7.17 A cyclic machine, shown in Fig. P7.17, receives 325 kJ from a 1000 K energy reservoir. It rejects 125 kJ to a 400 K energy reservoir and the cycle produces 200 kJ of work as output. Is this cycle reversible, irreversible, or impossible?

Solution:

\[ \eta_{\text{Carnot}} = 1 - \frac{T_L}{T_H} = 1 - \frac{400}{1000} = 0.6 \]
\[ \eta_{\text{eng}} = \frac{W}{Q_H} = \frac{200}{325} = 0.615 > \eta_{\text{Carnot}} \]

This is impossible.

7.23 An inventor has developed a refrigeration unit that maintains the cold space at \(-10^\circ\text{C}\), while operating in a 25°C room. A coefficient of performance of 8.5 is claimed. How do you evaluate this?

Solution:

\[ \beta_{\text{Carnot}} = \frac{Q_L}{W_{\text{in}}} = \frac{T_L}{(T_H - T_L)} = \frac{263.15}{25 - (-10)} = 7.52 \]

\[ 8.5 > \beta_{\text{Carnot}} \Rightarrow \text{impossible claim} \]

7.43 A heat engine has a solar collector receiving 0.2 kW per square meter inside which a transfer media is heated to 450 K. The collected energy powers a heat engine which rejects heat at 40 C. If the heat engine should deliver 2.5 kW what is the minimum size (area) solar collector?

Solution:

\[ T_H = 450 \text{ K} \quad T_L = 40^\circ\text{C} = 313.15 \text{ K} \]
\[ \eta_{\text{HE}} = 1 - \frac{T_L}{T_H} = 1 - \frac{313.15}{450} = 0.304 \]
\[ \dot{W} = \eta \dot{Q}_H \Rightarrow \dot{Q}_H = \frac{\dot{W}}{\eta} = \frac{2.5}{0.304} = 8.224 \text{ kW} \]
\[ \dot{Q}_H = 0.2 \text{ A} \Rightarrow A = \frac{\dot{Q}_H}{0.2} = 41 \text{ m}^2 \]
7.33 We wish to produce refrigeration at −30°C. A reservoir, shown in Fig. P7.33, is available at 200°C and the ambient temperature is 30°C. Thus, work can be done by a cyclic heat engine operating between the 200°C reservoir and the ambient. This work is used to drive the refrigerator. Determine the ratio of the heat transferred from the 200°C reservoir to the heat transferred from the −30°C reservoir, assuming all processes are reversible.

Solution: Equate the work from the heat engine to the refrigerator.

\[
\frac{Q_{H1}}{Q_{L2}} = \left( \frac{T_0 - T_L}{T_L} \right) \left( \frac{T_H}{T_H - T_0} \right) = \left( \frac{60}{243.2} \right) \left( \frac{473.2}{170} \right) = 0.687
\]

7.34 A combination of a heat engine driving a heat pump (similar to Fig. P7.33) takes waste energy at 50°C as a source \( Q_{W1} \) to the heat engine rejecting heat at 30°C. The remainder \( Q_{W2} \) goes into the heat pump that delivers a \( Q_H \) at 150°C. If the total waste energy is 5 MW find the rate of energy delivered at the high temperature.

Solution:

Waste supply: \( \dot{Q}_{W1} + \dot{Q}_{W2} = 5 \text{ MW} \)

Heat Engine:
\[
\dot{W} = \eta \dot{Q}_{W1} = (1 - T_{L1}/T_{H1}) \dot{Q}_{W1}
\]

Heat pump:
\[
\dot{W} = \dot{Q}_H/\beta_{HP} = \dot{Q}_{W2}/\beta'
\]
\[
= \dot{Q}_{W2} / [T_{H1} / (T_H - T_{H1})]
\]

Equate the two work terms:
\[
(1 - T_{L1}/T_{H1}) \dot{Q}_{W1} = \dot{Q}_{W2} \times (T_H - T_{H1}) / T_{H1}
\]

Substitute \( \dot{Q}_{W1} = 5 \text{ MW} - \dot{Q}_{W2} \)
\[
(1 - 303.15/323.15)(5 - \dot{Q}_{W2}) = \dot{Q}_{W2} \times (150 - 50) / 323.15
\]

20 (5 - \( \dot{Q}_{W2} \)) = \( \dot{Q}_{W2} \times 100 \) \( \Rightarrow \dot{Q}_{W2} = 0.8333 \text{ MW} \)

\( \dot{Q}_{W1} = 5 - 0.8333 = 4.1667 \text{ MW} \)

\( \dot{W} = \eta \dot{Q}_{W1} = 0.06189 \times 4.1667 = 0.258 \text{ MW} \)

\( \dot{Q}_H = \dot{Q}_{W2} + \dot{W} = 1.09 \text{ MW} \)

(For the heat pump \( \beta' = 423.15 / 100 = 4.23 \))