chapter 4 FORCES AND NEWTON'S LAWS OF MOTION

Section 4.1 The Concepts of Force and Mass
Section 4.2 Newton's First Law of Motion
Section 4.3 Newton's Second Law of Motion

☐ 1. With one exception, each of the following units can be used to express mass. What is the exception?
(a) newton (c) gram (e) kilogram
(b) slug (d) $N \cdot s^2/m$

☐ 2. Complete the following statement: The term *net force* most accurately describes
(a) the mass of an object
(b) the inertia of an object.
(c) the quantity that causes displacement.
(d) the quantity that keeps an object moving.
(e) the quantity that changes the velocity of an object.

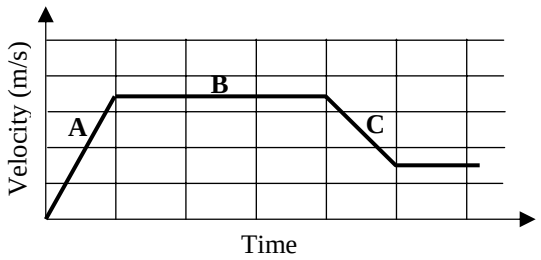
☐ 3. Which one of the following terms is used to indicate the natural tendency of an object to remain at rest or in motion at a constant speed along a straight line?
(a) velocity (c) acceleration (e) inertia
(b) force (d) equilibrium

◘ 4. Complete the following statement: An inertial reference frame is one in which
(a) Newton's first law of motion is valid.
(b) the inertias of objects within the frame are zero.
(c) the frame is accelerating.
(d) the acceleration due to gravity is greater than zero m/s^2.
(e) Newton's third law of motion is not valid.

☐ 5. A net force **F** is required to give an object with mass *m* an acceleration **a**. If a net force 6 **F** is applied to an object with mass 2*m*, what is the acceleration on this object?
(a) **a** (c) 3**a** (e) 6**a**
(b) 2**a** (d) 4**a**

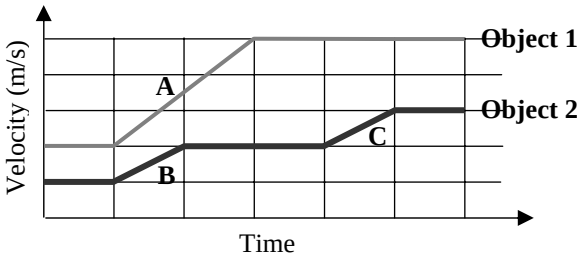
◘ 6. When the net force that acts on a hockey puck is 10 N, the puck accelerates at a rate of 50 m/s^2. Determine the mass of the puck.
(a) 0.2 kg (c) 5 kg (e) 50 kg
(b) 1.0 kg (d) 10 kg

◘ 7. The figure shows the velocity versus time curve for a car traveling along a straight line. Which of the following statements is false?



(a) No net force acts on the car during interval **B**.
(b) Net forces act on the car during intervals **A** and **C**.
(c) Opposing forces may be acting on the car during interval **B**.
(d) Opposing forces may be acting on the car during interval **C**.
(e) The magnitude of the net force acting during interval **A** is less than that during **C**.

8. The graph shows the velocities of two objects of equal mass as a function of time. Net forces $\mathbf{F}_A$, $\mathbf{F}_B$, and $\mathbf{F}_C$ acted on the objects during intervals A, B, and C, respectively. Which one of the following choices is the correct relationship between the magnitudes of the net forces?



(a) $F_B = F_C > F_A$
(b) $F_C > F_B > F_A$
(c) $F_A > F_B = F_C$
(d) $F_A = F_B = F_C$
(e) $F_A > F_B > F_C$

9. A 15-N net force is applied for 6.0 s to a 12-kg box initially at rest. What is the speed of the box at the end of the 6.0-s interval?
(a) 1.8 m/s
(b) 15 m/s
(c) 3.0 m/s
(d) 7.5 m/s
(e) 30 m/s

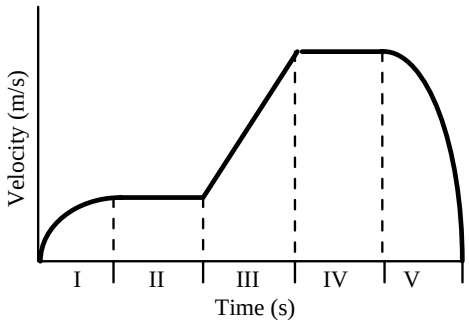
10. A 810-kg car accelerates from rest to 27 m/s in a distance of 120 m. What is the magnitude of the average net force acting on the car?
(a) 740 N
(b) 2500 N
(c) 91 N
(d) 1300 N
(e) 7900 N

11. A 2150-kg truck is traveling along a straight, level road at a constant speed of 55.0 km/h when the driver removes his foot from the accelerator. After 21.0 s, the truck's speed is 33.0 km/h. What is the magnitude of the average net force acting on the truck during the 21.0 s interval?
(a) 2250 N
(b) 626 N
(c) 1890 N
(d) 972 N
(e) 229 N

Questions 12 through 15 pertain to the situation described below:

A 2.0-kg object moves in a straight line on a horizontal frictionless surface.

The graph shows the velocity of the object as a function of time. The various equal time intervals are labeled using Roman numerals: I, II, III, IV, and V.



The net force on the object always acts along the line of motion of the object.

12. Which section(s) of the graph correspond to a condition of *zero net force*?
(a) V only
(b) III only
(c) II and IV
(d) II, III, and IV
(e) I, III, and V

13. Which section of the graph corresponds to the application of the *largest constant* net force?
(a) I
(b) II
(c) III
(d) IV
(e) V

14. In which section of the graph is the magnitude of the net force decreasing?
(a) I
(b) II
(c) III
(d) IV
(e) V

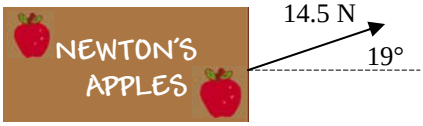
■ 15. In which section(s) of the graph is the net force changing?
(a) I and III (c) III (e) I and V
(b) II and IV (d) IV

Section 4.4 The Vector Nature of Newton's Second Law of Motion
Section 4.5 Newton's Third Law of Motion

◘ 16. An object moves due east at constant speed. A net force directed due north then acts on the object for 5.0 s. At the end of the 5.0-second period, the net force drops to zero newtons. Which one of the following statements is necessarily true?
(a) The object will be moving eastward when the force drops to zero newtons.
(b) The change in the velocity of the object will be directed north of west.
(c) The direction of the object's acceleration depends on how fast the object was initially moving.
(d) The final velocity of the object will be directed north of east.
(e) The magnitude of the object's acceleration depends on how fast the object was initially moving.

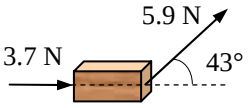
■ 17. Two forces act on a 16-kg object. The first force has a magnitude of 68 N and is directed 24° north of east. The second force is 32 N, 48° north of west. What is the acceleration of the object resulting from the action of these two forces?
(a) 1.6 m/s^2, 5.5° north of east (d) 3.6 m/s^2, 5.5° north of west
(b) 1.9 m/s^2, 18° north of west (e) 4.1 m/s^2, 52° north of east
(c) 2.4 m/s^2, 34° north of east

◘ 18. An apple crate with a weight of 225 N accelerates along a *frictionless* surface as the crate is pulled with a force of 14.5 N as shown in the drawing. What is the horizontal acceleration of the crate?



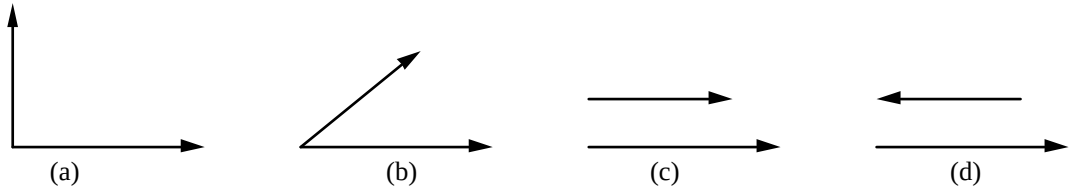
(a) 1.40 m/s^2 (c) 1.29 m/s^2 (e) 0.644 m/s^2
(b) 0.427 m/s^2 (d) 0.597 m/s^2

◘ 19. Two forces act on a 4.5-kg block resting on a frictionless surface as shown. What is the magnitude of the horizontal acceleration of the block?



(a) 1.8 m/s^2 (d) 3.2 m/s^2
(b) 1.2 m/s^2 (e) 8.9 m/s^2
(c) 0.82 m/s^2

□ 20. Two forces act on a hockey puck. For which orientation of the forces will the puck acquire an acceleration with the *largest* magnitude?



(e) The magnitude of the acceleration will be the same in all four cases shown above.

Questions 21 and 22 pertain to the situation described below:

A horse pulls a cart along a flat road. Consider the following four forces that arise in this situation.
(*1*) the force of the horse pulling on the cart
(*2*) the force of the cart pulling on the horse
(*3*) the force of the horse pushing on the road
(*4*) the force of the road pushing on the horse

☐ 21. Which two forces form an "action-reaction" pair that obeys Newton's third law?
(a) *1* and *4*
(b) *1* and *3*
(c) *2* and *4*
(d) *3* and *4*
(e) *2* and *3*

◘ 22. Suppose that the horse and cart have started from rest; and as time goes on, their speed increases in the same direction. Which one of the following conclusions is correct concerning the magnitudes of the forces mentioned above?
(a) Force *1* exceeds force *2*.
(b) Force *2* is less than force *3*.
(c) Force *2* exceeds force *4*.
(d) Force *3* exceeds force *4*.
(e) Forces *1* and *2* cannot have equal magnitudes.

Questions 23 and 24 pertain to the situation described below:

A physics student in a hot air balloon ascends vertically at constant speed. Consider the following four forces that arise in this situation:
$\mathbf{F}_1$ = the weight of the hot air balloon
$\mathbf{F}_2$ = the weight of the student
$\mathbf{F}_3$ = the force of the student pulling on the earth
$\mathbf{F}_4$ = the force of the hot air balloon pulling on the student

☐ 23. Which two forces form an "action-reaction" pair that obeys Newton's third law?
(a) $\mathbf{F}_1$ and $\mathbf{F}_2$
(b) $\mathbf{F}_2$ and $\mathbf{F}_3$
(c) $\mathbf{F}_1$ and $\mathbf{F}_3$
(d) $\mathbf{F}_2$ and $\mathbf{F}_4$
(e) $\mathbf{F}_3$ and $\mathbf{F}_4$

◘ 24. Which one of the following relationships concerning the forces or their magnitudes is true?
(a) $F_4 > F_2$
(b) $F_1 < F_2$
(c) $F_4 > F_1$
(d) $\mathbf{F}_2 = -\mathbf{F}_4$
(e) $\mathbf{F}_3 = -\mathbf{F}_4$

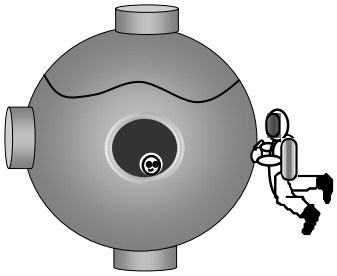
Questions 25 and 26 pertain to the situation described below:

A book is resting on the surface of a table. Consider the following four forces that arise in this situation:
(*1*) the force of the earth pulling on the book
(*2*) the force of the table pushing on the book
(*3*) the force of the book pushing on the table
(*4*) the force of the book pulling on the earth

☐ 25. Which two forces form an "action-reaction" pair that obeys Newton's third law?
(a) *1* and *2*
(b) *1* and *3*
(c) *1* and *4*
(d) *2* and *4*
(e) *3* and *4*

◘ 26. The book has an acceleration of 0 m/s^2. Which pair of forces, excluding "action-reaction" pairs, must be equal in magnitude and opposite in direction?
(a) *1* and *2*
(b) *1* and *3*
(c) *1* and *4*
(d) *2* and *3*
(e) *2* and *4*

Questions 27 and 28 pertain to the statement and figure shown:



A 70.0-kg astronaut pushes to the left on a spacecraft with a force **F** in "gravity-free" space. The spacecraft has a total mass of 1.0×10^4 kg. During the push, the astronaut accelerates to the right with an acceleration of 0.36 m/s^2.

☐ 27. Which one of the following statements concerning this situation is true?
(a) The spacecraft does not move, but the astronaut moves to the right with a constant speed.
(b) The astronaut stops moving after he stops pushing on the spacecraft.
(c) The force exerted on the astronaut is larger than the force exerted on the spacecraft.
(d) The force exerted on the spacecraft is larger than the force exerted on the astronaut.
(e) The velocity of the astronaut increases while he is pushing on the spacecraft.

◘ 28. Determine the magnitude of the acceleration of the spacecraft.
(a) 51.4 m/s^2
(b) 0.36 m/s^2
(c) 2.5×10^{-3} m/s^2
(d) 7.0×10^{-3} m/s^2
(e) 3.97×10^{-4} m/s^2

Section 4.6 Types of Forces: An Overview
Section 4.7 The Gravitational Force

◘ 29. Consider the following forces.
(*1*) frictional
(*2*) gravitational
(*3*) tension
(*4*) strong nuclear
(*5*) normal
(*6*) electroweak
Which of the forces listed are considered fundamental forces?
(a) *1*, *2*, and *4*
(b) *1*, *2*, *3*, and *5*
(c) *1*, *3*, and *5*
(d) *2*, *4*, and *6*
(e) *2*, *3*, *4*, and *6*

◘ 30. A rock is thrown straight up from the earth's surface. Which one of the following statements concerning the *net force* acting on the rock at the top of its path is true?
(a) The net force is equal to the weight of the rock.
(b) The net force is instantaneously equal to zero newtons.
(c) The net force's direction changes from up to down.
(d) The net force is greater than the weight of the rock.
(e) The net force is less than the weight of the rock, but greater than zero newtons.

☐ 31. Two point masses *m* and *M* are separated by a distance *d*. If the distance between the masses is increased to 3*d*, how does the gravitational force between them change?
(a) The force will be one-third as great.
(b) The force will be one-ninth as great.
(c) The force will be three times as great.
(d) The force will be nine times as great.
(e) It is impossible to determine without knowing the numerical values of *m*, *M*, and *d*.

◘ 32. Two point masses *m* and *M* are separated by a distance *d*. If the separation *d* remains fixed and the masses are increased to the values 3*m* and 3*M* respectively, how does the gravitational force between them change?
(a) The force will be one-third as great.
(b) The force will be one-ninth as great.
(c) The force will be three times as great.
(d) The force will be nine times as great.
(e) It is impossible to determine without knowing the numerical values of *m*, *M*, and *d*.

☐ 33. Which one of the following statements concerning the two "gravitational constants" *G*, the universal gravitational constant, and *g* the magnitude of the acceleration due to gravity is true?
(a) The values of *g* and *G* depend on location.
(b) The values of *g* and *G* do not depend on location.
(c) The value of *G* is the same everywhere in the universe, but the value of *g* is not.
(d) The value of *g* is the same everywhere in the universe, but the value of *G* is not.
(e) The values of *g* and *G* are equal on the surface of any planet, but in general, vary with location in the universe.

◘ 34. Two satellites of different masses are in the same circular orbit about the earth. Which one of the following statements is true concerning the magnitude of the gravitational force that acts on each of them?
(a) The magnitude of the gravitational force is zero newtons for both satellites.
(b) The magnitude of the gravitational force is the same for both satellites, but not zero newtons.
(c) The magnitude of the gravitational force is zero newtons for one, but not for the other.
(d) The magnitude of the gravitational force depends on their masses.
(e) The magnitude of the gravitational force varies from point to point in their orbits.

◘ 35. An astronaut orbits the earth in a space capsule whose height above the earth is equal to the earth's radius. How does the weight of the astronaut in the capsule compare to her weight on the earth?
(a) Her weight is equal to her weight on earth.
(b) Her weight is equal to one-fourth her weight on earth.
(c) Her weight is equal to one-half of her weight on earth.
(d) Her weight is equal to one-third of her weight on earth.
(e) Her weight is equal to one-sixteenth her weight on earth.

◘ 36. An astronaut orbits the earth in a space capsule whose height above the earth is equal to the earth's radius. How does the mass of the astronaut in the capsule compare to her mass on the earth?
(a) Her mass is equal to her mass on earth.
(b) Her mass is equal to one-fourth her mass on earth.
(c) Her mass is equal to one-half of her mass on earth.
(d) Her mass is equal to one-third of her mass on earth.
(e) Her mass is equal to one-sixteenth her mass on earth.

☐ 37. Which statement best explains why the weight of an object of mass *m* is different on Mars than it is on the Earth?
(a) The mass of Mars is different from that of Earth.
(b) The masses and radii of Mars and Earth are not the same.
(c) The mass *m* is further from the Earth's center when it is on Mars.
(d) The constant *G* is different on Mars.
(e) The mass *m* will be different on Mars.

☐ 38. What is the weight of a 2.50-kg bag of sand on the surface of the earth?
(a) 2.50 N (c) 24.5 N (e) 98.0 N
(b) 9.80 N (d) 49.0 N

■ 39. A 2.00-kg projectile is fired at an angle of 20.0°. What is the magnitude of the force exerted on the projectile when it is at the highest position in its trajectory? Neglect any effects of air resistance.
(a) 19.6 N (c) 9.80 N (e) 0 N
(b) 14.7 N (d) 4.90 N

■ 40. A marble is dropped straight down from a distance *h* above the floor.
Let F_m = the magnitude of the gravitational force *on the marble* due to the earth;
F_e = the magnitude of the gravitational force *on the earth* due to the marble;
a_m = the magnitude of the acceleration *of the marble* toward the earth;
a_e = the magnitude of the acceleration *of the earth* toward the marble.
Which set of conditions is true as the marble falls toward the earth? Neglect any effects of air resistance.
(a) $F_m = F_e$ and $a_m < a_e$
(b) $F_m < F_e$ and $a_m > a_e$
(c) $F_m < F_e$ and $a_m = a_e$
(d) $F_m > F_e$ and $a_m = a_e$
(e) $F_m = F_e$ and $a_m > a_e$

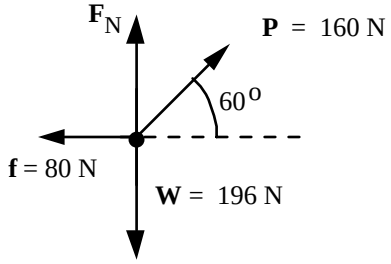
■ 41. What is the magnitude of the gravitational force acting on a 79.5-kg student due to a 60.0-kg student sitting 2.25 m away in the lecture hall?
(a) 3.14×10^{-9} N
(b) 2.82×10^{-8} N
(c) 7.91×10^{-10} N
(d) 1.41×10^{-7} N
(e) 6.29×10^{-8} N

Section 4.8 The Normal Force
Section 4.9 Static and Kinetic Frictional Forces

□ 42. A 44-kg child steps onto a scale and the scale reads 430 N. What is the magnitude of the normal force acting on the child?
(a) 44 N
(b) 215 N
(c) 430 N
(d) 645 N
(e) 860 N

Questions 43 and 44 pertain to the situation described below:

A force **P** pulls on a crate of mass *m* that is in contact with a rough surface. The figure shows the magnitudes and directions of the forces that act on the crate in this situation. **W** represents the weight of the crate. $\mathbf{F}_N$ represents the normal force on the crate, and **f** represents the frictional force.



■ 43. Which statement best describes the motion of the crate?
(a) The crate must be at rest.
(b) The crate must be moving with constant velocity.
(c) The crate must be moving with constant acceleration.
(d) The crate may be either at rest or moving with constant velocity.
(e) The crate may be either at rest or moving with constant acceleration.

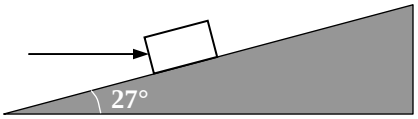
■ 44. What is the magnitude of $\mathbf{F}_N$, the normal force on the crate?
(a) 57 N
(b) 80 N
(c) 160 N
(d) 196 N
(e) 230 N

■ 45. A 10-kg block is set moving with an initial speed of 6 m/s on a rough horizontal surface. If the force of friction is 20 N, approximately how far does the block travel before it stops?
(a) 1.5 m
(b) 3 m
(c) 6 m
(d) 9 m
(e) 18 m

■ 46. The wheels of an automobile are locked as it slides to a stop from an initial speed of 30.0 m/s. If the coefficient of kinetic friction is 0.600 and the road is horizontal, approximately how long does it take the car to stop?

(a) 4.22 s (c) 8.75 s (e) 15.3 s
(b) 5.10 s (d) 10.4 s

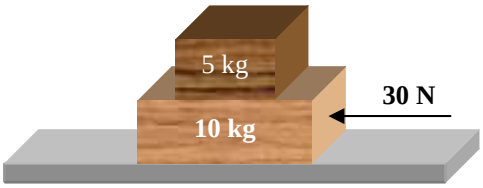
■ 47. A 250-N force is directed horizontally as shown to push a 29-kg box up an inclined plane at a constant speed. Determine the magnitude of the normal force, F_N, and the coefficient of kinetic friction, μ_k.



	F_N	μ_k
(a)	330 N	0.31
(b)	310 N	0.33
(c)	250 N	0.27
(d)	290 N	0.30
(e)	370 N	0.26

Questions 48 through 50 pertain to the situation described below:

Two blocks rest on a horizontal *frictionless* surface as shown. The surface between the top and bottom blocks is roughened so that there is no slipping between the two blocks. A 30-N force is applied to the bottom block as suggested in the figure.



□ 48. What is the magnitude of the acceleration of the "two block" system?

(a) 1 m/s^2 (c) 3 m/s^2 (e) 15 m/s^2
(b) 2 m/s^2 (d) 6 m/s^2

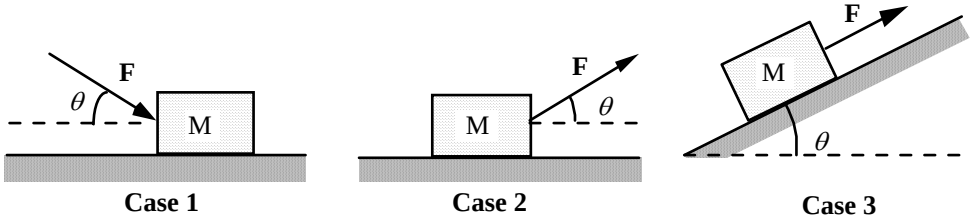
■ 49. What is the magnitude of the force of static friction between the top and bottom blocks?

(a) zero newtons (c) 20 N (e) 30 N
(b) 10 N (d) 25 N

◘ 50. What is the minimum coefficient of static friction necessary to keep the top block from slipping on the bottom block?

(a) 0.05 (c) 0.20 (e) 0.40
(b) 0.10 (d) 0.30

◘ 51. Note the following situations:



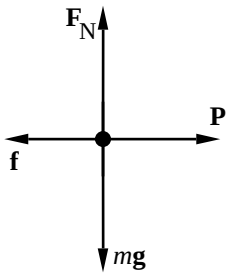
In which case will the magnitude of the normal force on the block be equal to ($Mg + F \sin \theta$)?

(a) case *1* only (c) both cases *1* and *2* (e) cases *1*, *2*, and *3*
(b) case *2* only (d) both cases *2* and *3*

Questions 52 and 53 pertain to the situation described below:

A block is pulled along a rough level surface at constant speed by the force **P**. The figure shows the free-body diagram for the block.

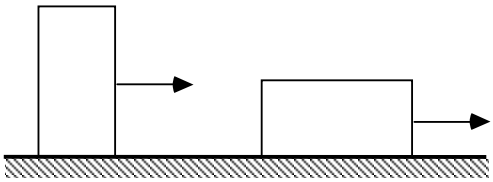
$\mathbf{F}_N$ represents the normal force on the block; and **f** represents the force of kinetic friction.



☐ 52. What is the magnitude of $\mathbf{F}_N$?
(a) $2mg$
(b) P
(c) f
(d) mg
(e) This cannot be determined from the information given.

◘ 53. If the coefficient of kinetic friction, μ_k, between the block and the surface is 0.30 and the magnitude of the frictional force is 80.0 N, what is the weight of the block?
(a) 1.6 N
(b) 4.0 N
(c) 160 N
(d) 270 N
(e) 410 N

◘ 54. Two identical blocks are pulled along a rough surface as suggested in the figure. Which one of the following statements is *false*?



(a) The coefficient of kinetic friction is the same in each case.
(b) A force of the same magnitude is needed to keep each block moving.
(c) A force of the same magnitude was required to start each block moving.
(d) The normal force exerted on the blocks by the surface is the same for both blocks.
(e) The magnitude of the force of kinetic friction is greater for the block on the right.

■ 55. A crate rests on the flatbed of a truck that is initially traveling at 15 m/s on a level road. The driver applies the brakes and the truck is brought to a halt in a distance of 38 m. If the deceleration of the truck is constant, what is the minimum coefficient of friction between the crate and the truck that is required to keep the crate from sliding?
(a) 0.20
(b) 0.30
(c) 0.39
(d) 0.59
(e) This cannot be determined without knowing the mass of the crate.

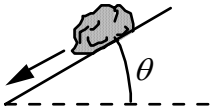
Questions 56 and 57 pertain to the statement below:

A 2.0-N force acts horizontally on a 10-N block that is initially at rest on a horizontal surface. The coefficient of static friction between the block and the surface is 0.50.

◘ 56. What is the magnitude of the frictional force that acts on the block?
(a) 0 N
(b) 2 N
(c) 5 N
(d) 8 N
(e) 10 N

☐ 57. Suppose that the block now moves across the surface with constant speed under the action of a horizontal 3.0-N force. Which statement concerning this situation is *not* true?
(a) The block is not accelerated.
(b) The net force on the block is zero newtons.
(c) The frictional force on the block has magnitude 3.0 N.
(d) The coefficient of kinetic friction between the block and the surface is 0.30.
(e) The direction of the total force that the surface exerts on the block is vertically upward.

■ 58. A 2.0-N rock slides on a frictionless inclined plane. Which one of the following statements is true concerning the normal force that the plane exerts on the rock?



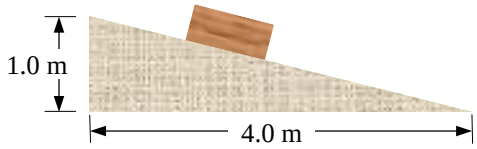
(a) The normal force is zero newtons.
(b) The normal force is 2.0 N.
(c) The normal force is less than 2.0 N, but greater than zero newtons.
(d) The normal force is greater than 2.0 N.
(e) The normal force *increases* as the angle of inclination, θ, is *increased*.

■ 59. A boy pulls a sled of mass 5.0 kg with a rope that makes a 60.0° angle with respect to the horizontal surface of a frozen pond. The boy pulls on the rope with a force of 10.0 N; and the sled moves with constant velocity. What is the coefficient of friction between the sled and the ice?

(a) 0.09 (c) 0.18 (e) 0.24
(b) 0.12 (d) 0.06

■ 60. In an experiment with a block of wood on an inclined plane, with dimensions shown in the figure, the following observations are made:

(1) If the block is placed on the inclined plane, it remains there at rest.
(2) If the block is given a small push, it will accelerate toward the bottom of the incline without any further pushing.



Which is the *best* conclusion that can be drawn from these observations?

(a) The coefficient of kinetic friction must be negative.
(b) Both coefficients of friction must be less than 0.25.
(c) Both coefficients of friction must be greater than 0.25.
(d) The coefficient of static friction must be less than the coefficient of kinetic friction.
(e) The coefficient of static friction is greater than 0.25 while the coefficient of kinetic friction is less than 0.25.

Section 4.10 The Tension Force
Section 4.11 Equilibrium Applications of Newton's Laws of Motion

□ 61. A rock is suspended from a string and moves downward at constant speed. Which statement is true concerning the tension in the string if air resistance is ignored?

(a) The tension is zero newtons.
(b) The tension points downward.
(c) The tension is equal to the weight of the rock.
(d) The tension is less than the weight of the rock.
(e) The tension is greater than the weight of the rock.

■ 62. A rock is suspended from a string; and it moves downward at constant speed. Which one of the following statements is true concerning the tension in the string *if air resistance is not ignored?*

(a) The tension is zero newtons.
(b) The tension points downward.
(c) The tension is equal to the weight of the rock.
(d) The tension is less than the weight of the rock.
(e) The tension is greater than the weight of the rock.

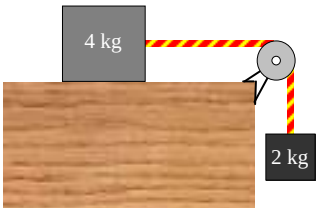
63. A rock is suspended from a string; and it accelerates downward. Which one of the following statements concerning the tension in the string is true?
(a) The tension points downward.
(b) The tension is less than the weight of the rock.
(c) The tension is equal to the weight of the rock.
(d) The tension is greater than the weight of the rock.
(e) The tension is independent of the magnitude of the rock's acceleration.

64. A rock is suspended from a string; and it accelerates upward. Which statement is true concerning the tension in the string?
(a) The tension points downward.
(b) The tension is less than the weight of the rock.
(c) The tension is equal to the weight of the rock.
(d) The tension is greater than the weight of the rock.
(e) The tension is independent of the magnitude of the rock's acceleration.

65. In a tug-of-war, each man on a 5-man team pulls with an average force of 500 N. What is the tension in the center of the rope?
(a) zero newtons (c) 500 N (e) 5000 N
(b) 100 N (d) 2500 N

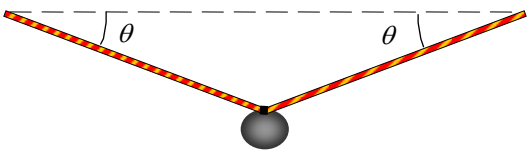
66. Under what condition(s) will an object be in *equilibrium*?
(a) If the object is either at rest or moving with constant velocity, it is in equilibrium.
(b) If the object is either moving with constant velocity or with constant acceleration, it is in equilibrium.
(c) Only if the object is at rest can it be in equilibrium.
(d) Only if the object is moving with constant velocity can it be in equilibrium.
(e) Only if the object is moving with constant acceleration can it be in equilibrium.

67. A 4-kg block is connected by means of a *massless* rope to a 2-kg block as shown in the figure. Complete the following statement: If the 4-kg block is to begin sliding, the coefficient of static friction between the 4-kg block and the surface must be
(a) less than zero.
(b) greater than 2.
(c) greater than 1, but less than 2.
(d) greater than 0.5, but less than 1.
(e) less than 0.5, but greater than zero.

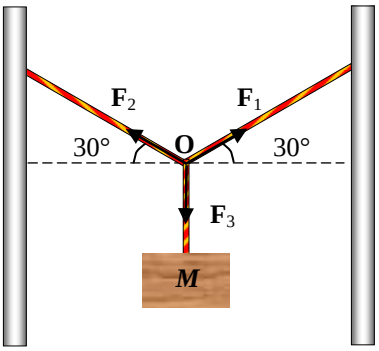


68. A small plane climbs with a constant velocity of 250 m/s at an angle of 28° with respect to the horizontal. Which statement is true concerning the magnitude of the *net force* on the plane?
(a) It is equal to zero newtons.
(b) It is equal to the weight of the plane.
(c) It is equal to the magnitude of the force of air resistance.
(d) It is less than the weight of the plane but greater than zero newtons.
(e) It is equal to the component of the weight of the plane in the direction of motion.

69. A muscle builder holds the ends of a massless rope. At the center of the rope, a 15-kg ball is hung as shown. What is the tension in the rope if the angle θ in the drawing is 4.5°?
(a) 1900 N (c) 470 N (e) 150 N
(b) 940 N (d) 230 N



■ 70. A block of mass M is hung by ropes as shown. The system is in equilibrium. The point O represents the knot, the junction of the three ropes. Which of the following statements is true concerning the magnitudes of the three forces in equilibrium?



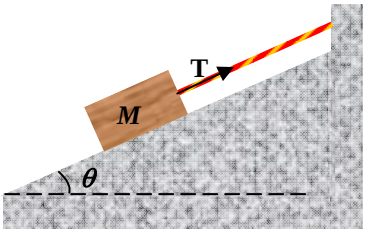
(a) $F_1 = F_2 = F_3$
(b) $F_2 = 2F_3$
(c) $F_2 < F_3$
(d) $F_1 = F_2 = \frac{F_3}{2}$
(e) $F_1 > F_3$

■ 71. A 20-kg crate is suspended from a fixed beam by two vertical ropes. What is the approximate tension in each rope?

(a) 10 N (c) 100 N (e) 390 N
(b) 40 N (d) 200 N

Questions 72 through 74 pertain to the situation described below:

A block of mass M is held motionless on a frictionless inclined plane by means of a string attached to a vertical wall as shown in the drawing.



■ 72. What is the magnitude of the tension **T** in the string?

(a) zero newtons (c) $Mg \cos \theta$ (e) $Mg \tan \theta$
(b) Mg (d) $Mg \sin \theta$

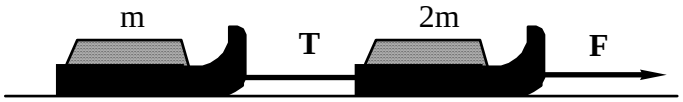
■ 73. If the string breaks, what is the magnitude of the acceleration of the block as it slides down the inclined plane?

(a) zero m/s^2 (c) $g \cos \theta$ (e) $g \tan \theta$
(b) g (d) $g \sin \theta$

□ 74. Assume the plane is not frictionless and the string breaks, what minimum value of the coefficient of static friction, μ_S, would prevent the block from sliding down the inclined plane?

(a) zero (c) $\cos \theta$ (e) $\tan \theta$
(b) 1 (d) $\sin \theta$

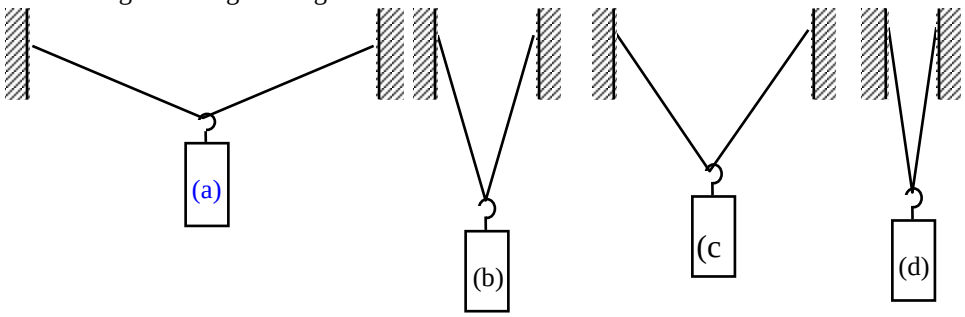
■ 75. Two sleds are hooked together in tandem as shown in the figure. The front sled is twice as massive as the rear sled.



The sleds are pulled along a frictionless surface by an applied force **F**. The tension in the rope between the sleds is **T**. Determine the ratio of the magnitudes of the two forces, $\frac{T}{F}$.

(a) 0.25 (c) 0.50 (e) 2.0
(b) 0.33 (d) 0.67

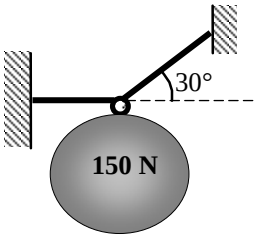
◘ 76. A block of weight *W* is suspended by a string of fixed length. The ends of the string are held at various positions as shown in the figures below. In which case, if any, is the magnitude of the tension along the string the largest?



(e) It will be the same in all four cases, since the string must support the entire weight of the block.

Questions 77 and 78 pertain to the system described below:

A system of two cables supports a 150-N ball as shown.



◘ 77. What is the tension in the right-hand cable?
(a) 87 N
(b) 150 N
(c) 170 N
(d) 260 N
(e) 300 N

◘ 78. What is the tension in the horizontal cable?
(a) 87 N
(b) 150 N
(c) 170 N
(d) 260 N
(e) 300 N

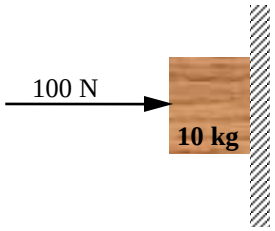
Section 4.12 Nonequilibrium Applications of Newton's Laws of Motion

□ 79. A woman stands on a bathroom scale in an elevator that is not moving. The scale reads 500 N. The elevator then moves downward at a constant velocity of 5 m/s. What does the scale read while the elevator descends with constant velocity?
(a) 100 N
(b) 250 N
(c) 500 N
(d) 600 N
(e) 750 N

◘ 80. A rope connects boat A to boat B. Boat A starts from rest and accelerates to a speed of 9.5 m/s in a time t = 47 s. The mass of boat B is 540 kg. Assuming a constant frictional force of 230 N acts on boat B, what is the magnitude of the tension in the rope that connects the boats during the time that boat A is accelerating?
(a) 340 N
(b) 1270 N
(c) 230 N
(d) 860 N
(e) 160 N

■ 81. A certain crane can provide a maximum lifting force of 25 000 N. It hoists a 2000-kg load starting at ground level by applying the maximum force for a 2-second interval; then, it applies just sufficient force to keep the load moving upward at constant speed. Approximately how long does it take to raise the load from ground level to a height of 30 m?
(a) 2 s
(b) 5 s
(c) 7 s
(d) 9 s
(e) 10 s

■ 82. A 10-kg block is pushed against a vertical wall by a horizontal force of 100 N as shown in the figure. The coefficient of static friction, μ_s, between the block and the wall is 0.60; and the coefficient of kinetic friction, μ_k, is 0.40. Which one of the following statements is true if the block is initially at rest?



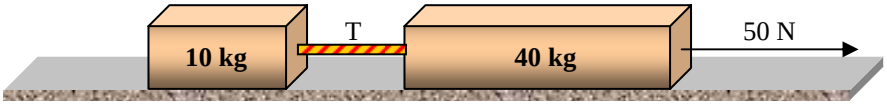
(a) The total force exerted on the block by the wall is directed horizontally.
(b) The block slides down the wall with an acceleration of magnitude 3.8 m/s^2.
(c) The block will slide down the wall because the force of static friction can be no larger than 60 N.
(d) The block will remain at rest because the coefficient of static friction is greater than the coefficient of kinetic friction.
(e) The block will slide down the wall because the coefficient of kinetic friction is less than the coefficient of static friction.

■ 83. A 20.0-kg package is dropped from a high tower in still air and is "tracked" by a radar system. When the package is 25 m above the ground, the radar tracking indicates that its acceleration is 7.0 m/s^2. Determine the force of air resistance on the package.

(a) 56 N (c) 340 N (e) 140 N
(b) 28 N (d) 196 N

Questions 84 and 85 pertain to the situation described below:

A 10-kg block is connected to a 40-kg block as shown in the figure. The surface on that the blocks slide is frictionless. A force of 50 N pulls the blocks to the right.



□ 84. What is the magnitude of the acceleration of the 40-kg block?

(a) 0.5 m/s^2 (c) 2 m/s^2 (e) 5 m/s^2
(b) 1 m/s^2 (d) 4 m/s^2

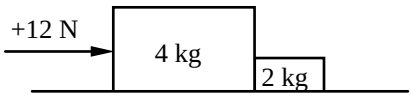
◘ 85. What is the magnitude of the tension **T** in the rope that connects the two blocks?

(a) 0 N (c) 20 N (e) 50 N
(b) 10 N (d) 40 N

◘ 86. A 71-kg man stands on a bathroom scale in an elevator. What does the scale read if the elevator is ascending with an acceleration of 3.0 m/s^2?

(a) 140 N (c) 690 N (e) 910 N
(b) 480 N (d) 830 N

◘ 87. A 4-kg block and a 2-kg block can move on the horizontal frictionless surface. The blocks are accelerated by a +12-N force that pushes the larger block against the smaller one. Determine the force that the 2-kg block exerts on the 4-kg block.



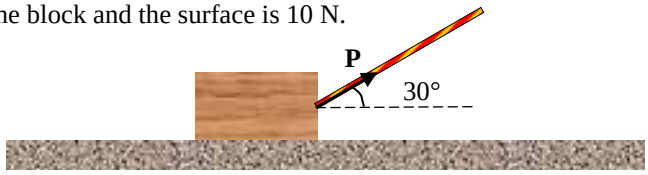
(a) –4 N (c) 0 N (e) +8 N
(b) –12 N (d) +4 N

□ 88. A man stands on a spring scale in a moving elevator and notices that the scale reading is 20% larger than when he weighs himself in his bathroom. Which statement can *not* be true?
(a) The tension in the supporting cable must exceed the weight of the elevator and its contents.
(b) The speed of the elevator changes by equal amounts in equal times.
(c) The elevator could be moving upward with increasing speed.
(d) The elevator could be moving downward with decreasing speed.
(e) The elevator could be moving upward at constant speed.

Additional Problems

Questions 89 through 91 pertain to the situation described below:

A block is pulled at constant speed along a rough level surface by a rope that makes an angle of 30° with respect to the horizontal. The applied force along the rope is **P**. The force of kinetic friction between the block and the surface is 10 N.



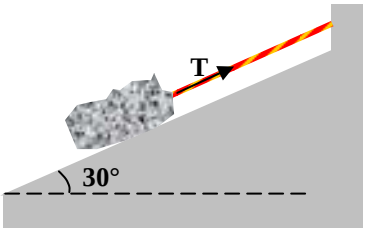
□ 89. Which one of the following expressions gives the magnitude of the force **P** in SI units?
(a) 10/(cos 30°) (c) 10(cos 30°) (e) tan 30°
(b) 10/(sin 30°) (d) 10(sin 30°)

■ 90. Complete the following statement: The magnitude of the normal force could be reduced by
(a) increasing the speed of the block. (d) decreasing the angle made by the rope.
(b) decreasing the coefficient of kinetic friction. (e) increasing the angle made by the rope.
(c) decreasing the velocity of the block.

◘ 91. Which one of the following actions will increase the frictional force on the block?
(a) increasing the contact surface area (d) decreasing the speed of the block
(b) decreasing the contact surface area (e) increasing the angle made by the rope
(c) increasing the weight of the block

Questions 92through 94 pertain to the situation described below:

A rope holds a 10-kg rock at rest on a *frictionless* inclined plane as shown.



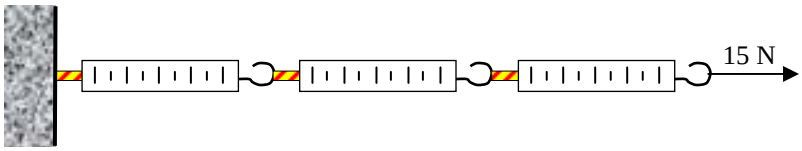
◘ 92. Determine the tension in the rope.
(a) 9.8 N (c) 49 N (e) 98 N
(b) 20 N (d) 85 N

□ 93. Which one of the following statements concerning the force exerted *on* the plane *by* the rock is true?
(a) It is 0 N. (d) It is less than 98 N, but greater than zero newtons.
(b) It is 98 N. (e) It *increases* as the angle of inclination is *increased*.
(c) It is greater than 98 N.

■ 94. Determine the magnitude of the acceleration of the rock down the inclined plane if the rope breaks?

(a) zero m/s^2
(b) 4.9 m/s^2
(c) 5.7 m/s^2
(d) 8.5 m/s^2
(e) 9.8 m/s^2

□ 95. Three spring scales are attached along a straight line as shown. The scale on the left is attached to a wall. A force of 15 N is applied to the scale at the right.

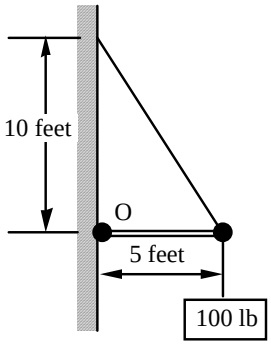


What is the reading on the middle scale?

(a) 0 N
(b) 45 N
(c) 10 N
(d) 5 N
(e) 15 N

■ 96. A *massless horizontal strut* is attached to the wall at the hinge O. Which one of the following phrases best describes the force that the hinge pin applies *to the strut* if the weight of the cables is also neglected?

(a) 50 lb, to the right
(b) 100 lb, straight up
(c) 200 lb, to the right
(d) 244 lb, 27° above the strut
(e) 56 lb, to the left

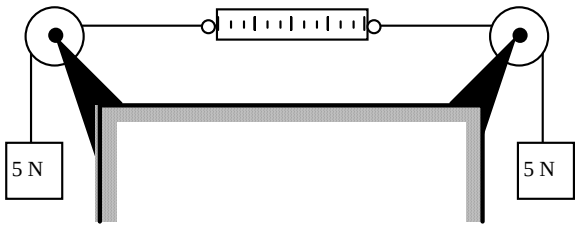


■ 97. At a playground, a child slides down a slide that makes a 42° angle with the horizontal direction. The coefficient of kinetic friction for the child sliding on the slide is 0.20. What is the magnitude of her acceleration during her sliding?

(a) 4.6 m/s^2
(b) 5.1 m/s^2
(c) 5.4 m/s^2
(d) 6.3 m/s^2
(e) 9.8 m/s^2

Questions 98 and 99 pertain to the situation described below:

Two 5-N boxes are attached to opposite ends of a spring scale and suspended from pulleys as shown.



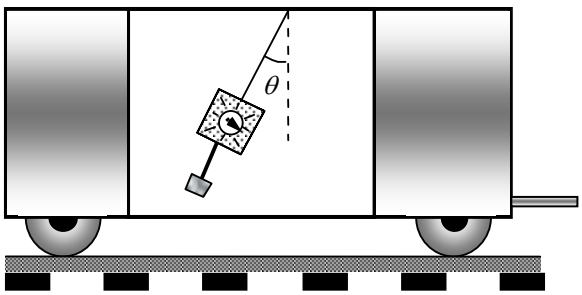
■ 98. What is the reading on the scale?

(a) 0 N
(b) 2.5 N
(c) 5 N
(d) 10 N
(e) 25 N

◘ 99. Suppose that the system were placed in an elevator that accelerated downward at 2 m/s^2. What would the scale read?

(a) 6 N (c) 0 N (e) 2 N
(b) 8 N (d) 4 N

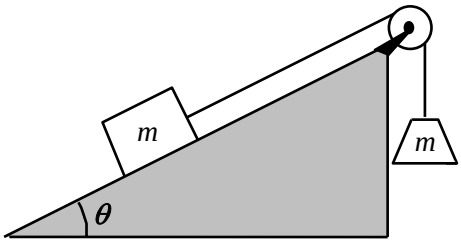
◘ 100. A spring scale is fastened to the ceiling of a railway car. When a 1.0-kg block is hung from the scale, it reads 12 N and is oriented as shown in the figure. What is the approximate acceleration of the car as measured by an observer at rest on the ground outside of the car?



(a) 7 m/s^2 to the right
(b) 7 m/s^2 to the left
(c) 12 m/s^2 to the right
(d) 12 m/s^2 to the left
(e) It is impossible to calculate since the angle θ has not been given.

Questions 101 through 103 pertain to the following situation:

A block is at rest on a rough inclined plane and is connected to an object with the same mass as shown. The rope may be considered massless; and the pulley may be considered frictionless. The coefficient of static friction between the block and the plane is μ_s; and the coefficient of kinetic friction is μ_k.



■ 101. What is the magnitude of the static frictional force acting on the block?

(a) $mg \sin\theta$ (c) $mg(1 - \sin\theta)$ (e) mg
(b) $mg \cos\theta$ (d) $mg(1 - \cos\theta)$

■ 102. If the rope were cut between the block and the pulley, what would be the magnitude of the acceleration of the block down the plane?

(a) g (c) $g - \mu_k \cos\theta$ (e) $g(\sin\theta - \mu_k \cos\theta)$
(b) $g - \mu_k \sin\theta$ (d) $g(\tan\theta - \mu_k \sin\theta)$

■ 103. If the mass of the suspended object is doubled, what will be the acceleration of the block up the plane?

(a) $g(2 - \mu_k \sin\theta)$ (c) $g(2\tan\theta - \mu_k \sin\theta)$ (e) $g(2\cos\theta - \mu_k \sin\theta)$
(b) $2g(\mu_k \sin\theta - \cos\theta)$ (d) $g(2 - \sin\theta - \mu_k \cos\theta)$