KEY TERMS

dynamics the study of how forces affect the motion of objects and systems

external force a force acting on an object or system that originates outside of the object or system

force a push or pull on an object with a specific magnitude and direction; can be represented by vectors; can be expressed as a multiple of a standard force

free-body diagram a diagram showing all external forces acting on a body

freefall a situation in which the only force acting on an object is the force of gravity

friction an external force that acts in the direction opposite to the direction of motion

inertia the tendency of an object at rest to remain at rest, or for a moving object to remain in motion in a straight line and at a constant speed

law of inertia Newton's first law of motion: a body at rest remains at rest or, if in motion, remains in motion at a constant speed in a straight line, unless acted on by a net external force; also known as the law of inertia

mass the quantity of matter in a substance; measured in kilograms

net external force the sum of all external forces acting on an object or system

net force the sum of all forces acting on an object or system

Newton's first law of motion a body at rest remains at rest or, if in motion, remains in motion at a constant speed in a straight line, unless acted on by a net external force; also known as the law of inertia

Newton's second law of motion the net external force, $\mathbf{F}_{\text{net}}$, on an object is proportional to and in the same direction as the acceleration of the object, $\mathbf{a}$, and also proportional to the object's mass, m; defined mathematically as $\mathbf{F}_{\text{net}} = m\mathbf{a}$ or $\Sigma\mathbf{F} = m\mathbf{a}$.

Newton's third law of motion when one body exerts a force on a second body, the first body experiences a force that is equal in magnitude and opposite in direction to the force that it exerts

normal force the force that a surface applies to an object; acts perpendicular and away from the surface with which the object is in contact

system one or more objects of interest for which only the forces acting on them from the outside are considered, but not the forces acting between them or inside them

tension a pulling force that acts along a connecting medium, especially a stretched flexible connector, such as a rope or cable; when a rope supports the weight of an object, the force exerted on the object by the rope is called tension

thrust a force that pushes an object forward in response to the backward ejection of mass by the object; rockets and airplanes are pushed forward by a thrust reaction force in response to ejecting gases backward

weight the force of gravity, $\mathbf{W}$, acting on an object of mass m; defined mathematically as $\mathbf{W} = m\mathbf{g}$, where $\mathbf{g}$ is the magnitude and direction of the acceleration due to gravity

SECTION SUMMARY

4.1 Force

- Dynamics is the study of how forces affect the motion of objects and systems.
- Force is a push or pull that can be defined in terms of various standards. It is a vector and so has both magnitude and direction.
- External forces are any forces outside of a body that act on the body. A free-body diagram is a drawing of all external forces acting on a body.

4.2 Newton's First Law of Motion: Inertia

- Newton's first law states that a body at rest remains at rest or, if moving, remains in motion in a straight line at a constant speed, unless acted on by a net external force. This law is also known as the law of inertia.
- Inertia is the tendency of an object at rest to remain at rest or, if moving, to remain in motion at constant velocity. Inertia is related to an object's mass.
- Friction is a force that opposes motion and causes an object or system to slow down.
- Mass is the quantity of matter in a substance.

4.3 Newton's Second Law of Motion

- Acceleration is a change in velocity, meaning a change in speed, direction, or both.
- An external force acts on a system from outside the system, as opposed to internal forces, which act between components within the system.
- Newton's second law of motion states that the acceleration of a system is directly proportional to and in the same direction as the net external force acting on the system, and inversely proportional to the system's mass.
- In equation form, Newton's second law of motion is $\mathbf{F}_{\text{net}} = m\mathbf{a}$ or $\Sigma\mathbf{F} = m\mathbf{a}$. This is sometimes written as $\mathbf{a} = \frac{\mathbf{F}_{\text{net}}}{m}$ or $\mathbf{a} = \frac{\Sigma\mathbf{F}}{m}$.
- The weight of an object of mass m is the force of gravity that acts on it. From Newton's second law, weight is

given by $\mathbf{W} = m\mathbf{g}$.

- If the only force acting on an object is its weight, then the object is in freefall.

4.4 Newton's Third Law of Motion

- Newton's third law of motion states that when one body exerts a force on a second body, the first body experiences a force that is equal in magnitude and opposite in direction to the force that it exerts.
- When an object rests on a surface, the surface applies a force on the object that opposes the weight of the object. This force acts perpendicular to the surface and is called the normal force.
- The pulling force that acts along a stretched flexible connector, such as a rope or cable, is called tension. When a rope supports the weight of an object at rest, the tension in the rope is equal to the weight of the object.
- Thrust is a force that pushes an object forward in response to the backward ejection of mass by the object. Rockets and airplanes are pushed forward by thrust.

KEY EQUATIONS

4.2 Newton's First Law of Motion: Inertia

Newton's first law of motion	$\mathbf{F}_{\text{net}} = 0$ or $\Sigma\mathbf{F} = 0$

4.3 Newton's Second Law of Motion

Newton's second law of motion	$\mathbf{F}_{\text{net}} = m\mathbf{a}$ or $\Sigma\mathbf{F} = m\mathbf{a}$
Newton's second law of motion to solve acceleration	$\mathbf{a} = \frac{\mathbf{F}_{\text{net}}}{m}$ or $\mathbf{a} = \frac{\Sigma\mathbf{F}}{m}$
Newton's second law of motion to solve weight	$\mathbf{W} = m\mathbf{g}$

4.4 Newton's Third Law of Motion

normal force for a nonaccelerating horizontal surface	$\mathbf{N} = m\mathbf{g}$
tension for an object at rest	$\mathbf{T} = m\mathbf{g}$

CHAPTER REVIEW

Concept Items

4.1 Force

1. What is dynamics?
   a. Dynamics is the study of internal forces.
   b. Dynamics is the study of forces and their effect on motion.
   c. Dynamics describes the motion of points, bodies, and systems without consideration of the cause of motion.
   d. Dynamics describes the effect of forces on each other.

2. Two forces acting on an object are perpendicular to one another. How would you draw these in a free-body diagram?
   a. The two force arrows will be drawn at a right angle to one another.
   b. The two force arrows will be pointing in opposite directions.
   c. The two force arrows will be at a 45° angle to one another.
   d. The two force arrows will be at a 180° angle to one another.

3. A free-body diagram shows the forces acting on an object. How is that object represented in the diagram?
   a. A single point
   b. A square box
   c. A unit circle
   d. The object as it is

4.2 Newton's First Law of Motion: Inertia

4. A ball rolls along the ground, moving from north to south. What direction is the frictional force that acts on the ball?
   a. North to south
   b. South to north
   c. West to east
   d. East to west

5. The tires you choose to drive over icy roads will create more friction with the road than your summer tires. Give another example where more friction is desirable.

a. Children's slide
b. Air hockey table
c. Ice-skating rink
d. Jogging track

6. How do you express, mathematically, that no external force is acting on a body?
   a. $F_{net} = -1$
   b. $F_{net} = 0$
   c. $F_{net} = 1$
   d. $F_{net} = \infty$

4.3 Newton's Second Law of Motion

7. What does it mean for two quantities to be inversely proportional to each other?
   a. When one variable increases, the other variable decreases by a greater amount.
   b. When one variable increases, the other variable also increases.
   c. When one variable increases, the other variable decreases by the same factor.
   d. When one variable increases, the other variable also increases by the same factor.

Critical Thinking Items

4.1 Force

12. Only two forces are acting on an object: force A to the left and force B to the right. If force B is greater than force A, in which direction will the object move?
   a. To the right
   b. To the left
   c. Upward
   d. The object does not move

13. In a free-body diagram, the arrows representing tension and weight have the same length but point away from one another. What does this indicate?
   a. They are equal in magnitude and act in the same direction.
   b. They are equal in magnitude and act in opposite directions.
   c. They are unequal in magnitude and act in the same direction.
   d. They are unequal in magnitude and act in opposite directions.

14. An object is at rest. Two forces, X and Y, are acting on it. Force X has a magnitude of x and acts in the downward direction. What is the magnitude and direction of Y?
   a. The magnitude is x and points in the upward direction.
   b. The magnitude is $2x$ and points in the upward direction.
   c. The magnitude is x and points in the downward direction.
   d. The magnitude is $2x$ and points in the downward direction.

8. True or False: Newton's second law can be interpreted based on Newton's first law.
   a. True
   b. False

4.4 Newton's Third Law of Motion

9. Which forces cause changes in the motion of a system?
   a. internal forces
   b. external forces
   c. both internal and external forces
   d. neither internal nor external forces

10. True or False—Newton's third law applies to the external forces acting on a system of interest.
   a. True
   b. False

11. A ball is dropped and hits the floor. What is the direction of the force exerted by the floor on the ball?
   a. Upward
   b. Downward
   c. Right
   d. Left

15. Three forces, A, B, and C, are acting on the same object with magnitudes a, b, and c, respectively. Force A acts to the right, force B acts to the left, and force C acts downward. What is a necessary condition for the object to move straight down?
   a. The magnitude of force A must be greater than the magnitude of force B, so $a > b$.
   b. The magnitude of force A must be equal to the magnitude of force B, so $a = b$.
   c. The magnitude of force A must be greater than the magnitude of force C, so $A > C$.
   d. The magnitude of force C must be greater than the magnitude of forces A or B, so $A < C > B$.

4.2 Newton's First Law of Motion: Inertia

16. Two people push a cart on a horizontal surface by applying forces F_1 and F_2 in the same direction. Is the magnitude of the net force acting on the cart, F_{net}, equal to, greater than, or less than $F_1 + F_2$? Why?
   a. $F_{net} < F_1 + F_2$ because the net force will not include the frictional force.
   b. $F_{net} = F_1 + F_2$ because the net force will not include

the frictional force

c. $F_{net} < F_1 + F_2$ because the net force will include the component of frictional force

d. $F_{net} = F_1 + F_2$ because the net force will include the frictional force

17. True or False: A book placed on a balance scale is balanced by a standard 1-kg iron weight placed on the opposite side of the balance. If these objects are taken to the moon and a similar exercise is performed, the balance is still level because gravity is uniform on the moon's surface as it is on Earth's surface.

a. True

b. False

4.3 Newton's Second Law of Motion

18. From the equation for Newton's second law, we see that F_{net} is directly proportional to **a** and that the constant of proportionality is ***m***. What does this mean in a practical sense?

a. An increase in applied force will cause an increase in acceleration if the mass is constant.

b. An increase in applied force will cause a decrease in acceleration if the mass is constant.

c. An increase in applied force will cause an increase in acceleration, even if the mass varies.

d. An increase in applied force will cause an increase in acceleration and mass.

4.4 Newton's Third Law of Motion

19. True or False: A person accelerates while walking on the ground by exerting force. The ground in turn exerts force F_2 on the person. F_1 and F_2 are equal in magnitude but act in opposite directions. The person is able to walk because the two forces act on the different systems and the net force acting on the person is nonzero.

a. True

b. False

20. A helicopter pushes air down, which, in turn, pushes the helicopter up. Which force affects the helicopter's motion? Why?

a. Air pushing upward affects the helicopter's motion because it is an internal force that acts on the helicopter.

b. Air pushing upward affects the helicopter's motion because it is an external force that acts on the helicopter.

c. The downward force applied by the blades of the helicopter affects its motion because it is an internal force that acts on the helicopter.

d. The downward force applied by the blades of the helicopter affects its motion because it is an external force that acts on the helicopter.

Problems

4.3 Newton's Second Law of Motion

21. An object has a mass of 1 kg on Earth. What is its weight on the moon?

a. 1 N

b. 1.67 N

c. 9.8 N

d. 10 N

22. A bathroom scale shows your mass as 55 kg. What will it read on the moon?

a. 9.4 kg

b. 10.5 kg

c. 55.0 kg

d. 91.9 kg

4.4 Newton's Third Law of Motion

23. A person pushes an object of mass 5.0 kg along the floor by applying a force. If the object experiences a friction force of 10 N and accelerates at 18 m/s^2, what is the magnitude of the force exerted by the person?

a. −90 N

b. −80 N

c. 90 N

d. 100 N

Performance Task

4.4 Newton's Third Law of Motion

24. A car weighs 2,000 kg. It moves along a road by applying a force on the road with a parallel component of 560 N. There are two passengers in the car, each weighing 55 kg. If the magnitude of the force of friction experienced by the car is 45 N, what is the acceleration of the car?

a. 0.244 m/s^2

b. 0.265 m/s^2

c. 4.00 m/s^2

d. 4.10 m/s^2

TEST PREP

Multiple Choice

4.1 Force

25. Which of the following is a physical quantity that can be described by dynamics but not by kinematics?
a. Velocity
b. Acceleration
c. Force

26. Which of the following is used to represent an object in a free-body diagram?
a. A point
b. A line
c. A vector

4.2 Newton's First Law of Motion: Inertia

27. What kind of force is friction?
a. External force
b. Internal force
c. Net force

28. What is another name for Newton's first law?
a. Law of infinite motion
b. Law of inertia
c. Law of friction

29. True or False—A rocket is launched into space and escapes Earth's gravitational pull. It will continue to travel in a straight line until it is acted on by another force.
a. True
b. False

30. A 2,000-kg car is sitting at rest in a parking lot. A bike and rider with a total mass of 60 kg are traveling along a road at 10 km/h. Which system has more inertia? Why?
a. The car has more inertia, as its mass is greater than the mass of the bike.
b. The bike has more inertia, as its mass is greater than the mass of the car.
c. The car has more inertia, as its mass is less than the mass of the bike.
d. The bike has more inertia, as its mass is less than the mass of the car.

4.3 Newton's Second Law of Motion

31. In the equation for Newton's second law, what does F_{net} stand for?
a. Internal force
b. Net external force
c. Frictional force

32. What is the SI unit of force?
a. Kg
b. dyn
c. N

33. What is the net external force on an object in freefall on Earth if you were to neglect the effect of air?
a. The net force is zero.
b. The net force is upward with magnitude *mg*.
c. The net force is downward with magnitude *mg*.
d. The net force is downward with magnitude 9.8 N.

34. Two people push a 2,000-kg car to get it started. An acceleration of at least 5.0 m/s^2 is required to start the car. Assuming both people apply the same magnitude force, how much force will each need to apply if friction between the car and the road is 300 N?
a. 4850 N
b. 5150 N
c. 97000 N
d. 10300 N

4.4 Newton's Third Law of Motion

35. One object exerts a force of magnitude F_1 on another object and experiences a force of magnitude F_2 in return. What is true for F_1 and F_2?
a. $F_1 > F_2$
b. $F_1 < F_2$
c. $F_1 = F_2$

36. A weight is suspended with a rope and hangs freely. In what direction is the tension on the rope?
a. parallel to the rope
b. perpendicular to the rope

37. A person weighing 55 kg walks by applying 160 N of force on the ground, while pushing a 10-kg object. If the person accelerates at 2 m/s^2, what is the force of friction experienced by the system consisting of the person and the object?
a. 30 N
b. 50 N
c. 270 N
d. 290 N

38. A 65-kg swimmer pushes on the pool wall and accelerates at 6 m/s^2. The friction experienced by the swimmer is 100 N. What is the magnitude of the force that the swimmer applies on the wall?
a. −490 N
b. −290 N
c. 290 N
d. 490 N

Short Answer

4.1 Force

39. True or False—An external force is defined as a force generated outside the system of interest that acts on an object inside the system.
   a. True
   b. False

40. By convention, which sign is assigned to an object moving downward?
   a. A positive sign (+)
   b. A negative sign (−)
   c. Either a positive or negative sign (±)
   d. No sign is assigned

41. A body is pushed downward by a force of 5 units and upward by a force of 2 units. How would you draw a free-body diagram to represent this?
   a. Two force vectors acting at a point, both pointing up with lengths of 5 units and 2 units
   b. Two force vectors acting at a point, both pointing down with lengths of 5 units and 2 units
   c. Two force vectors acting at a point, one pointing up with a length of 5 units and the other pointing down with a length of 2 units
   d. Two force vectors acting at a point, one pointing down with a length of 5 units and the other pointing up with a length of 2 units

42. A body is pushed eastward by a force of four units and southward by a force of three units. How would you draw a free-body diagram to represent this?
   a. Two force vectors acting at a point, one pointing left with a length of 4 units and the other pointing down with a length of 3 units
   b. Two force vectors acting at a point, one pointing left with a length of 4 units and the other pointing up with a length of 3 units
   c. Two force vectors acting at a point, one pointing right with a length of 4 units and the other pointing down with a length of 3 units
   d. Two force vectors acting at a point, one pointing right with a length of 4 units and the other pointing up with a length of 3 units

4.2 Newton's First Law of Motion: Inertia

43. A body with mass m is pushed along a horizontal surface by a force F and is opposed by a frictional force *f*. How would you draw a free-body diagram to represent this situation?
   a. A dot with an arrow pointing right, labeled F, and an arrow pointing left, labeled *f*, that is of equal length or shorter than F
   b. A dot with an arrow pointing right, labeled F, and an arrow pointing right, labeled *f*, that is of equal length or shorter than F
   c. A dot with an arrow pointing right, labeled F, and a smaller arrow pointing up, labeled *f*, that is of equal length or longer than F
   d. A dot with an arrow pointing right, labeled F, and a smaller arrow pointing down, labeled *f*, that is of equal length or longer than F

44. Two objects rest on a uniform surface. A person pushes both with equal force. If the first object starts to move faster than the second, what can be said about their masses?
   a. The mass of the first object is less than that of the second object.
   b. The mass of the first object is equal to the mass of the second object.
   c. The mass of the first object is greater than that of the second object.
   d. No inference can be made because mass and force are not related to each other.

45. Two similar boxes rest on a table. One is empty and the other is filled with pebbles. Without opening or lifting either, how can you tell which box is full? Why?
   a. By applying an internal force; whichever box accelerates faster is lighter and so must be empty
   b. By applying an internal force; whichever box accelerates faster is heavier and so the other box must be empty
   c. By applying an external force; whichever box accelerates faster is lighter and so must be empty
   d. By applying an external force; whichever box accelerates faster is heavier and so the other box must be empty

46. True or False—An external force is required to set a stationary object in motion in outer space away from all gravitational influences and atmospheric friction.
   a. True
   b. False

4.3 Newton's Second Law of Motion

47. A steadily rolling ball is pushed in the direction from east to west, which causes the ball to move faster in the same direction. What is the direction of the acceleration?
   a. North to south
   b. South to north
   c. East to west
   d. West to east

48. A ball travels from north to south at 60 km/h. After being hit by a bat, it travels from west to east at 60 km/

h. Is there a change in velocity?
   a. Yes, because velocity is a scalar.
   b. Yes, because velocity is a vector.
   c. No, because velocity is a scalar.
   d. No, because velocity is a vector

49. What is the weight of a 5-kg object on Earth and on the moon?
   a. On Earth the weight is 1.67 N, and on the moon the weight is 1.67 N.
   b. On Earth the weight is 5 N, and on the moon the weight is 5 N.
   c. On Earth the weight is 49 N, and on the moon the weight is 8.35 N.
   d. On Earth the weight is 8.35 N, and on the moon the weight is 49 N.

50. An object weighs 294 N on Earth. What is its weight on the moon?
   a. 50.1 N
   b. 30.0 N
   c. 249 N
   d. 1461 N

4.4 Newton's Third Law of Motion

51. A large truck with mass 30 m crashes into a small sedan with mass *m*. If the truck exerts a force F on the sedan, what force will the sedan exert on the truck?
   a. $\frac{F}{30}$
   b. F
   c. 2F
   d. 30F

52. A fish pushes water backward with its fins. How does this propel the fish forward?
   a. The water exerts an internal force on the fish in the opposite direction, pushing the fish forward.
   b. The water exerts an external force on the fish in the opposite direction, pushing the fish forward.
   c. The water exerts an internal force on the fish in the same direction, pushing the fish forward.
   d. The water exerts an external force on the fish in the same direction, pushing the fish forward.

53. True or False—Tension is the result of opposite forces in a connector, such as a string, rope, chain or cable, that pulls each point of the connector apart in the direction parallel to the length of the connector. At the ends of the connector, the tension pulls toward the center of the connector.
   a. True
   b. False

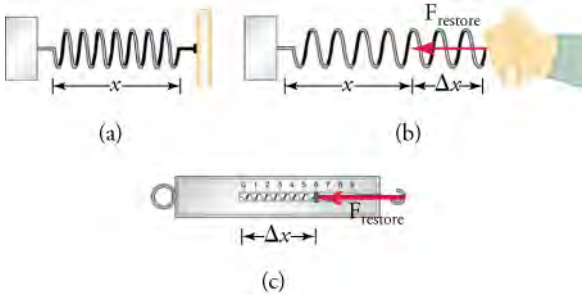
54. True or False—Normal reaction is the force that opposes the force of gravity and acts in the direction of the force of gravity.
   a. True
   b. False

Extended Response

4.1 Force

55. True or False—When two unequal forces act on a body, the body will not move in the direction of the weaker force.
   a. True
   b. False

56. In the figure given, what is $F_{restore}$? What is its magnitude?



   a. $F_{restore}$ is the force exerted by the hand on the spring, and it pulls to the right.
   b. $F_{restore}$ is the force exerted by the spring on the hand, and it pulls to the left.
   c. $F_{restore}$ is the force exerted by the hand on the spring, and it pulls to the left.
   d. $F_{restore}$ is the force exerted by the spring on the hand, and it pulls to the right.

4.2 Newton's First Law of Motion: Inertia

57. Two people apply the same force to throw two identical balls in the air. Will the balls necessarily travel the same distance? Why or why not?
   a. No, the balls will not necessarily travel the same distance because the gravitational force acting on them is different.
   b. No, the balls will not necessarily travel the same distance because the angle at which they are thrown may differ.
   c. Yes, the balls will travel the same distance because the gravitational force acting on them is the same.
   d. Yes, the balls will travel the same distance because the angle at which they are thrown may differ.

58. A person pushes a box from left to right and then lets the box slide freely across the floor. The box slows down as it slides across the floor. When the box is sliding

freely, what is the direction of the net external force?

a. The net external force acts from left to right.
b. The net external force acts from right to left.
c. The net external force acts upward.
d. The net external force acts downward.

4.3 Newton's Second Law of Motion

59. A 55-kg lady stands on a bathroom scale inside an elevator. The scale reads 70 kg. What do you know about the motion of the elevator?

a. The elevator must be accelerating upward.
b. The elevator must be accelerating downward.
c. The elevator must be moving upward with a constant velocity.
d. The elevator must be moving downward with a constant velocity.

60. True or False—A skydiver initially accelerates in his jump. Later, he achieves a state of constant velocity called terminal velocity. Does this mean the skydiver becomes weightless?

a. Yes
b. No

4.4 Newton's Third Law of Motion

61. How do rockets propel themselves in space?

a. Rockets expel gas in the forward direction at high velocity, and the gas, which provides an internal force, pushes the rockets forward.
b. Rockets expel gas in the forward direction at high velocity, and the gas, which provides an external force, pushes the rockets forward.
c. Rockets expel gas in the backward direction at high velocity, and the gas, which is an internal force, pushes the rockets forward.
d. Rockets expel gas in the backward direction at high velocity, and the gas, which provides an external force, pushes the rockets forward.

62. Are rockets more efficient in Earth's atmosphere or in outer space? Why?

a. Rockets are more efficient in Earth's atmosphere than in outer space because the air in Earth's atmosphere helps to provide thrust for the rocket, and Earth has more air friction than outer space.
b. Rockets are more efficient in Earth's atmosphere than in outer space because the air in Earth's atmosphere helps to provide thrust to the rocket, and Earth has less air friction than the outer space.
c. Rockets are more efficient in outer space than in Earth's atmosphere because the air in Earth's atmosphere does not provide thrust but does create more air friction than in outer space.
d. Rockets are more efficient in outer space than in Earth's atmosphere because the air in Earth's atmosphere does not provide thrust but does create less air friction than in outer space.