitude of the applied force must be equal to the magnitude of the tension in the cord plus the magnitude of the force of static friction on block B due to the floor. Thus,

$$F = T + f_{sB} = \mu_A mg + \mu_B mg = mg(\mu_A + \mu_B)$$
$$= (2.0\text{ kg})(9.80\text{ N/kg})(0.45 + 0.30) = \boxed{15\text{ N}}.$$



(b) $T = \mu_A mg = 0.45(2.0\text{ kg})(9.80\text{ N/kg}) = \boxed{8.8\text{ N}}$

Discussion We could say that we solve part (a) with an equation that represents the horizontal component of Newton's first law for the system of both blocks together; and we solve part (b) by applying the same law to block A by itself. Your choice of what you apply the law to governs how many unknowns appear in the equations.

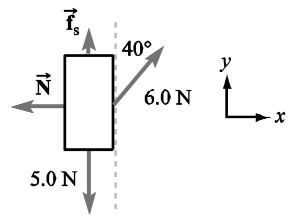
96. Strategy Consider the nature of normal and friction forces. Use Newton's first law of motion.

Solution In the FBD some forces are labeled with their magnitudes.

(a) We interpret the problem statement to mean that you are pushing on a completely flat vertical frame. Then the normal (perpendicular) force you exert must be $\boxed{\text{horizontal and toward the wall}}$. You manage to exert a force with a larger upward component by exerting a friction force at the same time. The coefficient of static friction between your hand and the frame must be large.

(b) The normal force exerted by the wall is directed $\boxed{\text{horizontally out from the wall}}$. (The normal force must be perpendicular to the plane of the wall.) From $\Sigma F_x = 0$, we have $N = 6.0\text{ N}\sin 40° = 3.9\text{ N}$

(c) The y-component of the force of the hand is $(6.0\text{ N})\cos 40° = 4.6\text{ N}$. This is less than the weight of the painting, so the force of friction has a magnitude of $5.0\text{ N} - 4.6\text{ N} = 0.4\text{ N}$ and points in the positive y-direction. (See the diagram.) The normal force is equal to the x-component of the force of the hand, which is $(6.0\text{ N})\sin 40° = 3.9\text{ N}$. Since

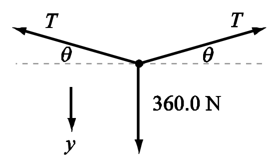


$$f_s \le \mu_s N, \quad \mu_s \ge \frac{f_s}{N} = \frac{0.4\text{ N}}{3.9\text{ N}} = \boxed{0.1}.$$

If the upward component of the force on the picture exerted by the hand is less than the gravitational force on the picture, the frictional force on the picture due to the wall is directed upward so that the net vertical force is zero. If the upward component of the force exerted by the hand is greater than that due to gravity, the frictional force due to the wall is directed downward for the same reason.

97. Strategy Let the +y-direction be in the direction of the 360.0-N force (F). Draw a diagram and use Newton's laws of motion. The forces in the diagram are labeled with their magnitudes.

Solution Find the force exerted on the poplar tree. Consider the equilibrium of the center bit of the rope.



$\sum F_y = F - 2T\sin\theta = 0$ before the poplar is cut through.

So, $F = 2T\sin\theta$. The force exerted on the poplar is the tension T, so

$$T = \frac{F}{2\sin\theta}.$$

Refer to the figure in the text to find $\sin\theta$.

$$\sin\theta = \frac{\text{displacement}}{\text{half length of rope}} = \frac{2.00\text{ m}}{\sqrt{(20.0\text{ m})^2 + (2.00\text{ m})^2}} = 0.0995$$

Thus, $T = \dfrac{360.0\text{ N}}{2(0.0995)} = \boxed{1810\text{ N}}$. Compare the forces.

$$\frac{1810\text{ N}}{360.0\text{ N}} \approx \boxed{\text{5 times the force with which Yoojin pulls}}$$

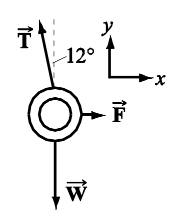
The values for the two situations are different because $\boxed{\text{the oak tree supplies additional force}}$.

Discussion 'Simple machines,' mentioned in some other problems, are devices to exert a larger output force when you exert a smaller input force. The usual list, of inclined plane, pulleys, wheel and axle, screw, lever, gears, and wedge, can be supplemented with a hammer and with a deformable frame such as we have in this problem. If the rope does not stretch, the tree will move by a distance that is about one-fifth of the distance moved by Yoojin.

98. Strategy Use Newton's first law.

Solution

(a) Find the magnitude of the horizontal force exerted on the tire by the wind.



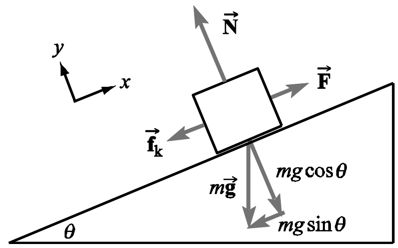
$\Sigma F_x = F - T\sin\theta = 0$, so $F = T\sin\theta$; $\Sigma F_y = T\cos\theta - W = 0$, so $T = \dfrac{W}{\cos\theta}$.

Thus, $F = \dfrac{W}{\cos\theta}\sin\theta = W\tan\theta = \boxed{W\tan 12°}$.

(b) From part (a), $T = \dfrac{W}{\cos\theta} = \boxed{\dfrac{W}{\cos 12^\circ}}$.

99. Strategy Draw a diagram and use Newton's first law of motion. In the diagram the components of the gravitational force are labeled with their magnitudes.

Solution According to the first law, for the box to move with constant speed, the net force on the box must by zero. Calculate the magnitude of the force of the push required.



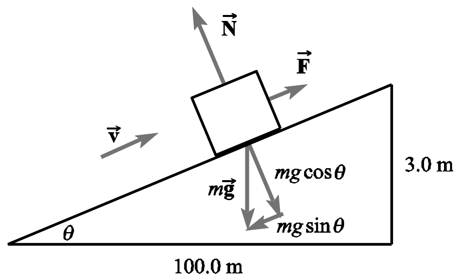
$\sum F_y = N - mg\cos\theta = 0,$ so $N = mg\cos\theta$.

$\sum F_x = F - f_k - mg\sin\theta = 0,$ so

$$F = f_k + mg\sin\theta = \mu_k N + mg\sin\theta$$
$$= \mu_k mg\cos\theta + mg\sin\theta = mg(\mu_k\cos\theta + \sin\theta)$$
$$= (65\text{ kg})(9.80\text{ N/kg})(0.30\cos 25^\circ + \sin 25^\circ) = \boxed{440\text{ N}}.$$

100. Strategy Use Newton's laws of motion. Neglect friction and draw a diagram. The slope of the incline is equal to $\tan\theta$. Let $+x$ be up the incline. The components of the gravitational force in the diagram are labeled with their magnitudes.

Solution Find the magnitude of the force exerted on the rollercoaster by the chain.



$\sum F_y = 0$

$\sum F_x = F - mg\sin\theta = 0,$ since the speed is constant.

Thus, $F = mg\sin\theta = mg\sin\left(\tan^{-1}\dfrac{\Delta y}{\Delta x}\right)$

$$= (400.0\text{ kg})(9.80\text{ N/kg})\sin\left(\tan^{-1}\frac{3.0\text{ m}}{100.0\text{ m}}\right) = \boxed{120\text{ N}}.$$

101. Strategy Use Newton's first law of motion.

Solution

(a) Since the airplane is cruising in a horizontal level flight (a straight line) at constant velocity, it is in equilibrium and the net force is $\boxed{\text{zero}}$.

(b) The air pushes upward with a force equal to the weight of the airplane: $\boxed{2.6\times10^4\text{ N}}$.

Discussion Galileo and Newton would have loved airplanes. The plane as a rule needs an engine. If it has a propeller, it paddles to get some of the surrounding air to push forward on the plane with a 'thrust' force to counterbalance the 'drag' force backward on the plane as a whole. The wings have to deflect downward the air through which the plane passes, exerting a 26 kN downward force on this air. We will have more to say about motion when we study energy, but zero really is the whole story about the net force for an airplane moving at constant velocity. It is like a glider moving on a horizontal air track, which you may get to study in laboratory.

102. Strategy Use Newton's first law of motion. Let the $+y$-direction be up and the $+x$-direction be to the right.

Solution

(a) The tension T is the same all along the length of the cord. Its magnitude is equal to the weight of the leg, which it supports through the sling at its left-hand end. And the tension is equal to the gravitational force on the hanging weight, 22 N. The only vertical force on the leg is due to this tension, so $F_y = 22$ N.

Find the magnitude of the total horizontal force of the traction apparatus applied to the leg. For the pulley attached to the boy's foot

$\sum F_x = T\cos\theta + T\cos\theta - F_x = 0$, so $F_x = 2T\cos\theta = 2(22\text{ N})\cos 30.0° = 38\text{ N}.$

Thus the magnitude of the total force of the cord on the leg is $F = \sqrt{(38\text{ N})^2 + (22\text{ N})^2} = \boxed{44\text{ N}}$.

(b) The horizontal force is $F_x = \boxed{38\text{ N}}$.

(c) The magnitude of the horizontal force acting on the femur is equal to the horizontal component of the traction force acting on the leg, $F_x = \boxed{38\text{ N}}$.

103. **Strategy** Use Newton's laws of motion. Let the +*y*-direction be up and the +*x*-direction be to the right. Since the tibia is at a 30.0° angle below the horizontal, the force due to the patellar tendon on the tibia is at an angle 20.0° + 30.0° = 50.0° above the horizontal. Assume the femur pushes down on the tibia and to the right.

Solution Find the components of the force exerted on the tibia by the femur. Consider the lower leg:

$\sum F_y = (337\text{ N})\sin 50.0° - (3.00\text{ kg} + 5.00\text{ kg})g - F_y = 0$, so $F_y = (337\text{ N})\sin 50.0° - 78.4\text{ N} = 179.76\text{ N}.$

$\sum F_x = F_x - (337\text{ N})\cos 50.0° = 0$, so $F_x = (337\text{ N})\cos 50.0° = 216.62\text{ N}.$

Find the magnitude and direction of the force.

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(216.62\text{ N})^2 + (179.76\text{ N})^2} = \boxed{281\text{ N}}$$

$$\theta = \tan^{-1}\frac{F_y}{F_x} = \tan^{-1}\frac{179.76\text{ N}}{216.62\text{ N}} = \boxed{39.7°\text{ below the horizontal to the right}}$$

104. **(a)** **Strategy** The diagram given with the problem shows all of the forces acting on the patella (kneecap), because it takes account of all of the things that touch it and negligible gravitational force acts on the patella. Then the force on the patella by the femur must bisect the angle between the directions of the equal tensions of the tendons. So, the angle between the normal force and each tension is $(37.0° + 80.0°)/2 = 58.5°$. Use Newton's first law of motion.

Solution Find the magnitude of the contact force exerted on the patella by the femur. Consider forces along the direction of the force by the femur.

$\Sigma F = F - T\cos\theta - T\cos\theta = 0$, so $F = 2T\cos\theta = 2(1.30\text{ kN})\cos 58.5° = \boxed{1360\text{ N}}$.

(b) **Strategy** Refer to part (a).

Solution Find the direction of the contact force.

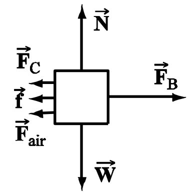
$\theta = 58.5° - 37.0° = 80.0° - 58.5° = \boxed{21.5°\text{ above the horizontal to the right}}$

105. **Strategy** Use Newton's laws of motion.

Solution

(a) Since the train is moving at constant speed, and air resistance and friction are negligible, the readings on the three scales are $\boxed{\text{all 0, and all the same}}$.

(b) Air resistance and friction are not considered negligible this time. The engine pulls the cars against these forces. Since the cars are identical, each car contributes one-third of the total frictional and drag force on the system of cars. Each spring scale will measure the total resistive force due to the cars behind it, so the relative readings on the three spring scales are $\boxed{A > B > C}$. The free-body diagram of the middle car is shown.



(c) Spring scale A measures the forces on all 3 cars. Spring B measures the forces on the latter 2 cars. Spring C measures the forces on the final 1 car.
A = 5.5 N + 5.5 N + 5.5 N = $\boxed{16.5\text{ N}}$; B = 5.5 N + 5.5 N = $\boxed{11.0\text{ N}}$; C = $\boxed{5.5\text{ N}}$

Discussion More formally, to find the reading of scale A consider the set of three cars as a system. The horizontal forces on the system add to zero according to $+F_A - 5.5\text{ N} - 5.5\text{ N} - 5.5\text{ N} = 0$ to give $F_A = 16.5$ N. To find the reading of scale B, consider as a system the middle car and the caboose together. For this system the summation of horizontal forces reads $+F_B - 5.5\text{ N} - 5.5\text{ N} = 0$ to give $F_B = 11.0$ N. To find the reading of scale C, consider just the last car. We have $+F_C - 5.5\text{ N} = 0$ to give $F_C = 5.5$ N. This method does not use the FBD of the middle car which the hint had us draw. But we can use it for a check, reading from it the equation $-F_C - (f + F_{air}) + F_B = -5.5\text{ N} - 5.5\text{ N} + 11.0\text{ N} = 0$, which is true.

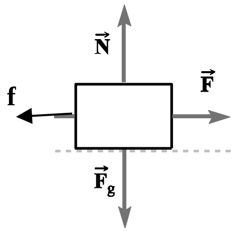
106. (a) Strategy The force required to start the block moving is that needed to counterbalance the maximum force of static friction. Draw a diagram.

Solution Find the applied horizontal force.

$\sum F_x = F - f_s = 0$, so $F = f_s = \mu_s N$.

$\sum F_y = N - F_g = N - mg = 0$, so $N = mg$.

So, the value of the applied force at the instant that the block starts to slide is $F = f_s = \mu_s mg = 0.40(5.0\text{ kg})(9.80\text{ N/kg}) = \boxed{20\text{ N}}$.



(b) Strategy The force required to keep the block moving steadily would be that needed to counterbalance kinetic friction. At the instant the block starts to slide, the net force on the block is the difference between the forces required to overcome static and kinetic friction.

Solution Calculate the net force.

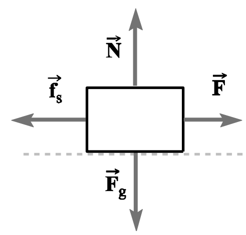
$\sum F = f_s - f_k = \mu_s mg - \mu_k mg = (\mu_s - \mu_k)mg = (0.40 - 0.15)(5.0\text{ kg})(9.80\text{ N/kg}) = \boxed{12\text{ N}}$

107. (a) Strategy The maximum force of static friction is greater than the applied force. Draw a diagram.

Solution Find the possible values for the coefficient of static friction.

$f_{s\,max} = \mu_s N > F$, so $\mu_s > \frac{F}{N} = \frac{120\text{ N}}{250\text{ N}} = 0.48.$

Therefore, $\boxed{\mu_s > 0.48}$.



(b) Strategy Refer to part (a).

Solution Compute the coefficient of static friction. $\mu_s = \frac{f_{s\,max}}{N} = \frac{F}{N} = \frac{150\text{ N}}{250\text{ N}} = \boxed{0.60}$

(c) Strategy Refer to part (a), but with the coefficient of kinetic friction instead of that for static friction.

Solution Compute the coefficient of kinetic friction. $\mu_k = f_k / N = F/N = (120\text{ N})/(250\text{ N}) = \boxed{0.48}$

108. (a) Strategy The tension due to the weight of the potatoes is divided evenly between the two vertical sets of scales.

Solution Find the tension and, thus, the reading of each scale.

$2T = mg$, so $T = mg/2 = (220.0\text{ N})/2 = \boxed{110.0\text{ N}}$.

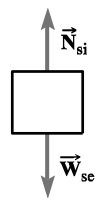
(b) Strategy Scales B and D will read 110.0 N as before. Scales A and C will read an additional 5.0 N due to the weights of B and D, respectively.

Solution Find the reading of each scale. $T_A = 110.0\text{ N} + 5.0\text{ N} = \boxed{115.0\text{ N}} = T_C$ and $T_B = \boxed{110.0\text{ N}} = T_D$.

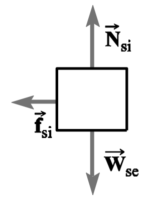
109. Strategy Let the subscripts be the following: i = ice e = Earth s = stone o = opponent's stone

Solution

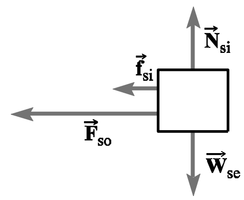
(a) The only forces on the stone are gravity due to the Earth and the normal force due to the ice.



(b) As the stone slides down the rink, it experiences a small force of kinetic friction opposite to its motion.



(c) The additional force is that due to the opponent's stone.



Discussion How does friction know when to act and when not to? It depends on whether there is sideways distortion of the temporary intermolecular bonds between the surfaces. If the ice is very slippery, the friction force in (b) might be too small to have any noticeable effects. Observe how the two vertical forces are the same in each diagram. Note again that forward motion to the right proceeds with no forward force. Only the ice touches the curling stone in (a) and (b), but Earth manages to exert a field force without contacting the stone. The ice manages to exert two forces in (b) by having both solidness and a bit of roughness.

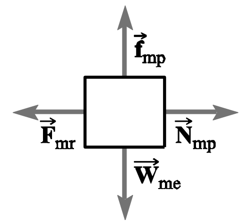
110. (a) Strategy Identify the interactions between the magnet and other objects.

Solution The interactions are:

1) The gravitational forces between the magnet and the Earth 2) The contact forces, normal and frictional, between the magnet and the photo 3) The magnetic forces between the magnet and the refrigerator

(b) Strategy Refer to part (a). Let the subscripts be the following:
m = magnet p = photo e = Earth r = refrigerator

Solution The refrigerator door and photograph are to the left. The magnet is in equilibrium, so the horizontal pair of forces and the vertical pair of forces are equal in magnitude and opposite in direction.



(c) Strategy Identify the range of each force and categorize each as long-range or contact.

Solution

The long-range forces are gravity and magnetism. The contact forces are friction and the normal force.

(d) Strategy Refer to part (b). W_{me} and F_{mr} are given.

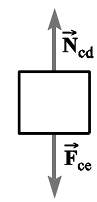
Solution

$W_{me} = 0.14\text{ N}, F_{mr} = 2.10\text{ N}, f_{mp} = W_{me} = 0.14\text{ N, and } N_{mp} = F_{mr} = 2.10\text{ N.}$

Discussion It does not matter to classifying the magnetic force that the refrigerator door and the magnet are separated only by the thickness of a photograph. Their attraction for each other is "long-range" because it is mediated by a magnetic field, which we will study later, and does not require contact. It does not matter that the magnet is the source of the field and the refrigerator door is ordinary sheet steel with no permanent magnetization—Newton's third law is general enough to say that they still exert equal magnitude, opposite-direction forces on each other. The weight of the photograph is unnecessary information, but with it we could find a minimum possible value for the coefficient of static friction between photograph and door.

111. (a) Strategy Let the subscripts be the following: c = computer d = desk e = Earth

Solution The only forces on the computer are due to the Earth's gravity and the normal force due to the desk. The free-body diagram is shown.



(b) Strategy Consider the nature of friction forces.

Solution Since the only forces acting on the computer are in the vertical direction, the friction force is zero.

(c) Strategy Find the maximum force of static friction on the computer due to the desk; this magnitude is the horizontal force necessary to make it begin to slide.

Solution $F = f_{s\,max} = \mu_s N = \mu_s W = 0.60(87\text{ N}) = \boxed{52\text{ N}}$

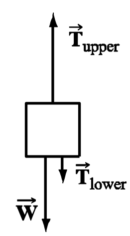
Discussion How does friction know when to act and when not to? It depends on whether there is sideways distortion of the temporary intermolecular bonds between the surfaces. Would you think of this problem as much more difficult if the desktop were tilted at a 5° angle? There is nothing new touching the computer in that case, so try it out for practice. Confirm your solution with your teacher or study group.

112. Strategy The force exerted on the upper scale must counterbalance the weight of the crate and the tension of the lower scale. The forces in the vertical direction sum to zero, since the crate is in equilibrium. Draw a diagram.

Solution Find the reading of the upper scale.

$0 = T_{upper} - W - T_{lower}$, so

$T_{upper} = W + T_{lower} = mg + 120\text{ N} = (50.0\text{ kg})(9.80\text{ N/kg}) + 120\text{ N} = \boxed{610\text{ N}}$.



113. (a) Strategy Scale A measures the weight of both masses. Scale B only measures the weight of the 4.0-kg mass.

Solution Find the readings of the two scales if the masses of the scales are negligible.

Scale A $= (10.0\text{ kg} + 4.0\text{ kg})(9.80\text{ N/kg}) = \boxed{137\text{ N}}$ and Scale B $= (4.0\text{ kg})(9.80\text{ N/kg}) = \boxed{39\text{ N}}$.

(b) Strategy Scale A measures the weight of both masses and scale B. Scale B only measures the weight of the 4.0-kg mass.

Solution Find the readings if each scale has a mass of 1.0 kg.

$$\text{Scale A} = (10.0\text{ kg} + 4.0\text{ kg} + 1.0\text{ kg})(9.80\text{ N/kg}) = \boxed{147\text{ N}} \text{ and Scale B} = \boxed{39\text{ N}}.$$

Discussion More formally, we can use Newton's first law. Choose the two blocks as the system. In (a), $\Sigma F_y = 0$ becomes $+T_A - 98.0\text{ N} - 39.2\text{ N} = 0$ which gives $T_A = 137$ N. In (b), the same condition for equilibrium becomes $+T_A - 98.0\text{ N} - 9.8\text{ N} - 39.2\text{ N} = 0$ which gives $T_A = 147$ N. Now choose just the 4-kg block as the object in equilibrium. In (a) the vertical forces on it add as $+T_B - 39.2\text{ N} = 0$ which gives $T_B = 39$ N. In (b) we have the same $+T_B - 39.2\text{ N} = 0$ which gives $T_B = 39$ N.

114. Strategy Use the method of Example 2.10.

Solution We choose to first find the fraction describing the gravitational field at the mountaintop.

$$\frac{W}{W_{\text{surface}}} = \frac{g}{g_{\text{surface}}} = \frac{GM/(R_E+h)^2}{GM/R_E^2} = \frac{R_E^2}{(R_E+h)^2} = \left(1+\frac{h}{R_E}\right)^{-2}, \text{ so } g = g_{\text{surface}}\left(1+\frac{h}{R_E}\right)^{-2}.$$

Now compute the change in the gravitational field strength.

$$|\Delta g| = g_{\text{surface}} - g = g_{\text{surface}}\left[1-\left(1+\frac{h}{R_E}\right)^{-2}\right] = (9.826\text{ N/kg})\left[1-\left(1+\frac{8850\text{ m}}{6.37\times10^6\text{ m}}\right)^{-2}\right] = \boxed{0.027\text{ N/kg}}$$

115. Strategy The free-fall accelerations at sea level at the equator and at the North Pole are 9.784 N/kg and 9.832 N/kg, respectively. Weight is directly proportional to g.

Solution Find the percentage by which the weight of an object changes when moved from the equator to the North Pole. It increases by

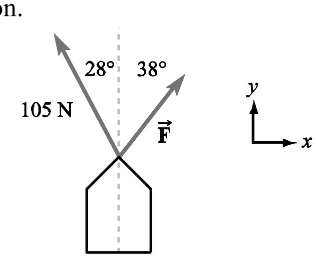
$$\frac{9.832-9.784}{9.784}\times100\% = \boxed{0.49\%}$$

116. (a) Strategy For the sum of the two forces to be in the forward (+y) direction, the net force in the x-direction must be zero. Draw a diagram and use Newton's laws of motion.

Solution Compute the magnitude of the force.

$$\sum F_x = F\sin 38° - (105\text{ N})\sin 28° = 0, \text{ so}$$

$$F = \frac{(105\text{ N})\sin 28°}{\sin 38°} = \boxed{80\text{ N}}.$$

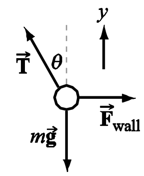


(b) Strategy Find the sum of the y-components of the two forces to find the magnitude of the net force on the barge from the two tow ropes.

Solution Find the magnitude of the force.

$$F_{y\text{ due to both}} = F\cos 38° + (105\text{ N})\cos 28° = (80\text{ N})\cos 38° + (105\text{ N})\cos 28° = \boxed{160\text{ N}}$$

117. Strategy Use Newton's first law of motion and draw a free-body diagram.



Solution Find the tension in the cable.

$\sum F_y = T\cos\theta - mg = 0$, so $T = \boxed{\dfrac{mg}{\cos\theta}}$.

Discussion The cable tension is larger than the weight of the ball, because the tension must also supply some horizontal force to hold the ball against the wall (perhaps for safety overnight). If the ball were so large that $\theta = 30°$, we would have $T = 1.15\ mg$. On the other hand, as θ approaches zero, the tension approaches mg.

118. Strategy Use Newton's first law of motion. Let $+y$ be up and $+x$ be to the right.

Solution

(a) Find the magnitude of $\vec{\mathbf{F}}_c$. Represent $35°$ by θ and 50.0 N by W.

$$\Sigma F_x = F_m\cos\theta - F_c\cos\phi = 0,\ \text{so}\ F_c = F_m\frac{\cos\theta}{\cos\phi}.$$

$$\Sigma F_y = -F_m\sin\theta + F_c\sin\phi - W = 0,\ \text{so}\ F_c = \frac{W + F_m\sin\theta}{\sin\phi}.$$

Eliminate F_c and solve for ϕ.

$$F_m\frac{\cos\theta}{\cos\phi} = \frac{W + F_m\sin\theta}{\sin\phi}$$

$$\tan\phi = \frac{W + F_m\sin\theta}{F_m\cos\theta} = \frac{W}{F_m\cos\theta} + \tan\theta$$

$$\phi = \tan^{-1}\left(\frac{W}{F_m\cos\theta} + \tan\theta\right) = \tan^{-1}\left[\frac{50.0\ \text{N}}{(60.0\ \text{N})\cos 35°} + \tan 35°\right] = 60°$$

So, $F_c = (60.0\ \text{N})\dfrac{\cos 35°}{\cos 59.8°} = \boxed{98\ \text{N}}$.

(b) As found in part (a), $\phi = \boxed{60°\ \text{above the horizontal}}$.

119. Strategy Set the magnitudes of the forces on the spaceship due to the Earth and the Moon equal. (The forces are along the same line and in opposite directions.)

Solution Find the distance from the Earth expressed as a percentage of the distance between the centers of the Earth and the Moon.

$$F_{sE} = \frac{GM_E m}{r_E^2} = F_{sM} = \frac{GM_M m}{r_M^2},\ \text{so}\ r_E = r_M\sqrt{\frac{M_E}{0.0123 M_E}} = 9.02\ r_M.$$

Find the percentage.

$$\frac{r_E}{r_E + r_M} = \frac{9.02\ r_M}{9.02\ r_M + r_M} = \frac{9.02}{10.02} = 0.900$$

The distance from the Earth is $\boxed{\text{90.0\% of the Earth-Moon distance}}$.

Discussion If a manned spacecraft goes through this point, the people on board do not feel a change. With the rocket engines turned off, they are floating about in "microgravity" or "normal-forcelessness" throughout the greater part of their journey. We choose not to use the term "weightless" because gravity really does act on them everywhere except at this one point. The coasting spacecraft slows down on one side and speeds up on the other side of the 90% point.

120. (a) Strategy Use Newton's law of universal gravitation.

Solution Find the weight of the satellite when in orbit.

$$F_g = \frac{GM_E m}{r^2} = \frac{(6.674\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.974\times10^{24}\ \text{kg})(320\ \text{kg})}{(6.371\times10^6\,\text{m}+16{,}000\times10^3\,\text{m})^2} = \boxed{250\ \text{N}}$$

(b) Strategy The weight on Earth is equal to the satellite's mass times g.

Solution Find the weight of the satellite when it was on the launch pad.

$$F_g = mg = (320\ \text{kg})(9.80\ \text{N/kg}) = \boxed{3100\ \text{N}}$$

(c) Strategy Use Newton's third law of motion.

Solution According to Newton's third law if motion, the satellite exerts a force on the Earth equal and opposite to the force the Earth exerts on it; that is, $\boxed{\text{250 N toward the satellite}}$.

121. (a) Strategy Set the magnitudes of the forces on the spacecraft due to the Earth and to the Sun equal.

Solution Find the distance of the spacecraft from Earth. Let D be the Sun-to-Earth distance

$$F_{sS} = \frac{GM_S m}{r_S^2} = F_{sE} = \frac{GM_E m}{r_E^2},\ \text{so}\ \frac{r_E}{r_S} = \sqrt{\frac{M_E}{M_S}}.$$

$$r_E + r_S = D = r_E + \frac{r_E}{\sqrt{M_E/M_S}} = r_E\left(1+\sqrt{M_S/M_E}\right)\ \text{so}\ r_E = \frac{D}{1+\sqrt{M_S/M_E}}$$

The distance of the spacecraft from the Earth is

$$r_E = \frac{1.50\times10^{11}\ \text{m}}{1+\sqrt{\dfrac{1.987\times10^{30}\ kg}{5.974\times10^{24}\ \text{kg}}}} = \boxed{2.60\times10^8\ \text{m from Earth}}$$

(b) Strategy Imagine the spacecraft is a small distance d closer to the Earth and find out which gravitational force is stronger, the Earth's or the Sun's.

Solution At the equilibrium point the net gravitational force is zero. If the spacecraft is closer to the Earth than the equilibrium point, then the force due to the Earth is greater than that due to the Sun. If the spacecraft is closer to the Sun than the equilibrium point, then the force due to the Sun is greater than that due to the Earth. So, if the spacecraft is close to, but not at, the equilibrium point, the net force tends to pull it $\boxed{\text{away from}}$ the equilibrium point.

Discussion In (b) we say that the equilibrium of the spacecraft is 'unstable.' We have assumed the Sun and Earth are at rest. If we more realistically assume the Earth is in orbit around the Sun, there are five Lagrange points at which an object can be at rest relative to the Earth, orbiting in synchronization with it. The SOHO spacecraft is at the Lagrange point between the Earth and the Sun.

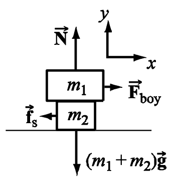
122. (a) Strategy Since the coefficient of static friction between the blocks is greater than that between the bottom block and the floor, the two blocks will just begin to slide as a unit $(a \approx 0)$. The boy must push with a horizontal force equal to the maximum force of static friction on the bottom block due to the floor. Let the top block be 1 and the bottom block be 2. Use Newton's first law.

Solution For the two blocks as a system

$\Sigma F_y = N - (m_1+m_2)g = 0$ and

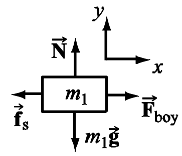
$\Sigma F_x = F_{boy} - f_{s,max} = F_{boy} - \mu_s N = F_{boy} - \mu_s(m_1+m_2)g = 0,$ so

$F_{boy} = \mu_s(m_1+m_2)g = 0.220(5.00\ \text{kg}+2.00\ \text{kg})(9.80\ \text{m/s}^2) = \boxed{15.1\ \text{N}}.$



(b) Strategy The block is now sliding and the boy is still pushing. There are two horizontal forces acting on the system of blocks, the push of the boy and the force of kinetic friction between the bottom block and the floor. There are also two horizontal forces acting on each block alone; for the top block, the forces are the push of the boy and the force of static friction due to the bottom block; for the bottom block, the force of static friction due to the top block and the force of kinetic friction due to the floor. Use Newton's second law.

Solution For the two-block system:



$\Sigma F_x = F_{\text{boy}} - \mu_k(m_1+m_2)g = (m_1+m_2)a,$ so $a = \dfrac{F_{\text{boy}}}{m_1+m_2} - \mu_k g.$

For the top block alone:
$\Sigma F_y = N - m_1 g = 0$ and $\Sigma F_x = F_{\text{boy}} - f_s = F_{\text{boy}} - \mu_s N = F_{\text{boy}} - \mu_s m_1 g = m_1 a.$

Substitute the expression for the acceleration a found above and solve for the maximum force.

$F_{\text{boy}} - \mu_s m_1 g = m_1 a = m_1\left(\dfrac{F_{\text{boy}}}{m_1+m_2} - \mu_k g\right),$ so clearing of parentheses and gathering like terms gives

$$F_{\text{boy}} = \frac{(\mu_s - \mu_k)m_1 g(m_1+m_2)}{m_2} = \frac{(0.400-0.200)(5.00\text{ kg})(9.80\text{ m/s}^2)(5.00\text{ kg}+2.00\text{ kg})}{2.00\text{ kg}} = \boxed{34.3\text{ N}}.$$

Discussion You may need to think hard to visualize the two simultaneous sliding motions (or one actual plus one almost ready to happen). In part (a) the forces of interaction between the blocks do not appear when we consider the two-block system.

123. Strategy The rope has the same tension throughout its length. Use Newton's second law.

Solution Since the box is to be lifted with constant velocity, the acceleration must be zero. For the pulley on the left, we have $\Sigma F_y = 2T - mg = 0,$ so $T = mg/2.$ Since the tension is the same along the length of the rope, the minimum force required is equal to the tension. Thus, the pull force is

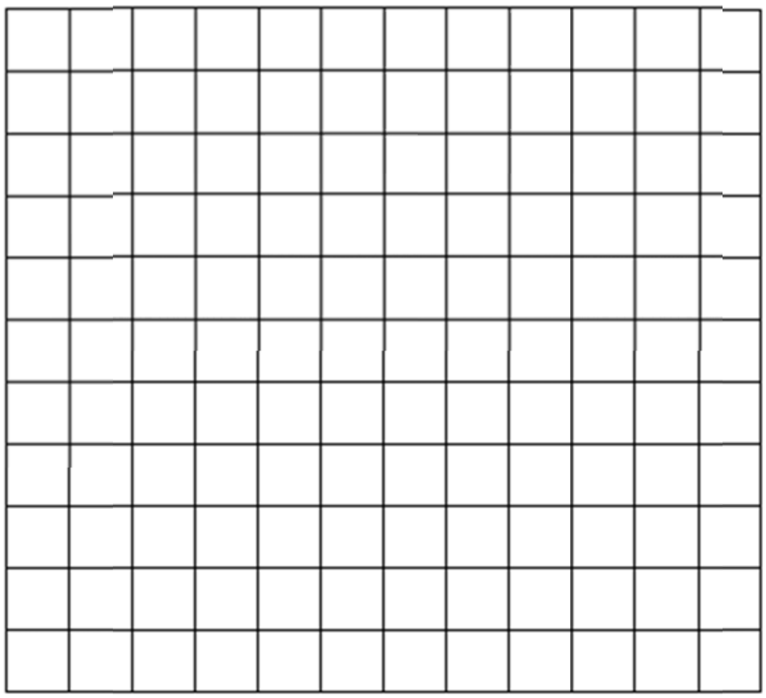
$$F = T = \frac{mg}{2} = \frac{(98.0\text{ kg})(9.80\text{ m/s}^2)}{2} = \boxed{480\text{ N}}.$$

Chapter

Section .1

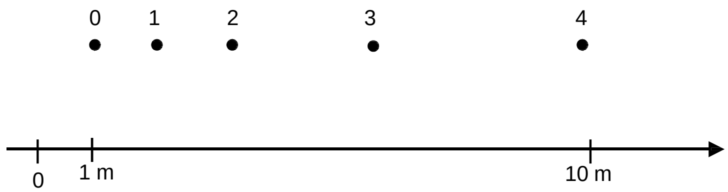
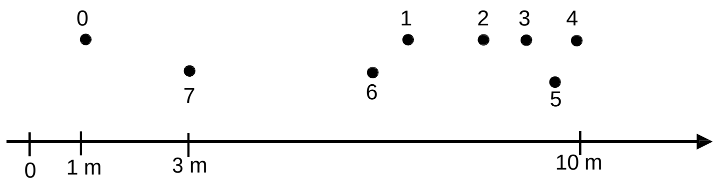
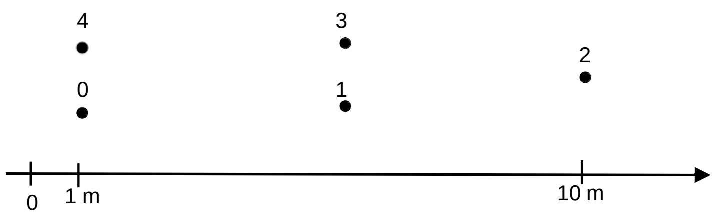
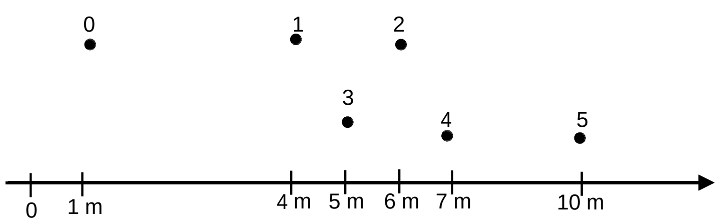
1. Displacement

A sailboat travels west for 3.0 km, then south for 6.0 km south, then 45° north of east for 7.0 km. Draw vector arrows on the grid below to illustrate the sum of the three displacements. Based on your sketch, what is the *approximate* magnitude and direction of the total displacement? One grid represents 1 km.



2. **Position and Displacement**

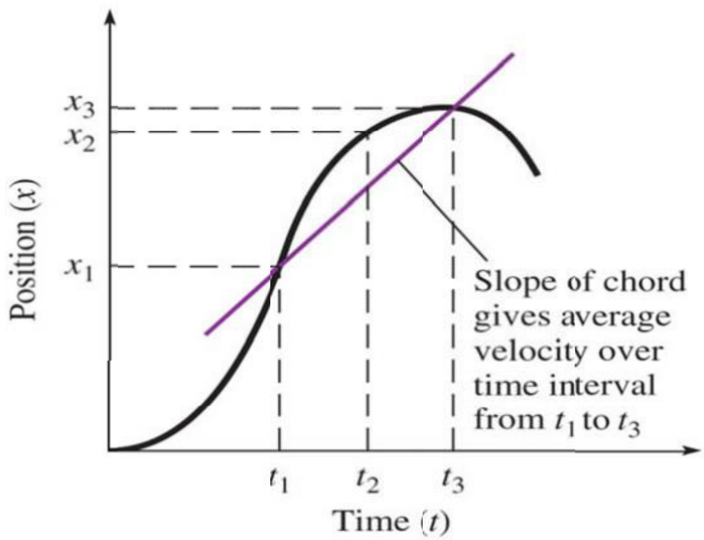
Motion diagrams for several objects in horizontal 1-D motion are shown below. Use the given scales to determine the distance traveled and the displacement for each case. Explain why or why not these numbers are different.

	Distance Traveled (m)	Displacement (m) Δx
		
		
		
		

Section .2

3. Speed and Velocity

The graph below shows the position of a train on an east-west track as a function of time. The +*x* direction is east. *[this is from Fig 3.11 in text]*

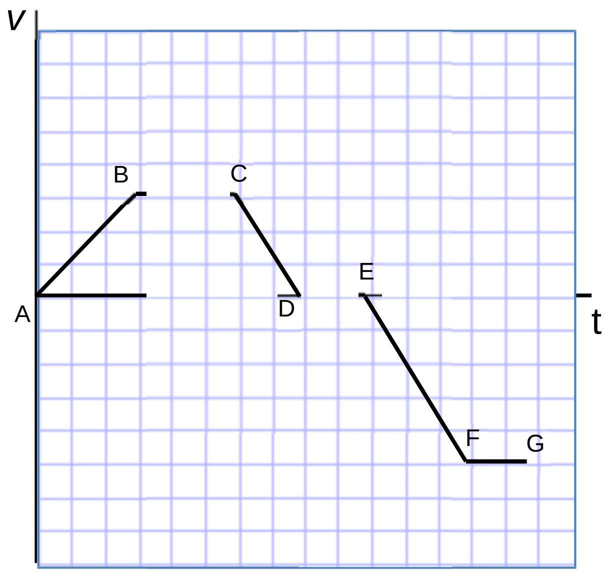


(a) Rank the instants t_1, t_2, t_3 in order of decreasing instantaneous speed. Explain your reasoning.

(b) During which of the time intervals ($0 < t < t_1$, $t_1 < t < t_2$, $t_2 < t < t_3$, and $t < t_3$), if any, is the train's speed increasing? During which time intervals is the train's speed decreasing? Explain.

(c) During which of the time intervals, if any, is the train moving west? Explain.

4. Consider the velocity vs. time Graph shown below of a car moving along a horizontal road. The positive x-direction is to th right, and asume that the car starts at x=0 at time t=0s. For the questions a) thru e) find the correct answer(s) from the list below.



a) During which segment(s) does the car speed up while moving to the right?

______

b) During which segement (s) does the car speed up while moving to the left?

____

c) During which segment(s) does the car slow down while moving to the right?

______

d) During which segement (s) does the car slow down while moving to the left?

____

e) During which segment dies the car travel at a constant velocity?.

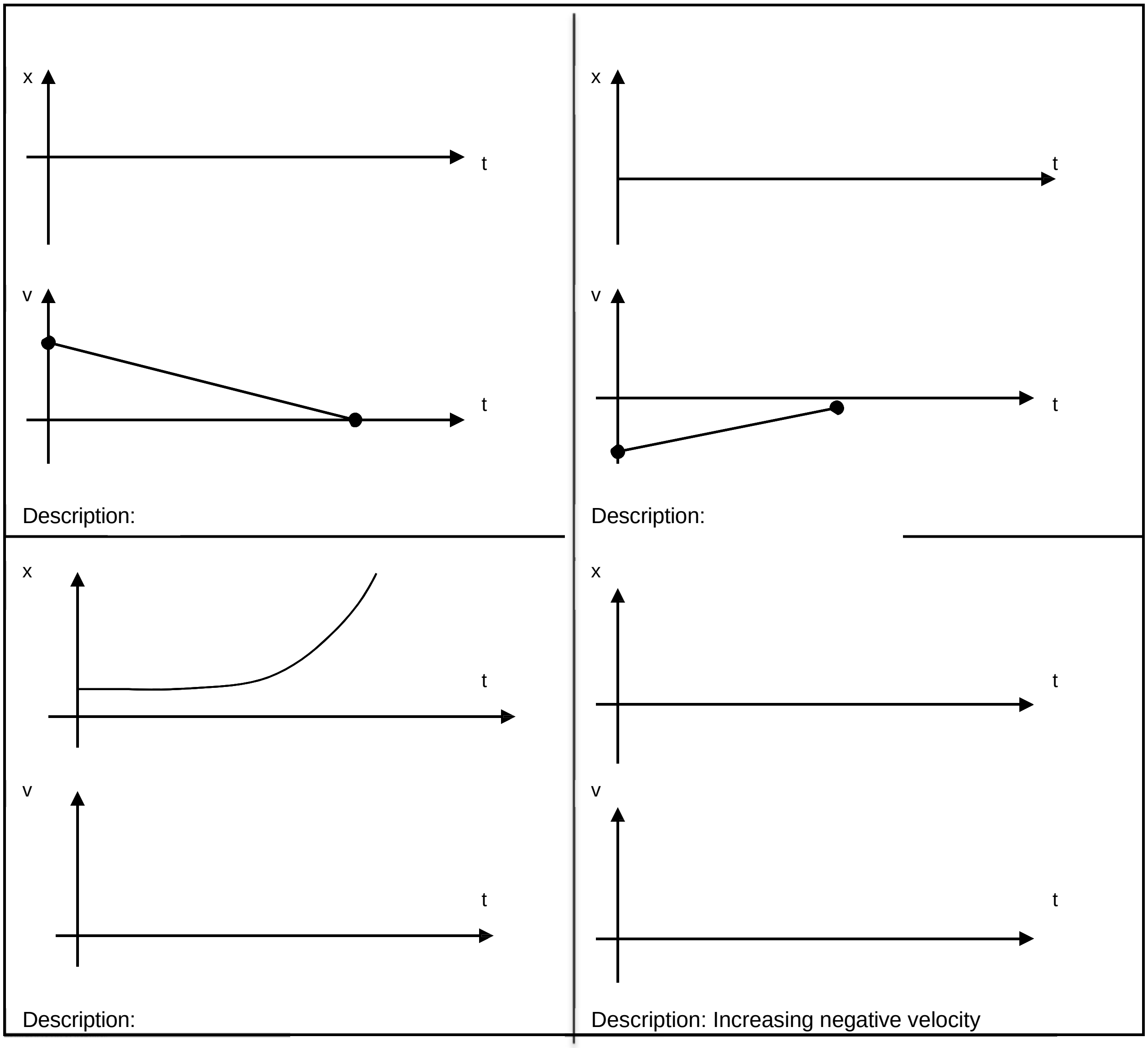
______

f) At which point (A, B, C, D, E, F, or G) is the car furthest from the origin (x=0)?

______

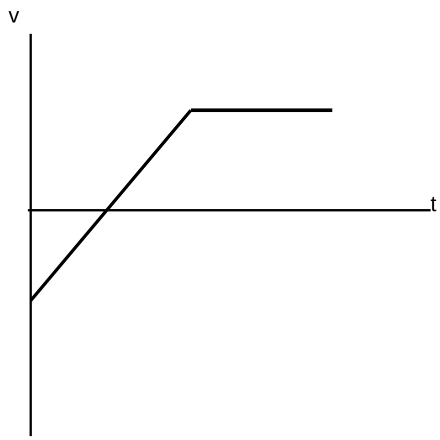
5. Velocity

For each of the following cases construct the missing graph(s) and give a written description of the motion.

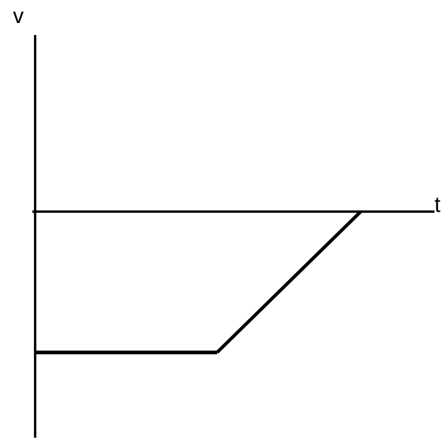


6. Given below are two velocity-vs-time graphs. Draw the a-vs-t and x-vs-t graphs, given that at time t=0 the object was at x=0.

a)

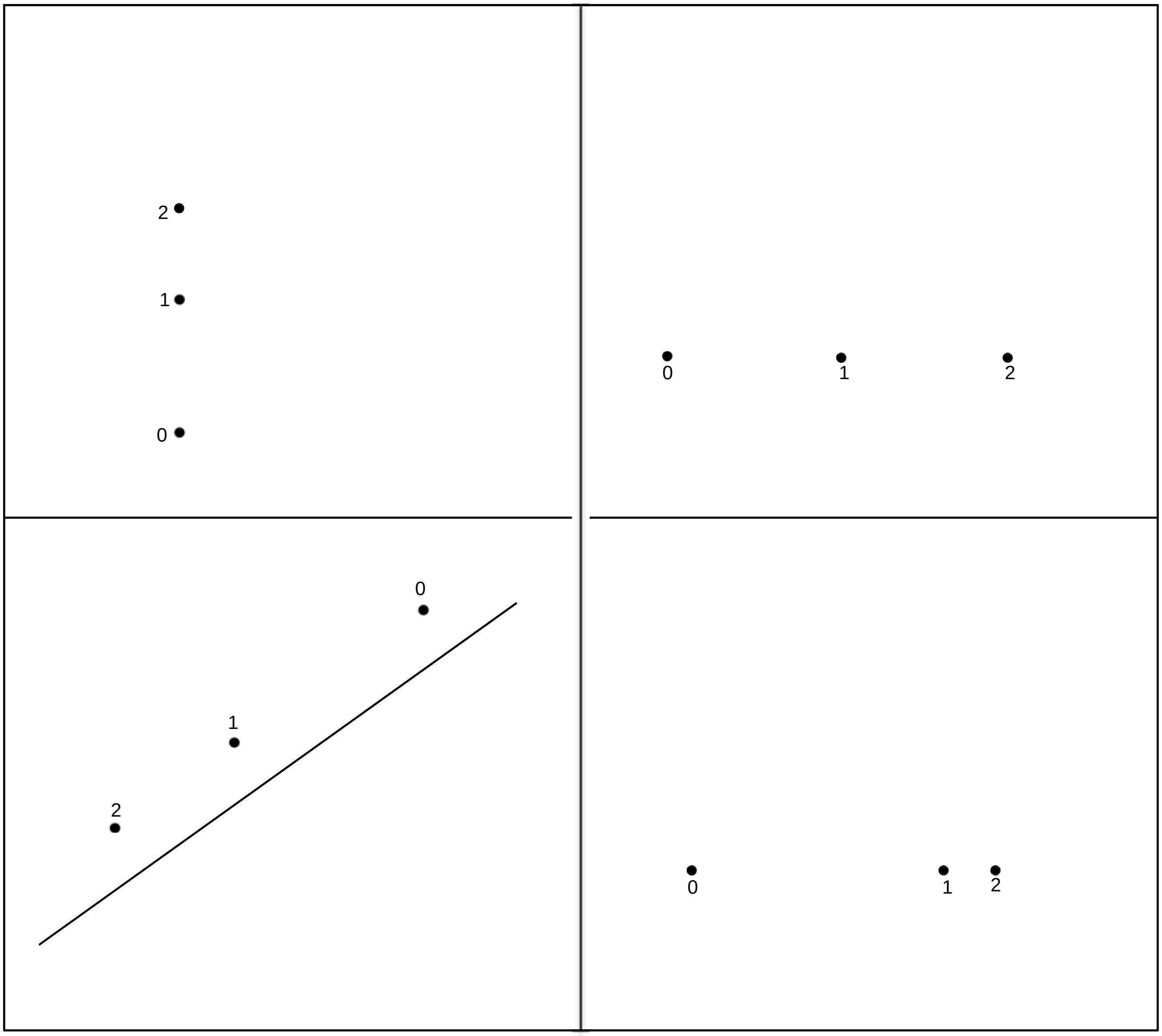


b)



7. Velocity - Average Velocity and Motion Diagrams

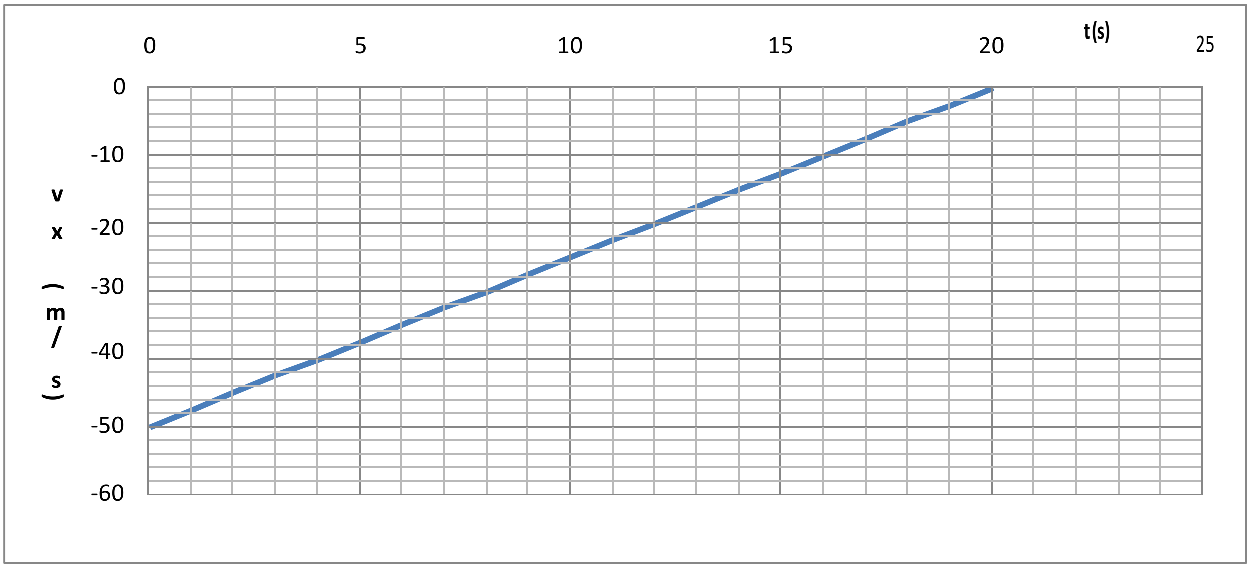
Partial motion diagrams for objects in 1-2D motion are shown below. Draw vectors for the initial velocity, final velocity, and acceleration on each diagram.



Section 2.3

Problems to 1 : Representations of Motion . [each SC]

A train of mass 2×10^5 kg is moving on a straight track, braking to slow down as it approaches a station. The *x*-axis points south. The graph below shows the velocity v_x as a function of time.



.(a) Is the velocity north or south? Explain.

(b) Draw velocity vectors for the train at t = 0, 5 s, and 10 s.

.   (a) Is the acceleration constant? Explain.

(b) Find the magnitude of the acceleration. Is the acceleration north or south? Explain.

(c) What is the net force acting on the train?

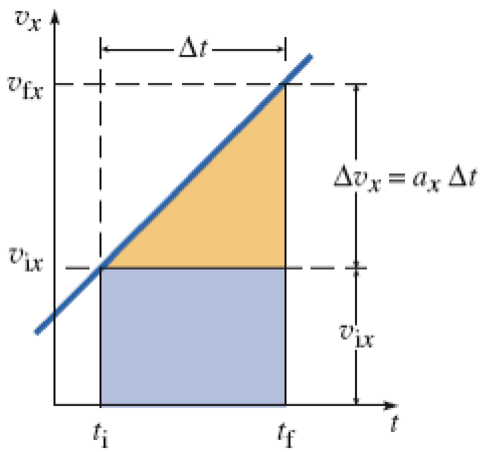
1 .(a) Is the displacement between t = 5 s and t = 10 s north or south? Explain.

(b) Show on the graph how you would calculate the displacement of the train between t = 5 s and t = 10 s. (No need to calculate the value; just represent the quantity visually.)

(c) Make a qualitative motion diagram for the train (i.e. a series of dots showing the train's position every 5 s). It's not necessary to calculate numerical values; just illustrate qualitatively what the motion is like.

1 . Graphical Representations of Motion

The graph below shows $v_x(t)$ for an airplane that is speeding up.



(a) Is the acceleration constant? Explain.

(b) Write an expression for the area of the shaded triangle above v_{ix} in terms of quantities specified on the graph.

(c) Write an expression for the area of the shaded rectangle above v_{ix} in terms of quantities specified on the graph.

(d) Write an expression for the sum of the areas of the triangle and rectangle. What quantity does the total area represent?

Section

Problems to : Motion Diagrams

For each of the motions below sketch a motion diagram as described in section . You may use a dot to represent the object in motion. First, establish a coordinate axis for each motion. Draw arrows to scale above each dot to represent the velocity vector. Indicate the acceleration direction for each constant-acceleration segment of the motion. (SC)

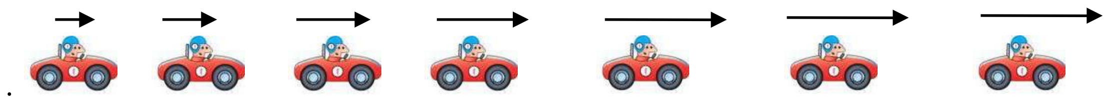
. A car is travelling at a constant speed of 35 mph when the driver sees a stop sign. The driver takes 5 seconds to start applying brakes and the car eventually comes to a stop at the stop sign.

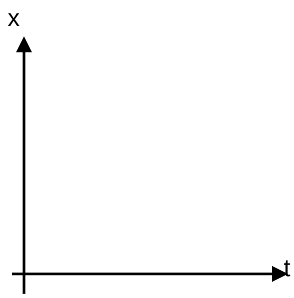
. In the 100-m dash, a runner begins from rest and accelerates at constant rate until the 60-m mark and then maintains her maximum speed until crossing the finish line.

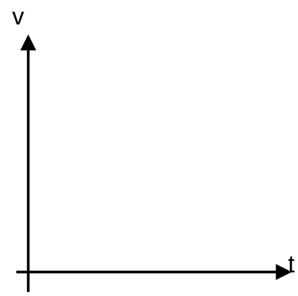
. You get into an elevator at the ground floor of a 50 story building and press the button for the 50^{th} floor. The elevator accelerates for 10 seconds, maintains the maximum speed for 60 seconds and then comes to a stop at the top floor.

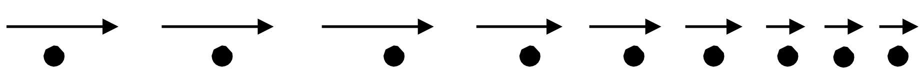
Problems & : Graphical Representations of Motion

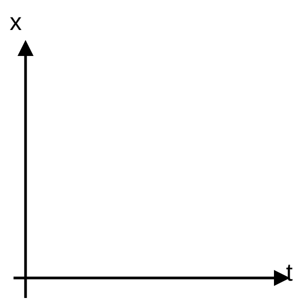
Draw position-vs-time and Velocity-vs-time graphs for the motions represented by the following motion diagrams.

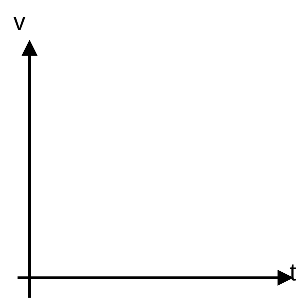












. Graphical Representations of Motion

You get on to an elevator on the 50^{th} floor and press the button for the ground floor. The elevator speeds up until it reaches the maximum speed, and then maintains this speed for most of the decent. Finally it slows down and stop on the ground floor.

a. Draw the motion diagram for the elevator.

b. Draw velocity-vs-time graph and position-vs-time graph for the elevator.

Section

. Kinematic Equations – Constant Force

Construct a physical situation involving 1-D horizontal motion of a point mass with a constant acceleration that is consistent with the following kinematic equations:

Case A:

$$625 \text{ m} = \tfrac{1}{2} (500\text{N} / 10 \text{ kg}) (5 \text{ sec})^2$$

Case B:

$$2600 \text{ m} = 50 \text{ m} + 5 \text{ m/s} (10 \text{ s}) + \tfrac{1}{2} (500\text{N} / 10 \text{ kg}) (10 \text{ sec})^2$$

Case C:

$$(20 \text{ m/s})^2 = 2 (1000 \text{ N} / 100 \text{ kg}) (20 \text{ m})$$

. Kinematic Equations – Constant Force

State the kinematic equation that would be used if given the following information:

Case A:

M, F_{net}, ⊗X, ⊗t, v_o

Case B:

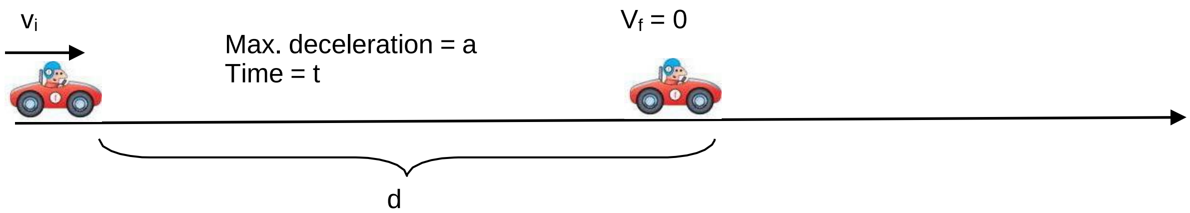
M, F_{net}, ⊗X, v_o, v_f

Case C:

M, F_{net}, v_o, v_f, ⊗t

. **Kinematics**

A car travelling at a constant speed of v_i can come to a stop in a minimum distance *d* in time t, given that the car has a maximum deceleration *a* when brakes are fully engaged.



Now suppose the same car (with the same maximum deceleration *a*) is traveling at an initial speed of $2v_i$, and has a minimum stopping distance *d'* in time *t'*. Using kinematic equations, find

a. The ratio $\frac{t'}{t}$

b. The ratio $\frac{d'}{d}$