Practice Problems

4.3 Interaction Forces pages 102–107

page 104

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.)

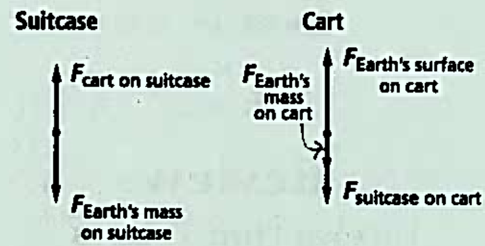
The only force acting on the brick is the gravitational attraction of Earth's mass. The brick exerts an equal and opposite force on Earth.

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**



page 106

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.

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

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

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

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

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

For the top mass with the positive direction upward:

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

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

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

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

$= 3.5$ **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.

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

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

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

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

$= 7.3\times10^2$ **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.

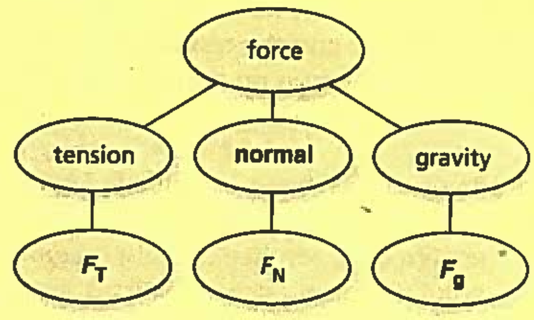
The tension would be 500 N. The rope is in equilibrium, so the net force on it is zero. The team and the tree exert equal forces in opposite directions.

Chapter Assessment

Concept Mapping

page 112

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



Mastering Concepts

page 112

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.

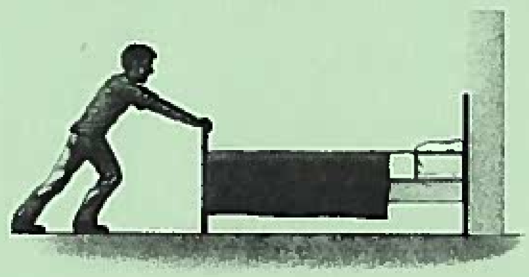
46. If your textbook is in equilibrium, what can you say about the forces acting on it? (4.2)

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

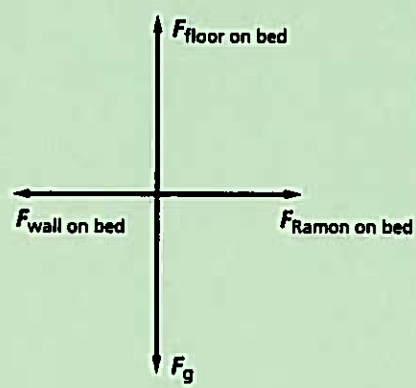
47. A rock is dropped from a bridge into a valley. Earth pulls on the rock and accelerates it downward. According to Newton's third law, the rock must also be pulling on Earth, yet Earth does not seem to accelerate. Explain. (4.3)

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)



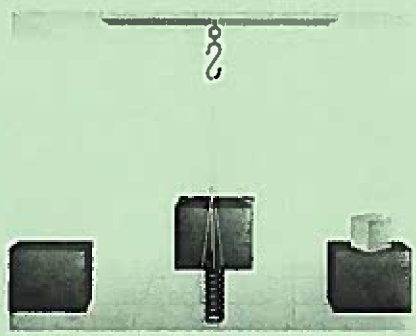
■ **Figure 4-17**



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 three 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)



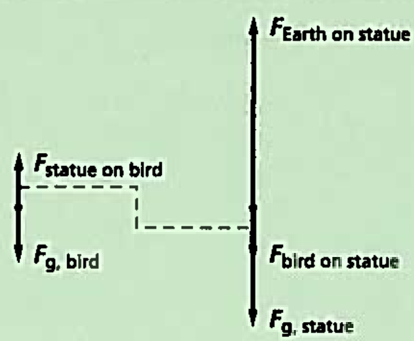
■ **Figure 4-18**

from left to right: third > first > second

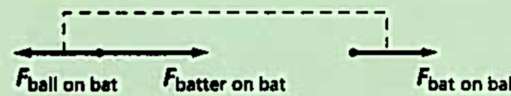
50. Explain why the tension in a massless rope is constant throughout it. (4.3)

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.

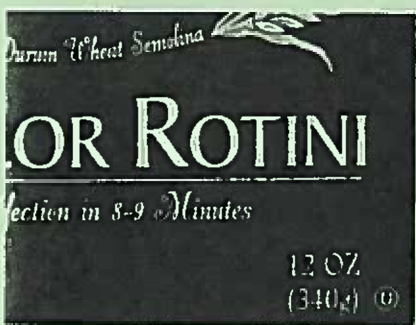
b. How does a headrest reduce whiplash?

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?

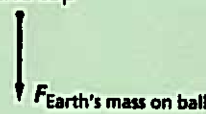
It means that on Earth's surface, the weight of 1 kg is equivalent to 2.2 lb. You should compare masses to masses and weights to weights. Thus 9.8 N equals 2.2 lb.

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

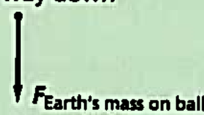
a. Draw a free-body diagram for the ball at three points during its motion: on the way up, at the very top, and on the way down. Specifically identify the forces acting on the ball and their agents.

On the way up

At the top



On the way down



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? Hint: 2.21 lb = 1.00 kg

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

Answers will vary.

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

$F_g = mg$

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

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

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?

$(100.0\text{ N})\left(\frac{1.00\text{ kg}}{9.80\text{ N}}\right)\left(\frac{2.21\text{ lb}}{1\text{ kg}}\right) = 22.55\text{ lb}$

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/s² 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/s² 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.

$$F_{scale} = F_g + F_{slowing}$$
$$= mg + ma$$
$$= m(g + a)$$
$$= (53\text{ kg})(9.80\text{ m/s}^2 + a)$$

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/s² 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.

$v_f^2 = v_i^2 + 2gd$

$v_i = 0\ \text{m/s}$

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.

$v_f^2 = v_i^2 + 2ad$

$v_f = 0$, so $a = \frac{-v_i^2}{2d}$

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?

$d = v_0t + \left(\frac{1}{2}\right)at^2$

Since $v_0 = 0$,

$a = \frac{2d}{t^2}$ and $F = ma$, 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?

$F_{net} = F_N - mg$ Fnet = 0

$F_N = F_{\text{7-kg block on 6-kg block}}$

$= mg$

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

$= 59\ \text{N}$; **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 55.0-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/s². 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