To print, please use the print page range feature within the application.

Chapter 9. Energy, Work, and Power

Practice Problems

1.

A solid, cast-iron sphere (density of 0.256 lbm/in^3 (7090 kg/m^3)) of 10 in (25 cm) diameter travels without friction at 30 ft/sec (9 m/s) horizontally. Its kinetic energy is most nearly

(A)

900 ft-lbf (1.2 kJ)

(B)

1200 ft-lbf (1.6 kJ)

(C)

1600 ft-lbf (2.0 kJ)

(D)

1900 ft-lbf (2.3 kJ)

2.

The work done when a balloon carries a 12 lbm (5.2 kg) load to 40,000 ft (12 000 m) height is most nearly

(A)

2.4×10^5 ft-lbf (300 kJ)

(B)

4.8×10^5 ft-lbf (610 kJ)

(C)

7.7×10^5 ft-lbf (980 kJ)

(D)

9.9×10^5 ft-lbf (1.3 MJ)

3.

The power in horsepower (kW) that is required to lift a 3300 lbm (1500 kg) mass 250 ft (80 m) vertically in 14 sec is most nearly

(A)

40 hp (30 kW)

(B)

70 hp (53 kW)

(C)

90 hp (68 kW)

(D)

110 hp (84 kW)
4.

Approximately what volume in ft^3 (m^3) of water can be pumped to a 130 ft (40 m) height in 1 hr by a 7 hp (5 kW) pump? Assume 85% efficiency.

(A)

1500 ft^3 (40 m^3)

(B)

1800 ft^3 (49 m^3)

(C)

2000 ft^3 (54 m^3)

(D)

2400 ft^3 (65 m^3)

Solutions

1.

Customary U.S. Solution

Since there is no friction, there is no rotation. The sphere slides. The kinetic energy can be found from the first law of thermodynamics (also *NCEES Handbook:* Open Thermodynamic Systems) or Bernoulli's equation (also *NCEES Handbook:* The Bernoulli Equation).

$$\begin{aligned} E_{\text{kinetic}} &= \tfrac{1}{2}\left(\frac{m}{g_c}\right)\mathrm{v}^2 = \tfrac{1}{2}\left(\frac{V\rho}{g_c}\right)\mathrm{v}^2 \\ &= \left(\tfrac{1}{2}\right)\left(\tfrac{4}{3}\pi r^3\right)\left(\frac{\rho}{g_c}\right)\mathrm{v}^2 \\ &= \tfrac{2}{3}\pi r^3\left(\frac{\rho}{g_c}\right)\mathrm{v}^2 \\ &= \frac{2}{3}\pi\left(\frac{10\ \text{in}}{2}\right)^3\left(\frac{0.256\ \frac{\text{lbm}}{\text{in}^3}}{32.2\ \frac{\text{lbm-ft}}{\text{lbf-sec}^2}}\right)\left(30\ \frac{\text{ft}}{\text{sec}}\right)^2 \\ &= 1873\ \text{ft-lbf} \quad (1900\ \text{ft-lbf}) \end{aligned}$$

The answer is (D).

SI Solution

Since there is no friction, there is no rotation. The sphere slides. The kinetic energy can be found from the first law of thermodynamics (also *NCEES Handbook:* Open Thermodynamic Systems) or Bernoulli's equation (also *NCEES Handbook:* The Bernoulli Equation).

$$
\begin{aligned}
E_{\text{kinetic}} &= \tfrac{1}{2}m\mathrm{v}^2 = \tfrac{1}{2}(\rho V)\,\mathrm{v}^2 \\
&= \tfrac{1}{2}\rho\left(\tfrac{4}{3}\pi r^3\right)\mathrm{v}^2 \\
&= \tfrac{2}{3}\pi r^3 \rho \mathrm{v}^2 \\
&= \tfrac{2}{3}\pi\left(\tfrac{0.25\ \mathrm{m}}{2}\right)^3\left(7090\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right)\left(9\ \frac{\mathrm{m}}{\mathrm{s}}\right)^2 \\
&= 2349\ \mathrm{J} \quad (2.3\ \mathrm{kJ})
\end{aligned}
$$

The answer is (D).

2.

Customary U.S. Solution

From equationCERM13011(b) (also *NCEES Handbook:* Closed Thermodynamic Systems) and equationCERM13012 (also *NCEES Handbook:* Open Thermodynamic Systems), the work done by the balloon is

$$
\begin{aligned}
W &= \Delta E_{\text{potential}} = \frac{mg\Delta h}{g_c} \\
&= \frac{(12\ \mathrm{lbm})\left(32.2\ \dfrac{\mathrm{ft}}{\mathrm{sec}^2}\right)(40{,}000\ \mathrm{ft})}{32.2\ \dfrac{\mathrm{lbm\text{-}ft}}{\mathrm{lbf\text{-}sec}^2}} \\
&= 4.8\times 10^5\ \mathrm{ft\text{-}lbf}
\end{aligned}
$$

The answer is (B).

SI Solution

From equationCERM13011(a) (also *NCEES Handbook:* Closed Thermodynamic Systems) and equationCERM13012 (also *NCEES Handbook:* Open Thermodynamic Systems), the work done by the balloon is

$$
\begin{aligned}
W &= \Delta E_{\text{potential}} = mg\Delta h \\
&= \frac{(5.2\ \mathrm{kg})\left(9.81\ \dfrac{\mathrm{m}}{\mathrm{s}^2}\right)(12\,000\ \mathrm{m})}{1000\ \dfrac{\mathrm{J}}{\mathrm{kJ}}} \\
&= 612.1\ \mathrm{kJ} \quad (610\ \mathrm{kJ})
\end{aligned}
$$

The answer is (B).

3.

Customary U.S. Solution

Apply the first law of thermodynamics (also *NCEES Handbook:* Closed Thermodynamic Systems or *NCEES Handbook:* Open Thermodynamic Systems). The work required to lift the mass is

$$
\begin{aligned}
W &= P\Delta t = \frac{mg\Delta h}{g_c} \\
P &= \frac{mg\Delta h}{g_c\Delta t} \\
&= \frac{(3300\ \mathrm{lbm})\left(32.2\ \dfrac{\mathrm{ft}}{\mathrm{sec}^2}\right)(250\ \mathrm{ft})}{\left(32.2\ \dfrac{\mathrm{lbm\text{-}ft}}{\mathrm{sec}^2\text{-}\mathrm{lbf}}\right)(14\ \mathrm{sec})\left(550\ \dfrac{\mathrm{ft\text{-}lbf}}{\mathrm{hp\text{-}sec}}\right)} \\
&= 107\ \mathrm{hp} \quad (110\ \mathrm{hp})
\end{aligned}
$$

The answer is (D).

SI Solution

Apply the first law of thermodynamics (also *NCEES Handbook:* Closed Thermodynamic Systems or *NCEES Handbook:* Open Thermodynamic Systems). The work required to lift the mass is

$$W = P\Delta t = mg\Delta h$$

$$P = \frac{mg\Delta h}{\Delta t} = \frac{(1500\ \text{kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(80\ \text{m})}{(14\ \text{s})\left(1000\ \frac{\text{W}}{\text{kW}}\right)}$$
$$= 84.1\ \text{kW} \quad (84\ \text{kW})$$

The answer is (D).
4.

Customary U.S. Solution

Apply the first law of thermodynamics (also *NCEES Handbook:* Closed Thermodynamic Systems or *NCEES Handbook:* Open Thermodynamic Systems). The volume of water is found from the work performed.

$$\begin{aligned}
P_{\text{actual}}\ \Delta t &= W_{\text{done by pump}} \\
\eta P_{\text{ideal}}\ \Delta t &= \Delta\ E_{\text{potential}} \\
&= \frac{mg\Delta h}{g_c} \\
&= \frac{(\rho V)\ g\Delta h}{g_c} \\
V &= \frac{\eta P_{\text{ideal}}\ \Delta t}{\frac{\rho g\Delta h}{g_c}} \\
&= \frac{(0.85)\ (7\ \text{hp})\left(550\ \frac{\text{ft-lbf}}{\text{hp-sec}}\right)(1\ \text{hr})\left(3600\ \frac{\text{sec}}{\text{hr}}\right)}{\frac{\left(62.4\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(32.2\ \frac{\text{ft}}{\text{sec}^2}\right)(130\ \text{ft})}{32.2\ \frac{\text{lbm-ft}}{\text{lbf-sec}^2}}} \\
&= 1452\ \text{ft}^3 \quad \left(1500\ \text{ft}^3\right)
\end{aligned}$$

The answer is (A).

SI Solution

Apply the first law of thermodynamics (also *NCEES Handbook:* Closed Thermodynamic Systems or Open Thermodynamic Systems). The volume of water is found from the work performed.

$$\begin{aligned}
P_{\text{actual}}\ \Delta t &= W_{\text{done by pump}} \\
\eta P_{\text{ideal}}\ \Delta t &= \Delta E_{\text{potential}} \\
&= mg\Delta h \\
&= (\rho V)\ g\Delta h \\
V &= \frac{\eta P_{\text{ideal}}\ \Delta t}{\rho g\Delta h} \\
&= \frac{(0.85)\ (5\ \text{kW})\left(1000\ \frac{\text{W}}{\text{kW}}\right)(1\ \text{h})\left(3600\ \frac{\text{s}}{\text{h}}\right)}{\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(40\ \text{m})} \\
&= 39.0\ \text{m}^3 \quad \left(40\ \text{m}^3\right)
\end{aligned}$$

The answer is (A).