57. (a) −2.33 m/s, 4.67 m/s (b) 0.277 m (c) 2.98 m (d) 1.49 m
59. (a) −0.667 m/s (b) 0.952 m
61. (a) 3.54 m/s (b) 1.77 m (c) 3.54×10^4 N (d) No, the normal force exerted by the rail contributes upward momentum to the system.
63. (a) 0.28 or 28% (b) 1.1×10^{-13} J for the neutron, 4.5×10^{-14} J for carbon
65. $\frac{2v_0^2}{9\mu_k g} - \frac{4d}{9}$
67. (a) No. After colliding, the cars, moving as a unit, would travel northeast, so they couldn't damage property on the southeast corner. (b) x-component: 16.3 km/h, y-component: 9.17 km/h, angle: the final velocity of the car is 18.7 km/h at 29.4° north of east, consistent with part (a).
69. (a) 4.85 m/s (b) 8.41 m
71. 0.312 N to the right
73. (a) 300 m/s, (b) 3.75 m/s, (c) 1.20 m

Chapter 7

QUICK QUIZZES

1. (c)
2. (b)
3. (b)
4. (b)
5. (a)
6. 1. (e) 2. (a) 3. (b)
7. (c)
8. (b), (c)
9. (e)
10. (d)

CONCEPTUAL QUESTIONS

1. (a) The head will tend to lean toward the right shoulder (that is, toward the outside of the curve). (b) When there is no strap, tension in the neck muscles must produce the centripetal acceleration. (c) With a strap, the tension in the strap performs this function, allowing the neck muscles to remain relaxed.
3. An object can move in a circle even if the total force on it is not perpendicular to its velocity, but then its speed will change. Resolve the total force into an inward radial component and a perpendicular tangential component. If the tangential force acts in the forward direction, the object will speed up, and if the tangential force acts backward, the object will slow down.
5. The speedometer will be inaccurate. The speedometer measures the number of tire revolutions per second, so its readings will be too low.
7. The car cannot round a turn at constant velocity, because "constant velocity" means the direction of the velocity is not changing. The statement is correct if the word "velocity" is replaced by the word "speed."
9. The gravitational force exerted on the moon by the planet produces a centripetal acceleration. Mathematically,
$$m_{\text{moon}}\left(\frac{v_t^2}{r}\right) = \frac{GMm_{\text{moon}}}{r^2}$$
or the mass of the planet is $M = \frac{(rv_t^2)}{G}$. Both r and v_t can be determined by observing the motion of the moon, and the mass of the planet is then easily computed.
11. Consider an individual standing against the inside wall of the cylinder with her head pointed toward the axis of the cylinder. As the cylinder rotates, the person tends to move in a straight-line path tangent to the circular path followed by the cylinder wall. As a result, the person presses against the wall, and the normal force exerted on her provides the radial force required to keep her moving in a circular path. If the rotational speed is adjusted such that this normal force is equal in magnitude to her weight on Earth, she will not be able to distinguish between the artificial gravity of the colony and ordinary gravity.
13. The tendency of the water is to move in a straight-line path tangent to the circular path followed by the container. As a result, at the top of the circular path, the water presses against the bottom of the pail, and the normal force exerted by the pail on the water provides the radial force required to keep the water moving in its circular path.
15. Any object that moves such that the *direction* of its velocity changes has an acceleration. A car moving in a circular path will always have a centripetal acceleration.
17. (b) decrease. The free-fall acceleration near the surface of the Earth is given by $g = GM_E/R_E^2$, therefore, doubling both the Earth's mass and its radius would reduce the value of g by a factor of 2.

PROBLEMS

1. (a) 3.2×10^8 rad (b) 5.0×10^7 rev
3. 1.99×10^{-7} rad/s, 0.986°/day
5. (a) 821 rad/s² (b) 4.21×10^3 rad
7. 3.2 rad
9. Main rotor: 179 m/s = $0.522v_{\text{sound}}$
Tail rotor: 221 m/s = $0.644v_{\text{sound}}$
11. $\sim 10^{-2}$ cm
13. 13.7 rad/s²
15. (a) 3.37×10^{-2} m/s² downward (b) 0
17. (a) 0.35 m/s² (b) 1.0 m/s (c) 0.35 m/s², 0.94 m/s², 1.0 m/s² at 20° forward with respect to the direction of a_c
19. (a) 1.10 kN (b) 2.04 times her weight
21. 22.6 m/s
23. (a) 18.0 m/s² (b) 900 N (c) 1.84; this large coefficient is unrealistic, and she will not be able to stay on the merry-go-round.
25. (a) 9.8 N (b) 9.8 N (c) 6.3 m/s
27. (a) 1.58 m/s² (b) 455 N upward (c) 329 N upward (d) 397 N directed inward and 80.8° above horizontal
29. 321 N toward Earth
31. 1.1×10^{-10} N at 72° above the $+x$-axis
33. (a) 2.50×10^{-5} N toward the 500-kg object (b) Between the two objects and 0.245 m from the 500-kg object
35. (a) 9.58×10^6 m (b) 5.57 h
37. 1.90×10^{27} kg
39. (a) 1.48 h (b) 7.79×10^3 m/s (c) 6.43×10^9 J
41. (a) 9.40 rev/s (b) 44.1 rev/s²; a_r = 2 590 m/s²; a_t = 206 m/s² (c) F_r = 514 N; F_t = 40.7 N
43. (a) 2.51 m/s (b) 7.90 m/s² (c) 4.00 m/s
45. (a) 7.76×10^3 m/s (b) 89.3 min

47. (a) $n = m\left(g - \frac{v^2}{r}\right)$ (b) 17.1 m/s

49. (a) $F_{g,\text{ true}} = F_{g,\text{ apparent}} + mR_E\omega^2$
(b) 732 N (equator), 735 N (either pole)

51. 0.131

55. 11.8 km/s

57. 0.75 m

59. (a) $v_0 = \sqrt{g\left(R - \frac{2h}{3}\right)}$ (b) $h' = \frac{R}{2} + \frac{2h}{3}$

61. (a) 15.3 km (b) 1.66×10^{16} kg (c) 1.13×10^4 s

63. 0.835 rev/s = 50.1 rev/min

65. (a) 10.6 kN (b) 14.1 m/s

67. (a) 106 N (b) 0.396

69. (a) 0.605 m/s (b) 17.3 rad/s (c) 5.82 m/s (d) The crank length is unnecessary.

71. (a) 2.0×10^{12} m/s^2 (b) 2.4×10^{11} N (c) 1.4×10^{12} J

Chapter 8

QUICK QUIZZES

1. (d)
2. (b)
3. (b)
4. (a)
5. (c)
6. (c)
7. (a)

CONCEPTUAL QUESTIONS

1. In order for you to remain in equilibrium, your center of gravity must always be over your point of support, the feet. If your heels are against a wall, your center of gravity cannot remain above your feet when you bend forward, so you lose your balance.

3. There are two major differences between torque and work. The primary difference is that the displacement in the expression for work is directed along the force, while the important distance in the torque expression is perpendicular to the force. The second difference involves whether there is motion. In the case of work, work is done only if the force succeeds in causing a displacement of the point of application of the force. By contrast, a force applied at a perpendicular distance from a rotation axis results in a torque regardless of whether there is motion.

As far as units are concerned, the mathematical expressions for both work and torque are in units that are the product of newtons and meters, but this product is called a joule in the case of work and remains a newton-meter in the case of torque.

5. No. For an object to be in equilibrium, the net external force acting on it must be zero. This is not possible when only one force acts on the object, unless that force should have zero magnitude. In that case, there is really no force acting on the object.

7. As the motorcycle leaves the ground, the friction between the tire and the ground suddenly disappears. If the motorcycle driver keeps the throttle open while leaving the ground, the rear tire will increase its angular speed and, hence, its angular momentum. The airborne motorcycle is now an isolated system, and its angular momentum must be conserved. The increase in angular momentum of the tire directed, say, clockwise must be compensated for by an increase in angular momentum of the entire motorcycle counterclockwise. This rotation results in the nose of the motorcycle rising and the tail dropping.

9. In general, you want the rotational kinetic energy of the system to be as small a fraction of the total energy as possible. That is, you want translation, not rotation. You want the wheels to have as little moment of inertia as possible, so that they present the lowest resistance to changes in rotational motion. Disklike wheels would have lower moments of inertia than hooplike wheels, so disks are preferable. The lower the mass of the wheels, the less is the moment of inertia, so light wheels are preferable. The smaller the radius of the wheels, the less is the moment of inertia, so smaller wheels are preferable—within limits: You want the wheels to be large enough to be able to travel relatively smoothly over irregularities in the road.

11. The angular momentum of the gas cloud is conserved. Thus, the product $I\omega$ remains constant. As the cloud shrinks in size, its moment of inertia decreases, so its angular speed ω must increase.

13. We can assume fairly accurately that the driving motor will run at a constant angular speed and at a constant torque. Therefore, as the radius of the take-up reel increases, the tension in the tape will decrease, in accordance with the equation.

$$T = \tau_{\text{const}}/R_{\text{take-up}} \qquad (1)$$

As the radius of the source reel decreases, given a decreasing tension, the torque in the source reel will decrease even faster, as the following equation shows:

$$\tau_{\text{source}} = TR_{\text{source}} = \tau_{\text{const}}R_{\text{source}}/R_{\text{take-up}} \qquad (2)$$

This torque will be partly absorbed by friction in the feed heads (which we assume to be small); some will be absorbed by friction in the source reel. Another small amount of the torque will be absorbed by the increasing angular speed of the source reel. However, in the case of a sudden jerk on the tape, the changing angular speed of the source reel becomes important. If the source reel is full, then the moment of inertia will be large and the tension in the tape will be large. If the source reel is nearly empty, then the angular acceleration will be large instead. Thus, the tape will be more likely to break when the source reel is nearly full. One sees the same effect in the case of paper towels: It is easier to snap a towel free when the roll is new than when it is nearly empty.

15. The initial angular momentum of the system (mouse plus turntable) is zero. As the mouse begins to walk clockwise, its angular momentum increases, so the turntable must rotate in the counterclockwise direction with an angular momentum whose magnitude equals that of the mouse. This conclusion follows from the fact that the final angular momentum of the system must equal the initial angular momentum (zero).

17. When a ladder leans against a wall, both the wall and the floor exert forces of friction on the ladder. If the floor is perfectly smooth, it can exert no frictional force in the horizontal direction to counterbalance the wall's normal force. Therefore, a ladder on a smooth floor cannot stand in equilibrium. However, a smooth wall can still exert a normal force to hold the ladder in equilibrium against horizontal motion. The counterclockwise torque of this force prevents rotation about the foot of the ladder. So you should choose a rough floor.

PROBLEMS

1. 133 N
3. (a) 30 N · m (counterclockwise)
   (b) 36 N · m (counterclockwise)
5. 5.1 N · m
7. $F_t = 724$ N, $F_s = 716$ N
9. 312 N
11. $x_{cg} = 3.33$ ft, $y_{cg} = 1.67$ ft
13. 1.01 m in Figure P8.13b; 0.015 m towards the head in Figure P8.13c.
15. $T = 2.71$ kN, $R_x = 2.65$ kN
17. (a) 443 N, (b) 222 N (to the right), 216 N (upwards)
19. $R = 107$ N, $T = 157$ N
21. $T_{\text{left wire}} = \frac{1}{3}w$, $T_{\text{right wire}} = \frac{2}{3}w$
23. $T_1 = 501$ N, $T_2 = 672$ N, $T_3 = 384$ N
25. 6.15 m
27. 209 N
29. (a) 99.0 kg · m² (b) 44.0 kg · m² (c) 143 kg · m²
31. (a) 24.0 N · m (b) 0.035 6 rad/s² (c) 1.07 m/s²
33. (a) 34 N (b) 33 cm
35. 177 N
37. 0.524
39. (a) 500 J (b) 250 J (c) 750 J
41. 276 J
43. 149 rad/s
45. 17.5 J · s counterclockwise
47. 8.0 rev/s
49. 6.73 rad/s
51. 5.99×10^{-2} J
53. (a) 0.360 rad/s counterclockwise (b) 99.9 J
55. (a) $\omega = \left(\frac{I_1}{I_1 + I_2}\right)\omega_0$ (b) $\frac{KE_f}{KE_i} = \frac{I_1}{I_1 + I_2} < 1$
57. (a) As the child walks to the right end of the boat, the boat moves left (towards the pier). (b) The boat moves 1.45 m closer to the pier, so the child will be 5.55 m from the pier. (c) No. He will be short of reaching the turtle by 0.45 m.
59. (a) 1.1 m/s² (b) $T_1 = 22$ N $T_2 = 44$ N
61. 36.9°
63. $a_{\text{sphere}} = \frac{g\sin\theta}{1.4}$, $a_{\text{disk}} = \frac{g\sin\theta}{1.5}$, $a_{\text{ring}} = \frac{g\sin\theta}{2.0}$
   Thus, the sphere wins and the ring comes in last.
65. (a) 1.63 m/s (b) 54.2 rad/s
67. 1.09 m
69. (a) Mvd (b) Mv^2 (c) Mvd (d) $2v$ (e) $4Mv^2$ (f) $3Mv^2$
71. 7.5×10^{-11} s
73. (a) $T = \frac{Mmg}{M + 4m}$ (b) $a_t = \frac{4mg}{M + 4m}$
75. (a) $\sim 10^{-22}\,\text{s}^{-2}$, (b) $\sim 10^{16}$ N · m, (c) $\sim 10^{13}$ m
77. 24.5 m/s
79. (a) 3.12 m/s² (b) $T_1 = 26.7$ N, $T_2 = 9.37$ N
81. (b) 3×10^2 N
83. $6w = 4.5$ kN

Chapter 9

QUICK QUIZZES

1. (c)
2. (a)
3. (c)
4. (b)
5. (c)
6. (b)
7. (a)

CONCEPTUAL QUESTIONS

1. The density of air is lower in the mile-high city of Denver than it is at lower altitudes, so the effect of air drag is less in Denver than it would be in a city such as New York. The reduced air drag means a well-hit ball will go farther, benefiting home-run hitters. On the other hand, curve ball pitchers prefer to throw at lower altitudes where the higher density air produces greater deflecting forces on a spinning ball.
3. She exerts enough pressure on the floor to dent or puncture the floor covering. The large pressure is caused by the fact that her weight is distributed over the very small cross-sectional area of her high heels. If you are the homeowner, you might want to suggest that she remove her high heels and put on some slippers.
5. If you think of the grain stored in the silo as a fluid, the pressure the grain exerts on the walls of the silo increases with increasing depth, just as water pressure in a lake increases with increasing depth. Thus, the spacing between bands is made smaller at the lower portions to counterbalance the larger outward forces on the walls in these regions.
7. The syringe doesn't really draw the blood from the vein. By moving the plunger in the syringe back, the nurse lowers the pressure inside the syringe below the pressure inside the vein. Then the blood pressure within the body forces blood out into the syringe, which "accepts" the blood.
9. In the ocean, the ship floats due to the buoyant force from *salt water*, which is denser than fresh water. As the ship is pulled up the river, the buoyant force from the fresh water in the river is not sufficient to support the weight of the ship, and it sinks.
11. The balance will not be in equilibrium: The side with the lead will be lower. Despite the fact that the weights on both sides of the balance are the same, the Styrofoam, due to its larger volume, will experience a larger buoyant force from the surrounding air. Thus, the net force of the weight and the buoyant force is larger in the downward direction for the lead than for the Styrofoam.
13. The two cans displace the same volume of water and hence are acted upon by buoyant forces of equal magnitude. The total weight of the can of diet cola must be less than this buoyant force, whereas the total weight of the can of regular cola is greater than the buoyant force. This is possible even though the two containers are identical and contain the same volume of liquid. Because of the difference in the quantities and densities of the sweeteners used, the volume V of the diet mixture will have less mass than an equal volume of the regular mixture.

15. As the truck passes, the air between your car and the truck is squeezed into the channel between the two vehicles and moves at a higher speed than when your car is in the open. According to Bernoulli's principle, this high-speed air has a lower pressure than the air on the outer side of your car. The difference in pressure exerts a net force on your car toward the truck.
17. Opening the windows results in a smaller pressure difference between the exterior and interior of the house and, therefore, less tendency for severe damage to the structure due to the Bernoulli effect.

PROBLEMS

1. 1.3 mm
3. 1.8×10^6 Pa
5. 3.5×10^8 Pa
7. 4.4 mm
9. 0.024 mm
11. 1.9 cm
13. (a) 1.88×10^5 Pa (b) 2.65×10^5 Pa
15. 1.4 atm
17. 3.4×10^2 m
19. 0.133 m
21. 271 kN horizontally toward the cellar
23. 1.05×10^5 Pa
25. 2.1 N · m
27. 9.41 kN
29. (b) 5.9 km
31. 2.67×10^3 kg
33. 5.57 N
35. (a) 1.46×10^{-2} m^3 (b) 2.10×10^3 kg/m^3
37. 1.07 m/s^2
39. 17.3 N (upper scale), 31.7 N (lower scale)
41. (a) 80 g/s (b) 0.27 mm/s
43. 12.6 m/s
45. 9.00 cm
47. 1.47 cm
49. (a) 28.0 m/s (b) 28.0 m/s (c) 2.11 MPa
51. (b) For any y less than $y_{max} = P_0/\rho g$
53. 8.3×10^{-2} N/m
55. 5.6×10^{-2} N/m
57. 8.6 N
59. 2.1 MPa
61. 2.8 μm
63. 0.41 mm
65. $RN = 4.3 \times 10^3$; turbulent flow
67. 1.8×10^{-3} kg/m^3
69. 1.4×10^{-5} N · s/m^2
71. (a) The buoyant forces are the same because the two blocks displace equal amounts of water. (b) The spring scale reads largest value for the iron block. (c) $B = 2.0 \times 10^3$ N for both blocks, $T_{iron} = 13 \times 10^3$ N, $T_{aluminum} = 3.3 \times 10^3$ N.
73. 2.5×10^7 capillaries
75. (a) 1.57 kPa, 1.55×10^{-2} atm, 11.8 mm of Hg (b) The fluid level in the tap should rise. (c) Blockage of flow of the cerebrospinal fluid
77. 4.14×10^3 m^3
79. 833 kg/m^3
81. 2.25 m above the level of point B
83. 6.4 m
85. 1.3 cm
87. 17.0 cm above the floor
89. 532 cm^3

Chapter 10

QUICK QUIZZES

1. (c)
2. (b)
3. (c)
4. (c)
5. (a)
6. (b)

CONCEPTUAL QUESTIONS

1. An ordinary glass dish will usually break because of stresses that build up as the glass expands when heated. The expansion coefficient for Pyrex glass is much lower than that of ordinary glass. Thus, the Pyrex dish will expand much less than the dish of ordinary glass and does not normally develop sufficient stress to cause breakage.
3. The accurate answer is that it doesn't matter! Temperatures on the Kelvin and Celsius scales differ by only 273 degrees. This difference is insignificant for temperatures on the order of 10^7 degrees. If we imagine that the temperature is given in kelvins and ignore any problems with significant figures, then the Celsius temperature is $1.499\,972\,7 \times 10^7$ °C.
5. Mercury must have the larger coefficient of expansion. As the temperature of a thermometer rises, both the mercury and the glass expand. If they both had the same coefficient of linear expansion, the mercury and the cavity in the glass would expand by the same amount, and there would be no apparent movement of the end of the mercury column relative to the calibration scale on the glass. If the glass expanded more than the mercury, the reading would go down as the temperature went up! Now that we have argued this conceptually, we can look in a table and find that the coefficient for mercury is about 20 times as large as that for glass, so that the expansion of the glass can sometimes be ignored.
7. We can think of each bacterium as being a small bag of liquid containing bubbles of gas at a very high pressure. The ideal gas law indicates that if the bacterium is raised rapidly to the surface, then its volume must increase dramatically. In fact, the increase in volume is sufficient to rupture the bacterium.
9. Velocity is a vector quantity, so direction must be considered. If there are the same number of particles moving to the right along the x-direction as there are to the left along the $-x$-direction, the x-components of the velocity of all the molecules will sum to zero.
11. The bags of chips contain a sealed sample of air. When the bags are taken up the mountain, the external atmospheric pressure on them is reduced. As a result, the difference between the pressure of the air inside the bags and the reduced pressure outside results in a net force pushing the plastic of the bag outward.
13. Additional water vaporizes into the bubble, so that the number of moles n increases.

PROBLEMS

1. (a) −460°C (b) 37.0°C (c) −280°C
3. (a) −423°C, 20.28 K (b) 68°F, 293 K
9. (a) 1 337 K, 2 933 K (b) 1 596°C, 1 596 K
11. 31 cm
13. 55.0°C
15. (a) −179°C (attainable) (b) −376°C (below 0 K, unattainable)

17. 2.171 cm
19. 2.7×10^2 N
21. 1.1 L (0.29 gal)
23. 0.548 gal
25. (a) increases (b) 1.603 cm
27. (a) 627°C (b) 927°C
29. (a) 2.5×10^{19} molecules (b) 4.1×10^{-21} mol
31. 287°C
33. 7.1 m
35. 16.0 cm^3
37. 6.21×10^{-21} J
39. 6.64×10^{-27} kg
41. (a) 8.76×10^{-21} J
(b) $v_{\text{rms, He}} = 1.62$ km/s, $v_{\text{rms, Ar}} = 514$ m/s
43. 16 N
45. 0.663 mm at 78.2° below the horizontal
47. 3.55 L
49. 6.57 MPa
51. The expansion of the mercury is almost 20 times that of the flask (assuming Pyrex glass).
53. shorter, by 0.061 mm
55. 2.74 m
57. 1.61 MPa
59. 0.417 L
61. (a) $\theta = \dfrac{(\alpha_2 - \alpha_1)L_0(\Delta T)}{\Delta r}$
(c) The bar bends in the opposite direction.
63. 0.53 kg

Chapter 11

QUICK QUIZZES

1. (a) Water, glass, iron. (b) Iron, glass, water.
2. (b) The slopes are proportional to the reciprocal of the specific heat, so a larger specific heat results in a smaller slope, meaning more energy is required to achieve a given temperature change.
3. (c)
4. (b)
5. (a) 4 (b) 16 (c) 64

CONCEPTUAL QUESTIONS

1. When you rub the surface, you increase the temperature of the rubbed region. With the metal surface, some of this energy is transferred away from the rubbed site by conduction. Consequently, the temperature in the rubbed area is not as high for the metal as it is for the wood, and it feels relatively cooler than the wood.
3. The fruit loses energy into the air by radiation and convection from its surface. Before ice crystals can form inside the fruit to rupture cell walls, all of the liquid water on the skin will have to freeze. The resulting time delay may prevent damage within the fruit throughout a frosty night. Further, a surface film of ice provides some insulation to slow subsequent energy loss by conduction from within the fruit.
5. The operation of an immersion coil depends on the convection of water to maintain a safe temperature. As the water near a coil warms up, the warmed water floats to the top due to Archimedes' principle. The temperature of the coil cannot go higher than the boiling temperature of water, 100°C. If the coil is operated in air, convection is reduced, and the upper limit of 100°C is removed. As a result, the coil can become hot enough to be damaged. If the coil is used in an attempt to warm a thick liquid like stew, convection cannot occur fast enough to carry energy away from the coil, so that it again may become hot enough to be damaged.
7. One of the ways that objects transfer energy is by radiation. The top of the mailbox is oriented toward the clear sky. Radiation emitted by the top of the mailbox goes upward and into space. There is little radiation coming down from space to the top of the mailbox. Radiation leaving the sides of the mailbox is absorbed by the environment. Radiation from the environment (tree, houses, cars, etc.), however, can enter the sides of the mailbox, keeping them warmer than the top. As a result, the top is the coldest portion and frost forms there first.
9. Tile is a better conductor of energy than carpet, so the tile conducts energy away from your feet more rapidly than does the carpeted floor.
11. The large amount of energy stored in the concrete during the day as the sun falls on it is released at night, resulting in an overall higher average temperature in the city than in the countryside. The heated air in a city rises as it's displaced by cooler air moving in from the countryside, so evening breezes tend to blow from country to city.
13. The fingers are wetted to create a layer of steam between the fingers and the molten lead. The steam acts as an insulator and prevents serious burns. This demonstration is dangerous: we don't recommend it.
15. The increase in the temperature of the ethyl alcohol will be about twice that of the water.
17. (d)

PROBLEMS

1. 10.1°C
3. (a) 1.67×10^{18} J (b) 53.1 yr
5. 1.03×10^3 J
7. 2.85 km
9. 176°C
11. 88 W
13. 185 g
15. 80 g
17. 1.8×10^3 J/kg·°C
19. 0.26 kg
21. 65°C
23. 21 g
25. 2.3 km
27. 16°C
29. $t_{\text{boil}} = 2.8$ min, $t_{\text{evaporate}} = 18$ min
31. (a) all ice melts, $T_f = 40$°C (b) 8.0 g melts, $T_f = 0$°C
33. (a) 0.22 kW (b) 13 mW (c) 56 mW
35. 402 MW
37. 14 ft^2·°F·h/Btu
39. 9.0 cm
41. 0.11 kW
43. $\sim 10^3$ W
45. 16:1
47. 12 kW
49. 6.0×10^3 kg
51. 2.3 kg
53. 29°C
55. 30.3 kcal/h
57. 109°C
59. 51.2°C

61. (a) 7 stops (b) Assumes that no energy is lost to the surroundings and that all internal energy generated stays with the brakes.
63. (b) 2.7×10^3 J/kg · °C
65. 1.4 kg
67. 12 h
69. 10.9 g

Chapter 12

QUICK QUIZZES

1. (b)
2. A is isovolumetric, B is adiabatic, C is isothermal, D is isobaric.
3. (c)
4. (b)
5. The number 7 is the most probable outcome. The numbers 2 and 12 are the least probable outcomes.

CONCEPTUAL QUESTIONS

1. First, the efficiency of the automobile engine cannot exceed the Carnot efficiency: it is limited by the temperature of the burning fuel and the temperature of the environment into which the exhaust is dumped. Second, the engine block cannot be allowed to exceed a certain temperature. Third, any practical engine has friction, incomplete burning of fuel, and limits set by timing and energy transfer by heat.

3. If there is no change in internal energy, then, according to the first law of thermodynamics, the heat is equal to the negative of the work done on the gas (and thus equal to the work done *by* the gas). Thus, $Q = -W = W_{\text{by gas}}$.

5. The energy that is leaving the body by work and heat is replaced by means of biological processes that transform chemical energy in the food that the individual ate into internal energy. Thus, the temperature of the body can be maintained.

7. The statement shows a misunderstanding of the concept of heat. Heat is energy in the process of being transferred, not a form of energy that is held or contained. If you wish to speak of energy that is contained, you speak of **internal energy**, not heat. Correct statements would be (1) "Given any two objects in thermal contact, the one with the higher temperature will transfer energy by heat to the other" and (2) "Given any two objects of equal mass, the one with the higher product of absolute temperature and specific heat contains more internal energy."

9. Although no energy is transferred into or out of the system by heat, work is done on the system as the result of the agitation. Consequently, both the temperature and the internal energy of the coffee increase.

11. Practically speaking, it isn't possible to create a heat engine that creates no thermal pollution, because there must be both a hot heat source (energy reservoir) and a cold heat sink (low-temperature energy reservoir). The heat engine will warm the cold heat sink and will cool down the heat source. If either of those two events is undesirable, then there will be thermal pollution.

Under some circumstances, the thermal pollution would be negligible. For example, suppose a satellite in space were to run a heat pump between its sunny side and its dark side. The satellite would intercept some of the energy that gathered on one side and would "dump" it to the dark side. Since neither of those effects would be particularly undesirable, it could be said that such a heat pump produced no thermal pollution.

13. The rest of the Universe must have an entropy change of +8.0 J/K or more.

15. The first law is a statement of conservation of energy that says that we cannot devise a cyclic process that produces more energy than we put into it. If the cyclic process takes in energy by heat and puts out work, we call the device a heat engine. In addition to the first law's limitation, the second law says that, during the operation of a heat engine, some energy must be ejected to the environment by heat. As a result, it is theoretically impossible to construct a heat engine that will work with 100% efficiency.

17. From the point of view of energy principles, the molecules strike the piston and move it through a distance, so the molecules do work on the piston. This work represents a transfer of energy out of the gas. As a result, the internal energy of the gas drops. Because the temperature is related to internal energy, the temperature of the gas drops.

PROBLEMS

3. 1.1×10^4 J
5. (a) −810 J (b) −507 J (c) −203 J
7. (a) -6.1×10^5 J (b) 4.6×10^5 J
9. (a) 1.09×10^3 K (b) −6.81 kJ
11. (a) $Q < 0$, $W = 0$, $\Delta U < 0$ (b) $Q > 0$, $W = 0$, $\Delta U > 0$
13. (a) 567 J (b) 167 J
15. (a) −88.5 J (b) 722 J
17. (a) −180 J (b) +188 J
19. (a) -9.12×10^{-3} J (b) −333 J
21. (a) 0.95 J (b) 3.2×10^5 J (c) 3.2×10^5 J
23. 0.489 (or 48.9%)
25. (a) 0.333 (or 33.3%) (b) 2/3
27. (a) 0.672 (or 67.2%) (b) 58.8 kW
29. (a) 0.294 (or 29.4%) (b) 500 J (c) 1.67 kW
31. 1/3
33. 0.49°C
35. (a) −1.2 kJ/K (b) 1.2 kJ/K
37. 57 J/K
39. 3.27 J/K
41. (a)

End Result	Possible Tosses	Total Number of Same Result
All H	HHHH	1
1T, 3H	HHHT, HHTH, HTHH, THHH	4
2T, 2H	HHTT, HTHT, THHT, HTTH, THTH, TTHH	6
3T, 1H	TTTH, TTHT, THTT, HTTT	4
All T	TTTT	1

Most probable result = 2H and 2T.

(b) all H or all T (c) 2H and 2T

43. The maximum efficiency possible with these reservoirs = 50%; the claim is false.
45. (a) $-|Q_h|/T_h$ (b) $|Q_c|/T_c$ (c) $|Q_h|/T_h - |Q_c|/T_c$ (d) 0
47. 2.8°C
49. 18°C
51. (a) 12.2 kJ (b) 4.05 kJ (c) 8.15 kJ