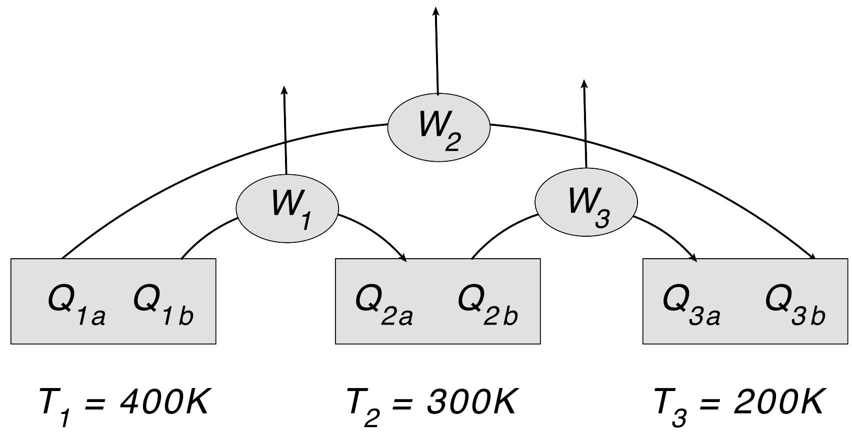
Problem 5-7 solution



(a)
We assume that the engines are Carnot engines, then

$$\begin{aligned} Q_{2a} &= \frac{T_2}{T_1}Q_{1b} = \frac{3Q_{1b}}{4}, \quad Q_{3b} = \frac{T_3}{T_1}Q_{1a} = \frac{Q_{1a}}{2}, \quad Q_{3a} = \frac{T_3}{T_2}Q_{2b} = \frac{2Q_{2b}}{3} \\ \Rightarrow W_1 &= Q_{1b} - Q_{2a} = \frac{Q_{1b}}{4}, \quad W_2 = Q_{1a} - Q_{3b} = \frac{Q_{1a}}{2}, \quad W_3 = Q_{2b} - Q_{3a} = \frac{Q_{2b}}{3} \end{aligned}$$

Also,

$$\begin{aligned} Q &= Q_{1a} + Q_{1b} = 1200J \\ W &= W_1 + W_2 + W_3 = \frac{Q_{1a}}{2} + \frac{Q_{1b}}{4} + \frac{Q_{2b}}{3} = 200J \end{aligned}$$

We get

$$\begin{aligned} W &= \frac{Q_{1a}}{2} + \frac{Q_{1b}}{4} + \frac{Q_{2b}}{3} = \frac{Q_{1a} + Q_{1b}}{2} - \frac{Q_{1b}}{4} + \frac{Q_{2b}}{3} = \frac{Q}{2} - \frac{Q_{2a}}{3} + \frac{Q_{2b}}{3} \\ \Rightarrow \quad Q_{2a} - Q_{2b} &= 3\left(\frac{Q}{2} - W\right) = 1200J \end{aligned}$$

$\Rightarrow$ 1200J is absorbed at the second reservoir.

Next, from the overall conservation of energy

$$W = Q_{1a} + Q_{1b} - Q_{2a} + Q_{2b} - Q_{3a} - Q_{3b} = -Q_{3a} - Q_{3b} = 200J \quad \Rightarrow \quad -Q_{3a} + Q_{3b} = -200J$$

$\Rightarrow$ 200J of heat is rejected at the third reservoir

(b), (c)

$$\Delta S_1 = -\frac{Q1a + Q_{1b}}{T_1} = -3\frac{J}{K}, \quad \Delta S_2 = \frac{Q2a - Q_{2b}}{T_2} = 4\frac{J}{K}, \quad \Delta S_3 = \frac{Q3a + Q_{3b}}{T_3} = -1\frac{J}{K}$$

$\Rightarrow \Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 = 0$ as it should be for a reversible process.

Problem 5-13 solution

(a): heat engine

(b)

$$\begin{aligned} Q_{ab} &= 0, \\ Q_{bc} &= T_2(s_2 - s_1) = 250R \simeq 2.1 \times 10^6 J, \\ Q_{cd} &= 0, \\ Q_{da} &= T_1(s_1 - s_2) = -100R \simeq -8.3 \times 10^5 J \end{aligned}$$

(c)

$$\eta \;=\; \frac{W}{Q_{bc}} \;=\; \frac{Q_{bc}+Q_{da}}{Q_{bc}} \;=\; \frac{T_2-T_1}{T_2} \;=\; 60\%$$

(d)
In reverse

$$c \;=\; \frac{Q_{ad}}{Q_{bc}-Q_{ad}} \;=\; \frac{T_2}{T_2-T_1} \;=\; \frac{2}{3} \;\simeq\; 67\%$$