energy.

$$W_i = 1/2mv^2 = 1/2 \times 10\,000 \text{ kg} \times (55\text{m/s})^2$$

$$W_i = 1.5 \times 10^7 \text{ J}$$

The general work equation is $W = F_{/\!/}\Delta d$ where $W = W_i$ and $F_{/\!/} = F_f$

$$F_f = \frac{W_i}{\Delta d} = \frac{1.5 \times 10^7 \text{ J}}{800 \text{ m}} = 1.9 \times 10^4 \text{ N.}$$

Exercise 3.22

All the kinetic energy at the bottom of the hill is transformed into potential energy at the top of the hill.

$$E_p = E_k$$

$$mgh = 1/2mv^2$$

$$h = \frac{v^2}{2g} = \frac{(12 \text{ m/s})^2}{2 \times 9.8 \text{ N/kg}}$$

$$h = 7.3 \text{ m}$$

Exercise 3.23

All of the potential energy stored in the spring is transformed into kinetic energy, then into potential energy at height h.

$$E_p = E_p$$

$$mgh = 1/2k\Delta l^2$$

$$h = \frac{k\Delta l^2}{2mg} = \frac{400 \text{ N/m} \times (0.15\text{m})^2}{2 \times 2.0 \text{ kg} \times 9.8 \text{ N/kg}}$$

$$h = 0.23 \text{ m or } 23 \text{ cm}$$

Exercise 3.24

a) According to the Law of Conservation of Energy, the total energy at Point P is equal to the total energy at h = 20 m at Point A.

$$E_{tA} = E_{tP}$$

At Point A and Point P, the car has both gravitational potential energy and kinetic energy. The total energy ($E_p + E_k$) is the same at both points since energy is conserved.

$$E_{pA} + E_{kA} = E_{pP} + E_{kP}$$

$$E_{kA} = E_{pP} - E_{pA} + E_{kP}$$

$$1/2m(v_A)^2 = mgh_P - mgh_A + 1/2m(v_P)^2$$

Simplify the equation by dividing each term by m.

$$1/2(v_A)^2 = g(h_P - h_A) + 1/2(v_P)^2$$

$$v_A^2 = 2(g(h_P - h_A) + 1/2(v_P)^2)$$

$$v_A^2 = 2(9.8 \text{ N/kg} \times -8 \text{ m} + 1/2(15 \text{ m/s})^2)$$

$$v_A^2 = 2(-78.4 \text{ m}^2/\text{s}^2 + 112.5 \text{ m}^2/\text{s}^2)$$

$$v_A^2 = 68.2 \text{ m}^2/\text{s}^2$$

$$v_A = 8.3 \text{ m/s}$$

A simpler way to solve this problem is to place the reference point at Point P. Then $h_P = 0$ and h_A = 8 m.

$$E_{tA} = E_{tP}, \quad \text{where } E_{pP} = 0 \text{ J}$$

$$E_{pA} + E_{kA} = E_{kP}$$

$$E_{kA} = E_{kP} - E_{pA}$$

$$1/2m(v_A)^2 = 1/2m(v_P)^2 - mgh_A$$

$$(v_A)^2 = 2(1/2(v_P)^2 - gh_A)$$

$$W_i = 1/2mv^2$$

$$W_i = 1/2 \times 600 \text{ kg} \times (75 \text{ m/s})^2$$

$$W_i = 1.7 \times 10^6 \text{ J}$$

The work done by the braking force is $F_f \Delta d$ where $\Delta d = 100$ m.

$$W_i = F_f \Delta d$$

$$F_f = \frac{W_i}{\Delta d} = \frac{1.7 \times 10^6 \text{ J}}{100 \text{ m}}$$

$$F_f = 1.7 \times 10^4 \text{ N}$$

Exercise 3.26

The work done to overcome the force of gravity is independent of the trajectory, and a function only of the height.

$$W_g = mgh$$

$$W_g = 70 \text{ kg} \times 9.8 \text{ N/kg} \times 146 \text{ m} = 1.0 \times 10^5 \text{ J}$$

Exercise 3.27

a) Work done to overcome the force of gravity:

$$W_g = mgh, \text{ where } h = 3\text{m} \times \sin 30° = 1.5 \text{ m}$$

$$W_g = 90 \text{ kg} \times 9.8 \text{ N/kg} \times 1.5 \text{ m} = 1.3 \times 10^3 \text{ J.}$$

b) Work done to overcome friction:

$$W_f = F_f \Delta d, \text{ where } \Delta d = l = 3.0 \text{ m}$$

$$W_f = 20 \text{ N} \times 3.0 \text{ m} = 60 \text{ J.}$$

c) Work done to overcome inertia:

$$W_i = 1/2mv^2$$

$$W_i = 1/2 \times 90 \text{ kg} \times (1.2 \text{ m/s})^2 = 65 \text{ J.}$$

d) Total work done:

$$W_t = 1.3 \times 10^3 \text{ J} + 60 \text{ J} + 65 \text{ J}$$

$$W_t = 1.4 \times 10^3 \text{ J.}$$

Exercise 3.28

Application of Hooke's Law:

$$F = k\Delta l, \text{ where } F = F_g = mg = 0.500 \text{ kg} \times 9.8 \text{ N/kg} = 4.9 \text{ N}$$

$$k = \frac{F_g}{\Delta l} = \frac{4.9 \text{ N}}{0.083 \text{ m}} = 59 \text{ N/m.}$$

Exercise 3.29

The potential energy stored in the spring is transformed into kinetic energy.

$$E_k = E_p$$

$$1/2mv^2 = 1/2k\Delta l^2$$

$$v^2 = \frac{k\Delta l^2}{\text{m}}$$

$$v = \pm\sqrt{\frac{k\Delta l^2}{m}}$$

$$v = \pm\sqrt{\frac{200 \text{ N/m} \times (0.12 \text{ m})^2}{0.015 \text{ kg}}}$$

$v = \pm 14$ m/s (Ignore the negative value.)

$v = 14$ m/s

Exercise 3.30

The work done is equivalent to the area below the curve. If we were to approximate by using a triangle, the area would be:

$$\frac{300\ \text{N} \times 0.05\ \text{m}}{2} = 7.5\ \text{J}$$

$$W = 7.5\ \text{J}.$$

Exercise 3.31

During descent, gravitational potential energy is transformed into kinetic energy. Calculation of the difference in height h needed to reach a velocity of 56 m/s:

loss of potential energy = gain in kinetic energy

$$\Delta E_p = \Delta E_k$$

$$mgh = 1/2mv^2$$

$$h = \frac{v^2}{2g} = \frac{(56\ \text{m/s})^2}{2 \times 9.8\ \text{N/kg}} = 160\ \text{m}.$$

The bird would have to start from a height of 210 m.

Exercise 3.32

The amount of thermal energy generated by friction is the difference between the potential energy at the top of the slope and the kinetic energy at the bottom of the slope.

$$E_p = mgh = 70\ \text{kg} \times 9.8\ \text{N/kg} \times 80\ \text{m} = 5.5 \times 10^4\ \text{J}$$

$$E_k = 1/2mv^2 = 1/2 \times 70\ \text{kg} \times (15\ \text{m/s})^2 = 7.9 \times 10^3\ \text{J or } 0.79 \times 10^4\ \text{J}$$

$$E_H = E_p - E_k$$

$$E_H = 5.5 \times 10^4\ \text{J} - 0.79 \times 10^4\ \text{J}$$

$$E_H = 4.7 \times 10^4\ \text{J}$$

Exercise 3.33

The kinetic energy on leaving the ground was transformed into potential energy at the top of the jump.

$$E_k = E_p$$

$$1/2v^2 = gh$$

$$v^2 = 2gh$$

$$v = \pm\sqrt{2gh} = \pm\sqrt{2 \times 9.8\ \text{N/kg} \times 2.0\ \text{m}}$$

$v = \pm 6.3$ m/s (Ignore the negative value.)

$$v = 6.3\ \text{m/s}$$

Exercise 3.34

a) If we ignore the effects of friction, the total amount of energy at Point A is the same as the total amount of energy at Point D since energy is conserved.

b) If the height of Point A were the same as that of Point D, the cart would stop at Point D since the velocity is zero at Point A. The difference in height between Point A and Point D provides the cart with the kinetic energy it needs to pass point D without stopping.

c) Calculation of height at Point A:

$$E_{tA} = E_{tD}.$$

If we place the reference point at Point D:

$$E_{pA} = E_{kD}$$

$mgh = 1/2mv^2$, where h is the difference in height between Points A and D

$$h = \frac{v^2}{2g} = \frac{(10\text{m/s})^2}{2 \times 9.8\ \text{N/kg}} = 5.1\ \text{m}.$$

Height of Point A = 5.1 m + 15 m = 20 m

d) No. The mass has no influence. If we ignore the effects of friction, the mass cancels itself out in the calculation of energy transformations.