Ch 3 (5th ed)

The weight of an object close to Earth's surface is given by **W** = m**g**, where **g** is the acceleration due to gravity, about 10 (meters per second) per second downward. Weight, a force, should not be confused with mass.

There is no such thing as an isolated force. All forces occur in pairs that are equal in size and opposite in direction. As you stand on the floor, you exert a downward force *on the floor.* According to Newton's third law, the floor must exert an upward force *on you* of the same size. These two forces do not cancel as they act on different objects—one on you and one on the floor. The other force acting on you is the force of gravity.

KEY TERMS

force: A push or a pull. Measured by the acceleration it produces on a standard, isolated object, **F** = m**a**. Measured in newtons.

inertia: An object's resistance to a change in its velocity.

inversely proportional: A relationship in which two quantities have a constant product. If one quantity increases by a certain factor, the other decreases by the same factor.

kilogram: The standard international (SI) unit of mass. A kilogram of material weighs about 2.2 pounds on Earth.

kinetic friction: The frictional force between two surfaces in relative motion. This force does not depend very much on the relative speed.

law of inertia: Newton's first law of motion.

mass: A measure of the quantity of matter in an object. The mass determines an object's inertia. Measured in kilograms.

newton: The SI unit of force. A net force of 1 newton accelerates a mass of 1 kilogram at a rate of 1 (meter per second) per second.

Newton's first law of motion: The velocity of an object remains constant unless an unbalanced force acts on the object.

Newton's second law of motion: $\mathbf{F}_{net} = m\mathbf{a}$. The net force on an object is equal to its mass times its acceleration. The net force and the acceleration are vectors that always point in the same direction.

Newton's third law of motion: If an object exerts a force on a second object, the second object exerts an equal force back on the first object.

proportional: A relationship in which two quantities have a constant ratio. If one quantity increases by a certain factor, the other increases by the same factor.

static friction: The frictional force between two surfaces at rest relative to each other. This force is equal and opposite to the net applied force if the force is not large enough to make the object accelerate.

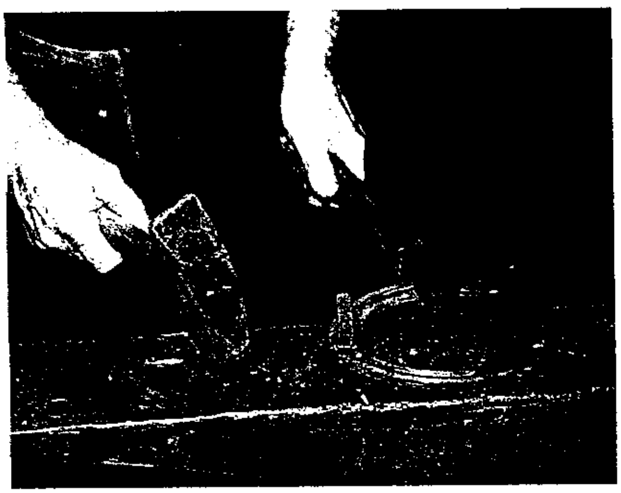
terminal speed: The speed obtained in free fall when the upward force of air resistance is equal to the downward force of gravity.

weight: **W** = m**g**. The force of gravitational attraction of Earth for an object. This definition is modified in Chapter 9 for accelerating systems such as elevators and spacecraft.

CONCEPTUAL QUESTIONS

1. The room you are sitting in is currently moving at about 400 meters per second as a result of Earth spinning about its axis. The walls of the room are attached to Earth but, if you jump up into the air, you are not. Why does the west wall *not* move across and strike you?
2. The room you are sitting in is currently moving at about 400 meters per second as a result of Earth spinning about its axis. The walls of the room are attached to Earth but, if your keys fall out of your pocket, they are not. Why do the keys *not* appear to fly back toward the west wall?
3. Assume that you are pushing a car across a level parking lot. When you stop pushing, the car comes to a stop. Does this violate Newton's first law? Why?
4. If you give this book a shove so that it moves across a tabletop, it slows and comes to a stop. How can you reconcile this observation with Newton's first law?
5. How does the net force on the first subway car compare with that on the last car if the subway train has a constant velocity?

6. What can you say about the forces acting on a motorcycle that is traveling at a constant speed down a straight stretch of highway?
7. Why does a tassel hanging from the rearview mirror appear to swing forward as you apply the brakes?
8. When dogs finish swimming, they often shake themselves to dry off. What is the physics behind this?
9. Modern automobiles are required to have headrests to protect your neck during collisions. For what type of collision are these headrests most effective?
10. Assume that you're not wearing your seat belt and the car stops suddenly. Why would your head hit the windshield?
11. Why does a blacksmith use an anvil when hammering a horseshoe?



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12. You find that every time you pound a steak on your kitchen counter, the bottles fall out of the spice rack hanging on your wall. To solve the problem, you buy a large oak cutting board, which you place on the counter under the steak. Why does this help?
13. In everyday use, *inertia* means that something is hard to get moving. Is this the only meaning it has in physics? If not, what other meaning does it have?
14. How would you determine if two objects have the same inertia?
15. When a number of different forces act on an object, is the net force necessarily in the same direction as one of the individual forces? Why?
16. You are analyzing a problem in which two forces act on an object. A 200-newton force pulls to the right, and a 40-newton force pulls to the left. Your classmate asserts that the net force is 200 newtons because that is the dominant force that is acting. What is wrong with this assertion?
17. Forces of 4 newtons and 6 newtons act on an object. What is the minimum value for the sum of these two forces?
18. Two ropes are being used to pull a car out of a ditch. Each rope exerts a force of 700 newtons on the car. Is it possible for the sum of these two forces to have a magnitude of 1000 newtons? Explain your reasoning.
19. You apply a 75-newton force to pull a child's wagon across the floor at constant speed. If you increase your pull to 80 newtons, will the wagon speed up to some new constant speed, or will it continue to speed up indefinitely? Explain your reasoning.
20. You push a crate full of books across the floor at a constant speed of 0.5 meter per second. You then remove some of the books and push exactly the same as you did before. How does the crate's motion differ, if at all, from before?
21. If the net force on a boat is directed due east, what is the direction of the acceleration of the boat? Would your answer change if the boat had a velocity due north but the net force still acted to the east?
22. If the net force on a hot-air balloon is directed vertically upward, what is the direction of the acceleration of the balloon? What would be the direction of the acceleration if the balloon were being blown westward (with the net force still acting vertically upward)?
23. You are riding an elevator from your tenth-floor apartment to the parking garage in the basement. As you approach the garage, the elevator begins to slow. What is the direction of the net force on you?
24. You are riding an elevator from the parking garage in the basement to the tenth floor of an apartment building. As you approach your floor, the elevator begins to slow. What is the direction of the net force on you?
25. If you double the net horizontal force applied to a wagon, what happens to the wagon's acceleration?
26. What happens to the acceleration of a rocket if the net force on it is cut in half?
27. A car can accelerate at 2 (meters per second) per second when towing an identical car. What will its acceleration be if the towrope breaks?
28. What happens to the acceleration of an object when the mass is tripled but the force remains the same?
29. When an astronaut walks on the Moon, is either her mass or her weight the same as on Earth? Explain.
30. If you buy a bag of oranges labeled 5 kilograms, are you buying the oranges by mass or by weight?
31. What happens to the weight of an object if you triple its mass?
32. What happens to the weight of an object if you take it from Earth to the Moon, where the acceleration due to gravity is only one-sixth as large?
33. A skier is speeding up as she skis down a constant slope. Draw a free-body diagram for the skier.
34. A car on an uphill section of the highway is speeding up to pass a truck. Draw a free-body diagram for the car.

35. Under what conditions will a golf ball and a Ping-Pong ball that are dropped simultaneously from the same height reach the ground at the same time?

36. If a golf ball and a Ping-Pong ball are simultaneously dropped from the same height, they do not reach the ground at the same time. How would Aristotle explain this? How would Galileo?

37. A marble dropped into a bottle of liquid soap quickly reaches a terminal speed. Draw a free-body diagram for the marble just before it hits the bottom of the bottle. What is the acceleration of the marble at this time?

38. Draw a free-body diagram for a parachutist who has reached terminal speed. What is his acceleration?

39. Alex is taking the high-speed elevator, which travels at a constant speed of 5 meters per second, to the 43rd floor of a high-rise building. Sam is stuck making the same trip in the freight elevator, which only travels at a constant speed of 1.5 meters per second. Compare the net forces on Alex and Sam.

40. Pat and Chris are pushing identical crates across a rough floor. Pat's crate is moving at a constant 1 meter per second while Chris's crate is moving at a constant 2 meters per second. Compare the net forces on the two crates.

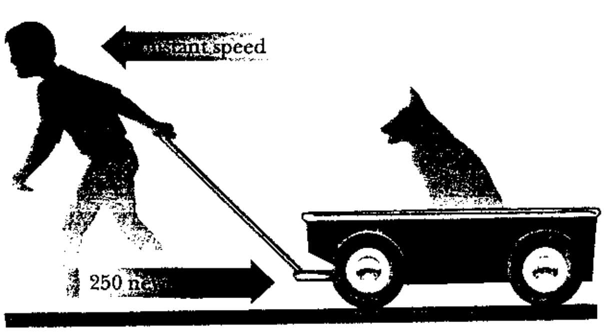
41. A friend falsely claims, "Newton's first law doesn't work if there is any friction." How would you correct this claim?

42. One of your classmates falsely asserts, "Newton's second law only works when there are no frictional forces." How would you correct this assertion?

43. You are applying a 400-newton force to a freezer full of chocolate chip ice cream in an attempt to move it across the basement. It will not budge. Is the frictional force exerted by the floor on the freezer greater than, equal to, or less than 400 newtons?

44. You find that you must push with a force of 12 newtons to keep a textbook sliding at constant speed across your desk. With the book at rest, you apply a force of 13 newtons. Is it possible that the book will stay at rest? Explain.

45. What force is required to pull a dog in a wagon along a level sidewalk, as in the figure, at a constant speed if the frictional force is 250 newtons?



46. A skier is skiing down a steep slope, traveling at constant speed (that is, the skier has reached terminal velocity). What are the size and direction of the net force on the skier?

47. You are driving along the freeway at 75 mph when a bug splats on your windshield. Compare the force of the bug on the windshield to the force of the windshield on the bug.

48. You leap from a bridge with a bungee cord tied around your ankles. As you approach the river below, the bungee cord begins to stretch and you begin to slow down. Which is greater (if either), the force of the cord on your ankles to slow you or the force of your ankles on the cord to stretch it? Explain.

49. Is the force that the Sun exerts on Earth bigger, smaller, or the same size as the force that Earth exerts on the Sun? Explain your reasoning.

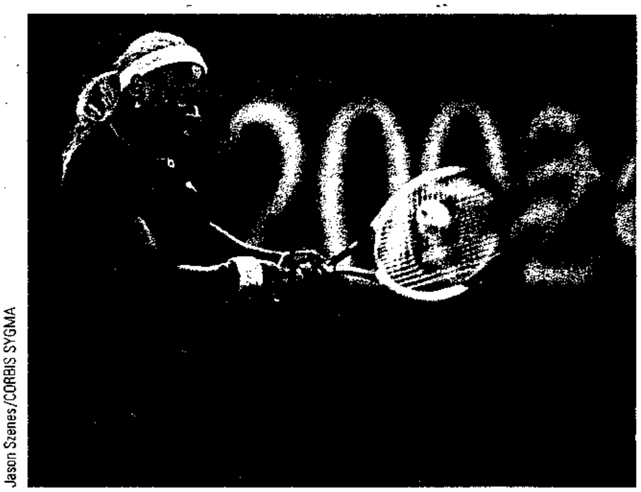
50. Earth exerts a force of 500,000 newtons on an orbiting communications satellite. Is the force that the satellite exerts on Earth greater than, equal to, or less than 500,000 newtons? Explain.

51. What is the net force on an apple that weighs 4 newtons when you hold it at rest?

52. Suppose you are holding an apple that weighs 4 newtons. What is the net force on the apple just after you drop it?

53. Why do the cannons aboard pirates' ships roll backward when they are fired?

54. Why does a tennis racket slow down when it hits a ball?



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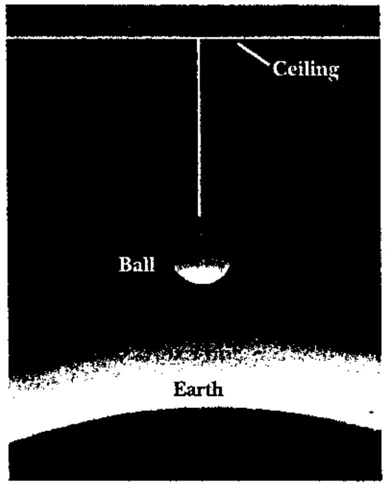
55. Describe the force(s) that allow you to walk across a room.

***56.** We often say that the engine supplies the forces that propel a car. This is an oversimplification. What are the forces that actually move the car?

57. A ball with a weight of 40 newtons is falling freely toward the surface of the Moon. What force does this ball exert on the Moon?

58. The figure shows a ball hanging by a string from the ceiling. Identify the action–reaction pairs in this drawing. Argue that the sizes of all six forces are the same.



***59.** If the force exerted by a horse on a cart is equal and opposite to the force exerted by the cart on the horse, as required by Newton's third law, how does the horse manage to move the cart?

60. Gary reads about Newton's third law while sitting in a room with a single closed door. He reasons that if he applies a force to the door there will be an equal and opposite force that will cancel his pull and he will never be able to escape. He bemoans: "Why did I ever take physics?" What is wrong with Gary's reasoning?

61. A soft-drink can sits at rest on a table. Which of Newton's laws explains why the upward force of the table acting on the can is equal and opposite to Earth's gravitational force pulling down on the can?

62. A book sits at rest on a table. Which force does Newton's third law tell us is equal and opposite to the gravitational force acting on the book?

EXERCISES

1. Find the size of the net force produced by a 6-N and an 8-N force in each of the following arrangements:
   a. The forces act in the same direction.
   b. The forces act in opposite directions.
   c. The forces act at right angles to each other.

2. Find the size of the net force produced by a 5-N and a 12-N force in each of the following arrangements:
   a. The forces act in the same direction.
   b. The forces act in opposite directions.
   c. The forces act at right angles to each other.

3. Two horizontal forces act on a wagon, 550 N forward and 300 N backward. What force is needed to produce a net force of zero?

4. Three forces act on an object. A 3-N force acts due west and a 4-N force acts due south. If the net force on the object is zero, what is the magnitude of the third force?

5. What is the acceleration of a 600-kg buffalo if the net force on the buffalo is 1800 N?

6. What is the acceleration of a 2000-kg car if the net force on the car is 4000 N?

7. A 30-06 bullet has a mass of 0.010 kg. If the average force on the bullet is 9000 N, what is the bullet's average acceleration?

8. The net horizontal force on a 60,000-kg railroad boxcar is 6000 N. What is the acceleration of the boxcar?

9. What net force is needed to accelerate a 60-kg ice skater at 2 m/s^2?

10. If a sled with a mass of 20 kg is to accelerate at 4 m/s^2, what net force is needed?

11. If a 30-kg instrument has a weight of 50 N on the Moon, what is its acceleration when it is dropped?

12. A salesperson claims a 1200-kg car has an average acceleration of 4 m/s^2 from a standing start to 100 km/h. What average net force is required to do this?

13. If a skydiver has a net force of 300 N and an acceleration of 4 m/s^2, what is the mass of the skydiver?

14. A child on roller skates undergoes an acceleration of 0.6 m/s^2 due to a horizontal net force of 24 N. What is the mass of the child?

15. A 0.5-kg ball has been thrown vertically upward. If we ignore the air resistance, what are the direction and size of each force acting on the ball while it is traveling upward?

16. A 1-kg ball is thrown straight up in the air. What is the net force acting on the ball when it reaches its maximum height? What is the ball's acceleration at this point?

17. If a space explorer with a mass of 80 kg has a weight of 400 N on a newly discovered planet, what is the acceleration due to gravity on this planet?

18. A fully equipped astronaut has a mass of 150 kg. If the astronaut has a weight of 555 N standing on the surface of Mars, what is the acceleration due to gravity on Mars?

***19.** A crate has a mass of 24 kg. What applied force is required to produce an acceleration of 3 m/s^2 if the frictional force is known to be 90 N?

***20.** A rope is used to pull a 10-kg block across the floor with an acceleration of 3 m/s^2. If the frictional force acting on the block is 50 N, what is the tension in the rope?

***21.** If a pull of 210 N accelerates a 40-kg child on ice skates at a rate of 5 m/s^2, what is the frictional force acting on the skates?

***22.** If you stand on a spring scale in your bathroom at home, it reads 600 N, which means your mass is 60 kg. If instead you stand on the scale while accelerating at 2 m/s^2 upward in an elevator, how many newtons would it read?

23. Terry and Chris pull hand-over-hand on opposite ends of a rope while standing on a frictionless frozen pond. Terry's mass is 75 kg, and Chris's mass is 50 kg. If Terry's acceleration is 2 m/s^2, what is Chris's acceleration?

***24.** A mother of mass 50 kg and her daughter of mass 25 kg are ice-skating. They face each other, and the mother pushes on the daughter such that the daughter's acceleration is 2 m/s^2. What is the force exerted by the mother on the daughter? What is the force exerted by the daughter on the mother? What is the mother's acceleration?

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