Model Question Paper

Subject :- Engineering Thermodynamics

Q.N.1 :- Explain the difference between a heat Engine, Refrigerator and Heat pump.

Q.N.2 A power plant using Steam as working fluid operates on a Rankine Cycle. The boiler and Condenser pressures are 30 bar and 1 bar. The condition of steam entering the prime-mover is dry and Saturated. Find the thermal efficiency of the cycle a) neglecting the feed pump work and b) considering the feed pump work.

Q.N.3 An open Cycle gas turbine plant uses heavy oil as fuel. The maximum pressure and temp^{o} in the cycle are 5 bar and 650°C. The pressure and temp^{o} of air entering into the compressor are 1 bar and 27°C. The exit pressure of the turbine is also 1 bar. Assuming isentropic efficiencies of compressor and turbine to be 80% and 85% respecti find the thermal efficiency of the Brayton Cycle.

A:F radio used is 60:1

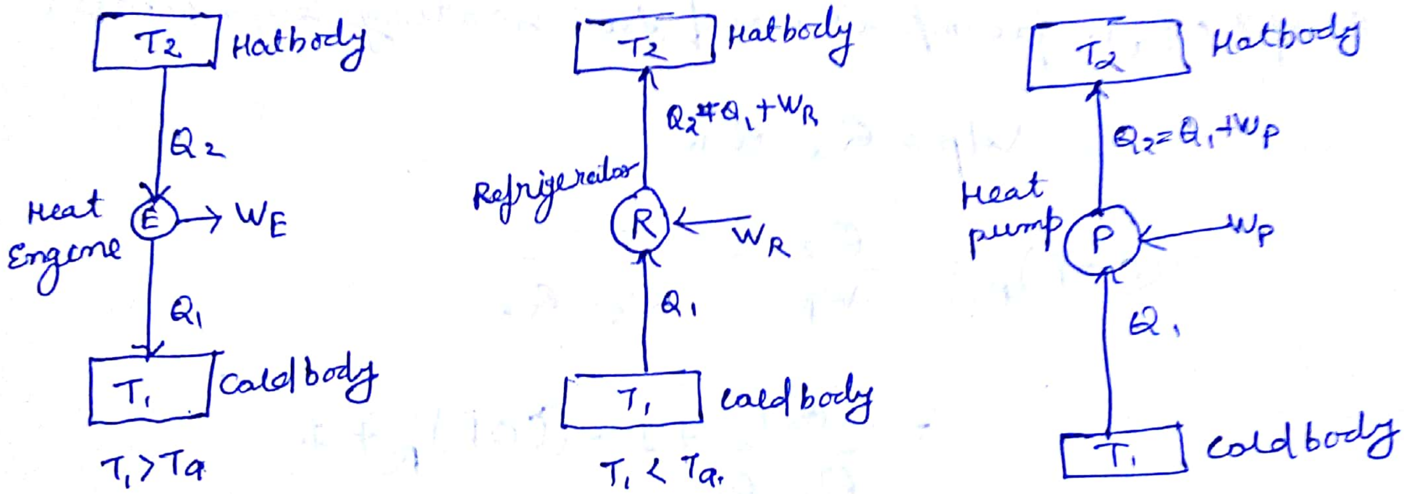
$C_p = 1 kJ/kg°C$, $\gamma = 1.4$

Answer of Model Question Paper

Subject:→ Engineering thermodynamics

Ans 1 :→ In a heat engine, the heat supplied to the engine is converted into useful work. If Q_2 is the heat supplied to the engine and Q_1 is the heat rejected from the engine as shown in fig. the net work done by the engine is given by

$$W_E = Q_2 - Q_1$$



The performance of a heat engine is

$$\eta_E \ (COP)_E = \frac{\text{Workdone}}{\text{Heat Supplied}} = \frac{W_E}{Q_2} = \frac{Q_2 - Q_1}{Q_2}$$

Refrigerator is reversed heat engine which either cool or maintain the temperature of a body (T_1) lower than the atmospheric temp^r (T_a). This is done by extracting heat (Q_1) from cold body and delivering it to a hot body (Q_2).

$$W_R = Q_2 - Q_1$$

and its

$$COP = \frac{Q_1}{W_R} = \frac{Q_1}{Q_2 - Q_1}$$

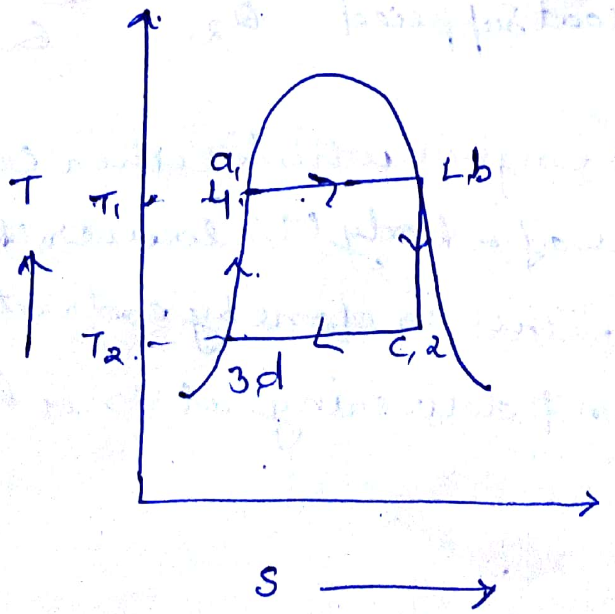
pump also extracts heat (Q_1) from cold body and delivers it to a hot body. there is no difference b/w the cycle of operation of a heat pump and a refrigerator. The main difference b/w the two is in their operating tempr. the pump operates b/w the hot body tempr (T_2) and the atmospheric tempr (T_a). pump is used for heating in winter

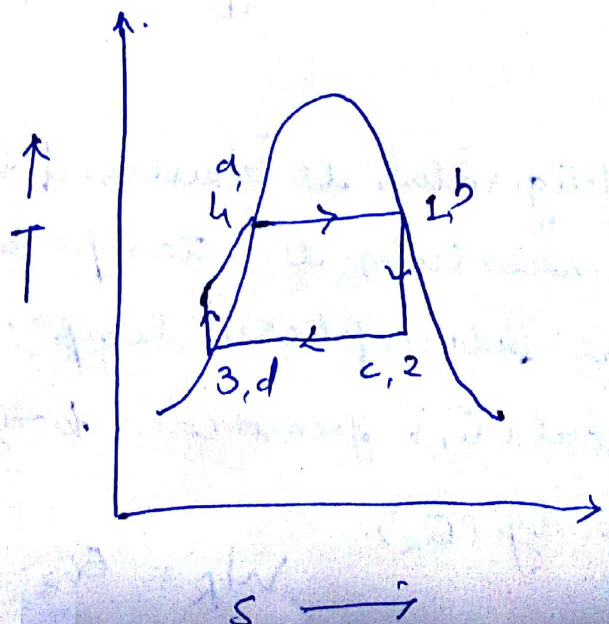
$$W_P = Q_2 - Q_1$$

$$(COP)_P = \frac{Q_2}{W_P} = \frac{Q_2}{Q_2 - Q_1}$$

$$= \frac{Q_1}{Q_2 - Q_1} + 1 = (COP)_R + 1$$

Ans 2 :





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a) Total heat at the point 'b' at pressure 30 bar is taken from the steam table

$$h_1 = 2796 \text{ kJ/kg}$$

for finding the dryness-fraction of steam at the point 'c', we can equate the entropies

At p^r 30 bar = At p^r 1 bar.

$$\log_e\left(\frac{T_{s1}}{273}\right) + \frac{h_{fg1}}{T_{s1}} = \log_e\left(\frac{T_{s2}}{273}\right) + \frac{x h_{fg2}}{T_{s2}}$$

above values from steam table

$$\log_e\left(\frac{232.2+273}{273}\right) + \frac{1797}{(232.2+273} = \log_e\left(\frac{99.1+273}{273}\right) + \frac{x_2 \times 2253}{(99.1+273)}$$

$$0.62 + 3.55 = 0.307 + 606 x_2$$

$$\boxed{x_2 = 0.637}$$

Total heat at point 'c'

$$h_2 = h_{f2} + x h_{fg2} = 414.6 + 0.637 \times 2253$$

$$= 1849.8 \text{ kJ/kg}$$

where h_{f2} is the feed water enthalpy at 1 bar

$$\eta_r = \frac{h_1 - h_2}{h_1 - h_{f2}} = \frac{2796 - 1849.8}{2796 - 414.6} \times 100$$

$$\eta_r = 39.55\%.$$

b) When the pump work is considered, the Rankine efficiency is given by

$$\eta_r = \frac{(h_1 - h_2) - W_p}{h_1 - (h_2 + W_p)}$$

where W_p = pump work.

$$W_p = \frac{V_{f_2}(P_1 - P_2)}{J}$$

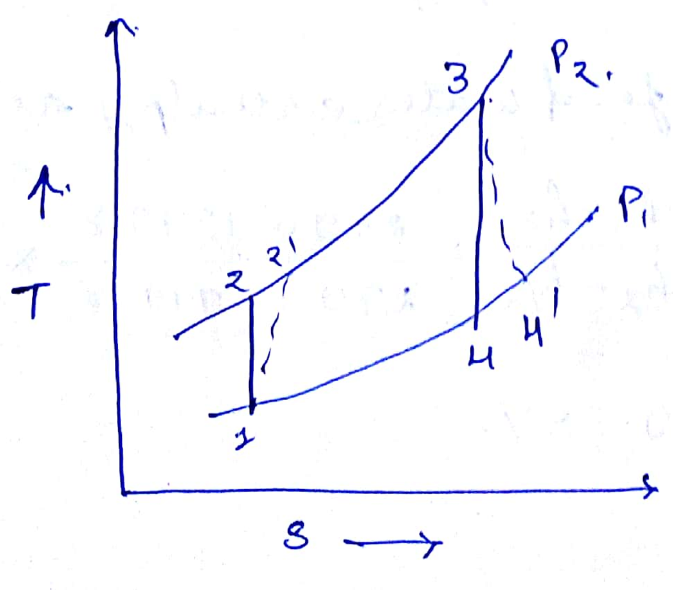
$V_{w_2} = 0.001043\ m^3/kg$ (steam table)

$$W_p = \frac{0.001043 \times 10^5 (30 - 1)}{1000 \times 1} = 3.02\ kJ$$

$$\eta_r = \frac{(2796 - 1840.8) - 3.02}{(2796 - 414.6) - 3.02} \times 100$$

$$\eta_r = 38.57\%$$

Ans 3 The Processes are represented on the cycle as shown in figure.



$P_1 = 1$ bar $\quad T_1 = 27 + 273 = 300$ K

$P_2 = 5$ bar $\quad T_3 = 650 + 273 = 923$ K

$$T_2' = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$= 300 (5)^{0.285}$$

$$= 474 \text{ K}$$

$$\eta_c = \frac{T_2' - T_1}{T_2 - T_1}$$

$$0.8 = \frac{474 - 300}{T_2 - 300}$$

$$T_2 = 518 \text{ K.}$$

$$(T_4)' = T_3 \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = 923 \left(1/5\right)^{0.285}$$

$$T_4' = 585 \text{ K}$$

$$\eta_t = \frac{T_3 - T_4}{T_3 - T_4'}$$

$$0.85 = \frac{923 - T_4}{923 - 584}$$

$$T_4 = 635 \text{ K.}$$

The thermal efficiency of the cycle is given by

$$\eta_{th} = \frac{C_{pg}(m_a + m_f)(T_3 - T_4) - C_{pa} m_a (T_2 - T_1)}{C_{pg}(m_a + m_f)(T_3 - T_2)}$$

$$\eta_{th} = \frac{\left(\frac{m_a}{m_f} + 1\right)(T_3 - T_4) - \frac{m_a}{m_f}(T_2 - T_1)}{\left(\frac{m_a}{m_f} + 1\right)(T_3 - T_2)}$$

$$\eta_{th} = \frac{(60+1)(923-635) - 60(518-300)}{(60+1)(923-518)}$$

$$\boxed{\eta_{th} = 18\%}$$