ME 24-221
Thermodynamics I

Solution to Assignment No: 8
Due Date: November 3, 2000
Fall 2000
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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:

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = 1 - 400/1000 = 0.6$$

$$\eta_{eng} = W/Q_H = 200/325 = 0.615 > \eta_{Carnot}$$

This is **impossible.**

7.23 An inventor has developed a refrigeration unit that maintains the cold space at –10°C, while operating in a 25°C room. A coefficient of performance of 8.5 is claimed. How do you evaluate this?

Solution:

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

$$8.5 > \beta_{Carnot} \Rightarrow \textbf{impossible claim}$$

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:

$$T_H = 450 \text{ K} \qquad T_L = 40\ ^oC = 313.15 \text{ K}$$

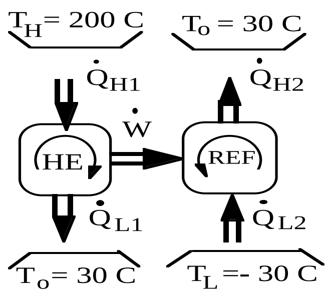
$$\eta_{HE} = 1 - T_L / T_H = 1 - 313.15 / 450 = 0.304$$

$$\dot{W} = \eta\, \dot{Q}_H \quad => \quad \dot{Q}_H = \dot{W} / \eta = 2.5 / 0.304 = 8.224 \text{ kW}$$

$$\dot{Q}_H = 0.2\, A \quad => \quad A = \dot{Q}_H / 0.2 = \mathbf{41\ m^2}$$

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.



$$W = Q_{H1}\left(\frac{T_H - T_0}{T_H}\right)$$

also

$$W = Q_{L2}\left(\frac{T_0 - T_L}{T_L}\right)$$

$$\frac{Q_{H1}}{Q_{L2}} = \left(\frac{T_o - T_L}{T_L}\right)\left(\frac{T_H}{T_H - T_o}\right) = \left(\frac{60}{243.2}\right)\left(\frac{473.2}{170}\right) = \mathbf{0.687}$$

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: $\dot{Q}_{W1} + \dot{Q}_{W2} = 5$ MW

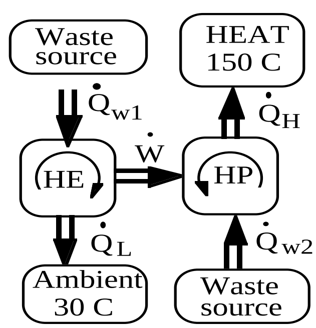
Heat Engine:

$\dot{W} = \eta\, \dot{Q}_{W1} = (1 - T_{L1} / T_{H1})\, \dot{Q}_{W1}$

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 $\dot{Q}_{W1} = 5\text{ MW} - \dot{Q}_{W2}$

$$(1 - 303.15/323.15)(5 - \dot{Q}_{W2}) = \dot{Q}_{W2} \times (150 - 50) / 323.15$$

$20\,(5 - \dot{Q}_{W2}) = \dot{Q}_{W2} \times 100$ => $\dot{Q}_{W2} = 0.8333$ MW

$\dot{Q}_{W1} = 5 - 0.8333 = 4.1667$ MW

$\dot{W} = \eta\, \dot{Q}_{W1} = 0.06189 \times 4.1667 = 0.258$ MW

$\dot{Q}_H = \dot{Q}_{W2} + \dot{W} =$ **1.09 MW**

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