Chapter 7

1. In 1990, Walter Arfeuille of Belgium lifted a 281.5-kg object through a distance of 17.1 cm using only his teeth. (a) How much work was done on the object by Arfeuille in this lift, assuming the object was lifted at constant speed? (b) What total force was exerted on Arfeuille's teeth during the lift?

Ans:

(a) The work done by a constant force is given by

$$W = Fd \cos \vartheta$$

where ϑ is the angle between the force and the displacement of the object. In this case, $F = -mg$ and $\vartheta = 180°$, giving

$$W = (281.5\,\text{kg})(9.80\,\text{m/s}^2)[(17.1\,\text{cm})(1\,\text{m} / 10^2\,\text{cm})] = \boxed{472\,\text{J}}$$

(b) If the object moved upward at constant speed, the net force acting on it was zero. Therefore, the magnitude of the upward force applied by the lifter must have been equal to the weight of the object:

$$F = mg = (281.5\,\text{kg})(9.80\,\text{m/s}^2) = 2.76\times10^3\,\text{N} = \boxed{2.76\,\text{kN}}$$

2. The force acting on a particle varies as shown in Figure P7.14. Find the work done by the force on the particle s it moves (a) from $x = 0$ to $x = 8.00$ m, (b) from $x = 8.00$ m to $x = 10.0$ m, and (c) from $x = 0$ to $x = 10.0$ m.

Ans:

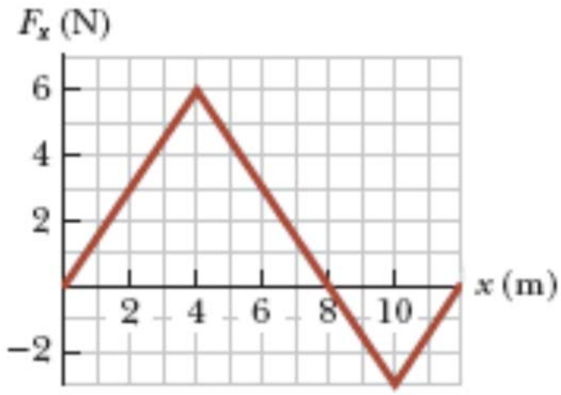


Figure P7.14

$$W = \int_i^f F dx \ = \text{area under curve from } x_i \text{ to } x_f$$

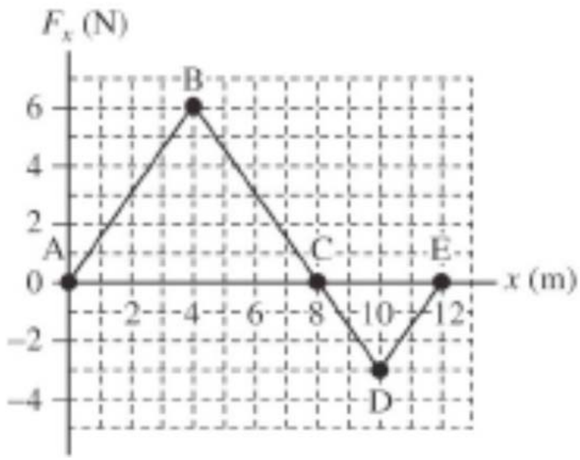
(a) $x_i = 0$ and $x_f = 800$ m

$$W_{0\to8} = \text{area of triangle ABC}$$

$$= \left(\frac{1}{2}\right) \text{AC} \times \text{height}$$

$$W_{0\to8} = \left(\frac{1}{2}\right) \times 8.00 \text{ m} \times 6.00 \text{ N}$$

$$= \boxed{24.0 \text{ J}}$$



ANS. FIG. P7.14

(b) $x_i = 8.00$ m and $x_f = 10.0$ m

$$W_{8\to10} = \text{area of } \Delta\text{CDE} = \left(\frac{1}{2}\right) \text{CE} \times \text{height}$$

$$W_{8\to10} = \left(\frac{1}{2}\right) \times (2.00 \text{ m}) \times (-3.00 \text{ N}) = \boxed{-3.00 \text{ J}}$$

(c) $W_{0\to10} = W_{0\to8} + W_{0\to10} = 24.0 + (-3.00) = \boxed{21.0 \text{ J}}$

3. A 3.00-kg object has a velocity $\left(6.00\hat{\mathbf{i}} - 2.00\hat{\mathbf{j}}\right)\text{m/s}$. (a) What is its kinetic energy at this moment? (b) What is the net work done on the object if its velocity changes to $\left(8.00\hat{\mathbf{i}} + 4.00\hat{\mathbf{j}}\right)\text{m/s}$? (*Note:* From the definition of the dot product, $\upsilon^2 = \vec{\mathbf{v}} \cdot \vec{\mathbf{v}}$.)

Ans:

$$\vec{\mathbf{v}}_i = \left(6.00\hat{\mathbf{i}} - 1.00\hat{\mathbf{j}}\right)\text{m/s}^2$$

(a) $$\upsilon_i = \sqrt{\upsilon_{ix}^2 + \upsilon_{iy}^2} = \sqrt{37.0}\ \text{m/s}$$

$$K_i = \frac{1}{2} m\upsilon_i^2 = \frac{1}{2}(3.00\,\text{m}^2/\text{s}^2) = \boxed{55.5\,\text{J}}$$

(b) $$\vec{\mathbf{v}}_f = 8.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}}$$

$$\upsilon_f^2 = \vec{\mathbf{v}}_f \cdot \vec{\mathbf{v}}_f = 64.0 + 16.0 = 80.0\,\text{m}^2/\text{s}^2$$

$$\Delta K = K_f - K_i = \frac{1}{2} m\left(\upsilon_f^2 - \upsilon_i^2\right) = \frac{3.00}{2}(80.0) - 55.5 = \boxed{64.5\,\text{J}}$$

4. A 0.20-kg stone is held 1.3 m above the top edge of a water well and then dropped into it. The well has a depth of 5.0 m. Relative to the configuration with the stone at the top edge of the well, what is the gravitational potential energy of the stone–Earth system (a) before the stone is released and (b) when it reaches the bottom of the well? (c) What is the change in gravitational potential energy of the system from release to reaching the bottom of the well?

Ans:

Use $u = mgy$, where y is measured relative to a reference level. Here, we measure y to be relative to the top edge of the well, where we take $y = 0$.

(a) $y = 1.3\text{ m}: \ u = mgy = (0.20\text{ kg})(9.80\text{ m/s}^2)(1.3\text{ m}) = \boxed{+2.5\text{ J}}$

(b) $y = -5.0\text{ m}: \ u = mgy = (0.20\text{ kg})(9.80\text{ m/s}^2)(-5.0\text{m}) = \boxed{-9.8\text{ J}}$

(c) $\Delta u = u_f - u_i = (-9.8\text{ J}) - (2.5\text{ J}) = -12.3 = \boxed{-12\text{ J}}$

5. A single conservative force acts on a 5.00-kg particle within a system due to its interaction with the rest of the system. The equation $F_x = 2x + 4$ describes the force, where F_x is in newtons and x is in meters. As the particle moves along the x axis from $x = 1.00$ m to $x = 5.00$ m, calculate (a) the work done by this force on the particle, (b) the change in the potential energy of the system, and (c) the kinetic energy the particle has at $x = 5.00$ m if its speed is 3.00 m/s at $x = 1.00$ m.

Ans:

(a) For a particle moving along the x axis, the definition of work by a variable force is

$$W_{\mathrm{F}} = \int_{x_i}^{x_f} F_x dx$$

Here $F_x = (2x + 4)$ N, $x_i = 1.00$ m, and $x_f = 5.00$ m.

So

$$\begin{aligned} W_F &= \int_{1.00\text{ m}}^{5.00\text{ m}} (2x+4)dx \text{ N}\cdot\text{m} = x^2 + 4x\Big]_{1.00\text{ m}}^{5.00\text{ m}} \text{N}\cdot\text{m} \\ &= (5^2 + 20 - 1 - 4)\,\text{J} = \boxed{40.0\,\text{J}} \end{aligned}$$

(b) The change in potential energy of the system is the negative of the internal work done by the conservative force on the particle:

$$\Delta u = -W_{\text{int}} = \boxed{-40.0\text{ J}}$$

(c) From $\Delta K = K_f - \frac{mv_i^2}{2}$, we obtain

$$K_f = \Delta K + \frac{mv_i^2}{2} = 40.0\text{ J} + \frac{(5.00\text{ kg})(3.00\text{ m/s})^2}{2} = \boxed{62.5\text{ J}}$$

Chapter 8

1. A ball of mass *m* falls from a height *h* to the floor. (a) Write the appropriate version of Equation 8.2 for the system of the ball and the Earth and use it to calculate the speed of the ball just before it strikes the Earth. (b) Write the appropriate version of Equation 8.2 for the system of the ball and use it to calculate the speed of the ball just before it strikes the Earth.

Ans:

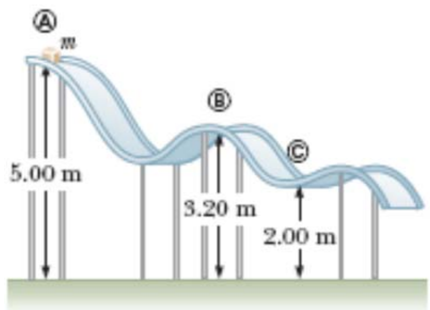
(a) The system of the ball and the Earth is isolated. The gravitational energy of the system decreases as the kinetic energy increases.

$$\boxed{\Delta K + \Delta U = 0}$$
$$\left(\frac{1}{2}m\upsilon^2 - 0\right) + \left(-mgh - 0\right) = 0 \rightarrow \frac{1}{2}m\upsilon^2 = mgy$$
$$\boxed{\upsilon = \sqrt{2gh}}$$

(b) The gravity force does positive work on the ball as the ball moves downward. The Earth is assumed to remain stationary, so no work is done on it.

$$\Delta K = W$$
$$\left(\frac{1}{2}m\upsilon^2 - 0\right) = -mgh \rightarrow \frac{1}{2}m\upsilon^2 = mgy$$
$$\boxed{\upsilon = \sqrt{2gh}}$$

2. A block of mass m = 5.00 kg is released from point



A and slides on the frictionless track shown in Figure P8.6. Determine (a) the block's speed at points B and C and (b) the net work done by the gravitational force on the block as it moves from point A to point C .

Ans: **Figure P8.6**

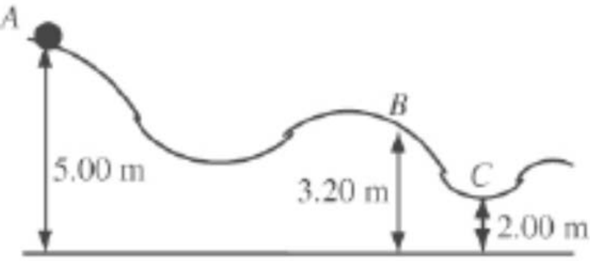
(a) Define the system as the block and the Earth.

$$\Delta K + \Delta U = 0$$

$$\left(\frac{1}{2}m\upsilon_B^2 - 0\right) + \left(mgh_B - mgh_A\right) = 0$$

$$\frac{1}{2}m\upsilon_B^2 = mg\left(h_A - h_B\right)$$

$$\upsilon_B = \sqrt{2g\left(h_4 - h_B\right)}$$



ANS. FIG. P8.6

$$\upsilon_B = \sqrt{2\left(9.80\text{ m/s}^2\right)\left(5.00\text{ m} - 3.20\text{ m}\right)} = \boxed{5.94\text{ m/s}}$$

Similarly,

$$\upsilon_C = \sqrt{2g\left(h_A - h_C\right)}$$
$$\upsilon_C = \sqrt{2g\left(5.00 - 2.00\right)} = \boxed{7.67\text{ m/s}}$$

(b) Treating the block as the system,

$$W_g\Big|_{A\to C} = \Delta K = \frac{1}{2}m\upsilon_C^2 - 0 = \frac{1}{2}\left(5.00\text{ kg}\right)\left(7.67\text{ m/s}\right)^2 = \boxed{147\text{ J}}$$

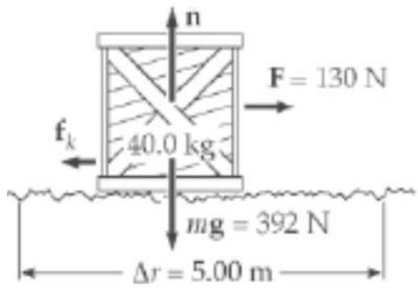
3. A 40.0-kg box initially at rest is pushed 5.00 m along a rough, horizontal floor with a constant applied horizontal force of 130 N. The coefficient of friction between

box and floor is 0.300. Find (a) the work done by the applied force, (b) the increase in internal energy in the box-floor system as a result of friction, (c) the work done by the normal force, (d) the work done by the gravitational force, (e) the change in kinetic energy of the box, and (f) the final speed of the box.

Ans:

$\sum F_y = ma_y$: $n - 392\text{ N} = 0$

$$n = 392\text{ N}$$
$$f_k = \mu_k n = (0.300)(392\text{ N}) = 118\text{ N}$$



ANS. FIG. P8.16

(a) The applied force and the motion are both horizontal.

$$\begin{aligned} W_F &= Fd\cos\theta \\ &= (130\text{ N})(5.00\text{ m})\cos 0° \\ &= \boxed{650\text{ J}} \end{aligned}$$

(b) $\Delta E_{\text{int}} = f_k d = (118\text{ N})(5.00\text{ m}) = \boxed{588\text{ J}}$

(c) Since the normal force is perpendicular to the motion,

$$W_n = nd\cos\theta = (392\text{ N})(5.00\text{ m})\cos 90° = \boxed{0}$$

(d) The gravitational force is also perpendicular to the motion, so

$$W_g = mgd\cos\theta = (392\text{ N})(5.00\text{ m})\cos(-90°) = \boxed{0}$$

(e) We write the energy version of the nonisolated system model a

$$\Delta K = K_f - K_i = \sum W_{\text{other}} - \Delta E_{\text{int}}$$

$$\frac{1}{2} m\upsilon_f^2 - 0 = 650 \text{ J} - 588 \text{ J} + 0 + = \boxed{62.0 \text{ J}}$$

(f) $$\upsilon_f = \sqrt{\frac{2K_f}{m}} = \sqrt{\frac{2(62.0 \text{ J})}{40.0 \text{ kg}}} = \boxed{1.76 \text{ m/s}}$$