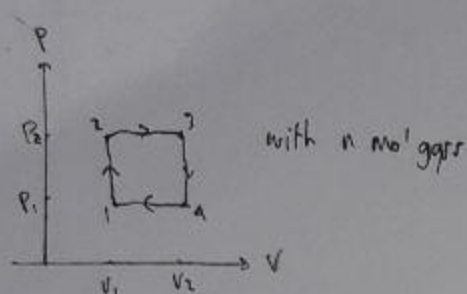


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### Problem 1



a. Determine  $T_1, T_2, T_3, T_4$

Process 1 to 2 and 3 to 4 is isochoric process. Therefore

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{Also process 3 and 4 is isochoric.} \rightarrow \frac{P_3}{T_3} = \frac{P_4}{T_4} \Rightarrow \frac{P_2}{T_3} = \frac{P_1}{T_4}$$

Process 2 and 3 is isobaric process. therefore

$$\frac{V_2}{T_2} = \frac{V_3}{T_3} \quad \text{Also 1 and 4 is isobaric.} \rightarrow \frac{V_1}{T_1} = \frac{V_4}{T_4} \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_4}$$

$$\text{Since } \frac{P_1}{P_2} = \frac{T_1}{T_2} \quad \text{and} \quad \frac{P_1}{P_2} = \frac{T_4}{T_3} \text{ so, } \frac{T_1}{T_2} = \frac{T_4}{T_3} \Rightarrow T_1 \cdot T_3 = T_2 \cdot T_4$$

$$\text{also } \frac{V_1}{V_2} = \frac{T_2}{T_3} \quad \text{and} \quad \frac{V_1}{V_2} = \frac{T_1}{T_4} \text{ so, } \frac{T_2}{T_3} = \frac{T_1}{T_4} \Rightarrow T_1 \cdot T_3 = T_2 \cdot T_4$$

$$\text{Therefore, } T_1 = \frac{T_2 \cdot T_4}{T_3}, \quad T_2 = \frac{T_1 \cdot T_3}{T_4}, \quad T_3 = \frac{T_2 \cdot T_4}{T_1}, \quad T_4 = \frac{T_1 \cdot T_3}{T_2}$$

b. Determine  $\Delta E_{th12}, \Delta E_{th23}, \Delta E_{th34}, \Delta E_{th41}$

Process 1 and 2 and 3 and 4 are isochoric. Therefore

$$\Delta E_{th12} = n \cdot C_v (T_2 - T_1)$$

$$\Delta E_{th34} = n \cdot C_v (T_4 - T_3)$$

Process 2 and 3 and 4 and 1 are isobaric. therefore

$$\Delta E_{th23} = n \cdot C_p (T_3 - T_2)$$

$$\Delta E_{th41} = n \cdot C_p (T_1 - T_4)$$

c. Determine the work done  $W_{12}$ ,  $W_{23}$ ,  $W_{34}$ ,  $W_{41}$

Isobaric

$$\begin{aligned} W_{12} &= 0 \\ W_{34} &= 0 \end{aligned} \quad \left. \vphantom{\begin{aligned} W_{12} &= 0 \\ W_{34} &= 0 \end{aligned}} \right\} \text{Because of the isochoric process.}$$

$$\begin{aligned} W_{12} &= nR(T_2 - T_1) \\ W_{41} &= nR(T_1 - T_4) \end{aligned} \quad \left. \vphantom{\begin{aligned} W_{12} &= nR(T_2 - T_1) \\ W_{41} &= nR(T_1 - T_4) \end{aligned}} \right\} \text{Because of isobaric process.}$$

d. Determine the  $Q_{12}$ ,  $Q_{23}$ ,  $Q_{34}$ ,  $Q_{41}$

$$\begin{aligned} Q_{23} &= n(C_v + R)(T_3 - T_2) \\ Q_{41} &= n(C_v + R)(T_1 - T_4) \end{aligned} \quad \left. \vphantom{\begin{aligned} Q_{23} &= n(C_v + R)(T_3 - T_2) \\ Q_{41} &= n(C_v + R)(T_1 - T_4) \end{aligned}} \right\} \text{Because of isobaric process}$$

$$\begin{aligned} Q_{12} &= nC_v(T_2 - T_1) \\ Q_{34} &= nC_v(T_4 - T_3) \end{aligned} \quad \left. \vphantom{\begin{aligned} Q_{12} &= nC_v(T_2 - T_1) \\ Q_{34} &= nC_v(T_4 - T_3) \end{aligned}} \right\} \text{Because of isochoric process}$$

E Determine  $\eta = W/Q$ . Integrate  $P_1$ ,  $P_2$ ,  $V_1$ ,  $V_2$ ,  $n$ ,  $R$ ,  $C_v$

$$\eta = \frac{W}{Q} = \frac{nR(T_2 - T_1 + T_1 - T_4)}{nR(T_2 - T_1 + T_3 - T_2 + T_4 - T_3 + T_1 - T_4)}$$