

47.16 A Carnot heat pump operates during winter when the outside air temperature is $20^{\circ}F$ and inside temperature is $68^{\circ}F$. During summer, the unit runs in reverse to provide cooling when the outside air temperature is $100^{\circ}F$ and inside temperature is $72^{\circ}F$. What is the coefficient of performance during summer operation?

- A. 3
- B. 4
- C. 17
- D. 19

Recall that a **Carnot** heat pump has the maximum theoretical **Coefficient of Performance** based on the temperatures of the reservoirs heat is being removed from and rejected to. In this case, winter operation may be ignored since the question is asking about the **COP** for summer operation only.

The COP for refrigeration for a Carnot cycle is given by:

$$COP_c = \frac{T_L}{T_H - T_L}$$

Temperature units must be absolute (Rankine). The denominator is a temperature differential and therefore may be left in Fahrenheit.

$$COP_c = \frac{72^{\circ}F + 460^{\circ}}{100^{\circ}F - 72^{\circ}F} = 19$$

Answer D

47.17 A refrigeration cycle using R-123 operates between 30psia and 125psia with no subcooling and isenthalpic expansion. What is the quality of the mixture entering the evaporator?

- A. 0.20
- B. 0.26
- C. 0.32
- D. 0.38

Look up the **R-123** properties table and **Pressure Versus Enthalpy Curves for Refrigerant 123**. Consider the high pressure side of the refrigeration cycle after the refrigerant passes through the condenser, it is expected to be a saturated liquid at 125psia . Let this be considered State 3. Use either the table or the chart to determine the enthalpy of saturated liquid, h_f . The table lends itself to slightly higher precision but may take a bit more time. Formal interpolation is not necessary. Beware of the logarithmic scale on the vertical axis if using the P-H chart. Since the expansion process in a typical refrigeration cycle is isenthalpic, the enthalpy after expansion is the same as the enthalpy prior to expansion. Let the low pressure condition after expansion be considered State 4.

$$h_4 = h_3 = h_{f@125psia} \approx 64.3 \frac{Btu}{lb}$$

Use the table to obtain h_f and h_g at the low pressure condition of 30psia.

$$h_{f@30psia} \approx 38.14 \frac{Btu}{lb}$$

$$h_{g@30psia} \approx 107.4 \frac{Btu}{lb}$$

Calculate the enthalpy at State 4.

$$\chi_4 = \frac{h_4 - h_f}{h_g - h_f} = \frac{64.3 \frac{Btu}{lb} - 38.14 \frac{Btu}{lb}}{107.4 \frac{Btu}{lb} - 38.14 \frac{Btu}{lb}} = 0.378$$

Answer D

47.18 A kitchen contains lighting and cooking equipment which draws 30KW. There is also a moisture load of $2 \frac{lb}{min}$. What is the sensible heat ratio?

- A. 0.02
- B. 0.45
- C. 0.55
- D. 0.98

Change the units of the sensible heat load from KW to $\frac{Btu}{hr}$.

$$Q_S = (30KW) \left(\frac{3412 \frac{Btu}{hr}}{KW} \right) = 102,360 \frac{Btu}{hr}$$

Calculate the latent load. Use the steam table by looking up **Properties of Saturated Water** by temperature. Assume the kitchen is around 80°F. Note the latent heat of vaporization for steam, $h_{fg} \approx 1050 \frac{Btu}{lb}$ at this approximate temperature.

$$Q_L = \dot{m} \Delta h = \dot{m} h_{fg} = \left(2 \frac{lb}{min} \right) \left(1050 \frac{Btu}{lb} \right) \left(\frac{60min}{1hr} \right) = 126,000 \frac{Btu}{hr}$$

Find the **Sensible Heat Ratio**.

$$SHR = \frac{Q_S}{Q_T} = \frac{Q_S}{Q_S + Q_L} = \frac{102,360 \frac{Btu}{hr}}{102,360 \frac{Btu}{hr} + 126,000 \frac{Btu}{hr}} = 0.448$$

Answer B