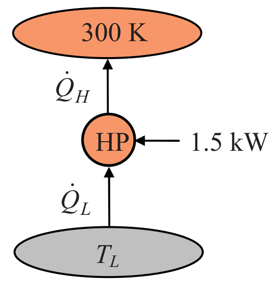
7-106 A reversible heat pump is considered. The temperature of the source and the rate of heat transfer to the sink are to be determined.

Assumptions The heat pump operates steadily.

Analysis Combining the first law, the expression for the coefficient of performance, and the thermodynamic temperature scale gives



$$\text{COP}_{\text{HP,max}} = \frac{T_H}{T_H - T_L}$$

which upon rearrangement becomes

$$T_L = T_H\left(1 - \frac{1}{\text{COP}_{\text{HP,max}}}\right) = (300\text{ K})\left(1 - \frac{1}{1.6}\right) = \mathbf{112.5\ K}$$

Based upon the definition of the heat pump coefficient of performance,

$$\dot{Q}_H = \text{COP}_{\text{HP,max}}\dot{W}_{\text{net,in}} = (1.6)(1.5\text{ kW}) = \mathbf{2.4\ kW}$$

7-107 A heat pump that consumes 5-kW of power when operating maintains a house at a specified temperature. The house is losing heat in proportion to the temperature difference between the indoors and the outdoors. The lowest outdoor temperature for which this heat pump can do the job is to be determined.

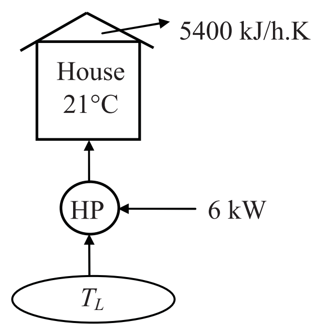
Assumptions The heat pump operates steadily.

Analysis Denoting the outdoor temperature by T_L, the heating load of this house can be expressed as

$$\dot{Q}_H = (5400\text{ kJ/h}\cdot\text{K})(294 - T_L) = (1.5\text{ kW/K})(294 - T_L)\text{K}$$

The coefficient of performance of a Carnot heat pump depends on the temperature limits in the cycle only, and can be expressed as

$$\text{COP}_{\text{HP}} = \frac{1}{1 - (T_L/T_H)} = \frac{1}{1 - T_L/(294\text{ K})}$$



or, as

$$\text{COP}_{\text{HP}} = \frac{\dot{Q}_H}{\dot{W}_{\text{net,in}}} = \frac{(1.5\text{ kW/K})(294 - T_L)\text{K}}{6\text{ kW}}$$

Equating the two relations above and solving for T_L, we obtain

$$T_L = 259.7\text{ K} = \mathbf{-13.3°C}$$