CHAPTER 4

Forces in One Dimension

Practice Problems

4.1 Force and Motion pages 87–95

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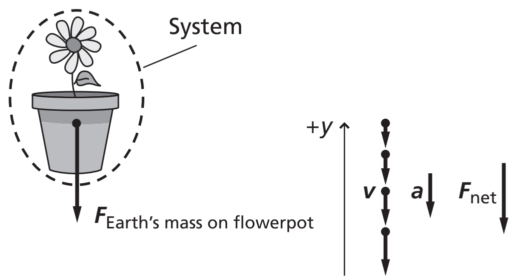
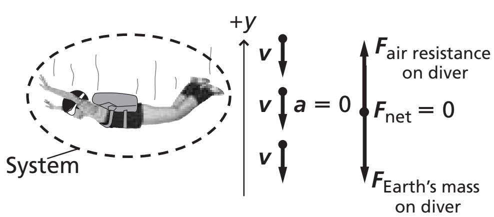
For each of the following situations, specify the system and draw a motion diagram and a free-body diagram. Label all forces with their agents, and indicate the direction of the acceleration and of the net force. Draw vectors of appropriate lengths.

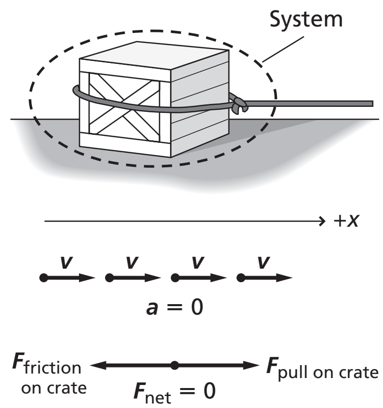
1. A flowerpot falls freely from a windowsill. (Ignore any forces due to air resistance.)



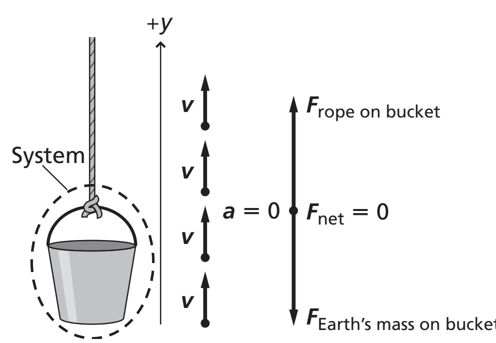
2. A sky diver falls downward through the air at constant velocity. (The air exerts an upward force on the person.)



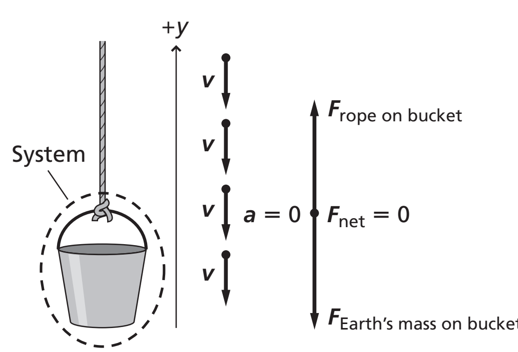
3. A cable pulls a crate at a constant speed across a horizontal surface. The surface provides a force that resists the crate's motion.



4. A rope lifts a bucket at a constant speed. (Ignore air resistance.)



5. A rope lowers a bucket at a constant speed. (Ignore air resistance.)



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6. Two horizontal forces, 225 N and 165 N, are exerted on a canoe. If these forces are applied in the same direction, find the net horizontal force on the canoe.

   $F_{net} = 225\ N + 165\ N = 3.90\times10^2\ N$

   in the direction of the two forces

7. If the same two forces as in the previous problem are exerted on the canoe in opposite directions, what is the net horizontal force on the canoe? Be sure to indicate the direction of the net force.

   $F_{net} = 225\ N - 165\ N = 6.0\times10^1\ N$

   in the direction of the larger force

8. Three confused sleigh dogs are trying to pull a sled across the Alaskan snow. Alutia pulls east with a force of 35 N, Seward also pulls east but with a force of 42 N, and big Kodiak pulls west with a force of 53 N. What is the net force on the sled?

   Identify east as positive and the sled as the system.

   $$F_{net} = F_{Alutia\ on\ sled} + F_{Seward\ on\ sled} - F_{Kodiak\ on\ sled}$$
   $$= 35\ N + 42\ N - 53\ N$$
   $$= 24\ N$$
   $$F_{net} = 24\ N\ east$$

Section Review

4.1 Force and Motion pages 87–95

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9. **Force** Identify each of the following as either **a, b,** or **c:** weight, mass, inertia, the push of a hand, thrust, resistance, air resistance, spring force, and acceleration.

   a. a contact force

   b. a field force

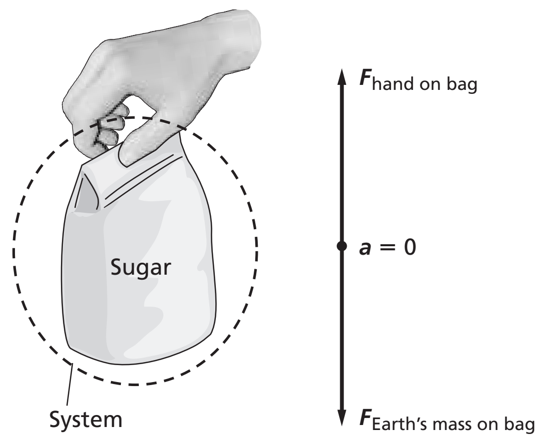
   c. not a force

   weight (b), mass (c), inertia (c), push of a hand (a), thrust (a), resistance (a), air resistance (a), spring force (a), acceleration (c)

10. **Inertia** Can you feel the inertia of a pencil? Of a book? If you can, describe how.

    Yes, you can feel the inertia of either object by using your hand to give either object an acceleration; that is, try to change the objects velocity.

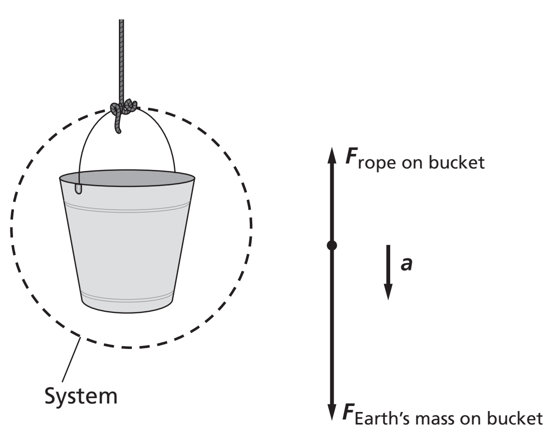
11. **Free-Body Diagram** Draw a free-body diagram of a bag of sugar being lifted by your hand at a constant speed. Specifically identify the system. Label all forces with their agents and make the arrows the correct lengths.



12. **Direction of Velocity** If you push a book in the forward direction, does this mean its velocity has to be forward?

    No, it could be moving backward and you would be reducing that velocity.

13. **Free-Body Diagram** Draw a free-body diagram of a water bucket being lifted by a rope at a decreasing speed. Specifically identify the system. Label all forces with their agents and make the arrows the correct lengths.



14. **Critical Thinking** A force of 1 N is the only force exerted on a block, and the acceleration of the block is measured. When the same force is the only force exerted on a second block, the acceleration is three times as large. What can you conclude about the masses of the two blocks?

Because $m = F/a$ and the forces are the same, the mass of the second block is one-third the mass of the first block.

Practice Problems

4.2 Using Newton's Laws pages 96–101

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15. You place a watermelon on a spring scale at the supermarket. If the mass of the watermelon is 4.0 kg, what is the reading on the scale?

The scale reads the weight of the watermelon:

$F_g = mg = (4.0\ \text{kg})(9.80\ \text{m/s}^2) = 39\ \text{N}$

16. Kamaria is learning how to ice-skate. She wants her mother to pull her along so that she has an acceleration of 0.80 m/s^2. If Kamaria's mass is 27.2 kg, with what force does her mother need to pull her? (Neglect any resistance between the ice and Kamaria's skates.)

$F_{net} = ma = (27.2\ \text{kg})(0.80\ \text{m/s}^2) = 22\ \text{N}$

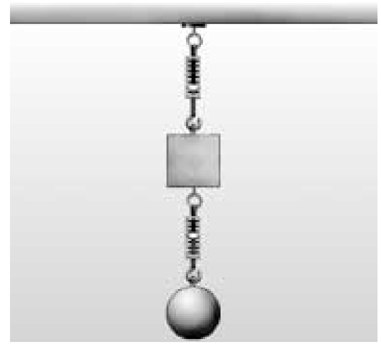
17. Taru and Reiko simultaneously grab a 0.75-kg piece of rope and begin tugging on it in opposite directions. If Taru pulls with a force of 16.0 N and the rope accelerates away from her at 1.25 m/s^2, with what force is Reiko pulling?

Identify Reiko's direction as positive and the rope as the system.

$F_{net} = F_{\text{Rieko on rope}} - F_{\text{Taru on rope}} = ma$

$$F_{\text{Rieko on rope}} = ma + F_{\text{Taru on rope}} = (0.75\ \text{kg})(1.25\ \text{m/s}^2) + 16.0\ \text{N} = 17\ \text{N}$$

18. In **Figure 4-8,** the block has a mass of 1.2 kg and the sphere has a mass of 3.0 kg. What are the readings on the two scales? (Neglect the masses of the scales.)



■ **Figure 4-8**

Bottom scale: Identify the sphere as the system and up as positive.

$F_{net} = F_{\text{scale on sphere}} - F_{\text{Earth's mass on sphere}} = ma = 0$

$$F_{\text{scale on sphere}} = F_{\text{Earth's mass on sphere}} = m_{\text{sphere}}g = (3.0\ \text{kg})(9.80\ \text{m/s}^2) = 29\ \text{N}$$

Top scale: Identify the block as the system and up as positive.

$F_{net} = F_{\text{top scale on block}} - F_{\text{bottom scale on block}} - F_{\text{Earth's mass on block}} = ma = 0$

$$F_{\text{top scale on block}} = F_{\text{bottom scale on block}} + F_{\text{Earth's mass on block}} = F_{\text{bottom scale on block}} + m_{\text{block}}g = 29\ \text{N} + (1.2\ \text{kg})(9.80\ \text{m/s}^2) = 41\ \text{N}$$

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19. On Earth, a scale shows that you weigh 585 N.

a. What is your mass?

The scale reads 585 N. Since there is no acceleration, your weight equals the downward force of gravity:

$F_g = mg$

so $m = \frac{F_g}{g} = \frac{585\text{ N}}{9.80\text{ m/s}^2} = 59.7\text{ kg}$

b. What would the scale read on the Moon ($g = 1.60\text{ m/s}^2$)?

On the moon, *g* changes:

$F_g = mg_{Moon}$

$= (59.7\text{ kg})(1.60\text{ m/s}^2)$

$= 95.5\text{ N}$

20. Use the results from Example Problem 2 to answer questions about a scale in an elevator on Earth. What force would be exerted by the scale on a person in the following situations?

a. The elevator moves at constant speed.

Constant speed, so $a = 0$ and $F_{net} = 0$.

$F_{scale} = F_g$

$= mg = (75.0\text{ kg})(9.80\text{ m/s}^2)$

$= 735\text{ N}$

b. It slows at 2.00 m/s^2 while moving upward.

Slowing while moving upward, so

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

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

$= ma + mg$

$= m(a + g)$

$= (75.0\text{ kg})(-2.00\text{ m/s}^2 + 9.80\text{ m/s}^2)$

$= 585\text{ N}$

c. It speeds up at 2.00 m/s^2 while moving downward.

Accelerating downward,

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

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

$= ma + mg$

$= m(a + g)$

$= (75.0\text{ kg})(-2.00\text{ m/s}^2 + 9.80\text{ m/s}^2)$

$= 585\text{ N}$

d. It moves downward at constant speed.

Constant speed, so $a = 0$ and $F_{net} = 0$

$F_{scale} = F_g = mg$

$= (75.0\text{ kg})(9.80\text{ m/s}^2)$

$= 735\text{ N}$

e. It slows to a stop at a constant magnitude of acceleration.

Constant acceleration = *a*, though the sign of *a* depends on the direction of the motion that is ending.

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

$= ma + mg$

$= (75.0\text{ kg})(a) + (75.0\text{ kg})(9.80\text{ m/s}^2)$

$= (75.0\text{ kg})(a) + 735\text{ N}$

Section Review

4.2 Using Newton's Laws pages 96–101

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21. Lunar Gravity Compare the force holding a 10.0-kg rock on Earth and on the Moon. The acceleration due to gravity on the Moon is 1.62 m/s^2.

To hold the rock on Earth:

$$F_{net} = F_{Earth\ on\ rock} - F_{hold\ on\ rock} = 0$$

$$F_{hold\ on\ rock} = F_{Earth\ on\ rock} = mg_{Earth}$$
$$= (10.0\ kg)(9.80\ m/s^2)$$
$$= 98.0\ N$$

To hold the rock on the Moon:

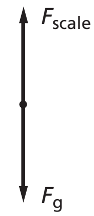
$$F_{net} = F_{Moon\ on\ rock} - F_{hold\ on\ rock} = 0$$

$$F_{hold\ on\ rock} = F_{Moon\ on\ rock} = mg_{Moon}$$
$$= (10.0\ kg)(1.62\ m/s^2)$$
$$= 16.2\ N$$

22. Real and Apparent Weight You take a ride in a fast elevator to the top of a tall building and ride back down while standing on a bathroom scale. During which parts of the ride will your apparent and real weights be the same? During which parts will your apparent weight be less than your real weight? More than your real weight? Sketch free-body diagrams to support your answers.

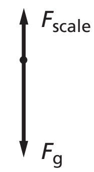
Apparent weight and real weight are the same when you are traveling either up or down at a constant velocity. Apparent weight is less than real weight when the elevator is slowing while rising or speeding up while descending. Apparent weight is greater when speeding up while rising or slowing while going down.

Constant Velocity



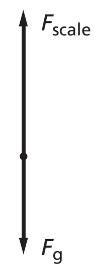
apparent weight = real weight

Slowing While Rising/ Speeding Up While Descending



apparent weight < real weight

Speeding Up While Rising/ Slowing While Descending



apparent weight > real weight

23. Acceleration Tecle, with a mass of 65.0 kg, is standing by the boards at the side of an ice-skating rink. He pushes off the boards with a force of 9.0 N. What is his resulting acceleration?

Identify Tecle as the system and the direction away from the boards as positive. The ice can be treated as a resistance-free surface.

$$F_{net} = F_{boards\ on\ Tecle} = ma$$

$$a = \frac{F_{boards\ on\ Tecle}}{m}$$
$$= \frac{9.0\ N}{65.0\ kg}$$
$$= 0.14\ m/s^2 \text{ away from the boards}$$

24. Motion of an Elevator You are riding in an elevator holding a spring scale with a 1-kg mass suspended from it. You look at the scale and see that it reads 9.3 N. What, if anything, can you conclude about the elevator's motion at that time?

If the elevator is stationary or moving at a constant velocity, the scale should read 9.80 N. Because the scale reads a lighter weight, the elevator must be accelerating downward. To find the exact acceleration: identify up as positive and the 1-kg mass as the system.

$$F_{\text{net}} = F_{\text{scale on 1 kg}} - F_{\text{Earth's mass on 1 kg}} = ma$$

$$a = \frac{F_{\text{scale on 1 kg}} - F_{\text{Earth's mass on 1 kg}}}{m}$$

$$= \frac{9.3\text{ N} - 9.80\text{ N}}{1\text{ kg}}$$

$$= -0.5\text{ m/s}^2$$

$$= 0.5\text{ m/s}^2\text{ downward}$$

25. Mass Marcos is playing tug-of-war with his cat using a stuffed toy. At one instant during the game, Marcos pulls on the toy with a force of 22 N, the cat pulls in the opposite direction with a force of 19.5 N, and the toy experiences an acceleration of 6.25 m/s^2. What is the mass of the toy?

Identify the toy as the system and the direction toward his cat as the positive direction.

$$F_{\text{net}} = F_{\text{Marcos on toy}} - F_{\text{cat on toy}} = ma$$

$$m = \frac{F_{\text{Marcos on toy}} - F_{\text{cat on toy}}}{a}$$

$$= \frac{22\text{ N} - 19.5\text{ N}}{6.25\text{ m/s}^2}$$

$$= 0.40\text{ kg}$$

26. Acceleration A sky diver falls at a constant speed in the spread-eagle position. After he opens his parachute, is the sky diver accelerating? If so, in which direction? Explain your answer using Newton's laws.

Yes, for a while the diver is accelerating upward because there is an additional upward force due to air resistance on the parachute. The upward acceleration causes the driver's downward velocity to decrease. Newton's second law says that a net force in a certain direction will result in an acceleration in that direction ($F_{\text{net}} = ma$).

27. Critical Thinking You have a job at a meat warehouse loading inventory onto trucks for shipment to grocery stores. Each truck has a weight limit of 10,000 N of cargo. You push each crate of meat along a low-resistance roller belt to a scale and weigh it before moving it onto the truck. However, right after you weigh a 1000-N crate, the scale breaks. Describe a way in which you could apply Newton's laws to figure out the approximate masses of the remaining crates.

Answers may vary. One possible answer is the following: You can neglect resistance if you do all your maneuvering on the roller belt. Because you know the weight of the 1000 N crate, you can use it as your standard. Pull on the 1000 N crate with a particular force for 1 s, estimate its velocity, and calculate the acceleration that your force gave to it. Next, pull on a crate of unknown mass with as close to the same force as you can for 1 s. Estimate the crate's velocity and calculate the acceleration your force gave to it. The force you pulled with on each crate will be the net force in each case.

$$F_{\text{net 1000-N crate}} = F_{\text{net unknown crate}}$$

$$(1000\text{ N})(a_{\text{1000-N crate}}) = (m_{\text{unk}})(a_{\text{unk}})$$

$$m_{\text{unk}} = \frac{(1000\text{ N})(a_{\text{1000-N crate}})}{a_{\text{unk}}}$$

Practice Problems

4.3 Interaction Forces pages 102–107

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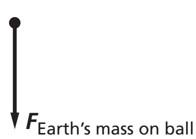
28. You lift a relatively light bowling ball with your hand, accelerating it upward. What are the forces on the ball? What forces does the ball exert? What objects are these forces exerted on?

The forces on the ball are the force of your hand and the gravitational force of Earth's mass. The ball exerts a force on your hand and a gravitational force on Earth. All these forces are exerted on your hand, on the ball, or on Earth.

29. A brick falls from a construction scaffold. Identify any forces acting on the brick. Also identify any forces that the brick exerts and the objects on which these forces are exerted. (Air resistance may be ignored.)

The only force acting on the brick is the gravitational attraction of Earth's mass. The brick exerts an equal and opposite force on Earth.

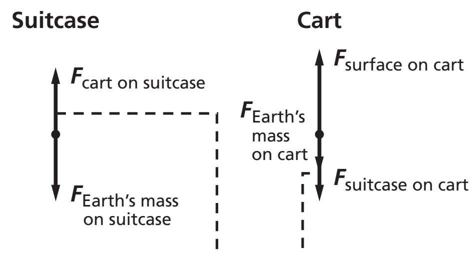
30. You toss a ball up in the air. Draw a free-body diagram for the ball while it is still moving upward. Identify any forces acting on the ball. Also identify any forces that the ball exerts and the objects on which these forces are exerted.



The only force acting on the ball is the force of Earth's mass on the ball, when ignoring air resistance. The ball exerts an equal and opposite force on Earth.

31. A suitcase sits on a stationary airport luggage cart, as in **Figure 4-13.** Draw a free-body diagram for each object and specifically indicate any interaction pairs between the two.

■ **Figure 4-13**



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32. You are helping to repair a roof by loading equipment into a bucket that workers hoist to the rooftop. If the rope is guaranteed not to break as long as the tension does not exceed 450 N and you fill the bucket until it has a mass of 42 kg, what is the greatest acceleration that the workers can give the bucket as they pull it to the roof?

Identify the bucket as the system and up as positive.

$$F_{\text{net}} = F_{\text{rope on bucket}} - F_{\text{Earth's mass on bucket}} = ma$$

$$a = \frac{F_{\text{rope on bucket}} - F_{\text{Earth's mass on bucket}}}{m}$$

$$= \frac{F_{\text{rope on bucket}} - mg}{m}$$

$$= \frac{450\ \text{N} - (42\ \text{kg})(9.80\ \text{m/s}^2)}{42\ \text{kg}}$$

$$= 0.91\ \text{m/s}^2$$

33. Diego and Mika are trying to fix a tire on Diego's car, but they are having trouble getting the tire loose. When they pull together, Mika with a force of 23 N and Diego with a force of 31 N, they just barely get the tire to budge. What is the magnitude of the strength of the force between the tire and the wheel?

Identify the tire as the system and the direction of pulling as positive.

$$F_{\text{net}} = F_{\text{wheel on tire}} - F_{\text{Mika on tire}} - F_{\text{Diego on tire}} = ma = 0$$

$$F_{\text{wheel on tire}} = F_{\text{Mika on tire}} + F_{\text{Diego on tire}} = 23\text{ N} + 31\text{ N} = 54\text{ N}$$

Section Review

4.3 Interaction Forces pages 102–107

page 107

34. Force Hold a book motionless in your hand in the air. Identify each force and its interaction pair on the book.

The forces on the book are downward force of gravity due to the mass of Earth and the upward force of the hand. The force of the book on Earth and the force of the book on the hand are the other halves of the interaction pairs.

35. Force Lower the book from problem 34 at increasing speed. Do any of the forces or their interaction-pair partners change? Explain.

Yes, the force of the hand on the book becomes smaller so there is a downward acceleration. The force of the book also becomes smaller; you can feel that. The interaction pair partners remain the same.

36. Tension A block hangs from the ceiling by a massless rope. A second block is attached to the first block and hangs below it on another piece of massless rope. If each of the two blocks has a mass of 5.0 kg, what is the tension in each rope?

For the bottom rope with the positive direction upward:

$$F_{\text{net}} = F_{\text{bottom rope on bottom block}} - F_{\text{Earth's mass on bottom block}} = ma = 0$$

$$F_{\text{bottom rope on bottom block}} = F_{\text{Earth's mass on bottom block}} = mg = (5.0\text{ kg})(9.80\text{ m/s}^2) = 49\text{ N}$$

For the top rope, with the positive direction upward:

$$F_{\text{net}} = F_{\text{top rope on top block}} - F_{\text{bottom rope on top block}} - F_{\text{Earth's mass on top block}} = ma = 0$$

$$F_{\text{top rope on top block}} = F_{\text{Earth's mass on top block}} + F_{\text{bottom rope on top block}} = mg + F_{\text{bottom rope on top block}} = (5.0\text{ kg})(9.80\text{ m/s}^2) + 49\text{ N} = 98\text{ N}$$

37. Tension If the bottom block in problem 36 has a mass of 3.0 kg and the tension in the top rope is 63.0 N, calculate the tension in the bottom rope and the mass of the top block.

For the bottom rope with the positive direction upward:

$$F_{\text{net}} = F_{\text{bottom rope on bottom block}} - F_{\text{Earth's mass on bottom block}} = ma = 0$$

$$F_{\text{bottom rope on bottom block}} = F_{\text{Earth's mass on bottom block}} = (3.0\text{ kg})(9.80\text{ m/s}^2) = 29\text{ N}$$

For the top mass with the positive direction upward:

$F_{\text{net}} = F_{\text{top rope on top block}} - F_{\text{bottom rope on top block}} - F_{\text{Earth's mass on top block}}$

$= ma = 0$

$F_{\text{Earth's mass on top block}} = mg$

$= F_{\text{top rope on top block}} - F_{\text{bottom rope on top block}}$

$m = \dfrac{F_{\text{top rope on top block}} - F_{\text{bottom rope on top block}}}{g}$

$= \dfrac{63.0\ \text{N} - 29\ \text{N}}{9.80\ \text{m/s}^2}$

$= 3.5\ \text{kg}$

38. Normal Force Poloma hands a 13-kg box to 61-kg Stephanie, who stands on a platform. What is the normal force exerted by the platform on Stephanie?

Identify Stephanie as the system and positive to be upward.

$F_{\text{net}} = F_{\text{platform on Stephanie}} - F_{\text{box on Stephanie}} - F_{\text{Earth's mass on Stephanie}}$

$F_{\text{platform on Stephanie}}$

$= F_{\text{box on Stephanie}} + F_{\text{Earth's mass on Stephanie}}$

$= m_{\text{box}}g + m_{\text{Stephanie}}g$

$= (13\ \text{kg})(9.80\ \text{m/s}^2) + (61\ \text{kg})(9.80\ \text{m/s}^2)$

$= 7.3\times10^2\ \text{N}$

39. Critical Thinking A curtain prevents two tug-of-war teams from seeing each other. One team ties its end of the rope to a tree. If the other team pulls with a 500-N force, what is the tension? Explain.

The tension would be 500 N. The rope is in equilibrium, so the net force on it is zero. The team and the tree exert equal forces in opposite directions.

Chapter Assessment

Concept Mapping

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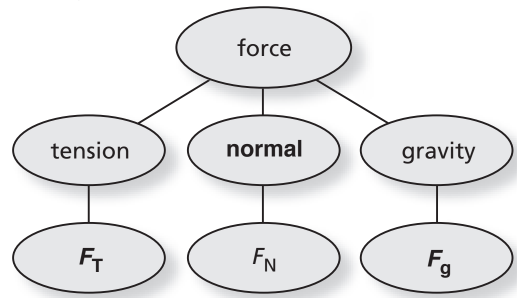
40. Complete the following concept map using the following term and symbols: *normal*, F_T, F_g.



Mastering Concepts

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41. A physics book is motionless on the top of a table. If you give it a hard push with your hand, it slides across the table and slowly comes to a stop. Use Newton's laws to answer the following questions. (4.1)

a. Why does the book remain motionless before the force of your hand is applied?

An object at rest tends to stay at rest if no outside force acts on it.

b. Why does the book begin to move when your hand pushes hard enough on it?

The force from your hand is greater than any opposing force such as friction. With a net force on it, the book slides in the direction of the net force.

c. Under what conditions would the book remain in motion at a constant speed?

The book would remain in motion if the net force acting on it is zero.

42. Cycling Why do you have to push harder on the pedals of a single-speed bicycle to start it moving than to keep it moving at a constant velocity? (4.1)

A large force is required to accelerate the mass of the bicycle and rider. Once the desired constant velocity is reached, a much smaller force is sufficient to overcome the ever-present frictional forces.

43. Suppose that the acceleration of an object is zero. Does this mean that there are no forces acting on it? Give an example supporting your answer. (4.2)

No, it only means the forces acting on it are balanced and the net force is zero. For example, a book on a table is not moving but the force of gravity pulls down on it and the normal force of the table pushes up on it and these forces are balanced.

44. Basketball When a basketball player dribbles a ball, it falls to the floor and bounces up. Is a force required to make it bounce? Why? If a force is needed, what is the agent involved? (4.2)

Yes, its velocity changed direction; thus, it was accelerated and a force is required to accelerate the basketball. The agent is the floor.

45. Before a sky diver opens her parachute, she may be falling at a velocity higher than the terminal velocity that she will have after the parachute opens. (4.2)

a. Describe what happens to her velocity as she opens the parachute.

Because the force of air resistance suddenly becomes larger, the velocity of the diver drops suddenly.

b. Describe the sky diver's velocity from when her parachute has been open for a time until she is about to land.

The force of air resistance and the gravitational force are equal. Their sum is zero, so there is no longer any acceleration. The sky diver continues downward at a constant velocity.

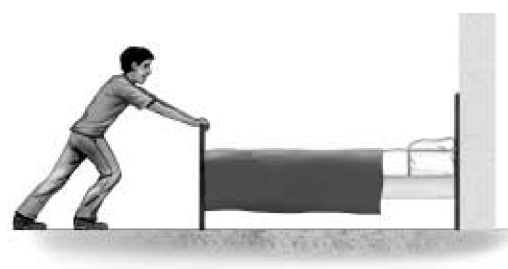
46. If your textbook is in equilibrium, what can you say about the forces acting on it? (4.2)

If the book is in equilibrium, the net force is zero. The forces acting on the book are balanced.

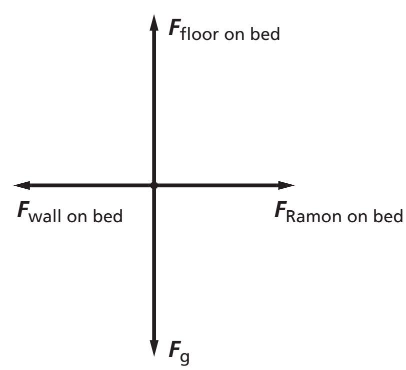
47. A rock is dropped from a bridge into a valley. Earth pulls on the rock and accelerates it downward. According to Newton's third law, the rock must also be pulling on Earth, yet Earth does not seem to accelerate. Explain. (4.3)

The rock does pull on Earth, but Earth's enormous mass would undergo only a minute acceleration as a result of such a small force. This acceleration would go undetected.

48. Ramon pushes on a bed that has been pushed against a wall, as in **Figure 4-17.** Draw a free-body diagram for the bed and identify all the forces acting on it. Make a separate list of all the forces that the bed applies to other objects. (4.3)



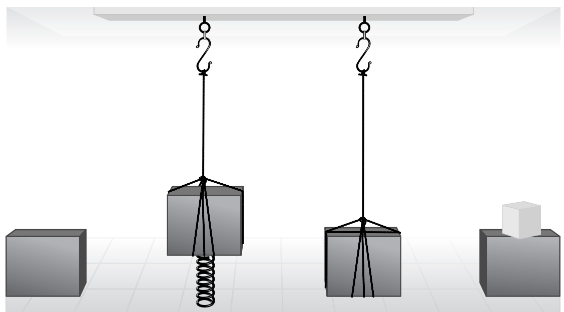
■ **Figure 4-17**



Forces that bed applies to other objects:

$F_{\text{bed on Ramon}}$, $F_{\text{bed on Earth}}$, $F_{\text{bed on floor}}$, $F_{\text{bed on wall}}$

49. **Figure 4-18** shows a block in four different situations. Rank them according to the magnitude of the normal force between the block and the surface, greatest to least. Specifically indicate any ties. (4.3)



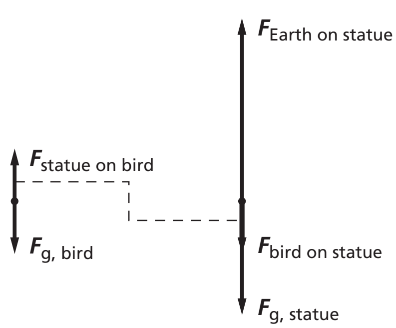
■ **Figure 4-18**

from left to right: second > fourth > third > first

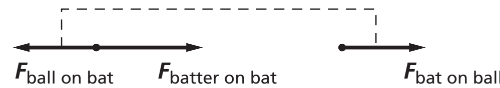
50. Explain why the tension in a massless rope is constant throughout it. (4.3)

If you draw a free-body diagram for any point on the rope, there will be two tension forces acting in opposite directions. $F_{net} = F_{up} - F_{down} = ma = 0$ (because it is massless). Therefore, $F_{up} = F_{down}$. According to Newton's third law, the force that the adjoining piece of rope exerts on this point is equal and opposite to the force that this point exerts on it, so the force must be constant throughout.

51. A bird sits on top of a statue of Einstein. Draw free-body diagrams for the bird and the statue. Specifically indicate any interaction pairs between the two diagrams. (4.3)



52. **Baseball** A slugger swings his bat and hits a baseball pitched to him. Draw free-body diagrams for the baseball and the bat at the moment of contact. Specifically indicate any interaction pairs between the two diagrams. (4.3)



Applying Concepts

pages 112–113

53. **Whiplash** If you are in a car that is struck from behind, you can receive a serious neck injury called whiplash.

a. Using Newton's laws, explain what happens to cause such an injury.

The car is suddenly accelerated forward. The seat accelerates your body, but your neck has to accelerate your head. This can hurt your neck muscles.

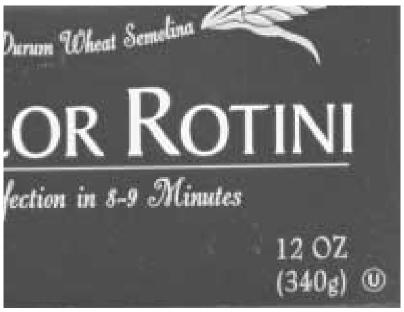
b. How does a headrest reduce whiplash?

The headrest pushes on your head, accelerating it in the same direction as the car.

54. **Space** Should astronauts choose pencils with hard or soft lead for making notes in space? Explain.

A soft lead pencil would work better because it would require less force to make a mark on the paper. The magnitude of the interaction force pair could push the astronaut away from the paper.

55. When you look at the label of the product in **Figure 4-19** to get an idea of how much the box contains, does it tell you its mass, weight, or both? Would you need to make any changes to this label to make it correct for consumption on the Moon?



■ **Figure 4-19**

The ounces tell you the weight in English units. The grams tell you the mass in metric units. The label would need to read "2 oz" to be correct on the Moon. The grams would remain unchanged.

56. From the top of a tall building, you drop two table-tennis balls, one filled with air and the other with water. Both experience air resistance as they fall. Which ball reaches terminal velocity first? Do both hit the ground at the same time?

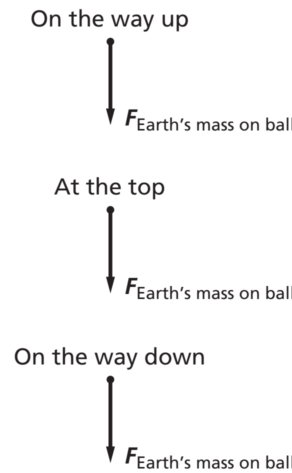
The lighter, air-filled table tennis ball reaches terminal velocity first. Its mass is less for the same shape and size, so the friction force of upward air resistance becomes equal to the downward force of *mg* sooner. Because the force of gravity on the water-filled table-tennis ball (more mass) is larger, its terminal velocity is larger, and it strikes the ground first.

57. It can be said that 1 kg equals 2.2 lb. What does this statement mean? What would be the proper way of making the comparison?

It means that on Earth's surface, the weight of 1 kg is equivalent to 2.2 lb. You should compare masses to masses and weights to weights. Thus 9.8 N equals 2.2 lb.

58. You toss a ball straight up into the air.

a. Draw a free-body diagram for the ball at three points during its motion: on the way up, at the very top, and on the way down. Specifically identify the forces acting on the ball and their agents.



b. What is the velocity of the ball at the very top of the motion?

0 m/s

c. What is the acceleration of the ball at this same point?

Because the only force acting on it is the gravitational attraction of Earth, $a = 9.80\ \text{m/s}^2$.

Mastering Problems

4.1 Force and Motion

page 113

Level 1

59. What is the net force acting on a 1.0-kg ball in free-fall?

$$F_{net} = F_g = mg$$
$$= (1.0\ \text{kg})(9.80\ \text{m/s}^2)$$
$$= 9.8\ \text{N}$$

60. **Skating** Joyce and Efua are skating. Joyce pushes Efua, whose mass is 40.0-kg, with a force of 5.0 N. What is Efua's resulting acceleration?

$F = ma$

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

$= \frac{5.0\text{ N}}{40.0\text{ kg}}$

$= 0.12\text{ m/s}^2$

61. A car of mass 2300 kg slows down at a rate of 3.0 m/s^2 when approaching a stop sign. What is the magnitude of the net force causing it to slow down?

$F = ma$

$= (2300\text{ kg})(3.0\text{ m/s}^2)$

$= 6.9\times10^3\text{ N}$

62. **Breaking the Wishbone** After Thanksgiving, Kevin and Gamal use the turkey's wishbone to make a wish. If Kevin pulls on it with a force 0.17 N larger than the force Gamal pulls with in the opposite direction, and the wishbone has a mass of 13 g, what is the wishbone's initial acceleration?

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

$= \frac{0.17\text{ N}}{0.013\text{ kg}}$

$= 13\text{ m/s}^2$

4.2 Using Newton's Laws

pages 113–114

Level 1

63. What is your weight in newtons?

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

Answers will vary.

64. **Motorcycle** Your new motorcycle weighs 2450 N. What is its mass in kilograms?

$F_g = mg$

$m = \frac{F_g}{g} = \frac{2450\text{ N}}{9.80\text{ m/s}^2}$

$= 2.50\times10^2\text{ N}$

65. Three objects are dropped simultaneously from the top of a tall building: a shot put, an air-filled balloon, and a basketball.

a. Rank the objects in the order in which they will reach terminal velocity, from first to last.

balloon, basketball, shot put

b. Rank the objects according to the order in which they will reach the ground, from first to last.

shot put, basketball, balloon

c. What is the relationship between your answers to parts a and b?

They are inverses of each other.

66. What is the weight in pounds of a 100.0-N wooden shipping case?

$(100.0\text{ N})\left(\frac{1\text{ kg}}{9.80\text{ N}}\right)\left(\frac{2.2\text{ lb}}{1\text{ kg}}\right) = 22\text{ lb}$

67. You place a 7.50-kg television on a spring scale. If the scale reads 78.4 N, what is the acceleration due to gravity at that location?

$F_g = mg$

$g = \frac{F_g}{m}$

$= \frac{78.4\text{ N}}{7.50\text{ kg}}$

$= 10.5\text{ m/s}^2$

Level 2

68. **Drag Racing** A 873-kg (1930-lb) dragster, starting from rest, attains a speed of 26.3 m/s (58.9 mph) in 0.59 s.

a. Find the average acceleration of the dragster during this time interval.

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

$= \frac{(26.3\text{ m/s} - 0.0\text{ m/s})}{0.59\text{ s}}$

$= 45\text{ m/s}^2$

b. What is the magnitude of the average net force on the dragster during this time?

$F = ma$

$= (873\text{ kg})(45\text{ m/s}^2)$

$= 3.9\times10^4\text{ N}$

c. Assume that the driver has a mass of 68 kg. What horizontal force does the seat exert on the driver?

$F = ma = (68\ \text{kg})(45\ \text{m/s}^2)$

$= 3.1\times10^3\ \text{N}$

69. Assume that a scale is in an elevator on Earth. What force would the scale exert on a 53-kg person standing on it during the following situations?

a. The elevator moves up at a constant speed.

$F_{scale} = F_g$

$= mg$

$= (53\ \text{kg})(9.80\ \text{m/s}^2)$

$= 5.2\times10^2\ \text{N}$

b. It slows at 2.0 m/s^2 while moving upward.

Slows while moving up or speeds up while moving down,

$F_{scale} = F_g + F_{slowing}$

$= mg + ma$

$= m(g + a)$

$= (53\ \text{kg})(9.80\ \text{m/s}^2 - 2.0\ \text{m/s}^2)$

$= 4.1\times10^2\ \text{N}$

c. It speeds up at 2.0 m/s^2 while moving downward.

Slows while moving up or speeds up while moving down,

$F_{scale} = F_g + F_{speeding}$

$= mg + ma$

$= m(g + a)$

$= (53\ \text{kg})(9.80\ \text{m/s}^2 - 2.0\ \text{m/s}^2)$

$= 4.1\times10^2\ \text{N}$

d. It moves downward at a constant speed.

$F_{scale} = F_g$

$= mg$

$= (53\ \text{kg})(9.80\ \text{m/s}^2)$

$= 5.2\times10^2\ \text{N}$

e. It slows to a stop while moving downward with a constant acceleration.

Depends on the magnitude of the acceleration.

$F_{scale} = F_g + F_{slowing}$

$= mg + ma$

$= m(g + \text{a})$

$= (53\ \text{kg})(9.80\ \text{m/s}^2 + a)$

70. A grocery sack can withstand a maximum of 230 N before it rips. Will a bag holding 15 kg of groceries that is lifted from the checkout counter at an acceleration of 7.0 m/s^2 hold?

Use Newton's second law $F_{net} = ma$.

If $F_{groceries} > 230$, then the bag rips.

$F_{groceries} = m_{groceries}a_{groceries} + m_{groceries}g$

$= m_{groceries}(a_{groceries} + g)$

$= (15\ \text{kg})(7.0\ \text{m/s}^2 + 9.80\ \text{m/s}^2)$

$= 250\ \text{N}$

The bag does not hold.

71. A 0.50-kg guinea pig is lifted up from the ground. What is the smallest force needed to lift it? Describe its resulting motion.

$F_{lift} = F_g$

$= mg$

$= (0.50\ \text{kg})(9.80\ \text{m/s}^2)$

$= 4.9\ \text{N}$

It would move at a constant speed.

Level 3

72. Astronomy On the surface of Mercury, the gravitational acceleration is 0.38 times its value on Earth.

a. What would a 6.0-kg mass weigh on Mercury?

$F_g = mg(0.38)$

$= (6.0\ \text{kg})(9.80\ \text{m/s}^2)(0.38)$

$= 22\ \text{N}$

b. If the gravitational acceleration on the surface of Pluto is 0.08 times that of Mercury, what would a 7.0-kg mass weigh on Pluto?

$$F_g = mg(0.38)(0.08)$$
$$= (7.0\text{ kg})(9.80\text{ m/s}^2)(0.38)(0.08)$$
$$= 2.1\text{ N}$$

73. A 65-kg diver jumps off of a 10.0-m tower.

a. Find the diver's velocity when he hits the water.

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

b. The diver comes to a stop 2.0 m below the surface. Find the net force exerted by the water.

$$v_f^2 = v_i^2 + 2ad$$
$$v_f = 0,\text{ so } a = \frac{-v_i^2}{2d}$$
$$\text{and } F = ma$$
$$= \frac{-mv_i^2}{2d}$$
$$= \frac{-(65\text{ kg})(14.0\text{ m/s})^2}{2(2.0\text{ m})}$$
$$= -3.2\times10^3\text{ N}$$

74. **Car Racing** A race car has a mass of 710 kg. It starts from rest and travels 40.0 m in 3.0 s. The car is uniformly accelerated during the entire time. What net force is exerted on it?

$$d = v_0t + \left(\frac{1}{2}\right)at^2$$
$$\text{Since } v_0 = 0,$$
$$a = \frac{2d}{t^2}\text{ and } F = ma\text{, so}$$
$$F = \frac{2md}{t^2}$$
$$= \frac{(2)(710\text{ kg})(40.0\text{ m})}{(3.0\text{ s})^2}$$
$$= 6.3\times10^3\text{ N}$$

4.3 Interaction Forces

page 114

Level 1

75. A 6.0-kg block rests on top of a 7.0-kg block, which rests on a horizontal table.

a. What is the force (magnitude and direction) exerted by the 7.0-kg block on the 6.0-kg block?

$$F_{net} = N - mg$$
$$F_N = F_{\text{7-kg block on 6-kg block}}$$
$$= mg$$
$$= (6.0\text{ kg})(9.80\text{ m/s}^2)$$
$$= 59\text{ N; the direction is upward.}$$

b. What is the force (magnitude and direction) exerted by the 6.0-kg block on the 7.0-kg block?

equal and opposite to that in part a; therefore, 59 N downward

76. **Rain** A raindrop, with mass 2.45 mg, falls to the ground. As it is falling, what magnitude of force does it exert on Earth?

$$F_{\text{raindrop on Earth}} = F_g$$
$$= mg$$
$$= (0.00245\text{ kg})(9.80\text{ m/s}^2)$$
$$= 2.40\times10^{-2}\text{ N}$$

77. A 90.0-kg man and a 55-kg man have a tug-of-war. The 90.0-kg man pulls on the rope such that the 55-kg man accelerates at 0.025 m/s^2. What force does the rope exert on the 90.0-kg man?

same in magnitude as the force the rope exerts on the 55-kg man:

$$F = ma = (55\text{ kg})(0.025\text{ m/s}^2) = 1.4\text{ N}$$

Level 2

78. Male lions and human sprinters can both accelerate at about 10.0 m/s^2. If a typical lion weighs 170 kg and a typical sprinter weighs 75 kg, what is the difference in the force exerted on the ground during a race between these two species?

Use Newton's second law, $F_{net} = ma$.

The difference between F_{lion} and F_{human} is

$$F_{lion} - F_{human} = m_{lion}a_{lion} - m_{human}a_{human} = (170\ \text{kg})(10.0\ \text{m/s}^2) - (75\ \text{kg})(10.0\ \text{m/s}^2) = 9.5\times10^2\ \text{N}$$

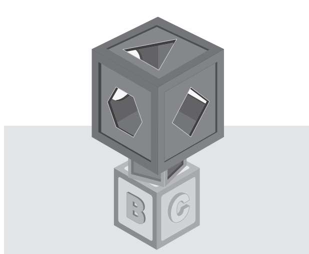
79. A 4500-kg helicopter accelerates upward at 2.0 m/s^2. What lift force is exerted by the air on the propellers?

$$ma = F_{net} = F_{appl} + F_g = F_{appl} + mg$$

$$\text{so } F_{appl} = ma - mg = m(a - g) = (4500\ \text{kg})((2.0\text{m/s}^2) - (-9.8\ \text{m/s}^2)) = 5.3\times10^4\ \text{N}$$

Level 3

80. Three blocks are stacked on top of one another, as in **Figure 4-20.** The top block has a mass of 4.6 kg, the middle one has a mass of 1.2 kg, and the bottom one has a mass of 3.7 kg. Identify and calculate any normal forces between the objects.



■ **Figure 4-20**

The normal force is between the top and middle blocks; the top block is the system; upward is positive.

$$F_{net} = F_{\text{middle block on top block}} - F_{\text{Earth's mass on top block}} = ma = 0$$

$$F_{\text{middle block on top block}} = F_{\text{Earth's mass on top block}} = m_{\text{top block}}g = (4.6\ \text{kg})(9.80\ \text{m/s}^2) = 45\ \text{N}$$

The normal force is between the bottom and middle block; the middle block is the system; upward is positive.

$$F_{net} = F_{\text{bottom block on middle block}} - F_{\text{top block on middle block}} - F_{\text{Earth's mass on middle block}} = ma = 0$$

$$F_{\text{top block on middle block}} = F_{\text{middle block on top block}}$$

$$F_{\text{bottom block on middle block}} = F_{\text{middle block on top block}} + F_{\text{Earth's mass on middle block}} = F_{\text{middle block on top block}} + m_{\text{middle block}}g = 45\ \text{N} + (1.2\ \text{kg})(9.80\ \text{m/s}^2) = 57\ \text{N}$$

The normal force is between the bottom block and the surface; the bottom block is the system; upward is positive.

$$F_{net} = F_{\text{surface on bottom block}} - F_{\text{middle block on bottom block}} - F_{\text{Earth's mass on bottom block}} = ma = 0$$

$F_{\text{surface on bottom block}}$

$= F_{\text{middle block on bottom block}} + F_{\text{Earth's mass on bottom block}}$

$= F_{\text{middle block on bottom block}} + m_{\text{bottom block}}g$

$= 57\text{ N} + (3.7\text{ kg})(9.80\text{ m/s}^2)$

$= 93\text{ N}$

Mixed Review

pages 114–115

Level 1

81. The dragster in problem 68 completed a 402.3-m (0.2500-mi) run in 4.936 s. If the car had a constant acceleration, what was its acceleration and final velocity?

$$d_f = d_i + v_i t + \frac{1}{2}at^2$$

$d_i = v_i = 0$, so

$$a = \frac{2d_f}{t^2} = \frac{(2)(402.3\text{ m})}{(4.936\text{ s})^2} = 33.02\text{ m/s}^2$$

$$d_f = d_i + \frac{1}{2}(v_f - v_i)t$$

$d_i = v_i = 0$, so

$$v_f = \frac{2d_f}{t} = \frac{(2)(402.3\text{ m})}{4.936\text{ s}} = 163.0\text{ m/s}$$

Level 2

82. Jet A 2.75×10^6-N catapult jet plane is ready for takeoff. If the jet's engines supply a constant thrust of 6.35×10^6 N, how much runway will it need to reach its minimum takeoff speed of 285 km/h?

$$v_f = (285\text{ km/h})(1000\text{ m/km})\left(\frac{1\text{ h}}{3600\text{s}}\right) = 79.2\text{ m/s}$$

$F_{\text{thrust}} = ma$, so $a = \frac{F_{\text{thrust}}}{m}$

$F_g = mg$

$$m = \frac{F_g}{g}$$

$v_f = v_i + at$ and $v_i = 0$, so

$$t = \frac{v_f}{a} = \frac{v_f}{\left(\frac{F_{\text{thrust}}}{m}\right)} = \frac{v_f m}{F_{\text{thrust}}}$$

$$d_f = d_i + v_i t + \frac{1}{2}at^2$$

$d_i = v_i = 0$, so

$$d_f = \frac{1}{2}at^2 = \left(\frac{1}{2}\right)\left(\frac{F_{\text{thrust}}}{m}\right)\left(\frac{v_f m}{F_{\text{thrust}}}\right)^2 = \left(\frac{1}{2}\right)\frac{v_f^2 m}{F_{\text{thrust}}} = \left(\frac{1}{2}\right)\frac{v_f^2\left(\frac{F_g}{g}\right)}{F_{\text{thrust}}}$$

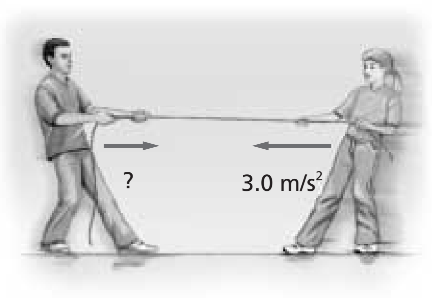
$$= \left(\frac{1}{2}\right)\frac{(79.2\text{ m/s})^2\left(\frac{2.75\times10^6\text{ N}}{9.80\text{ m/s}^2}\right)}{6.35\times10^6\text{ N}}$$

$$= 139\text{ m}$$

83. The dragster in problem 68 crossed the finish line going 126.6 m/s. Does the assumption of constant acceleration hold true? What other piece of evidence could you use to determine if the acceleration was constant?

126.6 m/s is slower than found in problem 81, so the acceleration cannot be constant. Further, the acceleration in the first 0.59 s was 45 m/s^2, not 33.02 m/s^2.

84. Suppose a 65-kg boy and a 45-kg girl use a massless rope in a tug-of-war on an icy, resistance-free surface as in **Figure 4-21.** If the acceleration of the girl toward the boy is 3.0 m/s^2, find the magnitude of the acceleration of the boy toward the girl.



■ **Figure 4-21**

$F_{1,2} = -F_{1,2}$, so $m_1a_1 = -m_2a_2$

and $a_1 = \frac{-m_2a_2}{m_1}$

$= \frac{-(45\ \text{kg})(3.0\ \text{m/s}^2)}{(65\ \text{kg})}$

$= -2.1\ \text{m/s}^2$

85. **Space Station** Pratish weighs 588 N and is weightless in a space station. If she pushes off the wall with a vertical acceleration of 3.00 m/s^2, determine the force exerted by the wall during her push off.

Use Newton's second law to obtain Pratish's mass, $m_{Pratish}$. Use Newton's third law $F_A = -F_B = m_Aa_A = -m_Ba_B$.

$m_{Pratish} = \frac{F_g}{g}$

$F_{\text{wall on Pratish}} = -F_{\text{Pratish on wall}}$

$= m_{Pratish}a_{Pratish}$

$= \frac{F_g a_{Pratish}}{g}$

$= \frac{(588\ \text{N})(3.00\ \text{m/s}^2)}{9.80\ \text{m/s}^2}$

$= 1.80\times10^2\ \text{N}$

86. **Baseball** As a baseball is being caught, its speed goes from 30.0 m/s to 0.0 m/s in about 0.0050 s. The mass of the baseball is 0.145 kg.

a. What is the baseball's acceleration?

$a = \frac{v_f - v_i}{t_f - t_i}$

$= \frac{0.0\ \text{m/s} - 30.0\ \text{m/s}}{0.0050\ \text{s} - 0.0\ \text{s}}$

$= -6.0\times10^3\ \text{m/s}^2$

b. What are the magnitude and direction of the force acting on it?

$F = ma$

$= (0.145\ \text{kg})(-6.0\times10^3\ \text{m/s}^2)$

$= -8.7\times10^2\ \text{N}$

(opposite direction of the velocity of the ball)

c. What are the magnitude and direction of the force acting on the player who caught it?

Same magnitude, opposite direction (in direction of velocity of ball)

Level 3

87. **Air Hockey** An air-hockey table works by pumping air through thousands of tiny holes in a table to support light pucks. This allows the pucks to move around on cushions of air with very little resistance. One of these pucks has a mass of 0.25 kg and is pushed along by a 12.0-N force for 9.0 s.

a. What is the puck's acceleration?

$F = ma$

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

$= \frac{12.0\ \text{N}}{0.25\ \text{kg}}$

$= 48\ \text{m/s}^2$

b. What is the puck's final velocity?

$v_f = v_i + at$

$v_i = 0$, **so** $v_f = at$

$= (48\ \text{m/s}^2)(9.0\ \text{s})$

$= 4.3\times10^2\ \text{m/s}$

88. A student stands on a bathroom scale in an elevator at rest on the 64th floor of a building. The scale reads 836 N.

a. As the elevator moves up, the scale reading increases to 936 N. Find the acceleration of the elevator.

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

$$F_{elevator} = F_{net} - F_g = ma$$

$$m = \frac{F_g}{g}\text{, so}$$

$$a = \frac{F_{net} - F_g}{\frac{F_g}{g}}$$

$$= \frac{g(F_{net} - F_g)}{F_g}$$

$$= \frac{(9.80\ \text{m/s}^2)(963\ \text{N} - 836\ \text{N})}{836\ \text{N}}$$

$$= 1.17\ \text{m/s}^2$$

b. As the elevator approaches the 74th floor, the scale reading drops to 782 N. What is the acceleration of the elevator?

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

$$F_{elevator} = F_{net} - F_g = ma$$

$$m = \frac{F_g}{g}\text{, so}$$

$$a = \frac{F_{net} - F_g}{\frac{F_g}{g}}$$

$$= \frac{g(F_{net} - F_g)}{F_g}$$

$$= \frac{(9.80\ \text{m/s}^2)(782\ \text{N} - 836\ \text{N})}{836\ \text{N}}$$

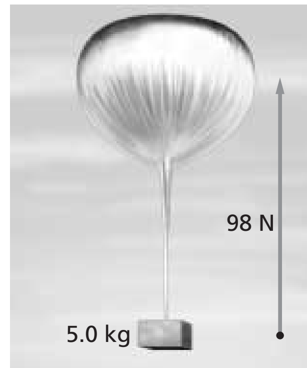
$$= -0.633\ \text{m/s}^2$$

c. Using your results from parts **a** and **b,** explain which change in velocity, starting or stopping, takes the longer time.

Stopping, because the magnitude of the acceleration is less and

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

89. **Weather Balloon** The instruments attached to a weather balloon in **Figure 4-22** have a mass of 5.0 kg. The balloon is released and exerts an upward force of 98 N on the instruments.



■ **Figure 4-22**

a. What is the acceleration of the balloon and instruments?

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

$$= F_{appl} + mg$$

$$= 98\ \text{N} + (5.0\ \text{kg})(-9.80\ \text{m/s}^2)$$

$$= +49\ \text{N (up)}$$

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

$$= \frac{+49\ \text{N}}{5.0\ \text{kg}}$$

$$= +9.8\ \text{m/s}^2$$

b. After the balloon has accelerated for 10.0 s, the instruments are released. What is the velocity of the instruments at the moment of their release?

$$v = at$$

$$= (+9.8\ \text{m/s}^2)(10.0\ \text{s})$$

$$= +98\ \text{m/s (up)}$$

c. What net force acts on the instruments after their release?

just the instrument weight, −49 N (down)

d. When does the direction of the instruments' velocity first become downward?

The velocity becomes negative after it passes through zero. Thus, use

$v_f = v_i + gt$, **where** $v_f = 0$, **or**

$$t = \frac{-v_i}{g}$$

$$= \frac{-(+98\ \text{m/s})}{(-9.80\ \text{m/s}^2)}$$

$$= 1.0\times10^1\ \text{s after release}$$

90. When a horizontal force of 4.5 N acts on a block on a resistance-free surface, it produces an acceleration of 2.5 m/s^2. Suppose a second 4.0-kg block is dropped onto the first. What is the magnitude of the acceleration of the combination if the same force continues to act? Assume that the second block does not slide on the first block.

$$F = m_{\text{first block}}a_{\text{initial}}$$

$$m_{\text{first block}} = \frac{F}{a_{\text{initial}}}$$

$$F = m_{\text{both blocks}}a_{\text{final}}$$

$$= (m_{\text{first block}} + m_{\text{second block}})a_{\text{final}}$$

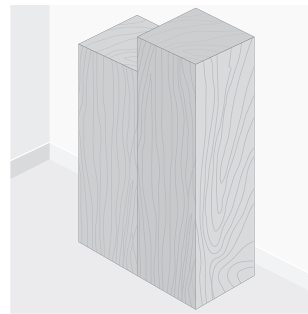
so, $$a_{\text{final}} = \frac{F}{m_{\text{first block}} + m_{\text{second block}}}$$

$$= \frac{F}{\frac{F}{a_{\text{initial}}} + m_{\text{second block}}}$$

$$= \frac{4.5\ \text{N}}{\frac{4.5\ \text{N}}{2.5\ \text{m/s}^2} + 4.0\ \text{kg}}$$

$$= 0.78\ \text{m/s}^2$$

91. Two blocks, masses 4.3 kg and 5.4 kg, are pushed across a frictionless surface by a horizontal force of 22.5 N, as shown in **Figure 4-23.**



■ **Figure 4-23**

a. What is the acceleration of the blocks?

Identify the two blocks together as the system, and right as positive.

$F_{net} = ma$, **and** $m = m_1 + m_2$

$$a = \frac{F}{m_1 + m_2}$$

$$= \frac{22.5\ \text{N}}{4.3\ \text{kg} + 5.4\ \text{kg}}$$

$$= 2.3\ \text{m/s}^2\ \text{to the right}$$

b. What is the force of the 4.3-kg block on the 5.4-kg block?

Identify the 5.4-kg block as the system and right as positive.

$$F_{net} = F_{\text{4.3-kg block on 5.4-kg block}}$$

$$= ma$$

$$= (5.4\ \text{kg})(2.3\ \text{m/s}^2)$$

$$= 12\ \text{N to the right}$$

c. What is the force of the 5.4-kg block on the 4.3-kg block?

According to Newton's third law, this should be equal and opposite to the force found in part b, so the force is 12 N to the left.

92. Two blocks, one of mass 5.0 kg and the other of mass 3.0 kg, are tied together with a massless rope as in **Figure 4-24.** This rope is strung over a massless, resistance-free pulley. The blocks are released from rest. Find the following.

a. the tension in the rope

b. the acceleration of the blocks

Hint: you will need to solve two simultaneous equations.

■ **Figure 4-24**

Equation 1 comes from a free-body diagram for the 5.0-kg block. Down is positive.

$F_{\text{net}} = F_{\text{Earth's mass on 5.0-kg block}} - F_{\text{rope on 5.0-kg block}} = m_{\text{5.0-kg block}}a$ **(1)**

Equation 2 comes from a free-body diagram for the 3.0-kg block. Up is positive.

$F_{\text{net}} = F_{\text{rope on 3.0-kg block}} - F_{\text{Earth's mass on 3.0-kg block}} = m_{\text{3.0-kg block}}a$ **(2)**

The forces of the rope on each block will have the same magnitude, because the tension is constant throughout the rope. Call this force T.

$F_{\text{Earth's mass on 5.0-kg block}} - T = m_{\text{5.0-kg block}}a$ **(1)**

$T - F_{\text{Earth's mass on 3.0-kg block}} = m_{\text{3.0-kg block}}a$ **(2)**

Solve equation 2 for T and plug into equation 1:

$$m_{\text{5.0-kg block}}a = F_{\text{Earth's mass on 5.0-kg block}} - F_{\text{Earth's mass on 3.0-kg block}} - m_{\text{3.0-kg block}}a$$

$$a = \frac{F_{\text{Earth's mass on 5.0-kg block}} - F_{\text{Earth's mass on 3.0-kg block}}}{m_{\text{5.0-kg block}} + m_{\text{3.0-kg block}}}$$

$$= \frac{(m_{\text{5.0-kg block}} - m_{\text{3.0-kg block}})g}{m_{\text{3.0-kg block}} + m_{\text{5.0-kg block}}}$$

$$= \frac{(5.0\text{ kg} - 3.0\text{ kg})(9.80\text{ m/s}^2)}{3.0\text{ kg} + 5.0\text{ kg}}$$

$$= 2.4\text{ m/s}^2$$

Solve equation 2 for T:

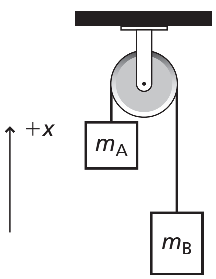
$$T = F_{\text{Earth's mass on 3.0-kg block}} + m_{\text{3.0-kg block}}a$$
$$= m_{\text{3.0-kg block}}g + m_{\text{3.0-kg block}}a$$
$$= m_{\text{3.0-kg block}}(g + a)$$
$$= (3.0\ \text{kg})(9.80\ \text{m/s}^2 + 2.4\ \text{m/s}^2)$$
$$= 37\ \text{N}$$

Thinking Critically

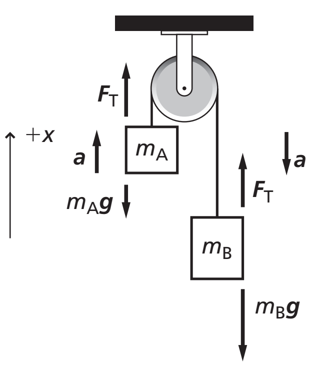
pages 115–116

93. Formulate Models A 2.0-kg mass, m_A, and a 3.0-kg mass, m_B, are connected to a lightweight cord that passes over a frictionless pulley. The pulley only changes the direction of the force exerted by the rope. The hanging masses are free to move. Choose coordinate systems for the two masses with the positive direction being up for m_A and down for m_B.

a. Create a pictorial model.



b. Create a physical model with motion and free-body diagrams.



c. What is the acceleration of the smaller mass?

$ma = F_{net}$ where m is the total mass being accelerated.

For m_A, $m_Aa = F_T - m_Ag$

For m_B, $m_Ba = -F_T + m_Bg$

$$F_T = m_Bg - m_Ba = m_B(g - a)$$

Substituting into the equation for m_A gives

$$m_Aa = m_Bg - m_Ba - m_Ag$$

or $(m_A + m_B)a = (m_B - m_A)g$

Therefore $a = \left(\dfrac{m_B - m_A}{m_A + m_B}\right)g$

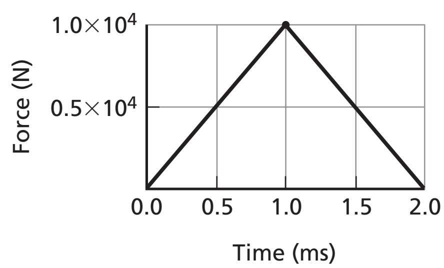
$$= \left(\frac{3.0\ \text{kg} - 2.0\ \text{kg}}{2.0\ \text{kg} + 3.0\ \text{kg}}\right)(9.80\ \text{m/s}^2)$$
$$= 2.0\ \text{m/s}^2\ \text{upward}$$

94. Use Models Suppose that the masses in problem 93 are now 1.00 kg and 4.00 kg. Find the acceleration of the larger mass.

$$a = \left(\frac{m_B - m_A}{m_A + m_B}\right)g$$
$$= \left(\frac{4.00\ \text{kg} - 1.00\ \text{kg}}{1.00\ \text{kg} + 4.00\ \text{kg}}\right)(9.80\ \text{m/s}^2)$$
$$= 5.88\ \text{m/s}^2\ \text{downward}$$

95. Infer The force exerted on a 0.145-kg baseball by a bat changes from 0.0 N to 1.0×10^4 N in 0.0010 s, then drops back to zero in the same amount of time. The baseball was going toward the bat at 25 m/s.

a. Draw a graph of force versus time. What is the average force exerted on the ball by the bat?



$$F_{ave} = \frac{1}{2}F_{peak}$$
$$= \left(\frac{1}{2}\right)(1.0\times10^4\ \text{N})$$
$$= 5.0\times10^3\ \text{N}$$

b. What is the acceleration of the ball?

$$a = \frac{F_{net}}{m} = \frac{5.0\times10^{3}\ \text{N}}{0.145\ \text{kg}}$$

$$= 3.4\times10^{4}\ \text{m/s}^2$$

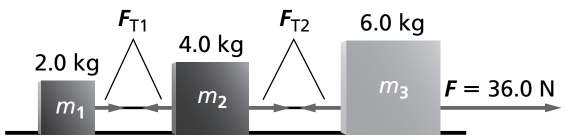
c. What is the final velocity of the ball, assuming that it reverses direction?

$$v_f = v_i + at$$

$$= -25\ \text{m/s} + (3.4\times10^{4}\ \text{m/s}^2)(0.0020\ \text{s})$$

$$= 43\ \text{m/s}$$

96. Observe and Infer Three blocks that are connected by massless strings are pulled along a frictionless surface by a horizontal force, as shown in **Figure 4-25.**



■ **Figure 4-25**

a. What is the acceleration of each block?

Since they all move together, the acceleration is the same for all 3 blocks.

$$F = ma$$

$$= (m_1 + m_2 + m_3)a$$

$$a = \frac{F}{m_1 + m_2 + m_3}$$

$$= \frac{36\ \text{N}}{2.0\ \text{kg} + 4.0\ \text{kg} + 6.0\ \text{kg}}$$

$$= 3.0\ \text{m/s}^2$$

b. What are the tension forces in each of the strings?

Hint: Draw a separate free-body diagram for each block.

$$F_{net} = ma$$

$$F - F_{T2} = m_3a$$

$$F_{T2} - F_{T1} = m_2a$$

$$F_{T1} = m_1a$$

$$= (2.0\ \text{kg})(3.0\ \text{m/s}^2)$$

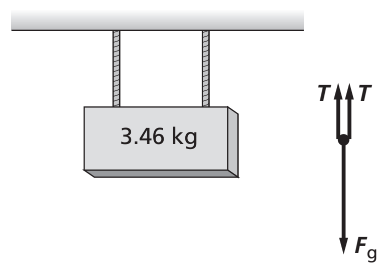
$$= 6.0\ \text{N}$$

$$F_{T2} = m_2a + F_{T1}$$

$$= (4.0\ \text{kg})(3.0\ \text{m/s}^2) + 6.0\ \text{N}$$

$$= 18\ \text{N}$$

97. Critique Using the Example Problems in this chapter as models, write a solution to the following problem. A block of mass 3.46 kg is suspended from two vertical ropes attached to the ceiling. What is the tension in each rope?



1 Analyze and Sketch the Problem

Draw free-body diagrams for the block and choose upward to be positive

Solve for the Unknown

Known:

$m_{block} = 3.46$ kg

Unknown:

$F_{rope1\ on\ block} = F_{rope2\ on\ block} = ?$

2 Solve for the Unknown

Use Newton's second law to find the tension in the ropes

$$F_{net} = 2F_{rope1\ on\ block} - F_{Earth's\ mass\ on\ block}$$

$$= ma = 0$$

$$F_{rope1\ on\ block} = \frac{F_{Earth's\ mass\ on\ block}}{2}$$

$$F_{rope1\ on\ block} = \frac{mg}{2}$$

$$= \frac{(3.46\ \text{kg})(9.80\ \text{m/s}^2)}{2}$$

$$= 17.0\ \text{N}$$

3 Evaluate the Answer

- **Are the units correct? N is the correct unit for a tension, since it is a force.**
- **Does the sign make sense? The positive sign indicates that the tension is pulling upwards.**
- **Is the magnitude realistic? We would expect the magnitude to be on the same order as the block's weight.**

98. Think Critically Because of your physics knowledge, you are serving as a scientific consultant for a new science-fiction TV series about space exploration. In episode 3, the heroine, Misty Moonglow, has been asked to be the first person to ride in a new interplanetary transport for use in our solar system. She wants to be sure that the transport actually takes her to the planet she is supposed to be going to, so she needs to take a testing device along with her to measure the force of gravity when she arrives. The script writers don't want her to just drop an object, because it will be hard to depict different accelerations of falling objects on TV. They think they'd like something involving a scale. It is your job to design a quick experiment Misty can conduct involving a scale to determine which planet in our solar system she has arrived on. Describe the experiment and include what the results would be for Pluto ($g = 0.30$ m/s^2), which is where she is supposed to go, and Mercury ($g = 3.70$ m/s^2), which is where she actually ends up.

Answers will vary. Here is one possible answer: She should take a known mass, say 5.00-kg, with her and place it on the scale. Since the gravitational force depends upon the local acceleration due to gravity, the scale will read a different number of newtons, depending on which planet she is on. The following analysis shows how to figure out what the scale would read on a given planet:

Identify the mass as the system and upward as positive.

$$F_{net} = F_{scale\ on\ mass} - F_g = ma = 0$$

$$F_{scale\ on\ mass} = F_g$$

$$F_{scale\ on\ mass} = mg$$

Pluto: $F_{scale\ on\ mass}$

$$= (5.00\ kg)(0.30\ m/s^2)$$

$$= 1.5\ N$$

Mercury: $F_{scale\ on\ mass}$

$$= (5.00\ kg)(3.7\ m/s^2)$$

$$= 19\ N$$

99. Apply Concepts Develop a CBL lab, using a motion detector, that graphs the distance a free-falling object moves over equal intervals of time. Also graph velocity versus time. Compare and contrast your graphs. Using your velocity graph, determine the acceleration. Does it equal *g*?

Student labs will vary with equipment available and designs. *p-t* graphs and *v-t* graphs should reflect uniform acceleration. The acceleration should be close to *g*.

Writing in Physics

page 116

100. Research Newton's contributions to physics and write a one-page summary. Do you think his three laws of motion were his greatest accomplishments? Explain why or why not.

Answers will vary. Newton's contributions should include his work on light and color, telescopes, astronomy, laws of motion, gravity, and perhaps calculus. One argument in favor of his three laws of motion being his greatest accomplishments is that mechanics is based on the foundation of these laws. His advances in the understanding of the concept of gravity may be suggested as his greatest accomplishment instead of his three laws of motion.

101. Review, analyze, and critique Newton's first law. Can we prove this law? Explain. Be sure to consider the role of resistance.

Answers will vary. Newton's first law of motion involves an object whose net forces are zero. If the object is at rest, it remains at rest; if it is in motion, it will continue to move in the same direction at a constant velocity. Only a force acting on an object at rest can cause it to move. Likewise, only a force acting on an object in motion can cause it to change its direction or speed. The two cases (object at rest, object in motion) could be viewed as two different frames of reference. This law can be demonstrated, but it cannot be proven.

102. Physicists classify all forces into four fundamental categories: gravitational, electromagnetic, strong nuclear, and weak nuclear. Investigate these four forces and describe the situations in which they are found.

Answers will vary. The strong nuclear force has a very short range and is what holds protons and neutrons together in the nucleus of an atom. The weak nuclear force is much less strong than the strong nuclear force and is involved in radioactive decay. The electromagnetic force is involved in holding atoms and molecules together and is based on the attraction of opposite charges. Gravity is a long-range force between two or more masses.

Cumulative Review

page 116

103. Cross-Country Skiing Your friend is training for a cross-country skiing race, and you and some other friends have agreed to provide him with food and water along his training route. It is a bitterly cold day, so none of you wants to wait outside longer than you have to. Taro, whose house is the stop before yours, calls you at 8:25 A.M. to tell you that the skier just passed his house and is planning to move at an average speed of 8.0 km/h. If it is 5.2 km from Taro's house to yours, when should you expect the skier to pass your house? (Chapter 2)

$d = vt$, **or** $t = \frac{d}{v}$

$d = 5.2\text{ km} = 5.2\times10^3\text{ m}$

$v = (8.0\text{ km/h})\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{h}}{3600\text{ s}}\right)$

$= 2.2\text{ m/s}$

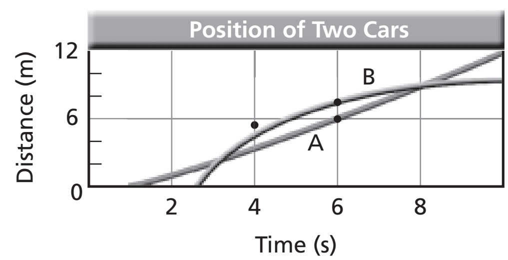
$t = \frac{5.2\times10^3\text{ m}}{2.2\text{ m/s}}$

$= 2.4\times10^3\text{ s}$

$= 39\text{ min}$

The skier should pass your house at 8:25 + 0:39 = 9:04 A.M.

104. Figure 4-26 is a position-time graph of the motion of two cars on a road. (Chapter 3)



■ **Figure 4-26**

a. At what time(s) does one car pass the other?

3 s, 8 s

b. Which car is moving faster at 7.0 s?

car A

c. At what time(s) do the cars have the same velocity?

5 s

d. Over what time interval is car B speeding up all the time?

none

e. Over what time interval is car B slowing down all the time?

~ 3 s to 10 s

105. Refer to Figure 4-26 to find the instantaneous speed for the following: (Chapter 3)

a. car B at 2.0 s

0 m/s

b. car B at 9.0 s

∼ 0 m/s

c. car A at 2.0 s

∼ 1 m/s

Challenge Problem

page 100

An air-track glider passes through a photoelectric gate at an initial speed of 0.25 m/s. As it passes through the gate, a constant force of 0.40 N is applied to the glider in the same direction as its motion. The glider has a mass of 0.50 kg.

1. What is the acceleration of the glider?

$$F = ma$$

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

$$= \frac{0.40\text{ N}}{0.50\text{ kg}}$$

$$= 0.80\text{ m/s}^2$$

2. It takes the glider 1.3 s to pass through a second gate. What is the distance between the two gates?

$$d_f = d_i + v_i t + \frac{1}{2}at^2$$

Let d_i = position of first gate = 0.0 m

$$d = 0.0\text{ m} + (0.25\text{ m/s})(1.3\text{ s}) + \left(\frac{1}{2}\right)(0.80\text{ m/s}^2)(1.3\text{ s})^2$$

$$= 1.0\text{ m}$$

3. The 0.40-N force is applied by means of a string attached to the glider. The other end of the string passes over a resistance-free pulley and is attached to a hanging mass, *m*. How big is *m*?

$$F_g = m_{mass}g$$

$$m_{mass} = \frac{F_g}{g}$$

$$= \frac{0.40\text{ N}}{9.80\text{ m/s}^2}$$

$$= 4.1\times10^{-2}\text{ kg}$$

4. Derive an expression for the tension, *T*, in the string as a function of the mass, *M*, of the glider, the mass, *m*, of the hanging mass, and *g*.

$$T = mg = Ma$$