

Chapter 7 – Student Solutions Manual

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

$$v = \sqrt{v_0^2 + 2a\Delta x} = \sqrt{(2.4 \times 10^7 \text{ m/s})^2 + 2 (3.6 \times 10^{15} \text{ m/s}^2)(0.035 \text{ m})} = 2.9 \times 10^7 \text{ m/s}.$$

(b) The initial kinetic energy is

$$K_i = \frac{1}{2}mv_0^2 = \frac{1}{2} (1.67 \times 10^{-27} \text{ kg})(2.4 \times 10^7 \text{ m/s})^2 = 4.8 \times 10^{-13} \text{ J}.$$

The final kinetic energy is

$$K_f = \frac{1}{2}mv^2 = \frac{1}{2} (1.67 \times 10^{-27} \text{ kg})(2.9 \times 10^7 \text{ m/s})^2 = 6.9 \times 10^{-13} \text{ J}.$$

The change in kinetic energy is $\Delta K = 6.9 \times 10^{-13} \text{ J} - 4.8 \times 10^{-13} \text{ J} = 2.1 \times 10^{-13} \text{ J}$.

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

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

which (with respect to significant figures) should be quoted as $1.2 \times 10^4 \text{ J}$.

(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

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

which should be quoted as $-1.1 \times 10^4 \text{ J}$.

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

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

$$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(1.06 \times 10^3 \text{ J})}{72 \text{ kg}}} = 5.4 \text{ m/s}.$$

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 $-3Mgd/4 + Mgd = Mgd/4$. Since the block starts from rest, we use Eq. 7-15 to conclude that this ($Mgd/4$) 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 .

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:

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

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

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

(b) The velocity of the particle is $v_f = 5.0 \text{ m/s}$ 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 $W = -3(x_f^2 - x_i^2)$, so the theorem leads to

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

Thus,

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

35. (a) The graph shows F as a function of x assuming x_0 is positive. The work is negative as the object moves from $x = 0$ to $x = x_0$ and positive as it moves from $x = x_0$ to $x = 2x_0$.

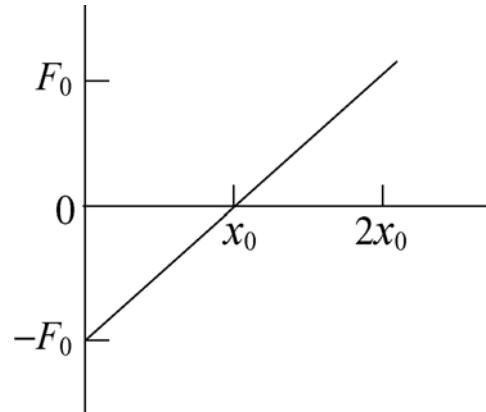
Since the area of a triangle is (base)(altitude)/2, the work done from $x = 0$ to $x = x_0$ is $-(x_0)(F_0)/2$ and the work done from $x = x_0$ to $x = 2x_0$ is

$$(2x_0 - x_0)(F_0)/2 = (x_0)(F_0)/2$$

The total work is the sum, which is zero.

(b) The integral for the work is

$$W = \int_0^{2x_0} F_0 \left(\frac{x}{x_0} - 1 \right) dx = F_0 \left(\frac{x^2}{2x_0} - x \right) \bigg|_0^{2x_0} = 0.$$



43. 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,

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

45. (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 $t_2 = 1.0\text{ s}$,

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

(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

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

47. The total work is the sum of the work done by gravity on the elevator, the work done by gravity on the counterweight, and the work done by the motor on the system:

$$W_T = W_e + W_c + W_s.$$

Since the elevator moves at constant velocity, its kinetic energy does not change and according to the work-kinetic energy theorem the total work done is zero. This means $W_e + W_c + W_s = 0$. The elevator moves upward through 54 m, so the work done by gravity on it is

$$W_e = -m_e g d = -(1200 \text{ kg})(9.80 \text{ m/s}^2)(54 \text{ m}) = -6.35 \times 10^5 \text{ J}.$$

The counterweight moves downward the same distance, so the work done by gravity on it is

$$W_c = m_c g d = (950 \text{ kg})(9.80 \text{ m/s}^2)(54 \text{ m}) = 5.03 \times 10^5 \text{ J}.$$

Since $W_T = 0$, the work done by the motor on the system is

$$W_s = -W_e - W_c = 6.35 \times 10^5 \text{ J} - 5.03 \times 10^5 \text{ J} = 1.32 \times 10^5 \text{ J}.$$

This work is done in a time interval of $\Delta t = 3.0 \text{ min} = 180 \text{ s}$, so the power supplied by the motor to lift the elevator is

$$P = \frac{W_s}{\Delta t} = \frac{1.32 \times 10^5 \text{ J}}{180 \text{ s}} = 7.4 \times 10^2 \text{ W}.$$

63. (a) In 10 min the cart moves

$$d = \left(6.0 \frac{\text{mi}}{\text{h}} \right) \left(\frac{5280 \text{ ft/mi}}{60 \text{ min/h}} \right) (10 \text{ min}) = 5280 \text{ ft}$$

so that Eq. 7-7 yields

$$W = F d \cos \phi = (40 \text{ lb})(5280 \text{ ft}) \cos 30^\circ = 1.8 \times 10^5 \text{ ft} \cdot \text{lb}.$$

(b) The average power is given by Eq. 7-42, and the conversion to horsepower (hp) can be found on the inside back cover. We note that 10 min is equivalent to 600 s.

$$P_{\text{avg}} = \frac{1.8 \times 10^5 \text{ ft} \cdot \text{lb}}{600 \text{ s}} = 305 \text{ ft} \cdot \text{lb/s}$$

which (upon dividing by 550) converts to $P_{\text{avg}} = 0.55 \text{ hp}$.

69. (a) Eq. 7-6 gives $W_a = Fd = (209 \text{ N})(1.50 \text{ m}) \approx 314 \text{ J}$.

(b) Eq. 7-12 leads to $W_g = (25.0 \text{ kg})(9.80 \text{ m/s}^2)(1.50 \text{ m})\cos(115^\circ) \approx -155 \text{ J}$.

(c) The angle between the normal force and the direction of motion remains 90° at all times, so the work it does is zero.

(d) The total work done on the crate is $W_T = 314 \text{ J} - 155 \text{ J} = 158 \text{ J}$.

71. (a) Hooke's law and the work done by a spring is discussed in the chapter. Taking absolute values, and writing that law in terms of differences ΔF and Δx , we analyze the first two pictures as follows:

$$|\Delta F| = k|\Delta x|$$

$$240 \text{ N} - 110 \text{ N} = k(60 \text{ mm} - 40 \text{ mm})$$

which yields $k = 6.5 \text{ N/mm}$. Designating the relaxed position (as read by that scale) as x_0 we look again at the first picture:

$$110 \text{ N} = k(40 \text{ mm} - x_0)$$

which (upon using the above result for k) yields $x_0 = 23 \text{ mm}$.

(b) Using the results from part (a) to analyze that last picture, we find

$$W = k(30 \text{ mm} - x_0) = 45 \text{ N} .$$

73. A convenient approach is provided by Eq. 7-48.

$$P = F v = (1800 \text{ kg} + 4500 \text{ kg})(9.8 \text{ m/s}^2)(3.80 \text{ m/s}) = 235 \text{ kW}.$$

Note that we have set the applied force equal to the weight in order to maintain constant velocity (zero acceleration).

77. (a) We can easily fit the curve to a concave-downward parabola: $x = \frac{1}{10} t(10 - t)$, from which (by taking two derivatives) we find the acceleration to be $a = -0.20 \text{ m/s}^2$. The (constant) force is therefore $F = ma = -0.40 \text{ N}$, with a corresponding work given by $W = Fx = \frac{2}{50} t(t - 10)$. It also follows from the x expression that $v_0 = 1.0 \text{ m/s}$. This means that $K_i = \frac{1}{2} mv^2 = 1.0 \text{ J}$. Therefore, when $t = 1.0 \text{ s}$, Eq. 7-10 gives $K = K_i + W = 0.64 \text{ J} \approx 0.6 \text{ J}$, where the second significant figure is not to be taken too seriously.

(b) At $t = 5.0 \text{ s}$, the above method gives $K = 0$.

(c) Evaluating the $W = \frac{2}{50} t(t - 10)$ expression at $t = 5.0 \text{ s}$ and $t = 1.0 \text{ s}$, and subtracting, yields -0.6 J . This can also be inferred from the answers for parts (a) and (b).