CONCEPTUAL QUESTIONS

1. An elevator suspended by a cable is descending at constant velocity. How many force vectors would be shown on a free-body diagram? Name them.
2. A compressed spring is pushing a block across a rough horizontal table. How many force vectors would be shown on a free-body diagram? Name them.
3. A brick is falling from the roof of a three-story building. How many force vectors would be shown on a free-body diagram? Name them.
4. In **FIGURE Q5.4**, block B is falling and dragging block A across a table. How many force vectors would be shown on a free-body diagram of block A? Name them.

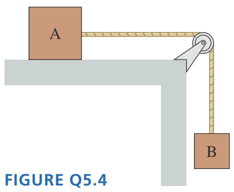

FIGURE Q5.4

5. You toss a ball straight up in the air. Immediately after you let go of it, what force or forces are acting on the ball? For each force you name, (a) state whether it is a contact force or a long-range force and (b) identify the agent of the force.
6. A constant force applied to object A causes it to accelerate at 4 m/s^2. The same force applied to object B causes an acceleration of 8 m/s^2. When applied to object C, the rate of acceleration is 6 m/s^2.
   a. Which object has the largest mass? Explain.
   b. Which object has the smallest mass?
   c. What is the ratio of the mass of object A to that of object B?
7. An object experiencing a constant force accelerates at 5 m/s^2. What will the acceleration of this object be if
   a. the force is halved? Explain.
   b. the mass is halved?
   c. both the force and mass are halved?
8. An object experiencing a constant force accelerates at 5 m/s^2. What will the acceleration of this object be if
   a. the force is doubled? Explain.
   b. the mass is doubled?
   c. both the force and the mass are doubled?
9. If an object is at rest, can you conclude that there are no forces acting on it? Explain.
10. If a force is exerted on an object, is it possible for that object to be moving with constant velocity? Explain.
11. Is the statement "An object always moves in the direction of the net force acting on it" true or false? Explain.
12. Newton's second law says $\vec{F}_{net} = m\vec{a}$. So is $m\vec{a}$ a force? Explain.
13. What is the condition under which the speed of an object remains constant, even when the net external force on it is not zero?
14. Suppose you press your physics book against a wall hard enough to keep it from moving. Does the friction force on the book point (a) into the wall, (b) out of the wall, (c) up, (d) down, or (e) is there no friction force? Explain.
15. **FIGURE Q5.15** shows a hollow tube forming three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C? Explain.

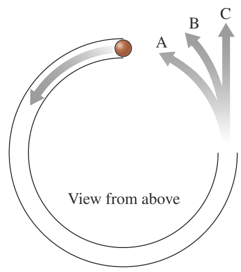

FIGURE Q5.15

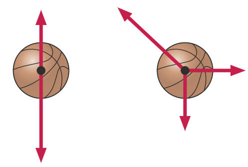
FIGURE Q5.16

16. Which, if either, of the basketballs in **FIGURE Q5.16** are in equilibrium? Explain.
17. Dental braces used to correct the alignment of teeth in young adults are made of a steel wire having a tension of about 30 N. This force is high enough to break a tooth. Despite this braces help correct the alignment of teeth over a long period of time. How is this made possible?

EXERCISES AND PROBLEMS

Exercises

Section 5.3 Identifying Forces

1. | A car is parked on a steep hill. Identify the forces on the car.
2. | A chandelier hangs from a chain in the middle of a dining room. Identify the forces on the chandelier.
3. | A baseball player is sliding into second base. Identify the forces on the baseball player.
4. || A jet plane is speeding down the runway during takeoff. Air resistance is not negligible. Identify the forces on the jet.
5. || An arrow has just been shot from a bow and is now traveling horizontally. Air resistance is not negligible. Identify the forces on the arrow.

Section 5.4 What Do Forces Do?

6. | Two rubber bands cause an object to accelerate with acceleration a. How many rubber bands are needed to cause an object with half the mass to accelerate three times as quickly?
7. | Two rubber bands pulling on an object cause it to accelerate at 1.2 m/s^2.
   a. What will be the object's acceleration if it is pulled by four rubber bands?
   b. What will be the acceleration of two of these objects glued together if they are pulled by two rubber bands?

8. || **FIGURE EX5.8** shows acceleration-versus-force graphs for two objects pulled by rubber bands. What is the mass ratio m_1/m_2?

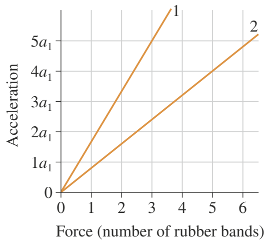

FIGURE EX5.8

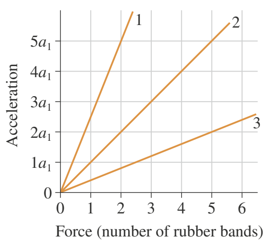

FIGURE EX5.9

9. || **FIGURE EX5.9** shows an acceleration-versus-force graph for three objects pulled by rubber bands. The mass of object 2 is 0.20 kg. What are the masses of objects 1 and 3? Explain your reasoning.

10. || For an object starting from rest and accelerating at a constant rate, distance traveled is proportional to the square of the time. If an object travels 3 furlongs in the first 2 s, how far will it travel in the first 3 s?

11. || You will learn in Chapter 25 that the *potential energy* of two electric charges is inversely proportional to the distance between them.Two charges 30 nm apart have 1.0 J of potential energy. What is their potential energy if they are 10 nm apart?

Section 5.5 Newton's Second Law

12. | **FIGURE EX5.12** shows an acceleration-versus-force graph for a 200 g object. What force values go in the blanks on the horizontal scale?

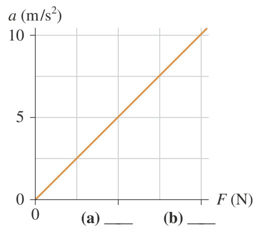

FIGURE EX5.12

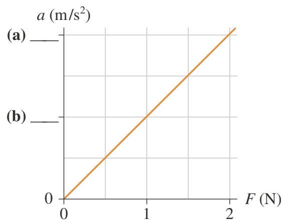

FIGURE EX5.13

13. | **FIGURE EX5.13** shows an acceleration-versus-force graph for a 500 g object. What acceleration values go in the blanks on the vertical scale?

14. || **FIGURE EX5.14** shows the acceleration of objects of different mass that experience the same force. What is the magnitude of the force?

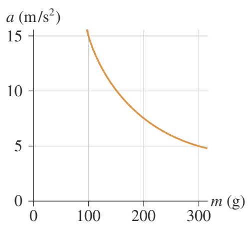

FIGURE EX5.14

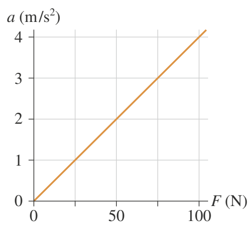

FIGURE EX5.15

15. | **FIGURE EX5.15** shows an object's acceleration-versus-force graph. What is the object's mass?

16. | Based on the information in Table 5.1, *estimate*
   a. The weight of a laptop computer.
   b. The propulsion force of a bicycle.

Section 5.6 Newton's First Law

Exercises 17 through 19 show two of the three forces acting on an object in equilibrium. Redraw the diagram, showing all three forces. Label the third force $\vec{F}_3$.

17. ||

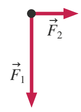

FIGURE EX5.17

18. ||

FIGURE EX5.18

19. ||

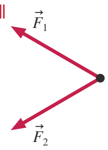

FIGURE EX5.19

Section 5.7 Free-Body Diagrams

Exercises 20 through 22 show a free-body diagram. For each, write a short description of a real object for which this would be the correct free-body diagram. Use Examples 5.4, 5.5, and 5.6 as examples of what a description should be like.

20. |

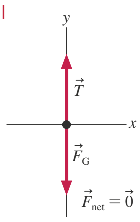

FIGURE EX5.20

21. |

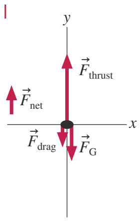

FIGURE EX5.21

22. |

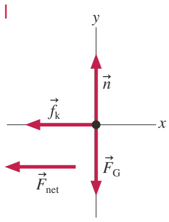

FIGURE EX5.22

Exercises 23 through 27 describe a situation. For each, identify all forces acting on the object and draw a free-body diagram of the object.

23. | A cat is sitting on a window sill.
24. | An ice hockey puck glides across frictionless ice.
25. | Your physics textbook is sliding across the table.
26. | A steel beam, suspended by a single cable, is being lowered by a crane at a steadily decreasing speed.
27. | A jet plane is accelerating down the runway during takeoff. Friction is negligible, but air resistance is not.

Problems

28. | Redraw the two motion diagrams shown in **FIGURE P5.28**, then draw a vector beside each one to show the direction of the net force acting on the object. Explain your reasoning.

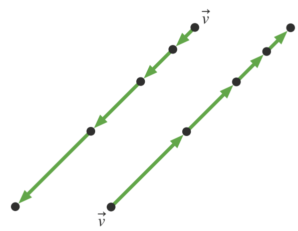

FIGURE P5.28 **(a)** **(b)**

29. | A single force with x-component F_x acts on a 2.0 kg object as it moves along the x-axis. The object's acceleration graph (a_x versus t) is shown in **FIGURE P5.29**. Draw a graph of F_x versus t.

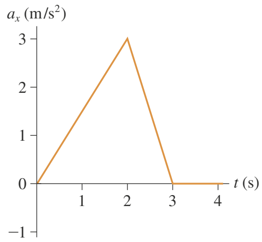

FIGURE P5.29

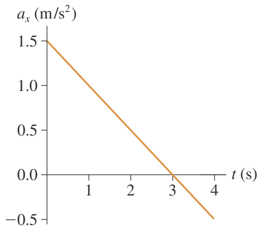

FIGURE P5.30

30. || A single force with x-component F_x acts on a 500 g object as it moves along the x-axis. The object's acceleration graph (a_x versus t) is shown in **FIGURE P5.30**. Draw a graph of F_x versus t.

31. | A single force with x-component F_x acts on a 2.0 kg object as it moves along the x-axis. A graph of F_x versus t is shown in **FIGURE P5.31**. Draw an acceleration graph (a_x versus t) for this object.

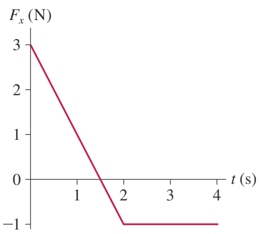

FIGURE P5.31

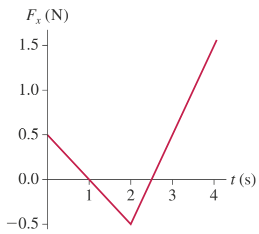

FIGURE P5.32

32. || A single force with x-component F_x acts on a 500 g object as it moves along the x-axis. A graph of F_x versus t is shown in **FIGURE P5.32**. Draw an acceleration graph (a_x versus t) for this object.

33. | A constant force is applied to an object, causing it to accelerate at 6.0 m/s^2. What will the acceleration be if
a. the force is doubled?
b. the object's mass is doubled?
c. both the force and the object's mass are doubled?
d. the force is doubled but the object's mass is halved?

34. | A constant force is applied to an object, causing it to accelerate at 8 m/s^2. What will the acceleration be if
a. the force is halved?
b. the object's mass is halved?
c. both force and the object's mass are halved?
d. the force is halved but the object's mass is doubled?

Problems 35 through 40 show a free-body diagram. For each:
a. Identify the direction of the acceleration vector $\vec{a}$ and show it as a vector next to your diagram. Or, if appropriate, write $\vec{a} = \vec{0}$.
b. If possible, identify the direction of the velocity vector $\vec{v}$ and show it as a labeled vector.
c. Write a short description of a real object for which this is the correct free-body diagram. Use Examples 5.4, 5.5, and 5.6 as models of what a description should be like.

35. |

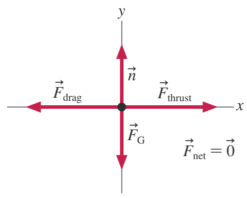

FIGURE P5.35

36. |

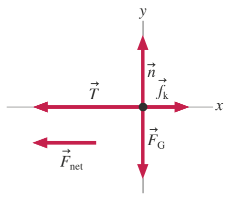

FIGURE P5.36

37. |

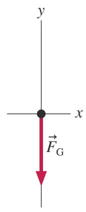

FIGURE P5.37

38. |

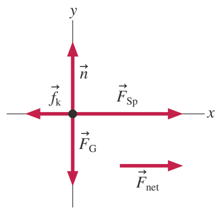

FIGURE P5.38

39. ||

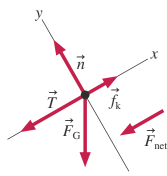

FIGURE P5.39

40. ||

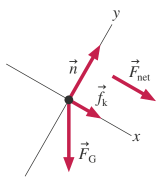

FIGURE P5.40

41. || In lab, you propel a cart with four known forces while using an ultrasonic motion detector to measure the cart's acceleration. Your data are as follows:

Force (N)	Acceleration (m/s^2)
0.25	0.5
0.50	0.8
0.75	1.3
1.00	1.8

a. How should you graph these data so as to determine the mass of the cart from the slope of the line? That is, what values should you graph on the horizontal axis and what on the vertical axis?
b. Is there another data point that would be reasonable to add, even though you made no measurements? If so, what is it?
c. What is your best determination of the cart's mass?

Problems 42 through 52 describe a situation. For each, draw a motion diagram, a force-identification diagram, and a free-body diagram.

42. | An elevator, suspended by a single cable, has just left the tenth floor and is speeding up as it descends toward the ground floor.

43. || A rocket is being launched straight up. Air resistance is not negligible.

44. | A Styrofoam ball has just been shot straight up. Air resistance is not negligible.

45. | You are a rock climber going upward at a steady pace on a vertical wall.

46. ‖ You've slammed on the brakes and your car is skidding to a stop while going down a 20° hill.
47. | You've just kicked a rock on the sidewalk and it is now sliding along the concrete.
48. ‖ You've jumped down from a platform. Your feet are touching the ground and your knees are flexing as you stop.
49. ‖ You are bungee jumping from a high bridge. You are moving downward while the bungee cord is stretching.
50. ‖ Your friend went for a loop-the-loop ride at the amusement park. Her car is upside down at the top of the loop.
51. ‖ A spring-loaded gun shoots a plastic ball. The trigger has just been pulled and the ball is starting to move down the barrel. The barrel is horizontal.
52. ‖ A person on a bridge throws a rock straight down toward the water. The rock has just been released.

53. ‖ BIO The leaf hopper, champion jumper of the insect world, can jump straight up at 4 m/s^2. The jump itself lasts a mere 1 ms before the insect is clear of the ground.
    a. Draw a free-body diagram of this mighty leaper while the jump is taking place.
    b. While the jump is taking place, is the force of the ground on the leaf hopper greater than, less than, or equal to the force of gravity on the leaf hopper? Explain.
54. ‖ Calculate the force that a sportsperson weighing 62 kg must exert on the ground during a high jump to produce an upward acceleration 4.5 times the acceleration due to gravity. What is the net force with which she leaves the ground?
55. ‖ What average net force is required to bring a car weighing 850 kg to rest from a speed of 120 km/h within a distance of 50 m? What conclusion can you draw from the answer?
56. ‖ If a car stops suddenly, you feel "thrown forward." We'd like to understand what happens to the passengers as a car stops. Imagine yourself sitting on a *very* slippery bench inside a car. This bench has no friction, no seat back, and there's nothing for you to hold onto.
    a. Draw a picture and identify all of the forces acting on you as the car travels at a perfectly steady speed on level ground.
    b. Draw your free-body diagram. Is there a net force on you? If so, in which direction?
    c. Repeat parts a and b with the car slowing down.
    d. Describe what happens to you as the car slows down.
    e. Use Newton's laws to explain why you seem to be "thrown forward" as the car stops. Is there really a force pushing you forward?
    f. Suppose now that the bench is not slippery. As the car slows down, you stay on the bench and don't slide off. What force is responsible for your deceleration? In which direction does this force point? Include a free-body diagram as part of your answer.
57. ‖ A rubber ball bounces. We'd like to understand *how* the ball bounces.
    a. A rubber ball has been dropped and is bouncing off the floor. Draw a motion diagram of the ball during the brief time interval that it is in contact with the floor. Show 4 or 5 frames as the ball compresses, then another 4 or 5 frames as it expands. What is the direction of $\vec{a}$ during each of these parts of the motion?
    b. Draw a picture of the ball in contact with the floor and identify all forces acting on the ball.
    c. Draw a free-body diagram of the ball during its contact with the ground. Is there a net force acting on the ball? If so, in which direction?
    d. Write a paragraph in which you describe what you learned from parts a to c and in which you answer the question: How does a ball bounce?