

## Part VI

# Solutions

### 39 Thermodynamics

**39.1** A 10hp pump with 90% efficiency transports water to an elevation of 200ft above the pump. What volume of water is transported in a 1 hour period?

- A. 300 gallons
- B. 1400 gallons
- C. 10,700 gallons
- D. 11,900 gallons

Start by considering the relationship between power, work, and energy. Note that work and energy have common units. Work is typically represented as a force exerted over a distance. For a mass of water being raised by a certain distance, it must experience an increase in **Potential Energy**:

$$PE = \frac{mgh}{g_c}$$

Using  $m = \rho V$

$$PE = \frac{mgh}{g_c} = \frac{\rho Vgh}{g_c}$$

Equate the potential energy added to the water to the amount of work done, which is a function of the power and the time.

$$P = \frac{W}{t} \rightarrow W = Pt$$

Since the pump has a stated efficiency, apply a multiplier with the pump horsepower rating:

$$W = \eta Pt$$

Equate the work and potential energy:

$$\eta Pt = \frac{\rho Vgh}{g_c}$$

Solve for volume, then substitute values. Find the conversion from hp to  $\frac{ft \cdot lb_f}{sec}$  by searching **Measurement Relationships**.

$$V = \frac{\eta Pt g_c}{\rho gh} = \frac{(.9)(10hp) \left(550 \frac{ft \cdot lb_f}{sec \cdot hp}\right) (3600sec) \left(32.2 \frac{lb_m \cdot ft}{lb_f \cdot sec^2}\right) \left(7.48 \frac{gallons}{ft^3}\right)}{\left(62.4 \frac{lb_m}{ft^3}\right) \left(32.2 \frac{ft}{sec^2}\right) (200ft)} = 10,680 gallons$$

**Answer C**

**39.2 What is the enthalpy of  $1\text{ lb} \cdot \text{mole}$  of  $300^\circ\text{F}$  steam with a quality of 60%?**

- A.  $630\text{Btu}$
- B.  $820\text{Btu}$
- C.  $11,400\text{Btu}$
- D.  $14,700\text{Btu}$

$1\text{ lb} \cdot \text{mol}$  of  $\text{H}_2\text{O}$  weighs:  $2(1) + 16 = 18\text{lbs}$

From the **Properties of Saturated Water and Steam** Table @ $300^\circ\text{F}$ :

$$h_f = 269.7 \frac{\text{Btu}}{\text{lb}}$$

$$h_{fg} = 910.2 \frac{\text{Btu}}{\text{lb}}$$

Find the specific enthalpy at 60% quality:

$$h = h_f + \chi h_{fg} = 269.7 \frac{\text{Btu}}{\text{lb}} + (.6) \left( 910.2 \frac{\text{Btu}}{\text{lb}} \right) = 815.8 \frac{\text{Btu}}{\text{lb}}$$

**Specific Enthalpy** is the total enthalpy per unit mass, expressed as:  $h = \frac{H}{m}$  which can be rearranged to  $H = mh$  where mass and specific enthalpy are both known.

Substitute and solve:

$$H = mh = (18\text{lbs}) \left( 815.8 \frac{\text{Btu}}{\text{lb}} \right) = 14,684\text{Btu}$$

**Answer D**

**39.3 What is the ratio of specific heats for  $1020^\circ\text{F}$  air? Assume  $c_{p,\text{air}} = 0.249 \frac{\text{Btu}}{\text{lb}_m \cdot ^\circ\text{R}}$  at  $1000^\circ\text{R}$  and  $c_{p,\text{air}} = 0.264 \frac{\text{Btu}}{\text{lb}_m \cdot ^\circ\text{R}}$  at  $1500^\circ\text{R}$ .**

- A. 1.35
- B. 1.38
- C. 1.40
- D. 1.43

The **Ratio of Specific Heats** is defined as:

$$k = \frac{c_p}{c_v}$$

Another important relationship between the specific heats for a gas is that their difference is the specific gas constant, as such: