「Thermodynamics」 第三章末問題の略解

1, The work L performed by the system in Carnot cycle of the ideal gas is

$$L = nR(T_H - T_L)\ln\frac{V_2}{V_1}\,,$$

where T_H is temperature of high temperature heat bath, T_L is temperature of low temperature heat bath, V_1 is the initial volume and V_2 is the final volume in the isothermal process at high temperature. Thus, we get

$$\begin{aligned} L &= 1[\mathrm{mol}]\cdot 8.3[\mathrm{J/(K\cdot mol)}]\cdot(400-300)[\mathrm{K}]\cdot\ln\frac{5[\mathrm{l}]}{1[\mathrm{l}]} \\ &= 1.3\times 10^3[\mathrm{J}]\,. \end{aligned}$$

Since this process is cycle, the initial state and the final state are identical. Hence, the energy variation of the system is 0. We comprehend the heat exchanged heat bath is equal to L.

2, The efficiency η of heat engine which work between low temperature of T_1 heat source and high temperature of T_2 heat source satisfy

$$\eta \le 1 - \frac{T_1}{T_2}\,.$$

Therefore, the maximum efficiency $\eta_{\max}$ is

$$\begin{aligned} \eta_{\max} &= 1 - \frac{(273+18)[\mathrm{K}]}{(273+400)[\mathrm{K}]} \\ &= 0.567\,. \end{aligned}$$

3, When we run Carnot cycle in reverse, the system obtains the heat Q_1 from low tempareture heat source as the work L is provided. In this process, L was written

$$\begin{aligned} L &= Q_1\frac{(T_2 - T_1)}{T_1} \\ &= Q_1\left(\frac{T_2}{T_1} - 1\right)\,. \end{aligned}$$

Since,

$$100^\circ\mathrm{F} = 311\mathrm{K}\,,$$
$$0^\circ\mathrm{F} = 255\mathrm{K}\,,$$

we find the minimum work

$$\begin{aligned} L &= 1[\mathrm{cal}] \cdot \left(\frac{311[\mathrm{K}]}{255[\mathrm{K}]} - 1 \right) \\ &= 0.91[\mathrm{J}]\,. \end{aligned}$$