Tutorial Sheet-5

Second Law of Thermodynamics

1. A heat engine, one heat pump, and a refrigerator are embedded between two heat reservoirs- one at 600 K while the other at 300 K. Determine:

(i) The efficiency of the heat engine.

(ii) The COP of the heat pump.

(iii) The COP of the refrigerator. **[Ans. 50%, 2, 1]**

2. A cold storage unit of 30 ton of refrigeration capacity operates between 263 K and 303 K. Determine the monthly cost of running the plant if it is run 16 h a day and if the plant sports half of the COP of a carnot cycle. (Take 30 days a month, cost of power = Rs. 5.25 per Kwh]. (Given : 1 ton of refrigeration = 3.5 kW) **[Ans. Rs. 80,486]**

3. A reversible heat engine operates in a carnot cycle between two temperature limits 260°C and 21°C. The overall expansion ratio is 15. Determine

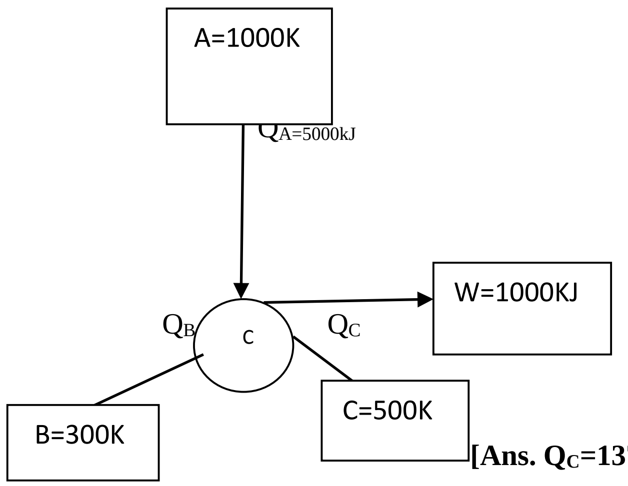
   (i) The volume ratios of the isothermal and adiabatic process.

   (ii) The thermal efficiency of the cycle. (γ = 1.4) **[Ans. 3.39, 44.8%]**

4. A reversible heat engine operates between 600°C and 40°C. This engine drives a reversible refrigerator operating between 40°C and –18°C, still there is a net work output of 370 kJ. The heat received by the engine is 2100 kJ. Determine the desired effect of refrigerator.

[Ans.: Q_3 = 4295 kJ]

5. Figure shows a system undergoing a reversible cycle, during which it exchanges heat with three thermal reservoir and develops 1000 kJ of work. Find the magnitude and direction of Q_B and Q_C.



[Ans. Q_C=13750KJ, Q_B=9750KJ]

6. Two reversible heat engines A and B are arranged in series. Heat engine A rejects heat directly to B. Engine A receives 300 kJ of heat at a temperature of 427°C from high temperature source while engine B rejects heat to a sink at 7°C. If the work output of A is two times that of B. Find

(i) Intermediate temperature of A and B. (ii) Efficiency of each engine. (iii) Heat rejected by engine A i.e., Heat received B. (iv) Heat rejected to sink.

[Ans. 420 K, η_A = 40%, η_B = 33.33%, 180 kJ, 120 kJ]

7. An ideal gas engine operating on a cycle which when represented on a P-V diagram is a rectangle as shown in figure. If the system is the closed system, then show that the efficiency of the engine is

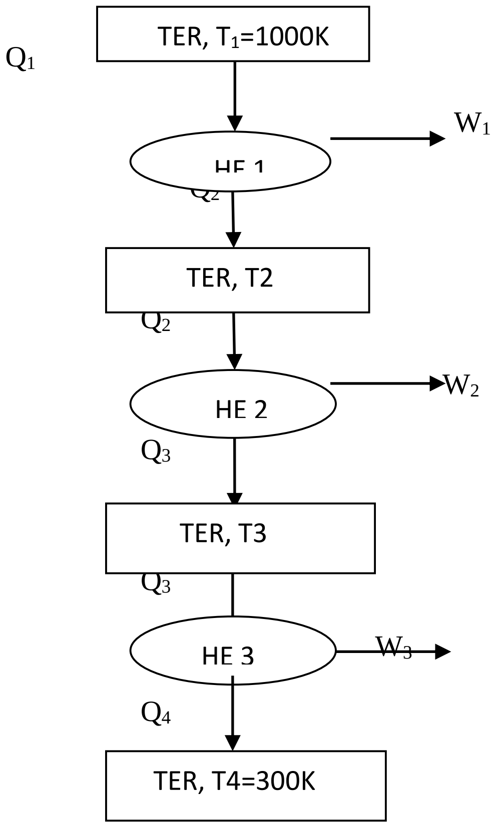
$$\eta=\frac{\gamma-1}{\left(\frac{\gamma P_{max}}{P_{max}-P_{min}}\right)+\left(\frac{V_{min}}{V_{max}-V_{min}}\right)}$$

8. A house is to be maintained at 25°C is summer as well as in winter. For this purpose it is proposed to use a reversible device as a refrigerator is summer and heat pump in winter. The energy loss as heat from roof as well as walls is estimated as 5 kW/°C temperature difference between and surrounding conditions. Calculate the power required to drive the device in summer and winter conditions. The ambient temp. is 40°C is summer and 3°C in winter.

[Ans. 3.78 kW, 8.12 kW]

9. A carnot engine is working between temperature limits of T_1 and T_2. Its efficiency can be increased by either increasing source temperature or by decreasing sink temperature. Find which is more effective. **[Ans. Decreasing sink temp.]**

10. Three carnot heat engines - HE1, HE2 and HE3 are lined up in a series as shown in figure. They are embedded between two end temperature limits of 1000 K and 300 K. They produce the work output in the ratio of $W_1 : W_2 : W_3 = 4 : 3 : 2$. Determine (i) T_2 (ii) T_3.



[Ans. T_2=688.88k, T_3=455.55]