Q(1(b) -10M

c) We know that a polytropic process for the Non flow Energy Eq^n.

$$Q = W + \Delta U$$

$$Q = \frac{P_1 V_1 - P_2 V_2}{n-1} + m c_v (T_2 - T_1)$$

We know that : $c_v = \frac{R}{\gamma - 1}$ & $P_1 V_1 = mRT_1$

$$\therefore Q = \frac{P_1 V_1 - P_2 V_2}{n-1} + \frac{mR}{\gamma - 1}(T_2 - T_1)$$

$$Q = \frac{P_1 V_1 - P_2 V_2}{n-1} + \frac{P_2 V_2 - P_1 V_1}{\gamma - 1} = \frac{P_1 V_1 - P_2 V_2}{n-1} - \left(\frac{P_1 V_1 - P_2 V_2}{\gamma - 1}\right)$$

$$Q = \frac{P_1 V_1 - P_2 V_2}{n-1}\left[1 - \frac{n-1}{\gamma - 1}\right]$$

$$Q = W\left[\frac{\gamma - n}{\gamma - 1}\right]$$

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Q 1(b) - 10 Marks → NOTES

Q2 (c) - 10 M

Ans Given at Initial cond^n

$m = 2kg$

$P_1 = 200kPa$

$T_1 = 60°C = 333K$

* $(1) - (2) \Rightarrow$ Gas is expanded at constant pressure

$V_2 = 2V_1$, $P_2 = P_1$

$(2) - (3) \Rightarrow$ Gas is heated at constant volume until pressure is doubled

$V_3 = V_2 = 2V_1$, $P_3 = 2P_1$

To find

W_T ie $W_{12} + W_{23}$ & T_3

* $W_{12} = \int_1^2 P\,dV = P\int_1^2 dV = P\left[V_2 - V_1\right]$

$W_{12} = P\left[2V_1 - V_1\right] = P_1V_1$

& we know

$P_1V_1 = mRT_1$

$P_1V_1 = 2 \times 0.6 \times 333$ kJ

$\boxed{W_{12} = 399.6 kJ}$

(a)

$W_{23} = 0$ {constant vol. process} $\Rightarrow$ $\boxed{W_T = W_{12} + \cancel{W_{23}}^{0} = 399.6kJ}$

(b) for T_3 ; $P_3 V_3 = mRT_3$

$$2P_1 \cdot 2V_1 = mRT_3$$

$$4(P_1V_1) = 2 \times 0.6\, T_3 \Rightarrow T_3 = \frac{4 \times 399.6}{2 \times 0.6} \text{ OR } \{4 \times 333\}$$

$$\boxed{T_3 = 1332K = 1059^\circ C}$$

Q (3)(a) - 5M

* Assumptions Made for the Derivatⁿ of efficiency of Carnot cycle

(1) A hot source i.e Heat Reservoir of infinite capacity at Maxᵐ constant Tempʳ T_1

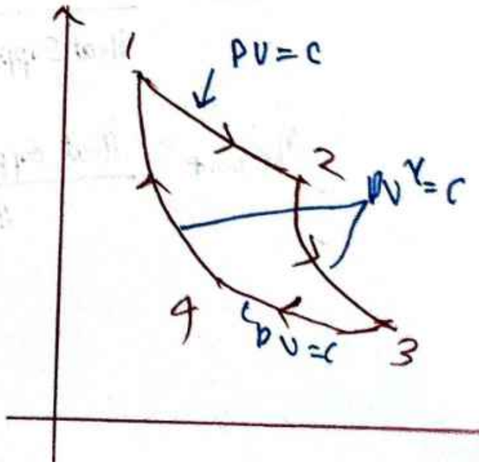
(b) A cold sink i.e heat Reservoir of infinite capacity at minᵐ constant tempʳ

(c) working fluid is perfect gas

(d) A frictionless piston sliding in a perfectly sealed cylinder, Both piston & cylinder Being perfect insulators.

(e) A perfect conducting cylinder head

(f) Since all processes have to be fully Reversible, it follows that they must be performed infinitely slowly



• 1-2, Isothermal heat Supplied

$$Q_{12} = RT_1 \ln \frac{V_2}{V_1}$$

2-3, Adiabatic Compression, $\frac{T_2}{T_3} = \left(\frac{V_3}{V_2}\right)^{\gamma-1}$

3-4, Isothermal Heat Rejecⁿ

$$Q_{34} = RT_2 \ln \frac{V_3}{V_4} \quad — \quad (*)$$

4-1 Adiabatic Compression

$$\cancel{\frac{T_1}{T_2} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}} \quad \left(\frac{V_1}{V_4}\right)^{\gamma-1} = \frac{T_4}{T_1} \Rightarrow \frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$$

as $T_1 = T_2$ & $T_3 = T_4$

$$\left\{\frac{T_2}{T_3} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} = \left(\frac{V_3}{V_2}\right)^{\gamma-1}\right\}$$

$$\frac{V_4}{V_1} = \frac{V_3}{V_2} \Rightarrow \left\{\frac{V_3}{V_4} = \frac{V_2}{V_1}\right\}$$

- Putting ~~(2-3~~ in — (*)

$$Q_{34} = RT_2 \ln \frac{V_2}{V_1}$$

- But the efficiency of the carnot cycle can be written as

$$\eta_{carnot} = \frac{\text{Work Done}}{\text{Heat Supplied}}$$

$$\eta_{carnot} = \frac{\text{Heat Supplied} - \text{Heat Rejected}}{\text{Heat Supplied.}}$$

$$\eta_{carnot} = \frac{RT_1 \ln\frac{V_2}{V_1} - RT_2 \ln\frac{V_2}{V_1}}{RT_1 \ln\frac{V_2}{V_1}}$$

$$\rightarrow \boxed{\eta_{carnot} = \frac{T_1 - T_2}{T_2}}$$

Q3 (b) → 5M , DUAL CYCLE

Q3 (c) → 10M → Ex - 10.3

Q4 (c) → 10M

Ans Given BP = 100 kW

N = 400 rpm

BMEP = 850 kPa

Bsfc = 0.335 kg/kWhr

C.V = 48500 kJ/kg

Stroke/Bore = 1.25 → $\frac{L}{D} = 1.25 \Rightarrow L = 1.25D$

$\eta_{mech} = 80\%$

- Brake power = $pLAnK$

$100 = 850 \times 1.25D \times \frac{\pi}{4} \times D^2 \times \frac{400}{60 \times 2}$, $n = \frac{N}{2}$ for 4 stroke

$D^3 = 0.03595$

$D = 0.33\ m = 330\ mm$

$L = 1.25D = 1.25 \times 330 = 412.5\ mm$

$$\boxed{\begin{aligned} D &= 330\ mm \\ L &= 412.5\ mm \end{aligned}}$$

$$\eta_{BTH} = \frac{3600}{b.sfc \times CV} = \frac{3600}{0.335 \times 43500}$$

(Kg/kwh)

$$\boxed{\eta_{Bth} = 0.247 = 24.7\%}$$

$$\eta_{mech} = \frac{BP}{IP}$$

$$0.8 = \frac{100}{IP} \Rightarrow \boxed{IP = 125\,kW}$$

$$IP = P_m LA\frac{N}{2}.K$$

$$125 = P_m \times 0.4125 \times \frac{\pi}{4} \times (0.33)^2 \times \frac{400}{2\times 60}$$

$$\rightarrow \boxed{P_m = 1062.893\,kPa = 10.62\ Bar}$$

~~imep = 10.62 bar~~

$$\dot{m}_f = b.P \times Bsfc$$

$$\dot{m}_f = 100 \times 0.335$$

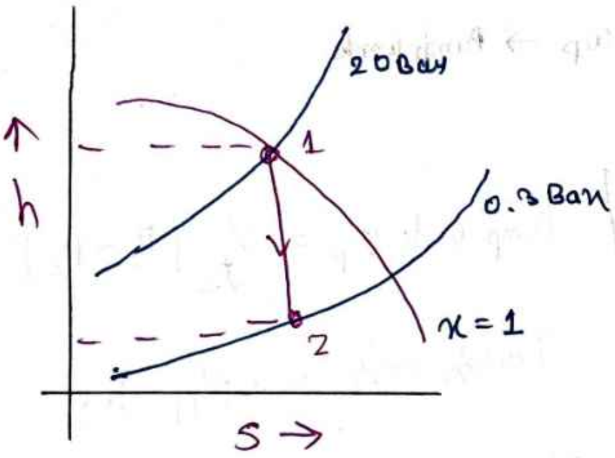
$$\boxed{\dot{m}_f = 33.5\,kg/h}$$

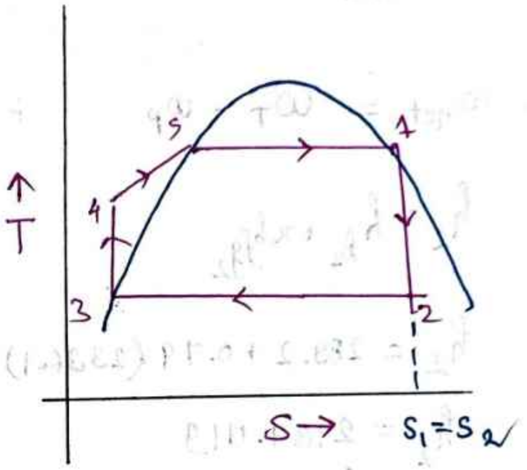
$$\eta_{ith} = \frac{3600}{\frac{\dot{m}_f}{I.P} \times CV} = \frac{3600}{\frac{33.5}{125} \times 43500}$$

$$\boxed{\begin{aligned}\eta_{ith} &= 0.3088 \\ &= 30.88\%\end{aligned}}$$

Q5(c)

Ans





At ① $P_1 = 20 Bar$, $x = 1$

$h_1 = h_{g_1} = 2800 kJ/kg$ [Mollier chart]

$S_1 = S_{g_1} = 6.3$ [Mollier chart]

At ② $P_2 = 0.3 Bar$

$h_{f_2} = 289.2$ kJ/kg , $h_{fg} = 2336.1 kJ/kg$

$S_{f_2} = 0.944 kJ/kgK$, $S_{fg_2} = 6.825 kJ/kgK$

$V_{f_2} = 0.001022 m^3/kg$, $\boxed{\begin{array}{l} S_2 = Sf_2 + x Sfg_2 \\ h_2 = h_{f_2} + x h_{fg_2} \end{array}}$

- for Rankine Cycle

$S_1 = S_2$

$6.341 = 0.944 + x \cdot \cancel{2336.1}\ 6.825$

$\boxed{x_2 = 0.79}$

- $\eta = \frac{W_{net}}{Q_{in}}$

$W_T \rightarrow$ Turbine work

$W_P \rightarrow$ Pump work

- $W_{net} = W_T - W_P$;

$h_2 = h_{f_2} + x h_{fg_2}$

$h_2 = 289.2 + 0.79(2336.1)$

$h_2 = 2134.719$

$W_T = h_1 - h_2$

$= 2799.5 - 2134.719$

$= 662.984$ kJ/kg

- due to Que. $W_P = 0$

$\therefore \eta = \frac{W_T - \cancel{W_P}^{0}}{Q_{in}}$

Pump work, $W_P = V_{f_2}(P_1 - P_2)$

Turbine work, $W_T = h_1 - h_2$

$\eta_R = \frac{W_T - W_P}{(h_1 - h_{f_2}) - W_P}$

$W_P = h_{f_4} - h_{f_3}$

if $W_P = 0$

$h_{f_4} = h_{f_3}$ & $h_{f_3} = h_{f_2}$

$\therefore h_{f_4} = 289.2$

$\eta = \frac{662.984}{2779.5 - 289.2} = \frac{662.984}{2510.3}$

$\eta = 0.2640$

$\boxed{\eta = 26.40\%}$

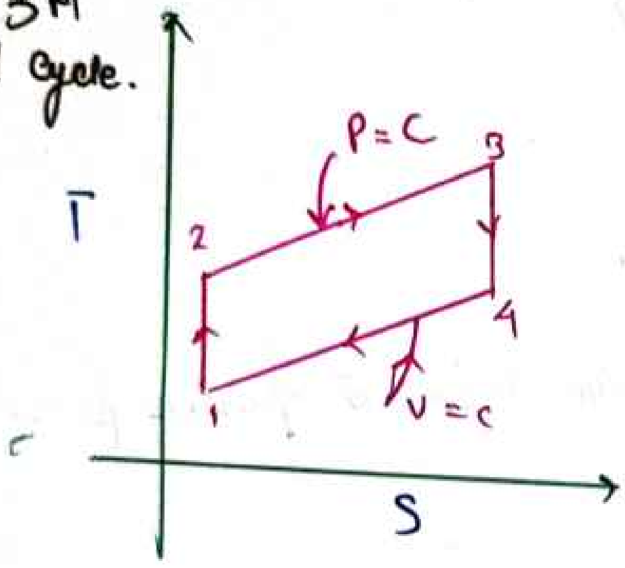
: Work Ratio $= \frac{W_T - W_P}{W_T}$

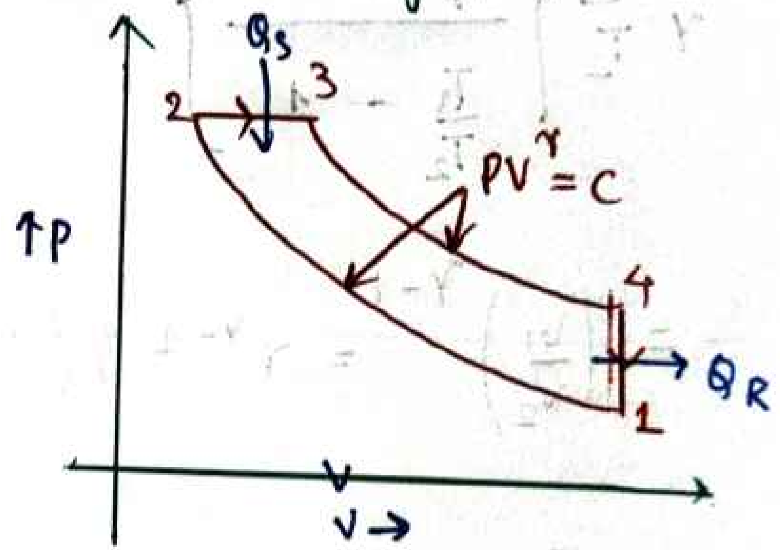
of uncontrolled combustion in Petrol engine.

- Self Ignition Temperature - Temp^r at which fuel starts to burn itself.

Q<(a)-5M

Diesel Cycle.





- Cycle that may be used approximate the operat^n of Compression Ignition IC engine is Diesel cycle.

- All processes are reversible

- The cycle is arranged as follows –

1 - 2 - Air is compressed adiabatically (Isentropically)

2 - 3 - Heat Added at Constant Pressure

(Heat Transfer to the air Replaces the fuel injecⁿ & combustⁿ of Actual engine)

3 - 4 - Air expands adiabatically.

4 - 1 , Heat is Rejected at constan Volume ; Heat is Rejected to a lower tempʳ Reservoir , completing the cycle.

- Compression ratio, r is the Volume ratio , $r = \frac{V_1}{V_2}$

- Cut-off Ratio is Defined as , $\rho = \frac{V_3}{V_2} = \frac{T_3}{T_2}$

- $Q_S = m c_p (T_3 - T_2)$, $Q_R = m c (T_4 - T_1)$

- Efficiency , $\eta = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H} = 1 - \frac{c_v}{c_p}\left(\frac{T_4 - T_1}{T_3 - T_2}\right)$

$$\eta = 1 - \frac{1}{\gamma}\frac{T_1}{T_2}\left\{\frac{\frac{T_4}{T_1} - 1}{\frac{T_3}{T_2} - 1}\right\} \quad — \quad (*)$$

Here $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} = r^{\gamma-1}$ & $\rho = \frac{T_3}{T_2}$ due to constant pressure process

$$\frac{T_4}{T_1} = \frac{T_4}{T_3} \times \frac{T_3}{T_2} \times \frac{T_2}{T_1}$$

$$\frac{T_4}{T_1} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} \times \frac{V_3}{V_2} \times \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= \left(\frac{V_3}{V_4} \times \frac{V_1}{V_2} \right)^{\gamma-1} \times \frac{V_3}{V_2} \quad \left\{ \text{Here } V_1 = V_4 \right\}$$

$$\boxed{\frac{T_4}{T_1} = \left(\frac{V_3}{V_2}\right)^{\gamma} = e^{\gamma}}$$

* Substituting values in eq ⊛

$$\eta = 1 - \frac{1}{\gamma (r)^{\gamma-1}} \left\{ \frac{e^{\gamma} - 1}{e - 1} \right\}$$

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}} \left\{ \frac{e^{\gamma} - 1}{\gamma (e-1)} \right\}$$

Q → 3(c) → 10M

Q In a steady flow system a substance flows at a rate of 300 kg/min. It enters at a pressure of 6 bar with a velocity of 300 m/s with specific internal energy 2000 kJ/kg & specific volume 0.4 m^3/kg. It leaves the system at a pressure of 0.1 MPa with a velocity of 150 m/s. Specific internal energy 1600 kJ/kg & specific volume 1.2 m^3/kg. The inlet is 10 m above the outlet. During its passage through the system a work transfer of 3MW to surrounding. Determine heat transfer in kJ/s.

Ans

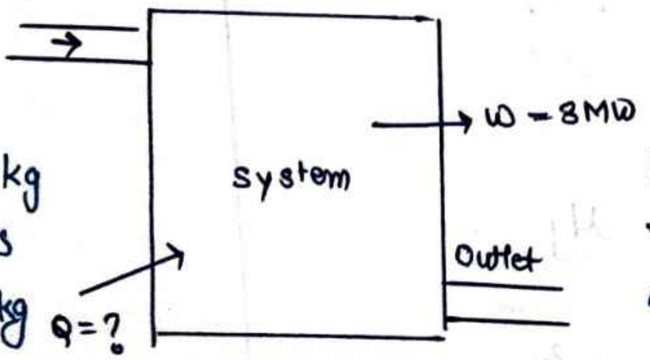
$P_1 = 6$ bar

$v_1 = 0.4\ m^3/kg$

$c_1 = 300$ m/s

$u_1 = 2000$ kJ/kg

$Z_1 = 10$



$P_2 = 0.1$ MPa

$v_2 = 1.2\ m^3/kg$

$c_2 = 150$ m/s

$u_2 = 1600$ kJ/kg

$z_2 = 0$

* Applying the steady flow Energy Eq^n, $E_{in} = E_{out}$.

$$m = 300\,kg/min = 5\,kg/s$$

$$\boxed{W = m\,w} \rightarrow 3000 = 5 \times w$$

$$\boxed{w = 600\ kJ/kg}$$

$$P_1 v_1 + u_1 + \frac{c_1^2}{2} + g z_1 + q = P_2 v_2 + u_2 + \frac{c_2^2}{2} + g z_2 + w$$

$$600 \times 0.4 + 2000 + \frac{300^2}{2 \times 1000} + \frac{9.81 \times 10}{1000} + q = 100 \times 1.2 + 1600 + \frac{150^2}{2 \times 1000} + 600$$

$$q = 46.1519 \text{ kJ/kg}$$

$$Q = q \times m$$

$$Q = 46.1519 \times 5 = 230.7595 \text{ (To the system)}$$