46.41 A $7lb_m$ cast iron pan ($c_p = 0.1\frac{Btu}{lb_m {}^\circ F}$) is heated uniformly to $500^\circ F$ during cooking, then placed in a sink filled with $4\ gallons$ of $60^\circ F$ water. Neglecting losses, what is the final equilibrium temperature?

A. $69^\circ F$

B. $79^\circ F$

C. $89^\circ F$

D. $99^\circ F$

All of the heat released from the pan is added to the water. Express both quantities of heat as the product of mass, specific heat capacity, and ΔT. Set them equal.

$$(mc_p\Delta T)_{iron} = (mc_p\Delta T)_{water}$$

In the case of water, the volume was given instead of the mass. Use the density of water to calculate the mass.

$$m_{water} = \rho V = \left(62.4\frac{lb_m}{ft^3}\right)\left(\frac{1ft^3}{7.48gal}\right)(4gal) = 33.4lb_m$$

Substitute into the first equation and solve for the final equilibrium temperature, T_f, which is the same for the pan and the water.

$$(7lb_m)\left(0.1\frac{Btu}{lb_m {}^\circ F}\right)(500^\circ F - T_f) = (33.4lb_m)\left(1\frac{Btu}{lb_m {}^\circ F}\right)(T_f - 60^\circ F)$$

Since the units are all consistent, it is fine to ignore the units while solving for the unknown temperature.

$$(0.7)(500 - T_f) = (33.4)(T_f - 60)$$

$$350 - 0.7T_f = 33.4T_f - 2002$$

$$2352 = 34.1T_f$$

$$T_f = 69^\circ F$$

Answer A

46.42 A refrigeration system using R-22 operates between $80°F$ condensing and $0°F$ evaporation. The refrigerant exits the evaporator as a dry, saturated vapor. What is the specific work done by the compressor assuming isentropic compression?

A. $9\frac{Btu}{lb}$

B. $11\frac{Btu}{lb}$

C. $15\frac{Btu}{lb}$

D. $18\frac{Btu}{lb}$

Draw the refrigeration cycle on the Pressure-Enthalpy diagram for Refrigerant 22, labelling all 4 States. The compression process is from State 1 to State 2. The specific work done by the compressor is the difference between the enthalpy at State 2 and the enthalpy at State 1. Specific work is distinct from 'Work' in that its units are $\frac{Btu}{lb}$ (as opposed to $\frac{Btu}{hr}$) and it does not require the mass flow rate.

$$Work = \dot{W}_{comp} = \dot{m}\Delta h = \dot{m}\left(h_2 - h_1\right)$$

$$Specific Work = w = h_2 - h_1$$

Start by analyzing State 1 which is a dry, saturated vapor with a known Temperature. Use the Refrigerant 22 table to obtain the enthalpy at State 1.

$$T_1 = 0°F$$

$$h_1 = h_f = 104.6\frac{Btu}{lb}$$

Use the Pressure Versus Enthalpy Curves for Refrigerant 22 to locate State 1. Since the compression process is isentropic, draw a line of constant entropy up and to the right.

The condensing temperature is $80°F$, which is implied to refer to the segment of the condensing process line which lies inside the vapor dome. The condensing process is constant *pressure* throughout the entire process, however it is only constant *temperature* inside the vapor dome. Extend a horizontal line to the right from the $80°F$ line.

Graphically locate State 2 as the intersection of the extended $80°F$ line and the constant entropy line previously drawn from State 1. Read the enthalpy at State 2 along the top horizontal axis. Some uncertainty and imprecision is to be expected due to graphical nature of this approach.

$$h_2 \approx 120\frac{Btu}{lb}$$

Calculate the specific work.

$$w = 120\frac{Btu}{lb} - 104.6\frac{Btu}{lb} = 15.4$$

Answer C