Chapter 7

Work and Kinetic Energy

Answers to Even-numbered Conceptual Questions

2. False. Any force acting on an object can do work. The work done by different forces may add to produce a greater net work, or they may cancel to some extent. It follows that the net work done on an object can be thought of in the following two equivalent ways: (i) The sum of the works done by each individual force; or (ii) the work done by the net force.

4. The tension in the string does no work on the bob, because it always acts at right angles to the motion of the bob. Gravity, on the other hand, does negative work on the bob as it rises, and positive work as it descends.

6. If the net work done on an object is zero, it follows that its change in kinetic energy is also zero. Therefore, its speed remains the same.

8. Frictional forces do negative work whenever they act in a direction that opposes the motion. For example, friction does negative work when you push a box across the floor, or when you stop your car.

10. A car with a speed of $v/2$ has a kinetic energy that is $1/4$ the kinetic energy it has when its speed is v. Therefore, the work required to accelerate this car from rest to $v/2$ is $W_0/4$.

12. Kinetic energy depends on the speed squared; therefore, increasing the speed by a factor of 3 increases the kinetic energy by a factor of 9.

14. The fact that the ski boat's velocity is constant means that its kinetic energy is also constant. Therefore, the net work done on the boat is zero. It follows that the net force acting on the boat does no work. (In fact, the net force acting on the boat is zero, since its velocity is constant.)

16. **(a)** Certainly. Kinetic energy depends on both mass and speed; therefore, what the elephant lacks in speed it can more than make up for in mass. **(b)** Yes. Again, both speed and mass contribute to the kinetic energy. For example, if the elephant were at rest, its kinetic energy would be zero – no matter how massive it is. A moving gazelle will always have a nonzero kinetic energy.

18. No. What we can conclude is that the net force acting on the object is zero.

20. **(a)** The work required to stretch a spring depends on the square of the amount of stretch. Therefore, to stretch a spring by the amount x requires only $1/4$ the work required to stretch it by the amount $2x$. In this case, the work required is $W_0/4$. **(b)** To stretch this spring by 3 cm requires $3^2 = 9$ times the work to stretch it 1 cm. Therefore, stretching to 3 cm requires the work $9W_0/4$. Subtracting from this the work W_0 required to stretch to 2 cm, we find that an addition work of $5W_0/4$ is required to stretch from 2 cm to 3 cm.

22. No. Power depends both on the amount of work done by the engine, and the amount of time during which the work is performed. If engine 2 does its work in less than half the time of engine 1, it can produce more power.

Solutions to Problems

1. $W = Fd = (80.0 \text{ N})(3.0 \text{ m}) = \boxed{240 \text{ J}}$

2. $W = Fd = mgd$

    $m = \dfrac{W}{gd}$

    $= \dfrac{201 \text{ J}}{\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(4.70 \text{ m})}$

    $= \boxed{4.36 \text{ kg}}$

3. **(a)** $W = Fd = mgd = (3.2 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(1.2 \text{ m}) = \boxed{38 \text{ J}}$

    (b) $W = Fd = (0)(50.0 \text{ m}) = \boxed{0}$

4. $\sum F_x = F - f_k = 0$

    $\sum F_y = N - mg = 0$

    $N = mg$

    $F = f_k = \mu_k N = \mu_k mg$

    $d = \dfrac{W}{F}$

    $= \dfrac{W}{\mu_k mg}$

    $= \dfrac{640 \text{ J}}{(0.26)(70.0 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)}$

    $= \boxed{3.6 \text{ m}}$

5. **(a)** $W = Fd = mgd = (3.6 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(2.1 \text{ m}) = \boxed{74 \text{ J}}$

    (b) $W = Fd = mgd = mg(0) = \boxed{0}$

    (c) $W = Fd = mgd = (3.6 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(-2.1 \text{ m}) = \boxed{-74 \text{ J}}$

6. **(a)** The tension vector points from the skier to the boat in the direction of motion. Both the force (tension) acting on the skier and the displacement are positive, so the work done on the skier is $\boxed{\text{positive}}$.

    (b) $W = Fd = Td = (120 \text{ N})(65 \text{ m}) = \boxed{7.8 \text{ kJ}}$

7. **(a)** The tension vector is directed opposite the direction of motion, so the work done on the boat by the rope is $\boxed{\text{negative}}$.

    (b) $W = Fd = Td = (-120 \text{ N})(65 \text{ m}) = \boxed{-7.8 \text{ kJ}}$

8. $\sum F_x = F \cos\theta$

   $W = (F \cos\theta)d = (16 \text{ N})(\cos 25°)(10.0 \text{ m}) = \boxed{150 \text{ J}}$

9. $W = Fd = (T \cos\theta)d = (125 \text{ N})(\cos 40.0°)(5.0 \text{ m}) = \boxed{480 \text{ J}}$

10. **(a)** $W = (F \cos\theta)d = (50.0 \text{ N})(\cos 55°)(0.50 \text{ m}) = \boxed{14 \text{ J}}$

    (b) If the force along the handle remains the same, the increased angle means a smaller force component in the direction of motion. The work done by the janitor $\boxed{\text{decreases}}$.

11. $W = (T \cos\theta)d$

    $\cos\theta = \dfrac{W}{Td}$

    $\theta = \cos^{-1}\dfrac{W}{Td} = \cos^{-1}\dfrac{2.00 \times 10^5 \text{ J}}{(2560 \text{ N})(145 \text{ m})} = \boxed{57.4°}$

12. $W = (T \cos\theta)d$

    $\cos\theta = \dfrac{W}{Td}$

    $\theta = \cos^{-1}\dfrac{W}{Td}$

    $= \cos^{-1}\dfrac{3500 \text{ J}}{(75 \text{ N})(50.0 \text{ m})}$

    $= \boxed{21°}$

13. **(a)** $W = \vec{\mathbf{F}} \cdot \vec{\mathbf{d}} = F_x d_x + F_y d_y$ (See Appendix A)

    $W = (2.2 \text{ N})(0.25 \text{ m}) + (1.1 \text{ N})(0) = \boxed{0.55 \text{ J}}$

    (b) $W = (2.2 \text{ N})(0) + (1.1 \text{ N})(0.25 \text{ m}) = \boxed{0.28 \text{ J}}$

    (c) $W = (2.2 \text{ N})(-0.50 \text{ m}) + (1.1 \text{ N})(-0.25 \text{ m}) = \boxed{-1.4 \text{ J}}$

14. $|\vec{\mathbf{F}}| = \sqrt{(2.2 \text{ N})^2 + (1.1 \text{ N})^2} = 2.46 \text{ N} = F$

    $\cos\theta = \dfrac{W}{Fd}$

    $\theta = \cos^{-1}\left(\dfrac{W}{Fd}\right) = \cos^{-1}\left[\dfrac{2.1 \text{ J}}{(2.46 \text{ N})(1.25 \text{ m})}\right] = 46.9°$

    Direction of $\vec{\mathbf{F}} = \tan^{-1}\left(\dfrac{1.1 \text{ N}}{2.2 \text{ N}}\right) = 26.6°$

    Direction of $\vec{\mathbf{d}} = 26.6° \pm 46.9° = 73.5°$ or $-20.3°$

    For 73.5°: $d_x = d \cos 73.5° = (1.25 \text{ m})(\cos 73.5°) = 0.36 \text{ m}$

                $d_y = d \sin 73.5° = (1.25 \text{ m})(\sin 73.5°) = 1.2 \text{ m}$

    $\boxed{\vec{\mathbf{d}} = (0.36 \text{ m})\hat{\mathbf{x}} + (1.2 \text{ m})\hat{\mathbf{y}}}$

For $-20.3°$: $d_x = (1.25 \text{ m})[\cos(-20.3°)] = 1.2 \text{ m}$
$\qquad\qquad\quad d_y = (1.25 \text{ m})[\sin(-20.3°)] = -0.43 \text{ m}$

$$\boxed{\vec{\textbf{d}} = (1.2 \text{ m})\hat{\textbf{x}} + (-0.43 \text{ m})\hat{\textbf{y}}}$$

15. $W = \Delta K = \dfrac{1}{2}m(v_f^2 - v_i^2) = \dfrac{1}{2}(65 \text{ kg})\left[\left(10.0 \dfrac{\text{m}}{\text{s}}\right)^2 - 0\right] = \boxed{3.3 \text{ kJ}}$

16. $K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}(1770 \text{ kg})\left(120 \dfrac{\text{m}}{\text{s}}\right)^2 = \boxed{13 \text{ MJ}}$

17. (a) $K_1 = \dfrac{1}{2}mv_1^2 = \dfrac{1}{2}(0.0095 \text{ kg})\left(1.30 \times 10^3 \dfrac{\text{m}}{\text{s}}\right)^2 = \boxed{8.03 \text{ kJ}}$

(b) $K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m\left(\dfrac{v_1}{2}\right)^2 = \dfrac{1}{4}\left(\dfrac{1}{2}mv_1^2\right) = \dfrac{1}{4}(8.03 \text{ kJ}) = \boxed{2.01 \text{ kJ}}$

(c) $K = \dfrac{1}{2}mv^2 = \dfrac{1}{2}m(2v_1)^2 = 4\left(\dfrac{1}{2}mv_1^2\right) = 4(8.03 \text{ kJ}) = \boxed{32.1 \text{ kJ}}$

18. (a) The work done by gravity on the pine cone is $W = mgh$, which in the absence of air resistance would result in a kinetic energy.
$\Delta K = K_f - K_i = K_f$

$K_f = \dfrac{1}{2}mv_f^2 = W$

$v_f = \sqrt{\dfrac{2W}{m}} = \sqrt{\dfrac{2mgh}{m}} = \sqrt{2gh} = \sqrt{2\left(9.81 \dfrac{\text{m}}{\text{s}^2}\right)(14 \text{ m})} = \boxed{17 \text{ m/s}}$

(b) The force of air resistance is opposite the direction of displacement, so the work done by it on the pine cone is $\boxed{\text{negative}}$.

19. (a) $W_{\text{total}} = W_{\text{gravity}} + W_{\text{air}} = \Delta K$

$W_{\text{air}} = \Delta K - W_{\text{gravity}}$

$\qquad = \dfrac{1}{2}m(v_f^2 - v_i^2) - mgh$

$\qquad = m\left[\dfrac{1}{2}v_f^2 - gh\right]$

$\qquad = (0.21 \text{ kg})\left[\dfrac{1}{2}\left(13 \dfrac{\text{m}}{\text{s}}\right)^2 - \left(9.81 \dfrac{\text{m}}{\text{s}^2}\right)(14 \text{ m})\right]$

$\qquad = \boxed{-11 \text{ J}}$

(b) $W = Fd$

$$F = \frac{W}{d}$$
$$= \frac{-11.1 \text{ J}}{14 \text{ m}}$$
$$= -0.793 \text{ N}$$

$$\vec{F} = \boxed{0.79 \text{ N upward}}$$

20. (a) $K_1 = \frac{1}{2}mv_1^2 = \frac{1}{2}(0.40 \text{ kg})\left(6.0 \ \frac{\text{m}}{\text{s}}\right)^2 = \boxed{7.2 \text{ J}}$

(b) $K_2 = \frac{1}{2}mv_2^2$

$$v_2 = \sqrt{\frac{2K_2}{m}} = \sqrt{\frac{2(25 \text{ J})}{0.40 \text{ kg}}} = \boxed{11 \text{ m/s}}$$

(c) $W = \Delta K = K_2 - K_1 = 25 \text{ J} - 7.2 \text{ J} = \boxed{18 \text{ J}}$

21. (a) $W_{\text{total}} = W_{\text{friction}} = \Delta K = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}(62.0 \text{ kg})\left[0 - \left(4.35 \ \frac{\text{m}}{\text{s}}\right)^2\right] = \boxed{-587 \text{ J}}$

(b) $W_{\text{friction}} = -f_k d = -\mu_k N d = -\mu_k mgd$

$$\mu_k = -\frac{W_{\text{friction}}}{mgd} = \frac{587 \text{ J}}{(62.0 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(3.40 \text{ m})} = \boxed{0.284}$$

22. (a) The speed of the car decreases, so $\Delta K < 0$. Since $W = \Delta K$, the net work done on the car is $\boxed{\text{negative}}$.

(b) $W = Fd = \Delta K$

$$F = \frac{\Delta K}{d} = \frac{m(v_f^2 - v_i^2)}{2d} = \frac{(1300 \text{ kg})\left[\left(15 \ \frac{\text{m}}{\text{s}}\right)^2 - \left(18 \ \frac{\text{m}}{\text{s}}\right)^2\right]}{2(30.0 \text{ m})} = -2100 \text{ N}$$

The magnitude of the average force acting on the car is $\boxed{2.1 \text{ kN}}$.

23. (a) From Problem 20,

$$F = \frac{m(v_f^2 - v_i^2)}{2d}$$

$$v_f = \sqrt{v_i^2 - \frac{2|F|}{m}d}$$

Since v_f varies approximately with the square root of d (the width of the sandy portion), dividing d by two reduces v_f $\boxed{\text{by less}}$ than 1.5 m/s.

(b) Assume that the average force is the same as that found in Problem 20.

$$\Delta v = \sqrt{\left(18 \ \frac{\text{m}}{\text{s}}\right)^2 - \frac{2(2145 \text{ N})}{1300 \text{ kg}}(15.0 \text{ m})} - 18 \ \frac{\text{m}}{\text{s}} = \boxed{-1.4 \text{ m/s}}$$

24. (a) $W = \Delta K = \frac{1}{2}(m_{\text{rider}} + m_{\text{bicycle}})(v_f^2 - v_i^2) = \frac{1}{2}(75 \text{ kg})\left[0 - \left(12 \frac{\text{m}}{\text{s}}\right)^2\right] = -5400 \text{ J}$

The brakes must do $\boxed{54 \text{ kJ}}$ of work on the bicycle and rider system to bring it to rest.

(b) $v_{\text{av}} = \frac{v_f + v_i}{2} = \frac{12 \frac{\text{m}}{\text{s}} + 0}{2} = 6.0 \frac{\text{m}}{\text{s}}$

$x = v_{\text{av}}t = \left(6.0 \frac{\text{m}}{\text{s}}\right)(4.0\text{s}) = \boxed{24 \text{ m}}$

(c) $W = Fd$

$F = \frac{W}{d}$

$= \frac{-5400 \text{ N}}{24 \text{ m}}$

$= -230 \text{ N}$

The magnitude of the braking force is $\boxed{230 \text{ N}}$.

25. (a) $W = \frac{1}{2}kx^2 = \frac{1}{2}\left(3.5 \times 10^4 \frac{\text{N}}{\text{m}}\right)(0.050 \text{ m})^2 = \boxed{44 \text{ J}}$

(b) Since $W \propto x^2$, the work required to compress the spring is the same as that required to stretch it, $\boxed{44 \text{ J}}$.

26. $W = \frac{1}{2}kx^2 = \Delta K = \frac{1}{2}mv^2$

$v^2 = \frac{kx^2}{m}$

$v = \sqrt{\frac{k}{m}}\, x$

$= \sqrt{\frac{1.0 \times 10^4 \frac{\text{N}}{\text{m}}}{1.2 \text{ kg}}}(0.15 \text{ m})$

$= \boxed{14 \text{ m/s}}$

27. The kinetic energy is stored in the spring.

$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

$k = \frac{mv^2}{x^2} = \frac{(1.8 \text{ kg})\left(2.2 \frac{\text{m}}{\text{s}}\right)^2}{(0.31 \text{ m})^2} = \boxed{91 \text{ N/m}}$

28. $W = F_1d_1 + F_2d_2 + F_3d_3$

$= (0.6 \text{ N})(0.25 \text{ m}) + (0.4 \text{ N})(0.25 \text{ m}) + (0.8 \text{ N})(0.25 \text{ m})$

$= (0.6 \text{ N} + 0.4 \text{ N} + 0.8 \text{ N})(0.25 \text{ m})$

$= \boxed{0.45 \text{ J}}$

29. (a) The work required to move the object from $x = 0.50$ m to $x = 0.75$ m is $W = (0.40 \text{ n})(0.25) = 0.10$ J. So, for the final position, we have

$$W = F(x_{\text{f}} - x_{\text{i}})$$

$$x_{\text{f}} = \frac{W + Fx_{\text{i}}}{F}$$

$$= \frac{(0.12 \text{ J} - 0.10 \text{ J}) + (0.20 \text{ N})(0.75 \text{ m})}{0.20 \text{ N}}$$

$$= \boxed{0.85 \text{ m}}$$

(b) The work required to move the object from $x = 0.50$ m to $x = 0.25$ m is $W = (0.80 \text{ N})(-0.25 \text{ m}) = -0.20$ J. So, for the final position, we have

$$x_{\text{f}} = \frac{W + Fx_{\text{i}}}{F} = \frac{[-0.29 \text{ J} - (-0.20 \text{ J})] + (0.60 \text{ N})(0.25 \text{ m})}{0.60 \text{ N}} = \boxed{0.10 \text{ m}}$$

30. $W_1 = \dfrac{1}{2}k_1 x_1^2$

$$k_1 = \frac{2W_1}{x_1^2} = \frac{2(150 \text{ J})}{(0.20 \text{ m})^2} = 7.5 \ \frac{\text{kN}}{\text{m}}$$

$$k_2 = \frac{2W_2}{x_2^2} = \frac{2(210 \text{ J})}{(0.30 \text{ m})^2} = 4.7 \ \frac{\text{kN}}{\text{m}}$$

$k_1 > k_2$; $\boxed{\text{Spring 1}}$ is stiffer.

31. (a) $W = \dfrac{1}{2}kx^2$

$$k = \frac{2W}{x^2} = \frac{2(130 \text{ J})}{(0.10 \text{ m})^2} = \boxed{26 \text{ kN/m}}$$

(b) Since $x \propto \sqrt{W}$, it will take a total of four times the work to double the compression of the spring. The net increase in the work is

$$4W - W = 3W = \boxed{\text{three times more work}} = 3(130 \text{ J}) = \boxed{390 \text{ J}}$$

32. (a) $W = F\Delta x = \Delta K = \dfrac{1}{2}m(v_{\text{f}}^2 - v_{\text{i}}^2)$

$$v_{\text{f}} = \sqrt{v_{\text{i}}^2 + \frac{2F\Delta x}{m}}$$

$$= \sqrt{\left(0.44 \ \frac{\text{m}}{\text{s}}\right)^2 + \frac{2[(0.8 \text{ N})(0.23 \text{ m}) + (0.4 \text{ N})(0.25 \text{ m}) + (0.2 \text{ N})(0.24 \text{ m})]}{1.7 \text{ kg}}}$$

$$= \boxed{0.76 \text{ m/s}}$$

(b) Determine the final speed at $x = 0.25$ m.

$$v_{\text{f}} = \sqrt{\left(0.44 \ \frac{\text{m}}{\text{s}}\right)^2 + \frac{2(0.8 \text{ N})(-0.02 \text{ m})}{1.7 \text{ kg}}} = 0.41806 \ \frac{\text{m}}{\text{s}}$$

Find x_{f}.

$$F\Delta x = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$x_f = x_i + \frac{m(v_f^2 - v_i^2)}{2F} = 0.25 \text{ m} + \frac{(1.7 \text{ kg})\left[\left(0.16 \frac{\text{m}}{\text{s}}\right)^2 - \left(0.41806 \frac{\text{m}}{\text{s}}\right)^2\right]}{2(0.6 \text{ N})} = \boxed{0.04 \text{ m}}$$

33. $$F = \begin{cases} \left(2.0 \times 10^4 \ \frac{\text{N}}{\text{m}}\right)x, & 0 \le x \le 0.21 \text{ m} \\ 4200 \text{ N}, & x > 0.21 \text{ m} \end{cases}$$

(a) From $x = 0$ to $x = 0.21$ m, the force varies linearly. The area under a graph of F vs. x gives the work. This area is a triangle.

$$W = \frac{1}{2}(\text{base})(\text{height}) + W_{\text{constant } F}$$
$$= \frac{1}{2}(0.21 \text{ m})\left(2.0 \times 10^4 \ \frac{\text{N}}{\text{m}}\right)(0.21 \text{ m}) + (4200 \text{ N})(0.30 \text{ m}{-}0.21 \text{ m})$$
$$= \boxed{820 \text{ J}}$$

(b) To determine the work from $x = 0.10$ m to $x = 0.40$ m, calculate it from $x = 0$ to $x = 0.40$ m and then subtract the work from $x = 0$ to $x = 0.10$.

$$W = \frac{1}{2}(0.21 \text{ m})^2\left(2.0 \times 10^4 \ \frac{\text{N}}{\text{m}}\right) + \left(4200 \ \frac{\text{N}}{\text{m}}\right)(0.40 \text{ m}{-}0.21 \text{ m}) - \frac{1}{2}(0.10 \text{ m})^2\left(2.0 \times 10^4 \ \frac{\text{N}}{\text{m}}\right) = \boxed{1.1 \text{ kJ}}$$

34. $$\frac{1}{2}kx^2 = W$$
$$\frac{1}{2}k_2(2x)^2 = \frac{W}{2}$$
$$k_2 = \frac{W}{4x^2}$$
$$= \frac{\frac{1}{2}kx^2}{4x^2}$$
$$= \boxed{\frac{k}{8}}$$

35. $$W = \Delta K = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}mv_f^2$$

$$P = \frac{W}{t} = \frac{\frac{1}{2}mv_f^2}{t} = \left[\frac{(950 \text{ kg})\left(65 \frac{\text{mi}}{\text{h}}\right)^2}{2(6.0 \text{ s})}\right]\left(1609 \ \frac{\text{m}}{\text{mi}}\right)^2\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)^2 = \boxed{67 \text{ kW}}$$

36. $$h = (1600 \text{ steps})\left(\frac{0.20 \text{ m}}{\text{step}}\right) = 320 \text{ m}$$

$$W = mgh$$

$$P = \frac{W}{t} = \frac{mgh}{t} = \frac{(70.0 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(320 \text{ m})}{659 \text{ s}} = \boxed{(330 \text{ W})}\left(\frac{1 \text{ hp}}{746 \text{ W}}\right) = \boxed{0.45 \text{ hp}}$$

37. $(1 \text{ kWh})\left(\dfrac{10^3 \text{ W}}{\text{kW}}\right)\left(\dfrac{3600 \text{ s}}{\text{h}}\right) = \boxed{3.6 \times 10^6 \text{ J}}$

38. $P = \dfrac{W}{t} = \dfrac{Fh}{t} = \dfrac{(mg)(vt)}{t} = mgv = (1.3 \times 10^{-3} \text{ kg})\left(9.81 \ \dfrac{\text{m}}{\text{s}^2}\right)\left(2.5 \times 10^{-2} \ \dfrac{\text{m}}{\text{s}}\right) = \boxed{3.2 \times 10^{-4} \text{ W}}$

39. $P = \dfrac{W}{t}$

$t = \dfrac{W}{P} = \dfrac{32,200 \text{ J}}{105 \text{ W}} = 306.7 \text{ s} = \boxed{5.11 \text{ min}}$

40. $P = Fv$

$v = \dfrac{P}{F}$

$\quad = \dfrac{P}{mg}$

$\quad = \dfrac{108 \text{ W}}{(5.00 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)}$

$\quad = \boxed{2.20 \text{ m/s}}$

41. $P = \dfrac{W}{t} = \dfrac{Fh}{t} = \left[\dfrac{(12.0 \text{ lb})(2.00 \text{ m})}{1 \text{ s}}\right]\left(\dfrac{1 \text{ N}}{0.2248 \text{ lb}}\right)\left(\dfrac{1 \text{ hp}}{746 \text{ W}}\right) = \boxed{0.143 \text{ hp}}$

42. (a) $P = Fv$

$F = \dfrac{P}{v}$

$\quad = \dfrac{50.0 \text{ W}}{1.50 \ \frac{\text{m}}{\text{s}}}$

$\quad = \boxed{33.3 \text{ N}}$

(b) Doubling the power will $\boxed{\text{increase the speed by a factor of 2}}$.

43. (a) $W = Pt = (0.30 \text{ hp})(10,140 \text{ s})\left(\dfrac{746 \text{ W}}{\text{hp}}\right) = \boxed{2.3 \text{ MJ}}$

(b) $(2.26 \times 10^6 \text{ J})\left(\dfrac{1 \text{ kcal}}{4186 \text{ J}}\right)\left(\dfrac{1 \text{ Snickers}}{280 \text{ kcal}}\right) = \boxed{2 \text{ Snickers}}$

44. (a) $P = \dfrac{W}{t} = \dfrac{mgh}{t} = \left[\dfrac{(4.00 \text{ kg})\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(0.750 \text{ m})}{3.00 \text{ days}}\right]\left(\dfrac{1 \text{ day}}{86,400 \text{ s}}\right) = \boxed{1.14 \times 10^{-4} \text{ W}}$

(b) Since $P \propto t^{-1}$, the power will be increased if the time is $\boxed{\text{decreased}}$.

45. For example:

$$P = \frac{W}{t} = \frac{mgh}{t} = \left[\frac{(65 \text{ kg})\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(3 \text{ m})}{3 \text{ s}}\right]\left(\frac{1 \text{ hp}}{746 \text{ W}}\right) = \boxed{0.9 \text{ hp}}$$

46. (a)
$$P = \frac{W}{t}$$
$$= \frac{\Delta K}{t}$$
$$= \frac{mv^2}{2T}$$
$$T = \frac{mv^2}{2P}$$
$$\Delta t = t_2 - t_1$$
$$= \frac{m}{2P}[(2v)^2 - v^2]$$
$$= \frac{3mv^2}{2P}$$
$$= \boxed{3T}$$

(b)
$$v_T^2 = \frac{2PT}{m}$$
$$v_T = \sqrt{\frac{2PT}{m}}$$
$$v_{2T} = \sqrt{\frac{2P(2T)}{m}}$$
$$= \sqrt{2}\sqrt{\frac{2PT}{m}}$$
$$= \boxed{\sqrt{2}v}$$

47. $P = Fv = (bv)v = bv^2$
$$v^2 = \frac{P}{b}$$
$$v = \boxed{\sqrt{\frac{P}{b}}}$$

48. $W = \Delta K = \frac{1}{2}m(v_f^2 - v_i^2) = \frac{1}{2}(60.0 \text{ kg} + 7.00 \text{ kg})\left[\left(6.00 \frac{\text{m}}{\text{s}}\right)^2 - \left(7.50 \frac{\text{m}}{\text{s}}\right)^2\right] = \boxed{-678 \text{ J}}$

49. $W = Fd = (7.5 \text{ pN})(8.0 \text{ nm}) = (7.5 \times 10^{-12} \text{ N})(8.0 \times 10^{-9} \text{ m}) = 60 \times 10^{-21} \text{ J} = \boxed{6.0 \times 10^{-20} \text{ J}}$

50. (a) $F = \frac{W}{d} = \frac{19 \text{ J}}{0.04 \text{ m}} = \boxed{500 \text{ N}}$

(b) $P = \dfrac{W}{t} = \dfrac{19 \text{ J}}{0.2 \text{ s}} = \boxed{100 \text{ W}}$

51. $K = \dfrac{1}{2}mv^2$

$v = \sqrt{\dfrac{2K}{m}}$

$= \sqrt{\left[\dfrac{2(210 \text{ kcal})}{0.045 \text{ kg}}\right]\left(\dfrac{4186 \text{ J}}{\text{kcal}}\right)}$

$= \boxed{6.3 \text{ km/s}}$

52. $P = \dfrac{W}{t} = \dfrac{mgh}{t} = \dfrac{(830 \text{ N})(12 \text{ m})}{25 \text{ s}} = \boxed{400 \text{ W}}$

53. (a) $\sum F_x = F - f_k = 0$

$F = f_k = \mu_k mg$

$P = Fv = \mu_k mgv = (0.55)(67 \text{ kg})\left(9.81 \ \dfrac{\text{m}}{\text{s}^2}\right)\left(0.50 \ \dfrac{\text{m}}{\text{s}}\right) = \boxed{180 \text{ W}}$

(b) $P = \dfrac{W}{t}$

$W = Pt$

$= (181 \text{ W})(35 \text{ s})$

$= \boxed{6.3 \text{ kJ}}$

54. $W = Fd = \Delta K = \dfrac{1}{2}m(v_f{}^2 - v_i{}^2)$

$v_i{}^2 = -\dfrac{2}{m}Fd$

$v_i = \sqrt{-\dfrac{2}{m}Fd}$

$= \sqrt{\dfrac{-2(65 \text{ N})(-2.6\times10^{-2} \text{ m})}{0.60\times10^{-3} \text{ kg}}}$

$= \boxed{75 \text{ m/s}}$

55. (a) $W = Fd = \Delta K$

$F = -f_k = -\mu_k N = -\mu_k mg$

$-\mu_k mgd = \Delta K$

$\mu_k = \dfrac{-\frac{1}{2}m(v_f{}^2 - v_i{}^2)}{mgd} = \dfrac{v_i{}^2 - v_f{}^2}{2gd} = \dfrac{\left(45 \ \frac{\text{m}}{\text{s}}\right)^2 - \left(44 \ \frac{\text{m}}{\text{s}}\right)^2}{2\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(25 \text{ m})} = \boxed{0.18}$

(b) $v_f = \sqrt{v_i^2 - 2\mu_k gd} = \sqrt{\left(44 \ \frac{m}{s}\right)^2 - 2(0.181)\left(9.81 \ \frac{m}{s^2}\right)(25 \ m)} = 42.98 \ \frac{m}{s} \boxed{< 43 \ \frac{m}{s}}$

The change in kinetic energy is the same, but since the initial speed is smaller than it was for the first 25 m, the change in speed is larger than it was in the first 25 m.

56. (a) $\sum F_x = F - f_k = ma_x = 0$

$F = f_k = \mu_k mg$

$W = Fd = \mu_k mgd = (0.240)(50.0 \ kg)\left(9.81 \ \frac{m}{s^2}\right)(2.60 \ m) = \boxed{306 \ J}$

(b) To cause the suitcase to speed up as you push it, a force greater than the force of kinetic friction is required to create the acceleration. This greater force results in the work done being $\boxed{\text{more than}}$ that in (a).

57. The work done on the glove by gravity is $W = -mgh = \Delta K = K_f - K = -K$.

$K = mgh$, so kinetic energy at $\dfrac{h}{2}$ is $K - mg\dfrac{h}{2} = \boxed{\dfrac{K}{2}}$.

58. (a) $F_0 = 0$, $F_2 = 0.64 \ N$, $F_4 = 0$

$W_{0 \ to \ 2} = W_{0 \ to \ 4} - W_{2 \ to \ 4} = \dfrac{1}{2}(4.0 \ m)(0.8 \ N) - \dfrac{1}{2}(2.0 \ m)(0.64 \ N) = \boxed{0.96 \ J}$

(b) $F_1 = 0.533 \ N$

$W_{1 \ to \ 4} = W_{0 \ to \ 4} - W_{0 \ to \ 1} = \dfrac{1}{2}(4.0 \ m)(0.8 \ N) - \dfrac{1}{2}(1.0 \ m)(0.533 \ N) = \boxed{1.3 \ J}$

(c) $F_3 = 0.32 \ N$

$W_{2 \ to \ 3} = \dfrac{1}{2}(0.64 \ N + 0.32 \ N)(1.0 \ m) = \boxed{0.48 \ J}$

59. (a) $W = \vec{F} \cdot \vec{d} = F_x d_x = F_y d_y$ (See Appendix A)

$W = (2.89 \ N)(4.55 \ m) + (0.131 \ N)(0) = \boxed{13.1 \ J}$

(b) $W = (2.89 \ N)(4.55 \ m) + (0.231 \ N)(0) = \boxed{13.1 \ J}$

(c) $\boxed{\text{If the pulling force remains the same, then the work done remains the same. If the increased mass results in a larger friction force and an increase in the required pulling force, then the work done increases.}}$

60. (a) $P = Fv$ After falling for 0.100 s the speed of the apple is $v = 0 + (9.81 \ m/s^2)(0.100 \ s) = 0.981 \ m/s$

$P = mgv = (0.175 \ kg)(9.81 \ m/s^2)(0.981 \ m/s) = \boxed{1.68 \ W}$

(b) $\boxed{\text{Increases}}$ because the speed of the apple increases.

(c) After falling for 0.200 s the speed of the apple is

$v = 0 + (9.81 \ m/s^2)(0.200 \ s) = 1.96 \ m/s$

$P = mgv = (0.175 \ kg)(9.81 \ m/s^2)(1.96 \ m/s) = \boxed{3.37 \ W}$

61. (a) $W = F\Delta y = -mg(h_{max} - h) = \boxed{mg(h - h_{max})}$

(b) $W_{total} = W_{up} + W_{down} = mg(h - h_{max}) + mgh_{max} = \boxed{mgh}$

(c) $K_{final} = K_i + W = \boxed{\dfrac{1}{2}mv_0^2 + mgh}$

62. (a) $W = Fd = (T\cos\theta)vt = (90.0 \text{ N})\cos(35°)\left(14 \ \dfrac{m}{s}\right)(10.0 \text{ s}) = \boxed{10 \text{ kJ}}$

(b) The skier moves with constant velocity, so the resistive force is equal and opposite to $T\cos\theta$.
$W = (-T\cos\theta)d = \boxed{-10 \text{ kJ}}$

63. (a) $\sum F_x = F - f_s = 0$
$F = -kx = f_s = \mu_s mg$

$x = \dfrac{-\mu_s mg}{k}$

$W = \dfrac{1}{2}kx^2 = \dfrac{1}{2}k\left(\dfrac{\mu_s mg}{k}\right)^2 = \dfrac{\mu_s^2 m^2 g^2}{2k} = \dfrac{(0.42)^2 (6.5 \text{ kg})^2 \left(9.81 \ \frac{m}{s^2}\right)^2}{2\left(1200 \ \frac{N}{m}\right)} = \boxed{0.30 \text{ J}}$

(b) $\boxed{\text{less}}$ The force of kinetic friction is generally smaller than the force of static friction. Therefore, a smaller force would be required to keep the block moving.

64. $P_1 = \dfrac{W_1}{t} = \dfrac{\Delta K_1}{t} = \dfrac{mv_{1f}^2}{2t} = \dfrac{m\left(60.0 \ \frac{mi}{h}\right)^2}{2t} = \left(1800 \ \dfrac{mi^2}{h^2}\right)\dfrac{m}{t} = P$

$P_2 = \dfrac{\Delta K_2}{t}$

$= \dfrac{2mv_{2f}^2}{2t}$

$= \dfrac{m\left(50.0 \ \frac{mi}{h}\right)^2}{t}$

$= \left(2500 \ \dfrac{mi^2}{h^2}\right)\dfrac{m}{t}$

$= \left[\left(2500 \ \dfrac{mi^2}{h^2}\right)\dfrac{m}{t}\right]\dfrac{P}{\left(1800 \ \frac{mi^2}{h^2}\right)\frac{m}{t}}$

$= \boxed{1.39P}$

65. $P = (F\cos\theta)v = mgv\cos\theta = (1.8\times10^{-3} \text{ kg})\left(9.81 \ \dfrac{m}{s^2}\right)\left(0.023 \ \dfrac{m}{s}\right)\cos 25° = \boxed{0.37 \text{ mW}}$

66. $P = Fv = 36,600$ W

$P' = (F + T)v = 37,800$ W

$P' - P = Tv = 1200$ W

$$T = \frac{1200 \text{ W}}{v}$$

$$= \frac{1200 \text{ W}}{14.0 \frac{\text{m}}{\text{s}}}$$

$$= \boxed{85.7 \text{ N}}$$

67. **(a)** $P = Fv = (23 \text{ N})\left(0.24 \ \frac{\text{m}}{\text{s}}\right) = \boxed{5.5 \text{ W}}$

(b) $W = Pt = (5.52 \text{ W})(90 \text{ s}) = 500 \text{ J} = \boxed{5.0 \times 10^2 \text{ J}}$

68. **(a)** $W = \Delta K = \frac{1}{2}m(v_\text{f}^2 - v_\text{i}^2) = \frac{1}{2}(0.14 \text{ kg})\left[\left(42.5 \ \frac{\text{m}}{\text{s}}\right)^2 - 0\right] = \boxed{130 \text{ J}}$

(b) $P = \dfrac{W}{t} = \dfrac{126 \text{ J}}{0.060 \text{ s}} = \boxed{2.1 \text{ kW}}$

(c) $\boxed{\text{More than}}$, because the same work is done in less time.

69. **(a)** $W = \Delta K = \dfrac{1}{2}m(v_\text{f}^2 - v_\text{i}^2)$

$$m = \frac{2W}{v_\text{f}^2 - v_\text{i}^2} = \frac{2(7.6 \times 10^7 \text{ J})}{\left(72 \ \frac{\text{m}}{\text{s}}\right)^2 - 0} = \boxed{2.9 \times 10^4 \text{ kg}}$$

(b) $P = \dfrac{\Delta W}{\Delta t} = \dfrac{7.6 \times 10^7 \text{ J}}{2.0 \text{ s}} = \boxed{38 \text{ MJ/s}}$

70. **(a)** $P = \dfrac{W}{t}$

$$t = \frac{W}{P} = \frac{(280 \text{ Cal})\left(\frac{4186 \text{ J}}{\text{Cal}}\right)}{22 \text{ J/s}} = 5.3 \times 10^4 \text{ s} = \boxed{15 \text{ h}}$$

(b) If lifting the container at constant speed, the force required is $mg = (3.6 \text{ kg})(9.81 \text{ m/s}^2) = 35.3 \text{ N}$.

$P = Fv$

$$v = \frac{P}{F} = \frac{22 \text{ J/s}}{35.3 \text{ N}} = \boxed{0.62 \text{ m/s}}$$

(c) $d = vt$

$$t = \frac{d}{v} = \frac{1.0 \text{ m}}{0.62 \text{ m/s}} = \boxed{1.6 \text{ s}}$$

71. (a) $a = \dfrac{F}{m}$

$P = Fv$

$F = \dfrac{P}{v} = \dfrac{(52 \text{ hp})\left(\frac{746 \text{ W}}{\text{hp}}\right)}{16 \text{ m/s}} = 2.42 \times 10^3 \text{ N}$

$a = \dfrac{2.42 \times 10^3 \text{ N}}{1600 \text{ kg}} = \boxed{1.5 \text{ m/s}^2}$

(b) For the same power, the force will be smaller at a higher speed. So the acceleration will $\boxed{\text{decrease}}$.

(c) $F = \dfrac{(52 \text{ hp})\left(\frac{746 \text{ W}}{\text{hp}}\right)}{32 \text{ m/s}} = 1.21 \times 10^3 \text{ N}$

$a = \dfrac{1.21 \times 10^3 \text{ N}}{1600 \text{ kg}} = \boxed{0.76 \text{ m/s}^2}$

72. $W = \Delta K = Fd$

$\dfrac{1}{2} mv^2 = Fd$

$F = \dfrac{mv^2}{2d}$

$m = \dfrac{mg}{g} = \dfrac{(27 \text{ lb})\left(4.448 \frac{\text{N}}{\text{lb}}\right)}{9.81 \frac{\text{m}}{\text{s}^2}} = 12.24 \text{ kg}$

$F = \dfrac{(12.24 \text{ kg})\left(550 \frac{\text{m}}{\text{s}}\right)^2}{2(22 \times 10^{-2} \text{ m})} = \boxed{8.4 \text{ MN}}$

73. $P = Fv = bv^3$

$v^3 = \dfrac{P}{b}$

$v = \boxed{\left(\dfrac{P}{b}\right)^{1/3}}$

74. (a) The work done on the block by the spring is $W = -\dfrac{1}{2} kx^2 = \Delta K$ where the negative sign comes from the fact

that the force of the spring on the mass is directed opposite to the displacement of the mass.

$k = -\dfrac{2}{x^2} \Delta K = -\dfrac{2}{x^2}\left(\dfrac{1}{2} mv_\text{f}^2 - \dfrac{1}{2} mv_\text{i}^2\right) = -\dfrac{2}{x^2}\left(0 - \dfrac{1}{2} mv_0^2\right) = \boxed{\dfrac{mv_0^2}{x^2}}$

(b) From (a),

$$k = \frac{mv_0^{\,2}}{x^2}$$

$$x = \sqrt{\frac{mv_0^{\,2}}{k}}$$

with $v_i = 2v_0$

$$d = \sqrt{\frac{m(2v_0)^2}{k}} = 2\sqrt{\frac{mv_0^{\,2}}{k}} = \boxed{2x}$$

75. $\displaystyle W_{\text{total}} = W_1 + W_2 = \frac{1}{2}k_1 x^2 + \frac{1}{2}k_2 x^2 = \boxed{\frac{1}{2}(k_1 + k_2)x^2}$

76. $\;x = x_1 + x_2$

$$F = k_1 x_1 = k_2 x_2$$

$$x = \frac{F}{k_1} + \frac{F}{k_2} = F\left(\frac{1}{k_1} + \frac{1}{k_2}\right)$$

$$F = \frac{x}{\frac{1}{k_1} + \frac{1}{k_2}} = kx$$

So, $\displaystyle k = \left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1}$

$$W = \frac{1}{2}kx^2 = \boxed{\frac{1}{2}\left(\frac{1}{k_1} + \frac{1}{k_2}\right)^{-1} x^2}$$

77. (a) $\quad W = F(\cos\theta)d$

$$\cos\theta = \frac{W}{Fd}$$

$$\theta = \cos^{-1}\frac{W}{Fd}$$

$$= \cos^{-1}\frac{50.0 \text{ J}}{(45.0 \text{ N})(1.50 \text{ m})}$$

$$= \boxed{42.2°}$$

(b) $\;W = \Delta K = \frac{1}{2}m(v_f^{\,2} - v_i^{\,2}) = \frac{1}{2}mv_f^{\,2}$

$$m = \frac{2W}{v_f^{\,2}} = \frac{2(50.0 \text{ J})}{\left(2.60 \;\frac{\text{m}}{\text{s}}\right)^2} = \boxed{14.8 \text{ kg}}$$