

**39.14 A Carnot heat pump operates between  $20^{\circ}F$  and  $70^{\circ}F$ . What is the coefficient of performance?**

- A. 0.4
- B. 1.4
- C. 9.6
- D. 10.6

Look up the **Carnot Cycle** in the reference handbook and find the **Coefficient of Performance** formulas. A Carnot heat pump operates at the upper limit of COP, which is a function of the temperatures of the hot and cold reservoirs which the heat pump is operating between.

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)}$$

The temperatures must be in absolute terms i.e. Rankine, so add 460 to  $^{\circ}F$  before substituting into the formula. (Technically, there is no need to change to absolute in the denominator since the difference will remain unchanged.)

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)} = \frac{(70 + 460)}{(70 - 20)} = \frac{530R}{50R} = 10.6$$

**Answer D**

**39.15 In a Carnot heat pump, R-22 evaporates at  $31psia$  and condenses at  $211psia$ . What is the coefficient of performance?**

- A. 0.9
- B. 4.3
- C. 5.1
- D. 6.8

Lookup the **Pressure Versus Enthalpy Curves for Refrigerant 22** and read from the chart the temperatures for the evaporator and condenser based on the pressures given. These correspond to the low and high temperature reservoirs, respectively, for the heat pump:

$$T_L = T_{evaporator@P=31psia} \approx -10^{\circ}F + 460 = 450^{\circ}R$$

$$T_H = T_{condenser@P=211psia} \approx 100^{\circ}F + 460 = 560^{\circ}R$$

Look up the **Carnot Cycle** in the reference handbook and find the **coefficient of performance** formula:

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)} = \frac{560^{\circ}R}{560^{\circ}R - 450^{\circ}R} = 5.1$$

**Answer C**

**39.16** A refrigerator draws  $800W$  of power and absorbs  $4000\frac{Btu}{hr}$  from the internal volume. What is the coefficient of performance?

- A. 0.7
- B. 1.5
- C. 1.7
- D. 5.0

Look up **Coefficient of Performance** for a **Refrigerator** in the reference handbook and use the formula:

$$COP_R = \frac{Q_L}{W}$$

where  $Q_L$  is the refrigeration effect i.e. the heat removed from the cold space and  $W$  is the work done by the compressor to drive the refrigeration process. Note that the units must cancel completely as the COP should be unitless. Substitute and solve.

$$COP_R = \frac{Q_L}{W} = \frac{4000\frac{Btu}{hr}}{800W \left(3.412\frac{Btu}{hr \cdot W}\right)} = 1.5$$

**Answer B**

**39.17** The cold and hot reservoirs of a reversed Carnot refrigeration cycle are  $-20^\circ F$  and  $80^\circ F$ , respectively.  $3000\frac{Btu}{hr}$  are absorbed from the cold reservoir. What is the work input?

- A.  $160W$
- B.  $200W$
- C.  $700W$
- D.  $1100W$

Find the **coefficient of performance** for a **Carnot Refrigerator** in the reference handbook as having the formula:

$$COP_{R,carnot} = \frac{T_L}{T_H - T_L}$$

where  $T_L$  and  $T_H$  are the low and high reservoir temperatures, respectively, in absolute degrees i.e. Rankine. Therefore the COP can be determined as such:

$$COP_{R,carnot} = \frac{T_L}{T_H - T_L} = \frac{-20^\circ F + 460}{[(80^\circ F + 460) - (-20^\circ F + 460)]} = \frac{440^\circ R}{100^\circ R} = 4.4$$

Having been given the rate of heat removal from the cold reservoir and calculated the COP for the cycle, the compressor work to drive the refrigeration process can be calculated: