Halliday/Resnick/Walker 7e
Chapter 7

2. (a) The change in kinetic energy for the meteorite would be

$$\Delta K = K_f - K_i = -K_i = -\frac{1}{2}m_i v_i^2 = -\frac{1}{2}\left(4\times10^6\text{ kg}\right)\left(15\times10^3\text{ m/s}\right)^2 = -5\times10^{14}\text{ J},$$

or $|\Delta K| = 5\times10^{14}$ J . The negative sign indicates that kinetic energy is lost.

(b) The energy loss in units of megatons of TNT would be

$$-\Delta K = \left(5\times10^{14}\text{ J}\right)\left(\frac{1\text{ megaton TNT}}{4.2\times10^{15}\text{ J}}\right) = 0.1\text{megaton TNT}.$$

(c) The number of bombs N that the meteorite impact would correspond to is found by noting that megaton = 1000 kilotons and setting up the ratio:

$$N = \frac{0.1\times1000\,\text{kiloton TNT}}{13\,\text{kiloton TNT}} = 8.$$

3. (a) From Table 2-1, we have $v^2 = v_0^2 + 2a\Delta x$. Thus,

$$v = \sqrt{v_0^2 + 2a\Delta x} = \sqrt{\left(2.4\times10^7\right)^2 + 2\left(3.6\times10^{15}\right)\left(0.035\right)} = 2.9\times10^7\text{ m/s}.$$

(b) The initial kinetic energy is

$$K_i = \frac{1}{2}mv_0^2 = \frac{1}{2}\left(1.67\times10^{-27}\text{ kg}\right)\left(2.4\times10^7\text{ m/s}\right)^2 = 4.8\times10^{-13}\text{ J}.$$

The final kinetic energy is

$$K_f = \frac{1}{2}mv^2 = \frac{1}{2}\left(1.67\times10^{-27}\text{ kg}\right)\left(2.9\times10^7\text{ m/s}\right)^2 = 6.9\times10^{-13}\text{ J}.$$

The change in kinetic energy is $\Delta K = (6.9\times10^{-13} - 4.8\times10^{-13})\text{ J} = 2.1\times10^{-13}$ J.

4. We apply the equation $x(t) = x_0 + v_0 t + \frac{1}{2}at^2$, found in Table 2-1. Since at t = 0 s, x_0 = 0 and $v_0 = 12$ m/s, the equation becomes (in unit of meters)

$$x(t) = 12t + \tfrac{1}{2}at^2 .$$

With $x = 10$ m when $t = 1.0$ s, the acceleration is found to be $a = -4.0\ \text{m/s}^2$. The fact that $a < 0$ implies that the bead is decelerating. Thus, the position is described by $x(t) = 12t - 2.0t^2$. Differentiating x with respect to t then yields

$$v(t) = \frac{dx}{dt} = 12 - 4.0t .$$

Indeed at t =3.0 s, $v(t = 3.0) = 0$ and the bead stops momentarily. The speed at $t = 10$ s is $v(t = 10) = -28$ m/s, and the corresponding kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}(1.8\times10^{-2}\,\text{kg})(-28\ \text{m/s})^2 = 7.1\ \text{J}.$$

6. By the work-kinetic energy theorem,

$$W = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}(2.0\,\text{kg})\left((6.0\,\text{m/s})^2 - (4.0\,\text{m/s})^2\right) = 20\ \text{J}.$$

We note that the *directions* of $\vec{v}_f$ and $\vec{v}_i$ play no role in the calculation.

7. Eq. 7-8 readily yields (with SI units understood)

$$W = F_x\,\Delta x + F_y\,\Delta y = 2\cos(100^\circ)(3.0) + 2\sin(100^\circ)(4.0) = 6.8\ \text{J}.$$

10. The change in kinetic energy can be written as

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

where we have used $v_f^2 = v_i^2 + 2a\Delta x$ from Table 2-1. From Fig. 7-27, we see that $\Delta K = (0 - 30)\ \text{J} = -30\ \text{J}$ when $\Delta x = +5$ m. The acceleration can then be obtained as

$$a = \frac{\Delta K}{m\Delta x} = \frac{(-30\ \text{J})}{(8.0\ \text{kg})(5.0\ \text{m})} = -0.75\ \text{m/s}^2.$$

The negative sign indicates that the mass is decelerating. From the figure, we also see that when $x = 5$ m the kinetic energy becomes zero, implying that the mass comes to rest momentarily. Thus,

$$v_0^2 = v^2 - 2a\Delta x = 0 - 2(-0.75\ \text{m/s}^2)(5.0\ \text{m}) = 7.5\ \text{m}^2/\text{s}^2 ,$$

or $v_0 = 2.7$ m/s . The speed of the object when $x = -3.0$ m is

$$v = \sqrt{v_0^2 + 2a\Delta x} = \sqrt{7.5 + 2(-0.75)(-3.0)} = \sqrt{12} = 3.5 \text{ m/s}.$$

11. We choose $+x$ as the direction of motion (so $\vec{a}$ and $\vec{F}$ are negative-valued).

(a) Newton's second law readily yields $\vec{F} = (85\,\text{kg})\,(-2.0\,\text{m/s}^2)$ so that

$$F = |\vec{F}| = 1.7 \times 10^2 \text{ N}.$$

(b) From Eq. 2-16 (with $v = 0$) we have

$$0 = v_0^2 + 2a\Delta x \quad \Rightarrow \quad \Delta x = -\frac{(37\,\text{m/s})^2}{2\left(-2.0\,\text{m/s}^2\right)} = 3.4 \times 10^2 \text{ m}.$$

Alternatively, this can be worked using the work-energy theorem.

(c) Since $\vec{F}$ is opposite to the direction of motion (so the angle ϕ between $\vec{F}$ and $\vec{d} = \Delta x$ is 180°) then Eq. 7-7 gives the work done as $W = -F\Delta x = -5.8 \times 10^4$ J .

(d) In this case, Newton's second law yields $\vec{F} = (85\,\text{kg})\left(-4.0\,\text{m/s}^2\right)$ so that $F = |\vec{F}| = 3.4 \times 10^2$ N .

(e) From Eq. 2-16, we now have

$$\Delta x = -\frac{(37\,\text{m/s})^2}{2\left(-4.0\,\text{m/s}^2\right)} = 1.7 \times 10^2 \text{ m}.$$

(f) The force $\vec{F}$ is again opposite to the direction of motion (so the angle ϕ is again 180°) so that Eq. 7-7 leads to $W = -F\Delta x = -5.8 \times 10^4$ J. The fact that this agrees with the result of part (c) provides insight into the concept of work.

13. (a) The forces are constant, so the work done by any one of them is given by $W = \vec{F} \cdot \vec{d}$, where $\vec{d}$ is the displacement. Force $\vec{F}_1$ is in the direction of the displacement, so

$$W_1 = F_1 d \cos\phi_1 = (5.00\,\text{N})(3.00\,\text{m})\cos 0° = 15.0 \text{ J}.$$

Force $\vec{F}_2$ makes an angle of 120° with the displacement, so

$$W_2 = F_2 d\cos\phi_2 = (9.00\,\text{N})(3.00\,\text{m})\cos 120° = -13.5\text{ J.}$$

Force $\vec{F}_3$ is perpendicular to the displacement, so $W_3 = F_3 d \cos \phi_3 = 0$ since $\cos 90° = 0$. The net work done by the three forces is

$$W = W_1 + W_2 + W_3 = 15.0\text{ J} - 13.5\text{ J} + 0 = +1.50\text{ J.}$$

(b) If no other forces do work on the box, its kinetic energy increases by 1.50 J during the displacement.

17. (a) We use $\vec{F}$ to denote the upward force exerted by the cable on the astronaut. The force of the cable is upward and the force of gravity is mg downward. Furthermore, the acceleration of the astronaut is $g/10$ upward. According to Newton's second law, $F - mg = mg/10$, so $F = 11\,mg/10$. Since the force $\vec{F}$ and the displacement $\vec{d}$ are in the same direction, the work done by $\vec{F}$ is

$$W_F = Fd = \frac{11mgd}{10} = \frac{11\,(72\text{ kg})\left(9.8\text{ m/s}^2\right)(15\text{ m})}{10} = 1.164 \times 10^4\text{ J}$$

which (with respect to significant figures) should be quoted as 1.2×10^4 J.

(b) The force of gravity has magnitude mg and is opposite in direction to the displacement. Thus, using Eq. 7-7, the work done by gravity is

$$W_g = -mgd = -\,(72\text{ kg})\left(9.8\text{ m/s}^2\right)(15\text{ m}) = -1.058 \times 10^4\text{ J}$$

which should be quoted as -1.1×10^4 J.

(c) The total work done is $W = 1.164\times10^4\text{ J} - 1.058\times10^4\text{ J} = 1.06\times10^3\text{ J}$. Since the astronaut started from rest, the work-kinetic energy theorem tells us that this (which we round to 1.1×10^3 J) is her final kinetic energy.

(d) Since $K = \frac{1}{2}mv^2$, her final speed is

$$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(1.06\times10^3\text{J})}{72\text{ kg}}} = 5.4\text{ m/s.}$$

19. (a) We use F to denote the magnitude of the force of the cord on the block. This force is upward, opposite to the force of gravity (which has magnitude Mg). The acceleration is $\vec{a} = g/4$ downward. Taking the downward direction to be positive, then Newton's second law yields

$$\vec{F}_{\text{net}} = m\vec{a} \Rightarrow Mg - F = M\left(\frac{g}{4}\right)$$

so $F = 3Mg/4$. The displacement is downward, so the work done by the cord's force is, using Eq. 7-7,

$$W_F = -Fd = -3Mgd/4.$$

(b) The force of gravity is in the same direction as the displacement, so it does work $W_g = Mgd$.

(c) The total work done on the block is $-3M\,gd/4 + M\,gd = M\,gd/4$. Since the block starts from rest, we use Eq. 7-15 to conclude that this $(M\,gd/4)$ is the block's kinetic energy K at the moment it has descended the distance d.

(d) Since $K = \frac{1}{2}Mv^2$, the speed is

$$v = \sqrt{\frac{2K}{M}} = \sqrt{\frac{2(Mgd/4)}{M}} = \sqrt{\frac{gd}{2}}$$

at the moment the block has descended the distance d.

21. Eq. 7-15 applies, but the wording of the problem suggests that it is only necessary to examine the contribution from the rope (which would be the "W_a" term in Eq. 7-15):

$$W_a = -(50\text{ N})(0.50\text{ m}) = -25\text{ J}$$

(the minus sign arises from the fact that the pull from the rope is anti-parallel to the direction of motion of the block). Thus, the kinetic energy would have been 25 J greater if the rope had not been attached (given the same displacement).

24. The spring constant is k = 100 N/m and the maximum elongation is x_i = 5.00 m. Using Eq. 7-25 with x_f = 0, the work is found to be

$$W = \frac{1}{2}kx_i^2 = \frac{1}{2}(100)(5.00)^2 = 1.25\times10^3\text{ J}.$$

27. The work done by the spring force is given by Eq. 7-25:

$$W_s = \frac{1}{2}k(x_i^2 - x_f^2).$$

Since $F_x = -kx$, the slope in Fig. 7-35 corresponds to the spring constant k. Its value is given by $k = 80\ \text{N/cm} = 8.0\times10^3\ \text{N/m}$.

(a) When the block moves from $x_i = +8.0\ \text{cm}$ to $x = +5.0\ \text{cm}$, we have

$$W_s = \frac{1}{2}(8.0\times10^3\ \text{N/m})[(0.080\ \text{m})^2 - (0.050\ \text{m})^2] = 15.6\ \text{J} \approx 16\ \text{J}.$$

(b) Moving from $x_i = +8.0\ \text{cm}$ to $x = -5.0\ \text{cm}$, we have

$$W_s = \frac{1}{2}(8.0\times10^3\ \text{N/m})[(0.080\ \text{m})^2 - (-0.050\ \text{m})^2] = 15.6\ \text{J} \approx 16\ \text{J}.$$

(c) Moving from $x_i = +8.0\ \text{cm}$ to $x = -8.0\ \text{cm}$, we have

$$W_s = \frac{1}{2}(8.0\times10^3\ \text{N/m})[(0.080\ \text{m})^2 - (-0.080\ \text{m})^2] = 0\ \text{J}.$$

(d) Moving from $x_i = +8.0\ \text{cm}$ to $x = -10.0\ \text{cm}$, we have

$$W_s = \frac{1}{2}(8.0\times10^3\ \text{N/m})[(0.080\ \text{m})^2 - (-0.10\ \text{m})^2] = -14.4\ \text{J} \approx -14\ \text{J}.$$

29. (a) As the body moves along the x axis from x_i = 3.0 m to x_f = 4.0 m the work done by the force is

$$W = \int_{x_i}^{x_f} F_x\ dx = \int_{x_i}^{x_f} -6x\ dx = -3(x_f^2 - x_i^2) = -3\ (4.0^2 - 3.0^2) = -21\ \text{J}.$$

According to the work-kinetic energy theorem, this gives the change in the kinetic energy:

$$W = \Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

where v_i is the initial velocity (at x_i) and v_f is the final velocity (at x_f). The theorem yields

$$v_f = \sqrt{\frac{2W}{m} + v_i^2} = \sqrt{\frac{2(-21)}{2.0} + (8.0)^2} = 6.6\ \text{m/s}.$$

(b) The velocity of the particle is v_f = 5.0 m/s when it is at $x = x_f$. The work-kinetic energy theorem is used to solve for x_f. The net work done on the particle is $W = -3\left(x_f^2 - x_i^2\right)$, so the theorem leads to

$$-3\left(x_f^2 - x_i^2\right) = \frac{1}{2}m\left(v_f^2 - v_i^2\right).$$

Thus,

$$x_f = \sqrt{-\frac{m}{6}\left(v_f^2 - v_i^2\right) + x_i^2} = \sqrt{-\frac{2.0\text{ kg}}{6\text{ N/m}}\left((5.0\text{ m/s})^2 - (8.0\text{ m/s})^2\right) + (3.0\text{ m})^2} = 4.7\text{ m}.$$

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31. According to the graph the acceleration a varies linearly with the coordinate x. We may write $a = \alpha x$, where α is the slope of the graph. Numerically,

$$\alpha = \frac{20\text{ m/s}^2}{8.0\text{ m}} = 2.5\text{ s}^{-2}.$$

The force on the brick is in the positive x direction and, according to Newton's second law, its magnitude is given by $F = a/m = (\alpha/m)x$. If x_f is the final coordinate, the work done by the force is

$$W = \int_0^{x_f} F\,dx = \frac{\alpha}{m}\int_0^{x_f} x\,dx = \frac{\alpha}{2m}x_f^2 = \frac{2.5}{2(10)}(8.0)^2 = 8.0\times 10^2\text{ J}.$$

$$W = W_{0<x<2} + W_{2<x<4} + W_{4<x<6} + W_{6<x<8} = (20 + 10 + 0 - 5)\text{ J} = 25\text{ J}.$$

35. We choose to work this using Eq. 7-10 (the work-kinetic energy theorem). To find the initial and final kinetic energies, we need the speeds, so

$$v = \frac{dx}{dt} = 3.0 - 8.0t + 3.0t^2$$

in SI units. Thus, the initial speed is v_i = 3.0 m/s and the speed at t = 4 s is v_f = 19 m/s. The change in kinetic energy for the object of mass m = 3.0 kg is therefore

$$\Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = 528\text{ J}$$

which we round off to two figures and (using the work-kinetic energy theorem) conclude that the work done is $W = 5.3\times 10^2$ J.

37. (a) We first multiply the vertical axis by the mass, so that it becomes a graph of the applied force. Now, adding the triangular and rectangular "areas" in the graph (for $0 \le x \le 4$) gives 42 J for the work done.

(b) Counting the "areas" under the axis as negative contributions, we find (for $0 \le x \le 7$) the work to be 30 J at x = 7.0 m.

(c) And at x = 9.0 m, the work is 12 J.

(d) Eq. 7-10 (along with Eq. 7-1) leads to speed v = 6.5 m/s at x = 4.0 m. Returning to the original graph (where a was plotted) we note that (since it started from rest) it has received acceleration(s) (up to this point) only in the $+x$ direction and consequently must have a velocity vector pointing in the $+x$ direction at x = 4.0 m.

(e) Now, using the result of part (b) and Eq. 7-10 (along with Eq. 7-1) we find the speed is 5.5 m/s at x = 7.0 m. Although it has experienced some deceleration during the $0 \le x \le 7$ interval, its velocity vector still points in the $+x$ direction.

(f) Finally, using the result of part (c) and Eq. 7-10 (along with Eq. 7-1) we find its speed v = 3.5 m/s at x = 9.0 m. It certainly has experienced a significant amount of deceleration during the $0 \le x \le 9$ interval; nonetheless, its velocity vector *still* points in the $+x$ direction.

39. We solve the problem using the work-kinetic energy theorem which states that the change in kinetic energy is equal to the work done by the applied force, $\Delta K = W$. In our problem, the work done is $W = Fd$, where F is the tension in the cord and d is the length of the cord pulled as the cart slides from x_1 to x_2. From Fig. 7-40, we have

$$\begin{aligned} d &= \sqrt{x_1^2 + h^2} - \sqrt{x_2^2 + h^2} = \sqrt{(3.00)^2 + (1.20)^2} - \sqrt{(1.00)^2 + (1.20)^2} \\ &= 3.23\text{ m} - 1.56\text{ m} = 1.67\text{ m} \end{aligned}$$

which yields $\Delta K = Fd = (25.0\text{ N})(1.67\text{ m}) = 41.7\text{ J}.$

40. Recognizing that the force in the cable must equal the total weight (since there is no acceleration), we employ Eq. 7-47:

$$P = Fv\cos\theta = mg\left(\frac{\Delta x}{\Delta t}\right)$$

where we have used the fact that $\theta = 0°$ (both the force of the cable and the elevator's motion are upward). Thus,

$$P = (3.0 \times 10^3 \text{ kg})(9.8 \text{ m/s}^2)\left(\frac{210 \text{ m}}{23 \text{ s}}\right) = 2.7 \times 10^5 \text{ W}.$$

41. The power associated with force $\vec{F}$ is given by $P = \vec{F} \cdot \vec{v}$, where $\vec{v}$ is the velocity of the object on which the force acts. Thus,

$$P = \vec{F} \cdot \vec{v} = Fv\cos\phi = (122 \text{ N})(5.0 \text{ m/s})\cos 37° = 4.9 \times 10^2 \text{ W}.$$

42. (a) Since constant speed implies $\Delta K = 0$, we require $W_a = -W_g$, by Eq. 7-15. Since W_g is the same in both cases (same weight and same path), then $W_a = 9.0 \times 10^2$ J just as it was in the first case.

(b) Since the speed of 1.0 m/s is constant, then 8.0 meters is traveled in 8.0 seconds. Using Eq. 7-42, and noting that average power is *the* power when the work is being done at a steady rate, we have

$$P = \frac{W}{\Delta t} = \frac{900 \text{ J}}{8.0 \text{ s}} = 1.1 \times 10^2 \text{ W}.$$

(c) Since the speed of 2.0 m/s is constant, 8.0 meters is traveled in 4.0 seconds. Using Eq. 7-42, with *average power* replaced by *power*, we have

$$P = \frac{W}{\Delta t} = \frac{900 \text{ J}}{4.0 \text{ s}} = 225 \text{ W} \approx 2.3 \times 10^2 \text{ W}.$$

43. (a) The power is given by $P = Fv$ and the work done by $\vec{F}$ from time t_1 to time t_2 is given by

$$W = \int_{t_1}^{t_2} P \, dt = \int_{t_1}^{t_2} Fv \, dt.$$

Since $\vec{F}$ is the net force, the magnitude of the acceleration is $a = F/m$, and, since the initial velocity is $v_0 = 0$, the velocity as a function of time is given by $v = v_0 + at = (F/m)t$. Thus

$$W = \int_{t_1}^{t_2} (F^2/m)t \, dt = \frac{1}{2}(F^2/m)(t_2^2 - t_1^2).$$

For $t_1 = 0$ and $t_2 = 1.0$s,

$$W = \frac{1}{2}\left(\frac{(5.0 \text{ N})^2}{15 \text{ kg}}\right)(1.0 \text{ s})^2 = 0.83 \text{ J}.$$

(b) For $t_1 = 1.0\,\text{s}$, and $t_2 = 2.0\,\text{s}$,

$$W = \frac{1}{2}\left(\frac{(5.0\ \text{N})^2}{15\ \text{kg}}\right)[(2.0\ \text{s})^2 - (1.0\ \text{s})^2] = 2.5\ \text{J}.$$

(c) For $t_1 = 2.0\,\text{s}$ and $t_2 = 3.0\,\text{s}$,

$$W = \frac{1}{2}\left(\frac{(5.0\ \text{N})^2}{15\ \text{kg}}\right)[(3.0\ \text{s})^2 - (2.0\ \text{s})^2] = 4.2\ \text{J}.$$

(d) Substituting $v = (F/m)t$ into $P = Fv$ we obtain $P = F^2\,t/m$ for the power at any time t. At the end of the third second

$$P = \left(\frac{(5.0\ \text{N})^2\ (3.0\ \text{s})}{15\ \text{kg}}\right) = 5.0\ \text{W}.$$

49. From Eq. 7-32, we see that the "area" in the graph is equivalent to the work done. We find the area in terms of rectangular [length × width] and triangular [$\frac{1}{2}$ base × height] areas and use the work-kinetic energy theorem appropriately. The initial point is taken to be $x = 0$, where v_0 = 4.0 m/s.

(a) With $K_i = \frac{1}{2}mv_0^2 = 16\ \text{J}$, we have

$$K_3 - K_0 = W_{0<x<1} + W_{1<x<2} + W_{2<x<3} = -4.0\ \text{J}$$

so that K_3 (the kinetic energy when x = 3.0 m) is found to equal 12 J.

(b) With SI units understood, we write $W_{3<x<x_f}$ as $F_x\Delta x = (-4.0)(x_f - 3.0)$ and apply the work-kinetic energy theorem:

$$\begin{aligned} K_{x_f} - K_3 &= W_{3<x<x_f} \\ K_{x\,f} - 12 &= (-4)(x_f - 3.0) \end{aligned}$$

so that the requirement $Kx_f = 8.0\ \text{J}$ leads to $x_f = 4.0$ m.

(c) As long as the work is positive, the kinetic energy grows. The graph shows this situation to hold until x = 1.0 m. At that location, the kinetic energy is

$$K_1 = K_0 + W_{0<x<1} = 16\ \text{J} + 2.0\ \text{J} = 18\ \text{J}.$$

50. (a) The compression of the spring is d = 0.12 m. The work done by the force of gravity (acting on the block) is, by Eq. 7-12,

$$W_1 = mgd = (0.25 \text{ kg})\left(9.8 \text{ m/s}^2\right)(0.12 \text{ m}) = 0.29 \text{ J}.$$

(b) The work done by the spring is, by Eq. 7-26,

$$W_2 = -\frac{1}{2}kd^2 = -\frac{1}{2}\ (250 \text{ N/m})\ (0.12 \text{ m})^2 = -1.8 \text{ J}.$$

(c) The speed v_i of the block just before it hits the spring is found from the work-kinetic energy theorem (Eq. 7-15).

$$\Delta K = 0 - \frac{1}{2}mv_i^2 = W_1 + W_2$$

which yields

$$v_i = \sqrt{\frac{(-2)(W_1 + W_2)}{m}} = \sqrt{\frac{(-2)(0.29 - 1.8)}{0.25}} = 3.5 \text{ m/s}.$$

(d) If we instead had $v_i' = 7 \text{ m/s}$, we reverse the above steps and solve for d'. Recalling the theorem used in part (c), we have

$$0 - \frac{1}{2}mv_i'^2 = W_1' + W_2' = mgd' - \frac{1}{2}kd'^2$$

which (choosing the positive root) leads to

$$d' = \frac{mg + \sqrt{m^2g^2 + mkv_i'^2}}{k}$$

which yields d' = 0.23 m. In order to obtain this result, we have used more digits in our intermediate results than are shown above (so $v_i = \sqrt{12.048} = 3.471 \text{ m/s}$ and v_i' = 6.942 m/s).

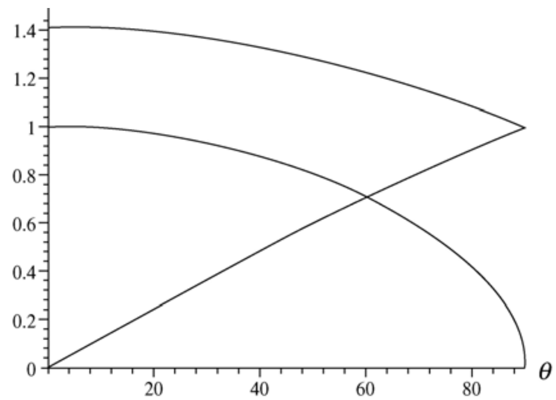
54. (a) Eq. 7-10 (along with Eq. 7-1 and Eq. 7-7) leads to $v_f = (2\,\frac{d}{m}F\cos\theta)^{1/2} = (\cos\theta)^{1/2}$, with SI units understood.

(b) With v_i = 1, those same steps lead to $v_f = (1 + \cos\theta)^{1/2}$.

(c) Replacing θ with 180º – θ, and still using $v_i = 1$, we find

$$v_f = [1 + \cos(180^\circ - \theta)]^{1/2} = (1 - \cos\theta)^{1/2}.$$

(d) The graphs are shown below. Note that as θ is increased in parts (a) and (b) the force provides less and less of a positive acceleration, whereas in part (c) the force provides less and less of a deceleration (as its θ value increases). The highest curve (which slowly decreases from 1.4 to 1) is the curve for part (b); the other decreasing curve (starting at 1 and ending at 0) is for part (a). The rising curve is for part (c); it is equal to 1 where $\theta = 90^\circ$.



57. (a) Noting that the x component of the third force is F_{3x} = (4.00 N)cos(60º), we apply Eq. 7-8 to the problem:

$$W = [5.00 - 1.00 + (4.00)\cos 60^\circ](0.20 \text{ m}) = 1.20 \text{ J}.$$

(b) Eq. 7-10 (along with Eq. 7-1) then yields $v = \sqrt{2W/m}$ = 1.10 m/s.

63. There is no acceleration, so the lifting force is equal to the weight of the object. We note that the person's pull $\vec{F}$ is equal (in magnitude) to the tension in the cord.

(a) As indicated in the *hint*, tension contributes twice to the lifting of the canister: $2T = mg$. Since $|\vec{F}| = T$, we find $|\vec{F}| = 98\,\text{N}$.

(b) To rise 0.020 m, two segments of the cord (see Fig. 7-48) must shorten by that amount. Thus, the amount of string pulled down at the left end (this is the magnitude of $\vec{d}$, the downward displacement of the hand) is d = 0.040 m.

(c) Since (at the left end) both $\vec{F}$ and $\vec{d}$ are downward, then Eq. 7-7 leads to

$$W = \vec{F} \cdot \vec{d} = (98)(0.040) = 3.9 \text{ J}.$$

(d) Since the force of gravity $\vec{F}_g$ (with magnitude mg) is opposite to the displacement $\vec{d}_c = 0.020$ m (up) of the canister, Eq. 7-7 leads to

$$W = \vec{F}_g \cdot \vec{d}_c = -\,(196)(0.020) = -3.9 \text{ J}.$$

This is consistent with Eq. 7-15 since there is no change in kinetic energy.

70. (a) To hold the crate at equilibrium in the final situation, $\vec{F}$ must have the same magnitude as the horizontal component of the rope's tension $T \sin\theta$, where θ is the angle between the rope (in the final position) and vertical:

$$\theta = \sin^{-1}\left(\frac{4.00}{12.0}\right) = 19.5°.$$

But the vertical component of the tension supports against the weight: $T\cos\theta = mg$. Thus, the tension is

$$T = (230)(9.80)/\cos 19.5° = 2391 \text{ N}$$

and $F = (2391) \sin 19.5° = 797$ N.

An alternative approach based on drawing a vector triangle (of forces) in the final situation provides a quick solution.

(b) Since there is no change in kinetic energy, the net work on it is zero.

(c) The work done by gravity is $W_g = \vec{F}_g \cdot \vec{d} = -mgh$, where $h = L(1 - \cos\theta)$ is the vertical component of the displacement. With $L = 12.0$ m, we obtain $W_g = -1547$ J which should be rounded to three figures: –1.55 kJ.

(d) The tension vector is everywhere perpendicular to the direction of motion, so its work is zero (since cos 90° = 0).

(e) The implication of the previous three parts is that the work due to $\vec{F}$ is $-W_g$ (so the net work turns out to be zero). Thus, $W_F = -W_g = 1.55$ kJ.

(f) Since $\vec{F}$ does not have constant magnitude, we cannot expect Eq. 7-8 to apply.