

**46.33** A pizza oven has a flame temperature of  $1000^\circ F$  and the internal walls are  $700^\circ F$ . Assuming all surfaces are considered to be black, what is the rate of heat transfer per square foot due to radiation?

- A.  $1300 \frac{Btu}{hr \cdot ft^2}$
- B.  $4700 \frac{Btu}{hr \cdot ft^2}$
- C.  $8800 \frac{Btu}{hr \cdot ft^2}$
- D.  $13,000 \frac{Btu}{hr \cdot ft^2}$

The energy exchange due to **Radiation** is given by the equation below.

$$\dot{Q}_r = \varepsilon \sigma A (T_1^4 - T_2^4)$$

Since all surfaces are considered to be black, the emissivity is assumed to be 1.

$$\varepsilon = 1$$

The question asks for the heat transfer per square foot, so divide both sides by area.

$$\frac{\dot{Q}_r}{A} = \dot{q}_r = \sigma (T_1^4 - T_2^4)$$

$\sigma$  is the **Stefan-Boltzmann Constant**. In order for the units to work out, absolute temperatures must be used i.e. Rankine. Solve for  $\dot{q}_r$ .

$$\dot{q}_r = \left( 0.1713 \times 10^{-8} \frac{Btu}{hr \cdot ft^2 \cdot ^\circ R^4} \right) \left[ (1460^\circ R)^4 - (1160^\circ R)^4 \right] = 4682 \frac{Btu}{hr \cdot ft^2}$$

**Answer B**

**46.34** A 50ft length of hot water piping with 1 in O.D. runs uninsulated through an open basement. The ambient temperature and average temperature of the walls and other surfaces is 60°F. The convective heat transfer coefficient is  $6 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F}$ . The average surface temperature of the pipe is 120°F. The emissivity for the pipe is 0.9. What is the total heat loss?

- A.  $800 \frac{Btu}{hr}$
- B.  $4680 \frac{Btu}{hr}$
- C.  $5520 \frac{Btu}{hr}$
- D.  $9640 \frac{Btu}{hr}$

Heat is lost from the pipe through both **Convection** and **Radiation**. For combined heat transfer, add the convection and radiation equations together.

$$\dot{Q}_{conv} = hA\Delta T$$

$$\dot{Q}_{rad} = \sigma \varepsilon A (T_s^4 - T_\infty^4)$$

$$\dot{Q}_t = \dot{Q}_{conv} + \dot{Q}_{rad} = hA\Delta T + \sigma \varepsilon A (T_s^4 - T_\infty^4)$$

Area is common to both equations and may be factored out of the combined equation.

$$\dot{Q}_t = A (h\Delta T + \sigma \varepsilon (T_s^4 - T_\infty^4))$$

Calculate the external surface area of the pipe.

$$A_s = \pi DL = \pi \left( \frac{1in}{12 \frac{in}{ft}} \right) (50ft) = 13.1ft^2$$

Substitute the convection coefficient, surface temperature, and surrounding air temperature into the convection portion of the equation. Substitute the **Stefan-Boltzmann Constant**, emissivity, pipe surface temperature, and the temperature of the surrounding surfaces in the radiation portion of the equation. Be sure to use absolute temperatures ie. Rankine for radiation. Determine the total heat loss.

$$\dot{Q}_t = (13.1ft^2) \times$$

$$\left[ \left( 6 \frac{Btu}{hr \cdot ft^2 \cdot ^\circ F} \right) (120^\circ F - 60^\circ F) + \left( 0.1713 \times 10^{-8} \frac{Btu}{hr \cdot ft^2 \cdot ^\circ R^4} \right) (0.9) \left( (580^\circ R)^4 - (520^\circ R)^4 \right) \right]$$

$$\dot{Q}_t = 5525 \frac{Btu}{hr}$$

**Answer C**