

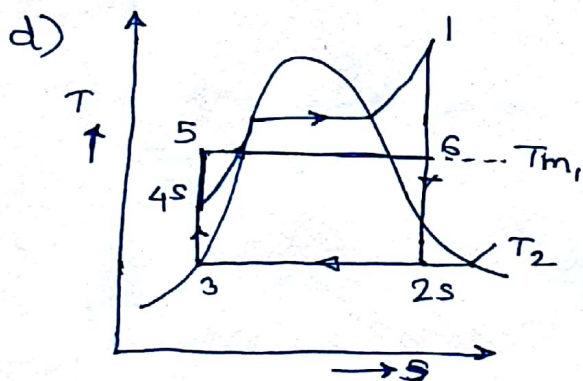
Q1

- a) Heat Engine
Refrigerator
Heat pump. } definition

$$\eta_{HE} = 1 - \frac{Q_2}{Q_1}, \quad (COP)_R = \frac{Q_2}{Q_1 - Q_2}, \quad (COP)_{HP} = \frac{Q_1}{Q_1 - Q_2}$$

- b) Vane type Blower
Schematic & P-v diagram
Explanation - working principle.

- c) definitions of -
Wet steam, superheated steam, dryness fraction & saturation temperature.



$$Q_1 = h_1 - h_{4s} = T_{m1} (s_1 - s_{4s})$$

T_{m1} = mean temperature of heat addition.

$$T_{m1} = \frac{h_1 - h_{4s}}{s_1 - s_{4s}}$$

$$Q_2 = \text{heat rejected} = h_{2s} - h_3 = T_2 (s_1 - s_{4s})$$

$$\eta_{Rankine} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2 (s_1 - s_{4s})}{T_{m1} (s_1 - s_{4s})} = 1 - \frac{T_2}{T_{m1}}$$

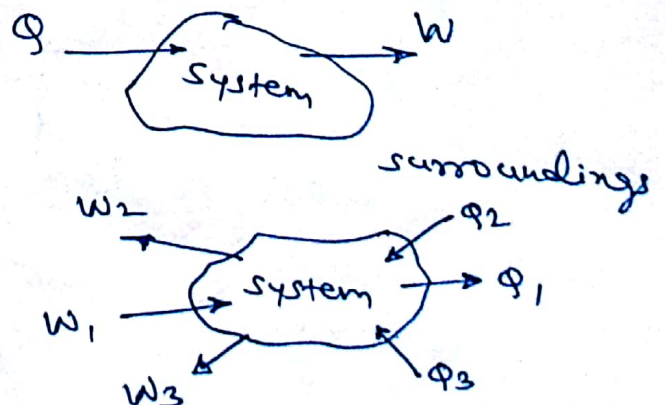
From this, it is clear that, for given value of temp. of heat rejection T_2 , $\eta_{Rankine}$ depends on T_{m1} .

- e) First law applied to closed system undergoing a change of state.

$$Q - W = \Delta E$$

$$Q = \Delta E + W$$

$$(Q_2 + Q_3 - Q_1) = \Delta E + (W_2 + W_3 - W_1)$$



Q2.
a) Given $\dot{V} = 2 \text{ m}^3/\text{min} = \frac{2}{60} \text{ m}^3/\text{s}$ | $P_2 = 1.5 \text{ MPa} = 1500000 \text{ N/m}^2$
 $P_1 = 0.11 \text{ MPa} = 110000 \text{ N/m}^2$ | $T_2 = 111^\circ\text{C} = 384 \text{ K}$
 $T_1 = 20^\circ\text{C} = 293 \text{ K}$ | $P_3 = P_2, T_3 = 25^\circ\text{C} = 298 \text{ K}$

$$\frac{dW}{dt} = -4.15 \text{ kW} = -4150 \text{ W for compressor.}$$

$$P = \rho RT \quad \rho = \frac{P}{RT} = \frac{110000}{287 \times 293} = 1.3081 \text{ kg/m}^3$$

$$\dot{m} = \rho \dot{V} = 0.0436 \text{ kg/s}$$

SFEE. for compressor:-

$$\dot{m} \left(h_1 + \frac{C_1^2}{2} + g z_1 \right) + \frac{dQ}{dt} = \dot{m} \left(h_2 + \frac{C_2^2}{2} + g z_2 \right) + \frac{dW}{dt}$$

using $h = c_p T$ in above eqⁿ & solving

$$\frac{dQ}{dt} = -162.56 \text{ W} \quad \boxed{\frac{dQ}{dt} = -0.1625 \text{ kW}} \text{ for compressor.}$$

Ans.

SFEE. for after cooler:-

$$\frac{dQ}{dt} = \dot{m} c_p \Delta T = 0.0436 \times 1.005 (298 - 384)$$

$$\frac{dQ}{dt} = -3768.3 \text{ W} \quad \boxed{\frac{dQ}{dt} = -3.76 \text{ kW}} \text{ for after cooler.}$$

Ans.

Q2.
b) $S = f(T, V)$

$$ds = \left(\frac{\partial S}{\partial T} \right)_V \cdot dT + \left(\frac{\partial S}{\partial V} \right)_T \cdot dV$$

$$Tds = T \left(\frac{\partial S}{\partial T} \right)_V \cdot dT + T \cdot \left(\frac{\partial S}{\partial V} \right)_T \cdot dV$$

Since, $T \left(\frac{\partial S}{\partial T} \right)_V = C_V$ & $\left(\frac{\partial S}{\partial V} \right)_T = \left(\frac{\partial P}{\partial T} \right)_V$ by Maxwell's eqⁿ.

$$\boxed{Tds = C_V dT + T \left(\frac{\partial P}{\partial T} \right)_V \cdot dV} \quad \text{--- (1)}$$

This is known as the 1st Tds equation.

continue...

$$\text{Let } S = f(T, P)$$

$$ds = \left(\frac{\partial S}{\partial T}\right)_P \cdot dT + \left(\frac{\partial S}{\partial P}\right)_T \cdot dP$$

$$Tds = T \left(\frac{\partial S}{\partial T}\right)_P dT + T \left(\frac{\partial S}{\partial P}\right)_T dP$$

Since, $T \left(\frac{\partial S}{\partial T}\right)_P = C_P$ & $\left(\frac{\partial S}{\partial P}\right)_T = - \left(\frac{\partial V}{\partial T}\right)_P$ by Maxwell's eqⁿ

$$\therefore \boxed{Tds = C_P dT - T \left(\frac{\partial V}{\partial T}\right)_P dP} \quad \dots \quad (2)$$

This is known as the second Tds equation

Q2.

C)

Heat transfer from steel

$$Q = m C_P \Delta T = 800 \times 0.5 (1250 - 500)$$

$$Q = 300000 \text{ KJ} = 300 \text{ MJ.}$$

change in entropy of steel as it cools from 1250 K to 500 K.

$$ds = m C_P \ln \frac{T_2}{T_1} = 800 \times 0.5 \ln \frac{500}{1250}$$

$$ds = -366.52 \text{ KJ/K}$$

$$\text{unavailable energy} = T_0 ds$$

$$= 300 \times 366.52$$

$$\text{U.E.} = 109956 \text{ KJ}, \quad \boxed{\text{U.E.} = 109.95 \text{ MJ}} \quad \underline{\text{Ans}}$$

$$\text{Available energy} = Q - T_0 ds$$

$$= 300 - 109.95$$

$$\boxed{\text{A.E.} = 190.05 \text{ MJ}} \quad \underline{\text{Ans}}$$

Q3
a) $(COP)_{HP} = \frac{Q_3}{Q_3 - Q_4} = \frac{T_3}{T_3 - T_4}$

as it is reversible H.P.

$$\therefore (COP)_{HP} = \frac{333}{333 - 278} = 6.05$$

$$\therefore \frac{Q_3}{Q_3 - 17} = 6.05$$

$$\boxed{Q_3 = 20.37 \text{ KJ}}$$

$$W - 30 = Q_3 - Q_4 = 20.37 - 17$$

$$\therefore \boxed{W = 33.37 \text{ KW}}$$

$$\eta_{HE} = 1 - \frac{T_2}{T_1} = 1 - \frac{Q_2}{Q_1}, \text{ reversible HE.}$$

$$\eta_{HE} = 1 - \frac{333}{1113} = 0.70, \quad 0.7 = 1 - \frac{Q_2}{Q_1}, \quad \frac{Q_2}{Q_1} = 0.3$$

$$Q_2 = 0.3 Q_1$$

$$W = Q_1 - Q_2, \quad 33.37 = Q_1 - 0.3 Q_1, \quad \boxed{Q_1 = 47.67 \text{ KJ}}$$

$$\boxed{Q_2 = 14.3 \text{ KJ}}$$

Total heat rejected to 60°C sink

$$= Q_2 + Q_3 = 14.3 + 20.37 = 34.67 \text{ KJ.}$$

Q3 b) $\Delta S_{\text{universe}} = \Delta S_{\text{block 1}} + \Delta S_{\text{block 2}}$
Two blocks shall attain first equilibrium temp. let's say T_f .
Then using energy conservation principle.
 $1 \times 0.393 (423 - T_f) = 0.5 \times 0.381 (T_f - 273)$

$$\boxed{T_f = 374 \text{ K}}$$

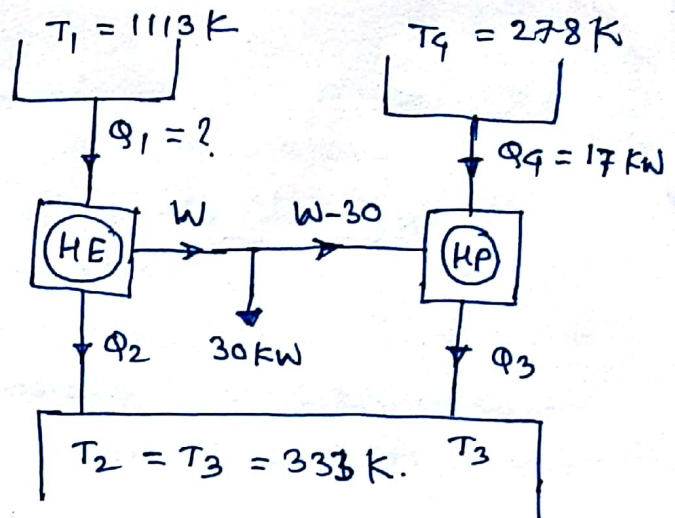
$$(\Delta S)_{\text{block 1}} = m C_p \ln \frac{T_f}{T_1} = 1 \times 0.393 \ln \frac{374}{423} = -0.0484 \text{ KJ/K}$$

$$(\Delta S)_{\text{block 2}} = m C_p \ln \frac{T_f}{T_2} = 0.5 \times 0.381 \ln \frac{374}{273} = 0.0599 \text{ KJ/K}$$

$$(\Delta S)_{\text{universe}} = -0.0484 + 0.0599$$

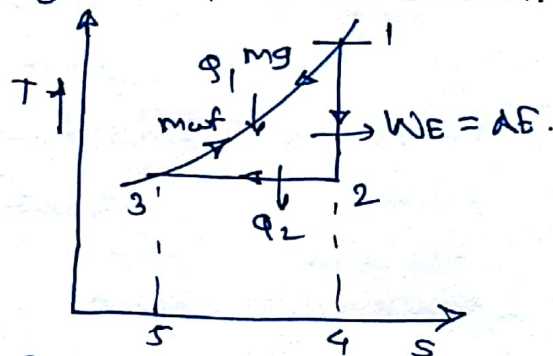
$$\boxed{(\Delta S)_{\text{univ}} = 0.0115 \text{ KJ/K}} \quad \underline{\Delta u.}$$

④



Q3.

c) Let, a hot gas of mass m_g at temp. T , when the environment is at T_0 , is used to heat a working fluid of mass m_{wf} . All the energy lost by the hot gas is absorbed by the working fluid. Working fluid then expands reversibly & adiabatically in an engine doing work W_E & then rejects heat Q_2 , reversibly & isothermally at temperature T_0 to return to the initial state 3 to complete a heat engine cycle. as shown.



$$Q_1 = m_g C_{pg} (T - T_0) \\ = m_{wf} C_{pwf} (T - T_0)$$

$$\therefore m_g C_{pg} = m_{wf} C_{pwf}$$

$$(\Delta S)_{gas} = \int_T^{T_0} m_g C_{pg} \frac{dT}{T} = m_g C_{pg} \ln \frac{T_0}{T} \quad (\text{negative})$$

$$(\Delta S)_{wf} = \int_{T_0}^T m_{wf} \cdot C_{pwf} \cdot \frac{dT}{T} = m_{wf} C_{pwf} \ln \frac{T}{T_0} \quad (\text{positive})$$

$$(\Delta S)_{universe} = (\Delta S)_{gas} + (\Delta S)_{wf} = 0$$

$$\text{also, } Q_2 = T_0 (\Delta S)_{wf} = T_0 m_{wf} C_{pwf} \ln \frac{T}{T_0}$$

Maximum available energy of a source at temp T is

$$W_{max} = Q_1 - Q_2 \\ = m_g C_{pg} (T - T_0) - T_0 m_g C_{pg} \ln \frac{T}{T_0} \quad (\because m_g C_{pg} = m_{wf} C_{pwf})$$

$$W_{max} = m_g C_{pg} \left[T - T_0 - T_0 \ln \frac{T}{T_0} \right]$$

$\therefore$ Maximum available energy from (maximum work obtainable) from a finite body at temp. T is

$$W_{max} = C \left[T - T_0 - T_0 \ln \frac{T}{T_0} \right]$$

where,
 C = heat capacity
at temp. T . ⑤

Q4 a) At state 2 (after expansion)

$$P_2 = 0.08 \text{ bar}, \quad x_2 = 0.85.$$

from steam table,

$$sf_2 = 0.593 \text{ kJ/kgK} \quad \& \quad sf_{g2} = 7.637 \text{ kJ/kgK}.$$

$$s_2 = sf_2 + x_2 sf_{g2}$$

$$= 0.593 + 0.85 \times 7.637$$

$$s_2 = 7.089 \text{ kJ/kgK} = s_1$$

at point 1. (inlet to turbine)

$$T_1 = 360^\circ\text{C} \quad \& \quad s_1 = 7.089.$$

steam is superheated at state 1.

from superheated, steam table.

	350	360	400	by interpolation
16 bar	7.072	7.089 x	7.239	x = 7.1059
17 bar	7.092	y	7.210	y = 7.0459

at 360°C

$$\therefore 16 \text{ bar} \quad 7.1059$$

$$z \quad 7.089$$

$$17 \text{ bar} \quad 7.0459,$$

$$\text{by interpolation, } \boxed{z = 16.356 \text{ bar}}$$

Max. allowable pressure

$$\boxed{P_1 = 16.356 \text{ bar}} \quad \text{Ans.}$$

for h :

	350	360	400	by interpolation
16 bar	3146.7	x	3255.0	x = 3168.36
17 bar	3149.7	y	3253.5	y = 3166.46

at 360°C

$$\therefore 16 \text{ bar} \quad 3168.36$$

$$16.356 \text{ bar} \quad z$$

$$17 \text{ bar} \quad 3166.46,$$

by interpolation

$$z = h_1 = 3167.68 \text{ kJ/kg}$$

$$h_2 = hf_2 + x_2 \cdot hfg_2 = 173.9 + 0.85 \times 2403.2 = 2216.62 \text{ kJ/kg}$$

$$h_3 = hf_3 = 173.9 \text{ kJ/kg}$$

$$h_4 - h_3 = v_3 (P_1 - P_2) \overset{\text{KPa}}{=} 0.001008 (16.356 - 0.08) \times 100, \quad \boxed{h_4 = 175.59 \text{ kJ/kg}}$$

$$Q_1 = h_1 - h_4, \quad \boxed{Q_1 = 2992.19 \text{ kJ/kg}}$$

$$Q_2 = h_2 - h_3, \quad \boxed{Q_2 = 2042.72 \text{ kJ/kg}}$$



$$\eta = \frac{W_{\text{net}}}{Q_1} = \frac{W_T - W_P}{Q_1}$$

$$T_m = \frac{h_1 - h_4}{s_1 - s_4}, \quad T_m = \frac{3167.68 - 175.59}{7.089 - 0.593}$$

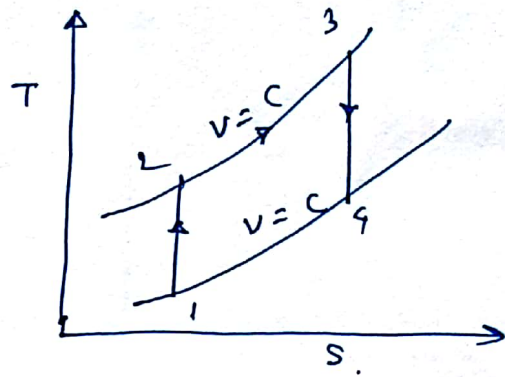
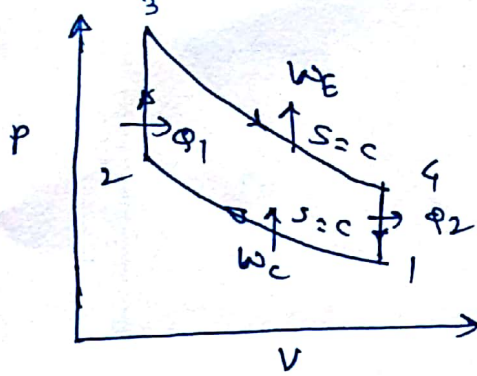
$$W_T = h_1 - h_2 = 951.06 \text{ kJ/kg}$$

$$W_P = h_4 - h_3 = 1.69 \text{ kJ/kg}$$

$$= \frac{951.06 - 1.69}{2992.19} = 0.3173 \quad \boxed{\eta = 31.73\%}$$

$$\boxed{T_m = 460.96 \text{ K}} \quad \text{Ans.} \quad \text{⑥}$$

Q4 b)



$$Q_1 = m C_v (T_3 - T_2), \quad Q_2 = m C_v (T_4 - T_1)$$

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{m C_v (T_4 - T_1)}{m C_v (T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \quad \text{--- (1)}$$

process 1-2 .. $\gamma-1$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

process 3-4

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3} \right)^{\gamma-1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

$$\frac{T_2}{T_1} = \frac{T_3}{T_4}, \quad \frac{T_3}{T_2} = \frac{T_4}{T_1}, \quad \frac{T_3}{T_2} - 1 = \frac{T_4}{T_1} - 1$$

$$\frac{T_3 - T_1}{T_3 - T_2} = \frac{T_1}{T_2} = \left(\frac{V_2}{V_1} \right)^{\gamma-1}, \quad \text{let } r_k = \text{compression ratio} = \frac{V_1}{V_2}$$

$$\boxed{\eta_{\text{otto}} = 1 - \frac{1}{r_k^{\gamma-1}}}$$

Q4.

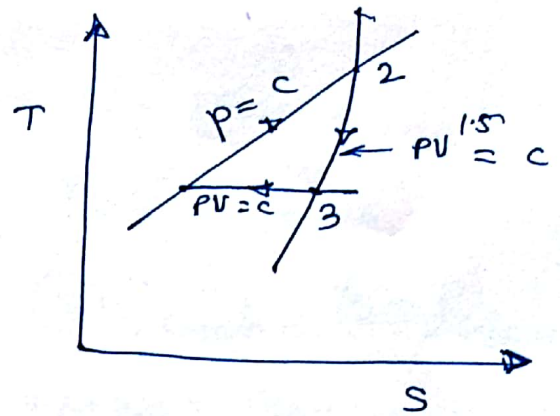
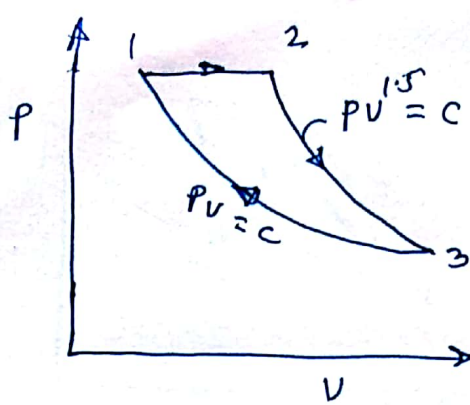
c) Defⁿ of volumetric efficiency of compressor ..

$$= \frac{V_{\text{act}}}{V_{\text{swept}}} = 1 + C - C \left(\frac{P_2}{P_1} \right)^{1/\gamma}, \quad C = \frac{V_c}{V_s}$$

It depends on.

- clearance volume.
- pressure ratio

Q5. a)



$$P_1 = 700 \text{ kPa}, T_1 = 280^\circ\text{C} = 553 \text{ K} = T_3$$

$$V_1 = 0.028 \text{ m}^3, V_2 = 0.084 \text{ m}^3$$

$$P_1 V_1 = m R T_1, m = \frac{P_1 V_1}{R T_1}, \boxed{m = 0.128 \text{ kg}}$$

$$\frac{T_2}{T_1} = \frac{P_2 V_2}{P_1 V_1} = \frac{V_2}{V_1}, T_2 = 553 \times \frac{0.084}{0.028} = \boxed{T_2 = 1599 \text{ K}}$$

$$\frac{P_2}{P_3} = \left(\frac{T_2}{T_3}\right)^{\frac{n}{n-1}} = \left(\frac{1599}{553}\right)^{\frac{1.5}{1.5-1}} = (3)^3 = 27, \frac{P_3}{P_2} = \frac{P_3}{P_1} = \frac{1}{27}.$$

$$Q_{1-2} = m C_p (T_2 - T_1) = 0.128 \times 1.005 (1599 - 553)$$

$$\boxed{Q_{1-2} = 137.13 \text{ kJ}}$$

$$Q_{2-3} = (\Delta U)_{2-3} + W_{2-3} = m C_v (T_3 - T_2) + \frac{m R (T_2 - T_3)}{n-1}$$

$$Q_{2-3} = 0.128 \times 0.718 (553 - 1599) + \frac{0.128 \times 0.287}{1.5-1} (1599 - 553)$$

$$\boxed{Q_{2-3} = -19.65 \text{ kJ}}$$

$$Q_{3-1} = (\Delta U)_{3-1} + (W)_{3-1}$$

$$Q_{3-1} = W_{3-1} = m R T_1 \ln \frac{V_1}{V_3} = m R T_1 \ln \frac{P_3}{P_1} = 0.128 \times 0.287 \ln \left(\frac{1}{27}\right) \times 553$$

$$\boxed{Q_{3-1} = -64.53 \text{ kJ}}$$

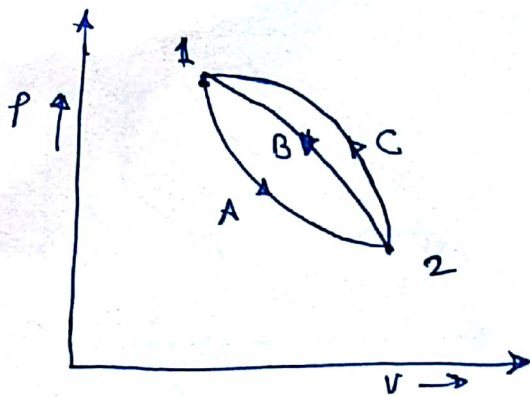
$$\text{Heat supplied in cycle} = 137.13 \text{ kJ}$$

$$\text{Heat rejected in cycle} = 19.65 + 64.53 = 84.18 \text{ kJ}$$

$$\eta_{\text{cycle}} = 1 - \frac{\text{Heat rejected}}{\text{Heat supplied}} = 1 - \frac{84.18}{137.13} = 0.386.$$

$$\boxed{\eta_{\text{cycle}} = 38.6\%}$$

Q5 b)



$$Q_A = \Delta E_A + W_A$$

$$Q_B = \Delta E_B + W_B$$

$$(\sum W)_{\text{cycle}} = (\sum Q)_{\text{cycle}}$$

$$W_A + W_B = Q_A + Q_B$$

$$Q_A - W_A = W_B - Q_B$$

$$\boxed{\Delta E_A = -\Delta E_B}$$

Similarly, if system return to State ① by path C, it can be shown that,

$$\boxed{\Delta E_A = -\Delta E_C}$$

$$\therefore \boxed{\Delta E_B = \Delta E_C}$$

change in energy is independent of path. Hence energy has definite value for every state of the system, and is point function & property of the system.

Q5.

c) Maxwell's equations.

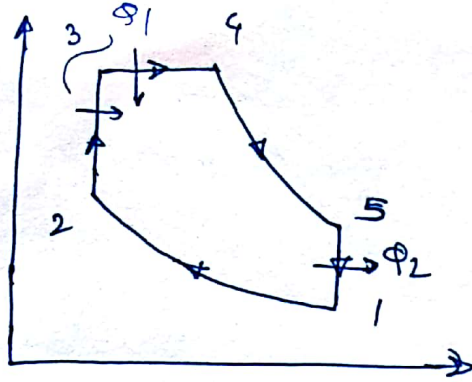
$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

$$\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial S}{\partial P}\right)_T$$

Q6.
a)



$$\gamma = 1.5, \quad P_1 = 0.1 \text{ MPa} = 100 \text{ kPa}$$

$$T_1 = 40^\circ\text{C} = 313 \text{ K},$$

$$P_3 = P_4 = 6 \text{ MPa} = 6000 \text{ kPa}$$

$$Q_1 = 1.675 \text{ MJ/kg} = 1675 \text{ kJ/kg}$$

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{1}{\gamma_c^{\gamma-1}},$$

$$T_2 = T_1 \times \gamma_c^{\gamma-1} = 313 \times 15^{1.4-1}$$

$$\boxed{T_2 = 924.66 \text{ K}}$$

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma = 0.1 \times 15^{1.4}, \quad \boxed{P_2 = 4.431 \text{ MPa}}$$

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}, \quad T_3 = T_2 \times \frac{P_3 V_3}{P_2 V_2} = 924.66 \times \frac{6}{4.431}, \quad \boxed{T_3 = 1252.08 \text{ K}}$$

$$Q_1 = C_v (T_3 - T_2) + C_p (T_4 - T_3), \quad 1675 = 0.718(1252.08 - 924.66) + 1.005(T_4 - 1252.08)$$

$$\therefore \boxed{T_4 = 2684.83 \text{ K}}$$

Heat supplied at const. volume = $C_v (T_3 - T_2) = 235.08 \text{ kJ/kg}$ Ans i)

Heat supplied at const. pressure = $C_p (T_4 - T_3) = 1439.91 \text{ kJ/kg}$ Ans ii)

$$\frac{P_3 V_3}{T_3} = \frac{P_4 V_4}{T_4}, \quad \frac{V_4}{V_3} = \gamma_c = \frac{T_4}{T_3} = 2.14, \quad \gamma_c = \gamma_e \cdot \gamma_c$$

$$\gamma_e = \frac{V_5}{V_4} = \frac{\gamma_c}{\gamma_c} = \frac{15}{2.14} = 7.$$

$$\frac{T_5}{T_4} = \left(\frac{V_4}{V_5}\right)^{\gamma-1}, \quad T_5 = 2684.83 \times \left(\frac{1}{7}\right)^{1.4-1}, \quad \boxed{T_5 = 1232.75 \text{ K}}$$

$$Q_2 = C_v (T_5 - T_1) = 0.718 (1232.75 - 313) \quad \boxed{Q_2 = 660.38 \text{ kJ/kg}}$$

$$W_{\text{net}} = Q_1 - Q_2 \quad \boxed{W_{\text{net}} = 1014.62 \text{ kJ/kg}} \quad \text{Ans iii)}$$

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{660.38}{1675} = 0.605 \quad \boxed{\eta = 60.5\%} \quad \text{Ans iv)}$$

$$P_1 V_1 = RT_1, \quad V_1 = 0.898 \text{ m}^3/\text{kg}, \quad V_2 = \frac{V_1}{\gamma_c} = \frac{0.898}{15}, \quad V_2 = 0.06 \text{ m}^3/\text{kg}$$

$$\text{m.e.p.} = \frac{W_{\text{net}}}{V_1 - V_2} = \frac{1014.62}{0.898 - 0.06} = 1210.76 \text{ kPa}$$

$$\boxed{\text{m.e.p.} = 1.21 \text{ MPa}} \quad \text{Ans v)}$$

Q6 b)

$$V_1 = V_s + V_c = V_s + 0.05 V_s$$

$$V_1 = 1.05 V_s, \quad T_1 = 15^\circ\text{C} = 288 \text{ K.}$$

Volume induced

$$\text{per cycle} = V_1 - V_4$$

$$= \frac{14}{300 \times 2}$$

$$V_1 - V_4 = 0.0233 \text{ m}^3/\text{cycle.} \quad \text{--- (1)}$$

$$\frac{V_4}{V_3} = \left(\frac{P_3}{P_1}\right)^{\frac{1}{n}} \quad V_4 = V_c \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = 0.05 V_s \left(\frac{7}{1.013}\right)^{\frac{1}{1.3}}$$

$$\boxed{V_4 = 0.221 V_s}$$

$$\therefore V_1 - V_4 = 1.05 V_s - 0.221 V_s = 0.829 V_s \quad \text{--- (2)}$$

$$\text{from (1) \& (2)} \quad V_s = \frac{0.0233}{0.829}, \quad \boxed{V_s = 0.0281 \text{ m}^3/\text{cycle}} \quad \text{Ans i)}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}, \quad T_2 = 288 \left(\frac{7}{1.013}\right)^{\frac{1.3-1}{1.3}},$$

$$\boxed{T_2 = 449.9 \text{ K} = 176.9^\circ\text{C}} \quad \text{Ans ii)}$$

$$\begin{aligned} \text{I.P.} &= \frac{n}{n-1} P_1 \dot{V} \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1 \right] \\ &= \frac{1.3}{1.3-1} \frac{1.013 \times 10^5}{1000} \times \frac{14}{60} \left[\left(\frac{7}{1.013}\right)^{\frac{1.3-1}{1.3}} - 1 \right] \end{aligned}$$

$$\boxed{\text{I.P.} = 57.58 \text{ kW}} \quad \text{Ans iii)}$$

$$\text{OR: } \dot{m} = \frac{P_1 \dot{V}}{R T_1} = \frac{101.3 \times 14}{60 \times 0.287 \times 288}, \quad \dot{m} = 0.286 \text{ kg/s}$$

$$\text{I.P.} = \frac{n}{n-1} \dot{m} R (T_2 - T_1) = \frac{1.3}{1.3-1} \times 0.286 \times 0.287 (449.9 - 288)$$

$$\boxed{\text{I.P.} = 57.58 \text{ kW}} \quad \text{Ans iii)}$$

