P7.40 (a) The distance moved upward in the first 3.00 s is

$$\Delta y = \bar{v}t = \left[\frac{0 + 1.75 \text{ m/s}}{2}\right](3.00 \text{ s}) = 2.63 \text{ m}.$$

The motor and the earth's gravity do work on the elevator car:

$$\frac{1}{2}mv_i^2 + W_{\text{motor}} + mg\Delta y \cos 180° = \frac{1}{2}mv_f^2$$

$$W_{\text{motor}} = \frac{1}{2}(650 \text{ kg})(1.75 \text{ m/s})^2 - 0 + (650 \text{ kg})g(2.63 \text{ m}) = 1.77 \times 10^4 \text{ J}$$

Also, $W = \bar{\mathcal{P}}t$ so $\bar{\mathcal{P}} = \frac{W}{t} = \frac{1.77 \times 10^4 \text{ J}}{3.00 \text{ s}} = \boxed{5.91 \times 10^3 \text{ W}} = 7.92 \text{ hp}$.

(b) When moving upward at constant speed $(v = 1.75 \text{ m/s})$ the applied force equals the weight $= (650 \text{ kg})(9.80 \text{ m/s}^2) = 6.37 \times 10^3 \text{ N}$. Therefore,

$$\mathcal{P} = Fv = (6.37 \times 10^3 \text{ N})(1.75 \text{ m/s}) = \boxed{1.11 \times 10^4 \text{ W}} = 14.9 \text{ hp}.$$

***P7.42** (a) Burning 1 lb of fat releases energy $1 \text{ lb}\left(\frac{454 \text{ g}}{1 \text{ lb}}\right)\left(\frac{9 \text{ kcal}}{1 \text{ g}}\right)\left(\frac{4\,186 \text{ J}}{1 \text{ kcal}}\right) = 1.71 \times 10^7 \text{ J}$.

The mechanical energy output is $(1.71 \times 10^7 \text{ J})(0.20) = nF\Delta r \cos\theta$.

Then $3.42 \times 10^6 \text{ J} = nmg\Delta y \cos 0°$

$$3.42 \times 10^6 \text{ J} = n(50 \text{ kg})(9.8 \text{ m/s}^2)(80 \text{ steps})(0.150 \text{ m})$$

$$3.42 \times 10^6 \text{ J} = n(5.88 \times 10^3 \text{ J})$$

where the number of times she must climb the steps is $n = \frac{3.42 \times 10^6 \text{ J}}{5.88 \times 10^3 \text{ J}} = \boxed{582}$.

This method is impractical compared to limiting food intake.

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(b) Her mechanical power output is

$$\mathcal{P} = \frac{W}{t} = \frac{5.88 \times 10^3 \text{ J}}{65 \text{ s}} = \boxed{90.5 \text{ W}} = 90.5 \text{ W}\left(\frac{1 \text{ hp}}{746 \text{ W}}\right) = \boxed{0.121 \text{ hp}}.$$

P7.65 If positive F represents an outward force, (same as direction as r), then

$$W = \int_i^f \mathbf{F} \cdot d\mathbf{r} = \int_{r_i}^{r_f} \left(2F_0\sigma^{13}r^{-13} - F_0\sigma^7 r^{-7}\right)dr$$

$$W = \left.\frac{2F_0\sigma^{13}r^{-12}}{-12} - \frac{F_0\sigma^7 r^{-6}}{-6}\right|_{r_i}^{r_f}$$

$$W = \frac{-F_0\sigma^{13}\left(r_f^{-12} - r_i^{-12}\right)}{6} + \frac{F_0\sigma^7\left(r_f^{-6} - r_i^{-6}\right)}{6} = \frac{F_0\sigma^7}{6}\left[r_f^{-6} - r_i^{-6}\right] - \frac{F_0\sigma^{13}}{6}\left[r_f^{-12} - r_i^{-12}\right]$$

$$W = 1.03\times 10^{-77}\left[r_f^{-6} - r_i^{-6}\right] - 1.89\times 10^{-134}\left[r_f^{-12} - r_i^{-12}\right]$$

$$W = 1.03\times 10^{-77}\left[1.88\times 10^{-6} - 2.44\times 10^{-6}\right]10^{60} - 1.89\times 10^{-134}\left[3.54\times 10^{-12} - 5.96\times 10^{-8}\right]10^{120}$$

$$W = -2.49\times 10^{-21}\text{ J} + 1.12\times 10^{-21}\text{ J} = \boxed{-1.37\times 10^{-21}\text{ J}}$$

Chapter Eight: Potential Energy

SOLUTIONS TO PROBLEMS

***P8.7** (a)

$$\frac{1}{2}mv_i^2 + \frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2$$

$$0 + \frac{1}{2}(10\text{ N/m})(-0.18\text{ m})^2 = \frac{1}{2}(0.15\text{ kg})v_f^2 + 0$$

$$v_f = (0.18\text{ m})\sqrt{\left(\frac{10\text{ N}}{0.15\text{ kg}\cdot\text{m}}\right)\left(\frac{1\text{ kg}\cdot\text{m}}{1\text{ N}\cdot\text{s}^2}\right)} = \boxed{1.47\text{ m/s}}$$

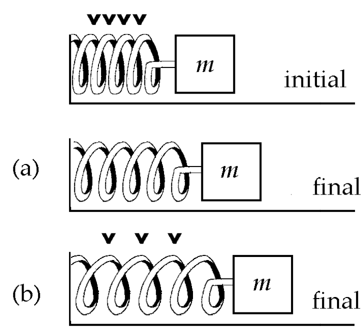

FIG. P8.7

(b)

$$K_i + U_{si} = K_f + U_{sf}$$

$$0 + \frac{1}{2}(10\text{ N/m})(-0.18\text{ m})^2 = \frac{1}{2}(0.15\text{ kg})v_f^2 + \frac{1}{2}(10\text{ N/m})(0.25\text{ m} - 0.18\text{ m})^2$$

$$0.162\text{ J} = \frac{1}{2}(0.15\text{ kg})v_f^2 + 0.024\,5\text{ J}$$

$$v_f = \sqrt{\frac{2(0.138\text{ J})}{0.15\text{ kg}}} = \boxed{1.35\text{ m/s}}$$

P8.17 (a) $K_i + U_{gi} = K_f + U_{gf}$

$$\frac{1}{2}mv_i^2 + 0 = \frac{1}{2}mv_f^2 + mgy_f$$

$$\frac{1}{2}mv_{xi}^2 + \frac{1}{2}mv_{yi}^2 = \frac{1}{2}mv_{xf}^2 + mgy_f$$

But $v_{xi} = v_{xf}$, so for the first ball

$$y_f = \frac{v_{yi}^2}{2g} = \frac{(1\,000\sin 37.0°)^2}{2(9.80)} = \boxed{1.85\times 10^4\text{ m}}$$

and for the second

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$$y_f = \frac{(1\,000)^2}{2(9.80)} = \boxed{5.10\times 10^4\text{ m}}$$

(b) The total energy of each is constant with value

$$\frac{1}{2}(20.0\ \text{kg})(1\,000\ \text{m/s})^2 = \boxed{1.00\times10^7\ \text{J}}.$$

P8.22 (a) $W = \int \mathbf{F}\cdot d\mathbf{r}$ and if the force is constant, this can be written as

$$W = \mathbf{F}\cdot\int d\mathbf{r} = \boxed{\mathbf{F}\cdot(\mathbf{r}_f - \mathbf{r}_i),\ \text{which depends only on end points, not path.}}$$

(b)

$$W = \int \mathbf{F}\cdot d\mathbf{r} = \int (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})\cdot(dx\hat{\mathbf{i}} + dy\hat{\mathbf{j}}) = (3.00\ \text{N})\int_0^{5.00\ \text{m}} dx + (4.00\ \text{N})\int_0^{5.00\ \text{m}} dy$$

$$W = (3.00\ \text{N})x\Big|_0^{5.00\ \text{m}} + (4.00\ \text{N})y\Big|_0^{5.00\ \text{m}} = 15.0\ \text{J} + 20.0\ \text{J} = \boxed{35.0\ \text{J}}$$

The same calculation applies for all paths.

P8.24 (a)

$$(\Delta K)_{A\to B} = \sum W = W_g = mg\Delta h = mg(5.00 - 3.20)$$

$$\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = m(9.80)(1.80)$$

$$v_B = \boxed{5.94\ \text{m/s}}$$

Similarly, $v_C = \sqrt{v_A^2 + 2g(5.00 - 2.00)} = \boxed{7.67\ \text{m/s}}$

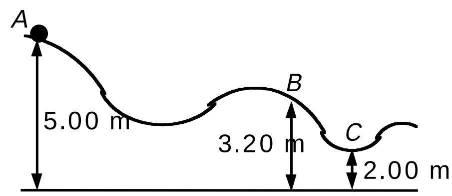

FIG. P8.24

(b)

$$W_g\Big|_{A\to C} = mg(3.00\ \text{m}) = \boxed{147\ \text{J}}$$

P8.29 As the locomotive moves up the hill at constant speed, its output power goes into internal energy plus gravitational energy of the locomotive-Earth system:

$$\mathcal{P}t = mgy + f\Delta r = mg\Delta r\sin\theta + f\Delta r \qquad \mathcal{P} = mgv_f\sin\theta + fv_f$$

As the locomotive moves on level track,

$$\mathcal{P} = fv_i \qquad 1\,000\ \text{hp}\left(\frac{746\ \text{W}}{1\ \text{hp}}\right) = f(27\ \text{m/s})$$

$$f = 2.76\times10^4\ \text{N}$$

Then also $746\,000\ \text{W} = (160\,000\ \text{kg})(9.8\ \text{m/s}^2)v_f\left(\frac{5\ \text{m}}{100\ \text{m}}\right) + (2.76\times10^4\ \text{N})v_f$

$$v_f = \frac{746\,000\ \text{W}}{1.06\times10^5\ \text{N}} = \boxed{7.04\ \text{m/s}}$$

P8.35 (a) $(K+U)_i + \Delta E_{\text{mech}} = (K+U)_f$:

$$0 + \frac{1}{2}kx^2 - f\Delta x = \frac{1}{2}mv^2 + 0$$
$$\frac{1}{2}(8.00\ \text{N/m})(5.00\times10^{-2}\ \text{m})^2 - (3.20\times10^{-2}\ \text{N})(0.150\ \text{m}) = \frac{1}{2}(5.30\times10^{-3}\ \text{kg})v^2$$
$$v = \sqrt{\frac{2(5.20\times10^{-3}\ \text{J})}{5.30\times10^{-3}\ \text{kg}}} = \boxed{1.40\ \text{m/s}}$$

(b) When the spring force just equals the friction force, the ball will stop speeding up. Here $|\mathbf{F}_s| = kx$; the spring is compressed by

$$\frac{3.20\times10^{-2}\ \text{N}}{8.00\ \text{N/m}} = 0.400\ \text{cm}$$

and the ball has moved

$$5.00\ \text{cm} - 0.400\ \text{cm} = \boxed{4.60\ \text{cm from the start.}}$$

(c) Between start and maximum speed points,

$$\frac{1}{2}kx_i^2 - f\Delta x = \frac{1}{2}mv^2 + \frac{1}{2}kx_f^2$$
$$\frac{1}{2}8.00(5.00\times10^{-2})^2 - (3.20\times10^{-2})(4.60\times10^{-2}) = \frac{1}{2}(5.30\times10^{-3})v^2 + \frac{1}{2}8.00(4.00\times10^{-3})^2$$
$$v = \boxed{1.79\ \text{m/s}}$$

P8.63 Launch speed is found from

$$mg\left(\frac{4}{5}h\right) = \frac{1}{2}mv^2: \qquad v = \sqrt{2g\left(\frac{4}{5}\right)h}$$
$$v_y = v\sin\theta$$

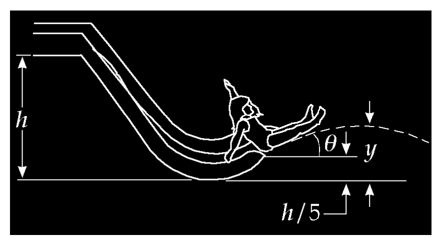

FIG. P8.63

The height y above the water (by conservation of energy for the child-Earth system) is found from

$$mgy = \frac{1}{2}mv_y^2 + mg\frac{h}{5} \quad \left(\text{since } \frac{1}{2}mv_x^2 \text{ is constant in projectile motion}\right)$$
$$y = \frac{1}{2g}v_y^2 + \frac{h}{5} = \frac{1}{2g}v^2\sin^2\theta + \frac{h}{5}$$
$$y = \frac{1}{2g}\left[2g\left(\frac{4}{5}h\right)\right]\sin^2\theta + \frac{h}{5} = \boxed{\frac{4}{5}h\sin^2\theta + \frac{h}{5}}$$