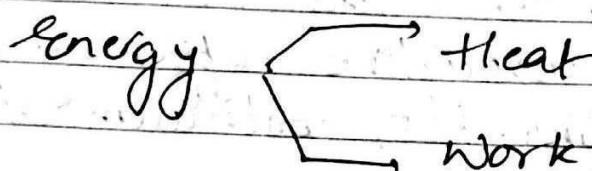


ME-101

Basic defn. of Concepts of Thermodynamics:

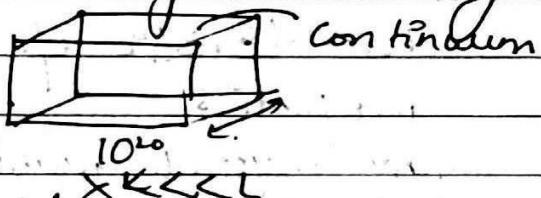
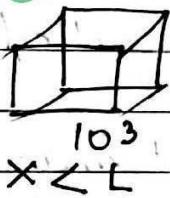


- Closed system
- Isolated system
- Open system
- Chemical approach to thermodynamics.
(Macroscopic view points).

Bulk of matter

* Statistical approach (Microscopic approach)

Search and every and how they are moving



Thermodynamics is the sc. of relations among heat and work interactions and these property of substances that where as relation of heat and work.

In thermodynamics the experimental obsⁿ have been formalised into certain basic laws which are known as 1st, 2nd and Third law thermodynamics.

In addⁿ to these the zeroth law of thermodynamic has also been said fourth

Continuum: Is the idealization to view a subs at the continuous homogeneous matter with no void space or holes

These assumption allows treating the property as point fun^c and considering their variation continuous in space with no jump or discontinuity in.

This is an inherent assumption in classical approach to thermodynamics

"No religion has mandated killing others as a requirement for its sustenance or promotion." -Dr.A.P.J.Abdul Kalam

Macroscopic View: It is point given amount of matter is considered as a whole and individual characteristic of molecule and associative happening of this level and this regarding. Also, continuum approach is apply.

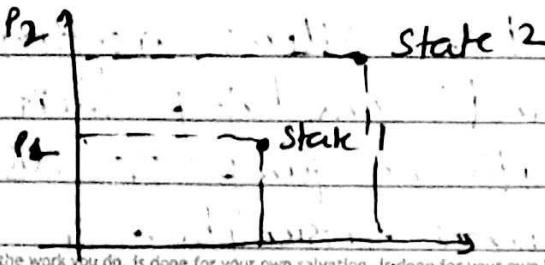
Microscopic View: In mc. approach only the individual characteristic of molecule and associative happening at this level are considered. The average outcome of happening at microscopic level is then calculated over the entire mass of matter under considering manner to find out associative property magnitude.

Thermodynamic Property: Any observable macroscopic characteristic of a system is called thermodynamic properties.

Any physical quantity that is permanently associated to a system is its property. A physical quantity which is not permanently associated to a system is not its property.

e.g.: Heat and work being path function are not the property. While pressure, temp., vol., density are properties and state functions.

State is the totality of the properties of a system. Totality is the other name of a set when all the elements of state are observed simultaneously.



"All the work you do, is done for your own salvation. Is done for your own benefit." —Swami Vivekananda

Process - The state change transition of a system is called process. The state of a system can be changed in a number of ways.

Path of the process is the way in which the state change has been brought about.

e.g.: An isobaric process is the one in which the pressure is maintained constant during process.

Similarly there are,

Isochoric - vol. const

Isothermal - temp. const

Isoenthalpic - H const

Isoentropic \rightarrow S (entropy) const

Cycle: When after executing a single or series of processes in sequence. The system attains back its initial state. It is said to have executed a cycle.

Thermodynamic eqⁿ:

- i) Mechanical eqⁿ.
- ii) Thermal eqⁿ.
- iii) Chemical eqⁿ.

When no change in magnitude of any property is taking place in it is in thermodynamic equilibrium.

When in thermo eq^b the system has unique state and can be represented by a point on a thermodynamic diagram.

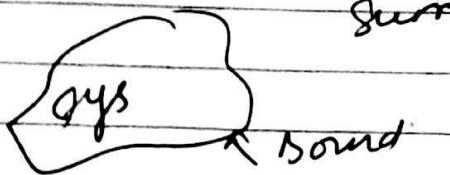
Thermal eqm: When no thermal interactions are taking place either among the constituent of the system or across its boundary. It is in thermal eqm, i.e., there are no temp. diff.

Mechanical eqm: When there are no balanced force within the system it is in mechanical eqm.

Chemical eqm: When chemical composition and aggregation inside the system doesn't change. For a system to be in thermal eqm all the above three eqm condⁿ must be satisfied by the system simultaneously.

Home Ass of ME-10!

Def of system, surrounding, Boundary,



Types of system

1) Closed system
(Dia)

2) Open system
(Dia)

3) Isolated sys
(Dia)

Dimension -

Units -

Various prop in thermo

Some transf of units of properties of thermo

force :

- Energy) Enthalpy :

- Pressure :

Mass :

Temp :

Vol;

Power

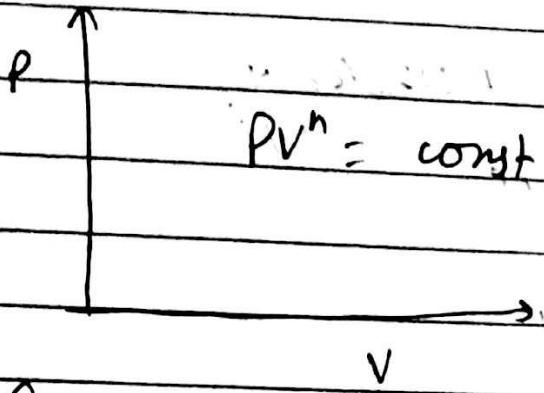
Enthalpy

"No religion has mandated killing others as a requirement for its sustenance or promotion." —Dr. A.P.J.Abdul Kalam

An engs approach by Yousuf and Michael.

PDF Compressor Pro

Polytropic Process

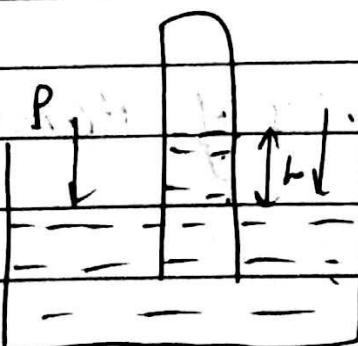


→ Quasi-equilibrium process
" - static "

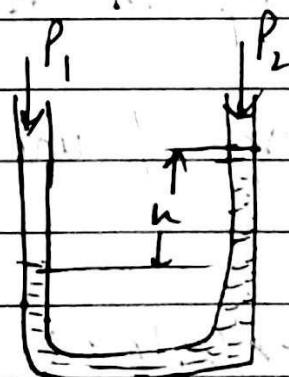
When a process is executed by a system in such a manner that the system goes on passing from one identifiable state to another, in sequence, throughout the process, the process is termed as quasi-static process. These instantaneous states are called quasi-equilibrium states.

Intensive prop^t which are independent of the amount of matter. for eg: Press^r, temp^r, specific vol.
Extensive prop^t depend on the amount of matter
for eg: total vol, total internal energy etc

PRESSURE:



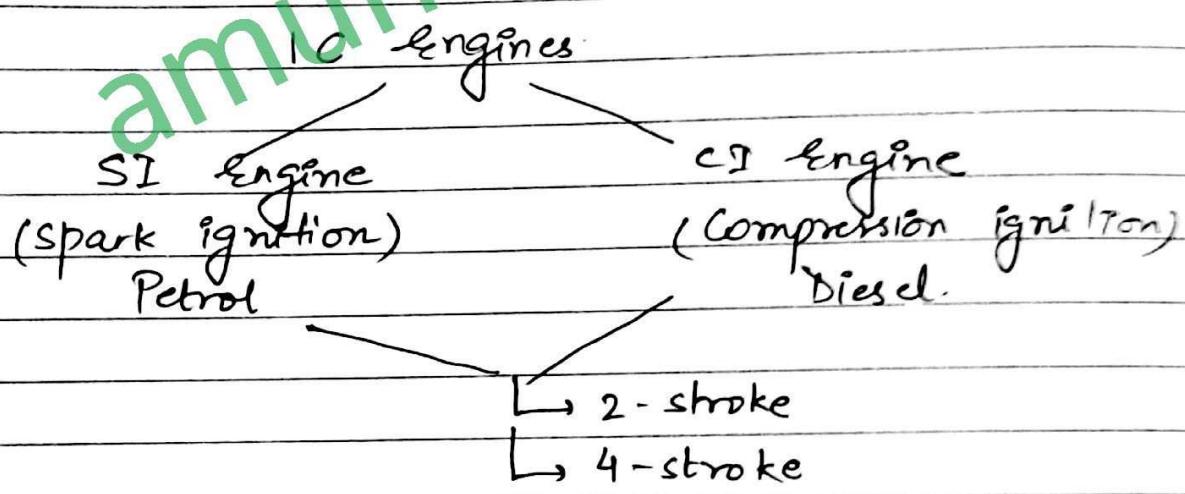
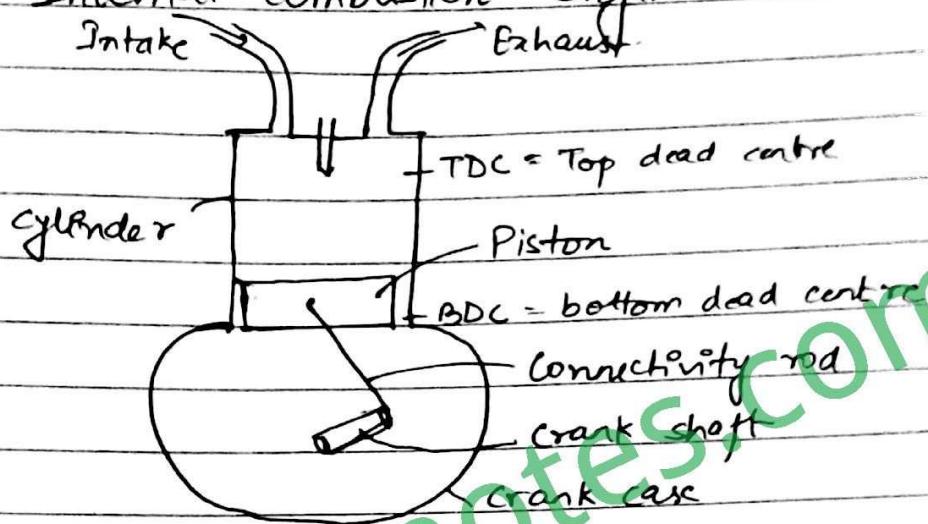
Barometer



Manometer

Bourdon's tube, Pressure gauge (Prop^t)

Internal Combustion Engines :



108/15.

Temperature Problem:

- Q) The temperature T on a thermometer $T = f(P)$
 $T = a \ln P + b$.

The temperature of ice point and steam point is 0K and 100°C .

$$\text{Ice point} \rightarrow P = 1.86 \rightarrow 0$$

$$\text{Steam point} \rightarrow P = 6.81 \rightarrow 100$$

At $P = 2.50$, what will be $T = ?$

$$T = a \ln P + b.$$

$$0 = a \ln(1.86) + b$$

$$0 = a \ln(1.86) + b \quad \dots \text{eq 1}$$

$$100 = a \ln(6.81) + b \quad \dots \text{eq 2}$$

Solve the two eq's

$$100 = a(\ln 6.81 - \ln 1.86)$$

$$100 = a \ln \frac{6.81}{1.86}$$

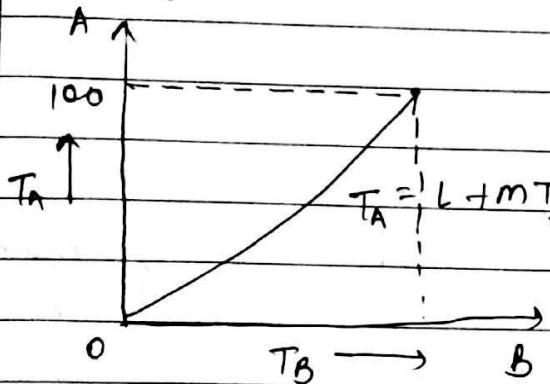
$$a = 77.5$$

21.86
5.58

$$\text{and } b = -47.5$$

Putting these values in eqⁿ we get $T_c = 22^\circ\text{C}$

Q)



$$\text{When } T_A = 51^\circ\text{C}, T_B = 50^\circ\text{C}$$

$$T_A = l + mT_B + nT_B^2 \quad \text{Find } T_B \text{ when } T_A = 25^\circ\text{C}?$$

$$\underline{\text{Ans:}} \quad T_A = l + mT_B + nT_B^2$$

$$51 = l + 50m + 2500n$$

$$0 = l + m(0) + n(0) \quad l = 0$$

$$51 = l + 50T_B m + 2500T_B^2 n$$

$$100 = l + \cancel{m(100)}T_B + \cancel{n10^4T_B^2} n$$

$$-49 \quad \cancel{-} \quad -50T_B - 7500n$$

$$49 = 50T_B m + 7500n \quad l = 0$$

$$49 = 50m + 7500n$$

$$51 = 50m + 2500n$$

$$-2 = 5000n$$

$$n = \frac{-2}{5000} = \frac{-1}{2500}$$

$$l = 0 \text{ and } m = \frac{26}{25}$$

After solving we get, $T_B = 24.275^\circ\text{C}$

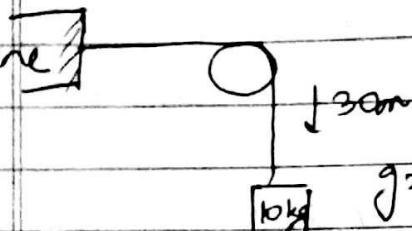
20/08/15

UNIT - IIWORK :

Thermodynamics definition:
 The sole effect external to the system when it is raising off mass, then work is said to be done

Q. 34). Find out how much work is done:

b) crane



$$W = -10 \times 6 \times 30$$

$$g = 6 \text{ m/s}^2$$

+ve work for raising mass.

-ve " " lowering mass.

$\hookrightarrow F = mg \propto h$ (for free fall) in this case

22/08/15

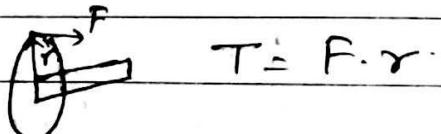
Electrical Work:

$$W_e = VI = I^2 R = V^2/R \text{ (Watt)}$$

$$W_e = \int_0^t VI \cdot dt \quad (\text{J})$$

Shaft work:

$$W_{sh} = F \cdot S$$



$$T = F \cdot r$$

$$= \frac{T}{r} (2\pi n)$$

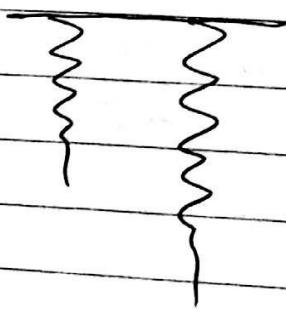
$$T = F \cdot r$$

$$= 2\pi n T$$

$$W_{sh} = 2\pi n T \text{ (Watt)}$$

$n \rightarrow$ revolutions per unit time

Spring work

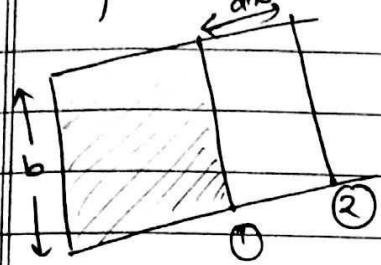


$$\Delta W_{spring} = F \cdot dx$$

$$F = kx$$

$$W_{spring} = \frac{1}{2} k (x_2^2 - x_1^2)$$

Surface tension work :

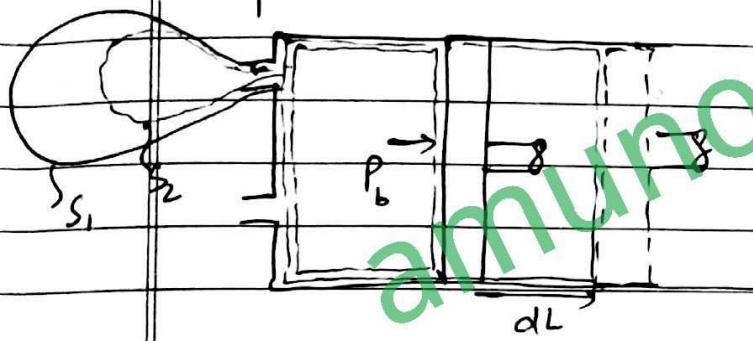


$$W_{\text{surface}} = \int_1^2 \sigma_s \cdot dA$$

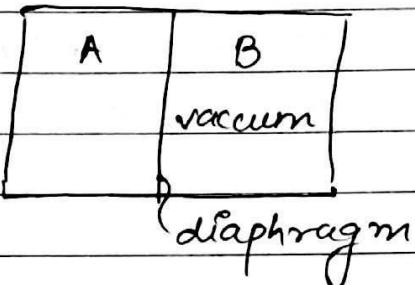
surface tension

$$dA = 2b(dx).$$

Displacement work :



Unresisted expansion :



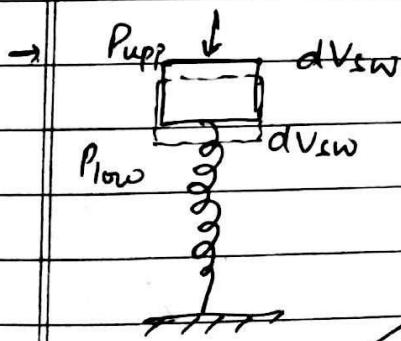
Resistance expansion :

$$F = P_b A$$

$$\delta W_{\text{disp}} = F \cdot dL = P_b A \cdot dL$$

$$W_{\text{disp}} = \int_1^2 P_b A dL = \int_1^2 P_b dV_{\text{sw}}$$

swept volume



Isobaric $\rightarrow p = \text{const}$ $W_{\text{disp}} = P_b(V_2 - V_1)$

Isochoric $\rightarrow V = \text{const}$ $W_{\text{disp}} = 0.$

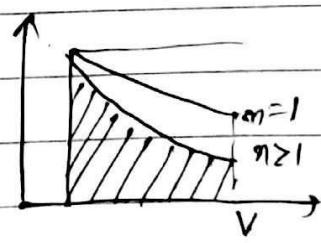
Isothermal $\rightarrow PV = \text{const}$

Polytropic process $\rightarrow PV^n = \text{const}$

$$W_{\text{disp}} = \int_1^2 P \cdot dV = \int_1^2 \frac{C}{V} dV = C \ln \left(\frac{V_2}{V_1} \right)$$

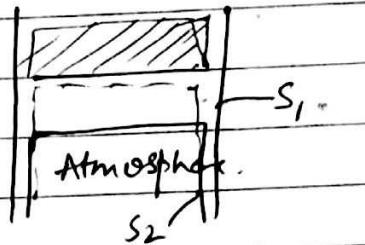
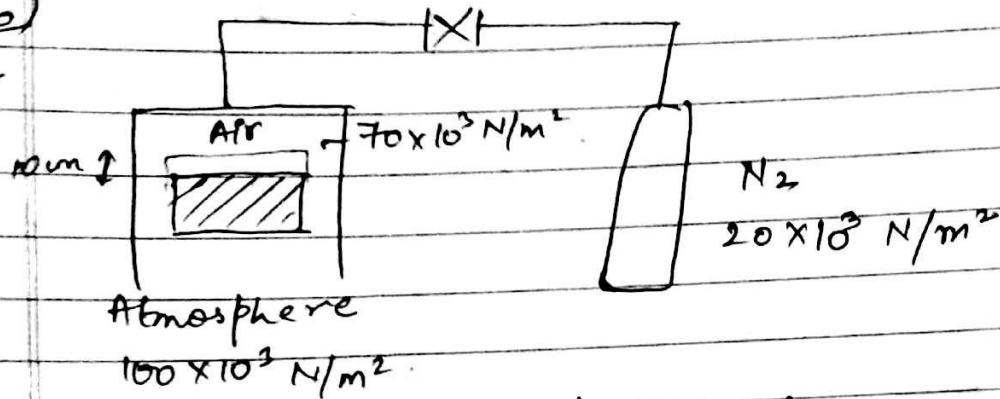
$$= P_1 V_1 \ln \left(\frac{V_2}{V_1} \right)$$

$$W_{\text{disp}} = \int_1^2 \frac{C}{V^n} dV$$



Ex 3.2 Pg. 62

Q3.6)
Pg #2



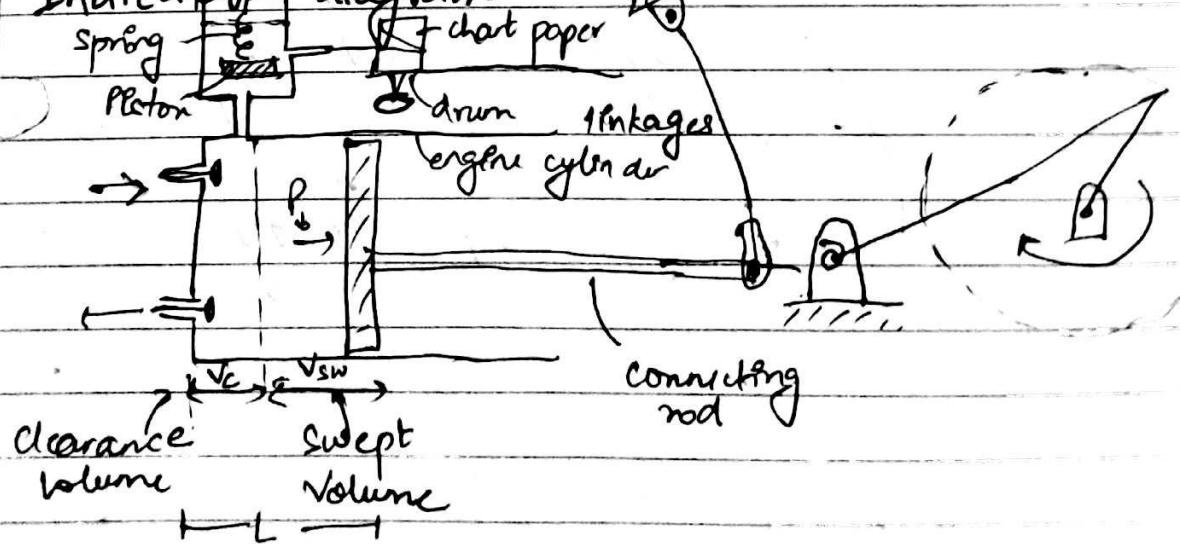
$$W_{\text{piston}} = W_{\text{piston}}_{\text{on air}} + W_{\text{atm on piston}}$$

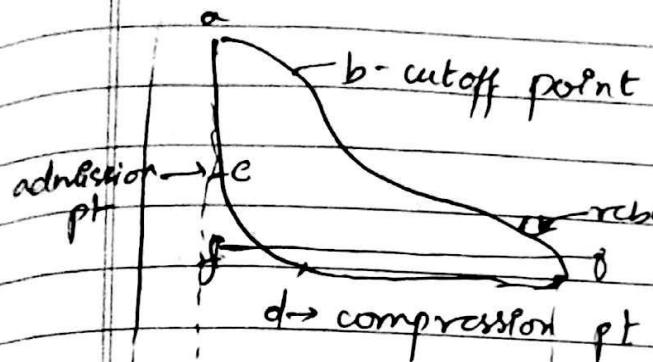
$$= 70 \times 10^3 \times (2 \times 10^{-4} \times 0.1) - 100 \times 10^3 \times (2 \times 10^{-4} \times 0.1)$$

$$W_{\text{atm}} = + 100 \times 10^3 \times 2 \times 10^{-4} \times 0.1$$

$$W_{\text{air} + \text{N}_2} = 70 \times 10^3 \times (-2 \times 10^{-4} \times 0.1)$$

4/08/15 Indicator diagram:





Planimeter - measures area

release pt Horizontal scale

$$1\text{cm} \rightarrow V_{sw}(\text{m}^3)$$

$$1(\text{cm})$$

Steam engine Indicator diagram S → Spring no.

is measured in N/m^2 and represents

the change in press in N/m^2 which cause the stylus to rise 1 m on paper.

'a' → Area of Indicator diagram

$$W_{disp} = a \times S \times \frac{V_{sw}}{l} = \left(\frac{AS}{l} \right) \times V_{sw} = P_m \cdot V_{sw} = W_{indicator}$$

where P_m is the mean effective pressure.

$$P_i = P_m \cdot V_{sw} \cdot N \quad \text{rev/sec}$$

$$P_i = P_m \cdot L \cdot A \cdot N$$

2-stroke single acting engine

Four stroke single acting $P = \frac{P_m \cdot L \cdot A \cdot N}{2}$

- The mean effective pressure is a fictitious pressure that if it acted on a piston during the entire power stroke would produce the same amount of net work as that produced during the actual cycle. P_m can be used as a parameter compare the performances of reciprocating engines of equal size. The engine with a larger value of P_m will deliver more net work per cycle than and thus will perform better.

$$3.10) N = 2520 \text{ rev/min} = \frac{2520}{60} \text{ rev/sec.}$$

area = $2.33 \times 10^3 \text{ mm}^2$

$L = 62.1 \text{ mm}$

$D = 150 \text{ mm}$ (box is diameter of piston)

$L = 160 \text{ mm}$

$$P_i = \frac{6 \times P_m \times A \times L \times N}{2} \quad P_m = \frac{aS}{L}$$

$$= 3 \times \frac{aS}{L} \times A \times L \times N$$

$$= \frac{3 \times 2520}{160 \times 10^{-3}} \times \frac{20 \times 10^6}{60} \times 2.33 \times 10^3 \times 62.1 \times 10^{-3} \times 10^{-6} \times \frac{(150)^2}{2} \times 3.14 \times 10^6$$

$$= 3 \times 252 \times 20 \times 2.33 \times 62.1 \times 150 \times 150 \times 3.14 \times 10^6$$

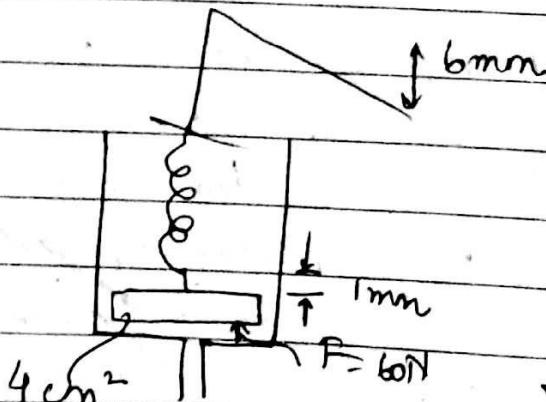
$$160 \times 6 \times 4,$$

$$= \frac{1.545 \times 10^{11} \times 10^{-6}}{160 \times 6 \times 4} = \frac{1.5456 \times 10^5}{160 \times 6 \times 4}$$

$$= \frac{1.5456}{3840} \times 10^5$$

$$= 267 \text{ kW}$$

3.9)



$$S = \frac{W_{\text{displ}} \times l \times a}{V_{\text{sw}}}$$

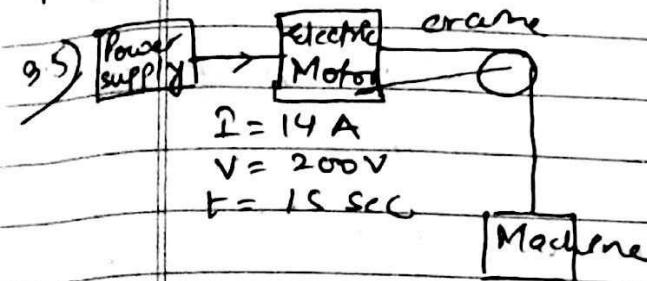
$$P_i = 4.5 \text{ kW}, a = 3, l = 0.1 \text{ m}$$

$$D = 150 \text{ mm}, N = 216 \text{ rev/min}$$

$$S = 2.5 \times 10^7$$

$$P_{\text{in}} = \frac{P_m \times A \times l \times N}{2} = \frac{566 \text{ mm}^2}{2} = 5.66 \text{ cm}^2 \text{ Ans.}$$

27/08/15



$$W = Vit = 200 \times 14 \times 15$$

$$mgh = 2 \times 10^3 \times 2 \times 9.8$$

$$= 39.2 \times 10^3$$

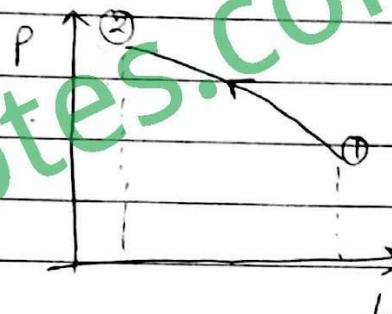
$$42 \times 10^3 - 39.2 \times 10^3$$

3.7) $P_c = 150 \times 10^3 \text{ N/m}^2$

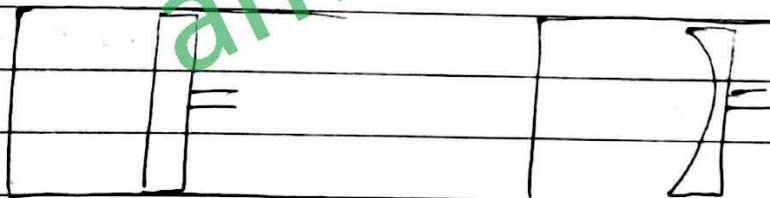
$$P_2 = 300 \times 10^3 \text{ N/m}^2$$

$$A = 220 \text{ cm}^2$$

$$L = 200 \text{ mm}$$



$$P_i = P_m \times V_{sw}$$



$$W = P_m \times A \times L$$

$$= 150 \times 10^3 \times 220 \times 10^{-4} \times 200 \times 10^{-3}$$

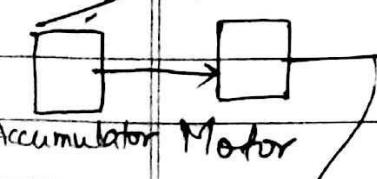
$$= 660 \text{ J}$$

Home Assignment

3.11, 3.13, 3.15, 3.16

$$\begin{aligned} I &= P_m \times A \times L \\ &= 150 \times 10^3 \times 220 \times 10^{-4} \times 200 \times 10^{-3} \\ &= \frac{\pi (200)^2}{101.7 \times 10^3} \end{aligned}$$

3.20)



$$P_{atm} = 101.3 \times 10^3 \quad W_{fluid} = 2000 \text{ N-m}$$

$$\text{Torque} =$$

$$v = 840 \times 60 \text{ rev/min}$$

$$485 \text{ mm} \quad \text{Torque} = P \times r$$

$$840 \text{ rpm} \quad r = 400 \text{ mm}$$

$$10 \text{ mm}$$

$$P = \text{Work done by stirrer}$$

Let W_1 = work done by fluid.

W_2 = work done by stirrer

Date _____
Page _____

Work done by fluid and stirrer = Work done by piston
 $P_{atm} \times dV$

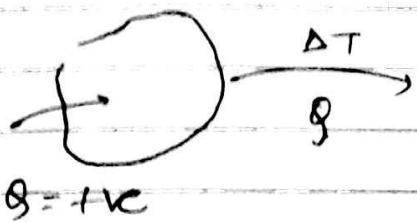
$$\begin{aligned}
 &= 101.3 \times 10^3 \times 3.14 \times (200 \times 10^{-3})^2 \times 185 \times 10^{-2} \\
 &= 101.3 \times 3.14 \times 4 \times 10^{-2} \times 185 \\
 &= 10.13 \times 3.14 \times 485 \\
 &= 137.23 \quad 6176 \text{ Nm} \\
 &\quad - 1872.76 \\
 &-(6176 - 2000) = -4176 \text{ N-m}
 \end{aligned}$$

$$\text{Power} = \frac{4176}{t} = 6.96 \text{ W} = 2\pi NT$$

$$T = \frac{6.96}{2 \times 3.14 \times 840 \times 60} = \frac{6.96}{316512} = 2.19 \times 10^{-5}$$

$$\omega = \frac{Vit}{motor \text{ (acumulator)}} = 5040 \text{ N-m}$$

$$\omega_{motor} = +4176 - 5040$$

Heat :

$$Q = mc \Delta T$$

↳ 1 kcal → 1 kg at 14.5°C
 at 1 atm pressr $\rightarrow Q \text{ is } 15.5^\circ\text{C}$

Conduction : $Q = -KA \frac{dT}{dx}$ Fourier's law

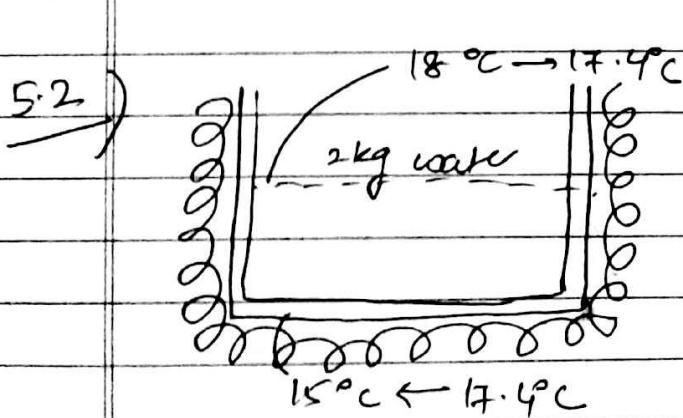
Newton's law of cooling :

$$Q = hA (T - T_s)$$

heat transfer co-efficient

Radiation : $\frac{Q}{A} = \sigma T^4$

$$\frac{Q}{A_{T_1, T_2}} = \sigma (T_1^4 - T_2^4)$$

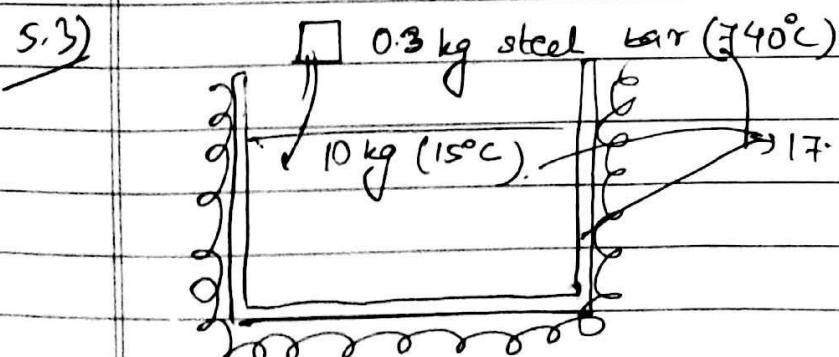


$$Q_w = -mc \Delta T$$

$$= -2 \times 4200 \times 0.6$$

$$= -5040 \text{ J.}$$

$$Q_v = -Q_w = 5040 \text{ J.}$$



- i) water
- ii) vessel & insulation
- iii) steel bar
- iv) for all

$$\begin{aligned}
 \text{Ans: i) } Q_w &= mc \Delta T \\
 &= 10 \times 2.4 \times 4200 \\
 &= 24 \times 4200 \\
 &= 100800 = 100.8 \text{ kJ}
 \end{aligned}$$

42
 24
 1168
 .840
 1008

$$\begin{aligned}
 \text{ii). } Q_w &= 10 \times 3.04 \text{ kJ} \\
 &\quad (\text{from previous problem})
 \end{aligned}$$

740.0
 12.4
 722.6

$$\begin{aligned}
 \text{iii) } Q_s &= -0.3 \times 722.6 - (Q_w + Q_v) \\
 &= -(105.84) \text{ kJ}
 \end{aligned}$$

	Q	W
(a)	-ve	0
(b)	0	+ve
(c)	+ve	0
(d)	+ve	-ve
(e)	when the ice melts, the volume decreases.	

(piston is held stationary)

~~(e)~~ $Q=0$ -ve

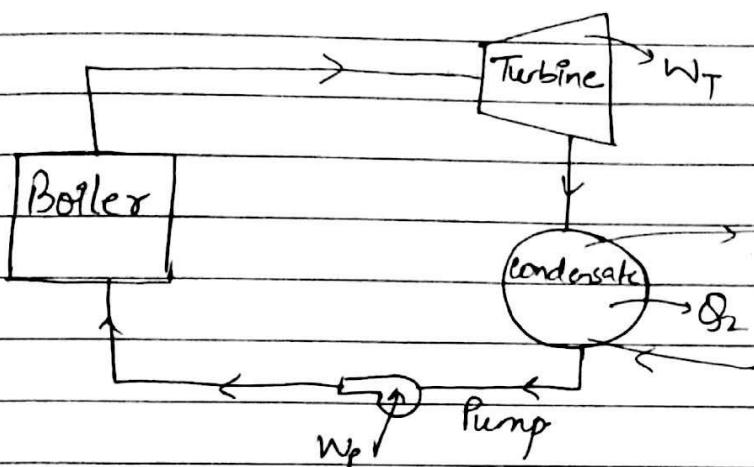
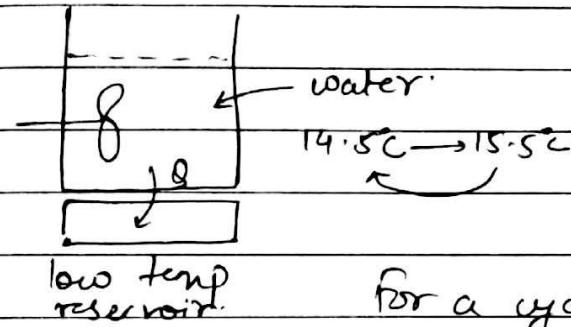
displacement work is 0 as piston is stationary

(f) 0 -ve
both displacement and shining work is no

3/09/15

FIRST LAW OF THERMODYNAMICS:

(considering for a closed system)

Steam Power plant \rightarrow Rankine cycle (Vapour Power cycle)

$$\frac{W}{Q} = \text{constant} = J$$

Mechanical equivalent of
heat.
 $= 4.8 \frac{\text{N} \cdot \text{m}}{\text{cal}}$

for a cyclic process;

$$\sum W = \sum JQ \quad \text{or} \quad \sum JQ - \sum W = 0$$

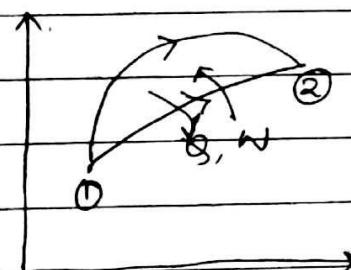
$$\sum (JQ - W) = 0$$

Heat absorbed \rightarrow +ve

$$\sum (Q - W) = 0$$

" released \rightarrow -ve

$$\text{or } (Q_1 + Q_2) - (W_T + W_P) = 0$$

Total energy of a system E
 $\rightarrow U + K.E + P.E + \dots$

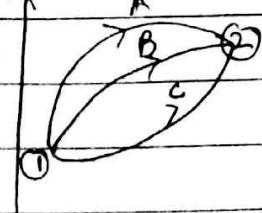
for a non-cyclic process,

$$\sum Q - \sum W = \underbrace{E_2 - E_1}_{\text{not dependent on path.}}$$

Proof: Energy is a property

1-A-2-C-1

$$\oint (dQ - dW) = 0$$



1-B-2-C-1

$$\int_{T_A}^2 (dQ - dW) + \int_{T_A}^3 (dQ - dW) = 0$$

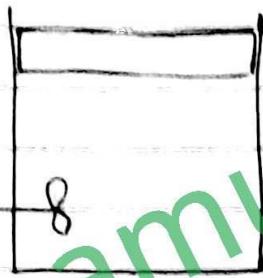
$$(E_2 - E_1)_A$$

Similarly, $\int_{1B}^2 (dQ - dW) + \int_{2C}^1 (dQ - dW) = 0$

$$\therefore (E_2 - E_1)_A = (E_2 - E_1)_B$$

$(E_2 - E_1)_A = (E_2 - E_1)_B$. Therefore it depends only on end states and not on the path.

B 6.2



Insulated

$$(i) W_{\text{other}} = 1200 \text{ N-m} \quad ① \rightarrow ②$$

$$dV = 2.8 \text{ cm}^3$$

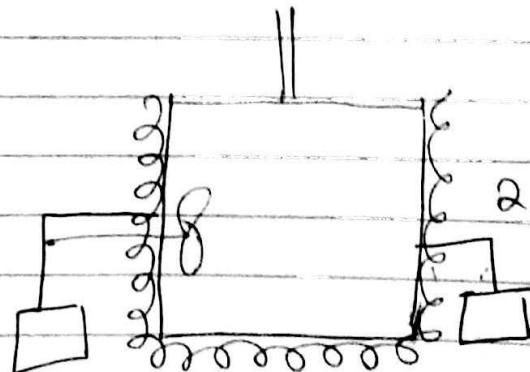
$$W_{\text{fluid}} = P \frac{dV}{m} \\ = 200 \times 10^3 \times 2.8 \times 10^{-3} \\ = 20 \times 2.8 = 560$$

$$\text{Net work} = 560 - 1200 \\ = -640 \text{ J}$$

$$(ii) W_{\text{displ}} = -(200 \times 10^3 \times 2.8 \times 10^{-3}) \quad (\text{CN} \rightarrow -\text{ve}) \\ = -560$$

$$Q = -W_{\text{displ}} = -1200 \text{ N-m} \quad (Q = U + W)$$

iii)



$$m_w = 173 \text{ kg} \quad t = 5 \text{ min}$$

$$-3060 \text{ sec}$$

$$270 \text{ rev/min}$$

$$270 \times 60 \text{ rev/sec.}$$

$$T = 492 \times 1.5$$

$$= 738 \text{ J}$$

$$W = 2\pi n T \quad W = 270 \times 60 \quad 738 \times 360 \cancel{- 2000} \\ = 2 \times 3.14 \times 270 \times 60 \times 7.8 \quad \cancel{360} \\ = 6381879.208 \quad = \cancel{33210} \quad 4304016 \times 10^3 \text{ J}$$

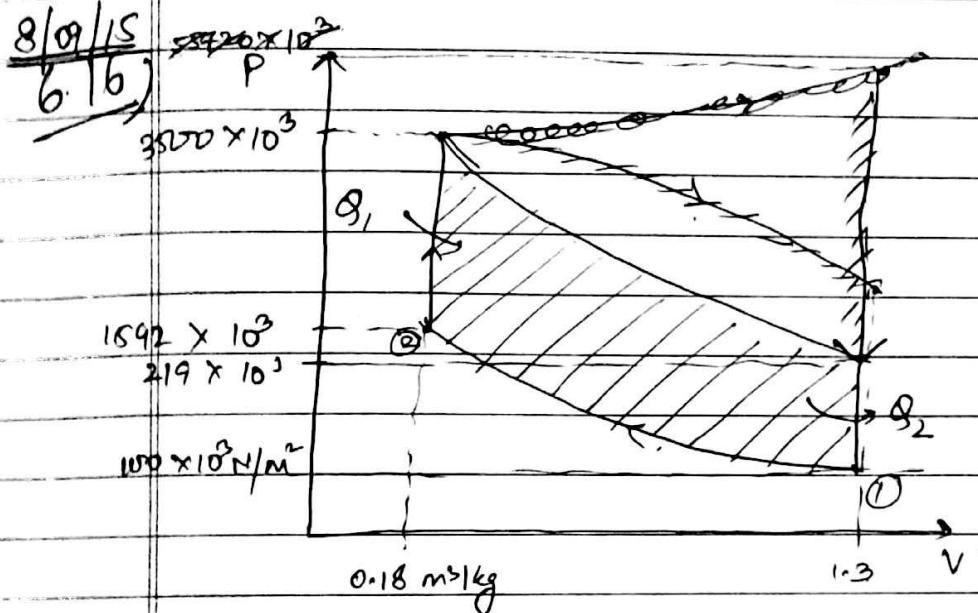
$$Q = mc \Delta T$$

$$= 173 \times 4.19 \times 10^3 \times 88$$

$$= 63788.5 \text{ kJ}$$

$$\text{Heat transfer} = \frac{W}{Q} = \frac{32210}{63788.5} = \frac{4304016}{63788.5}$$

$$= \cancel{67.47} \frac{63818.99 \cdot 2.8}{63788.500} =$$



$$(i) P V^{1.4} = \text{const}$$

$$\Rightarrow 10^5 \times \left(\frac{0.18}{0.3}\right)^{1.4} = P_2 \times$$

$$\text{or } 10^5 \times (0.6)^{1.4} = P_2$$

$$\text{or } 1592 \times 10^3 = P_2$$

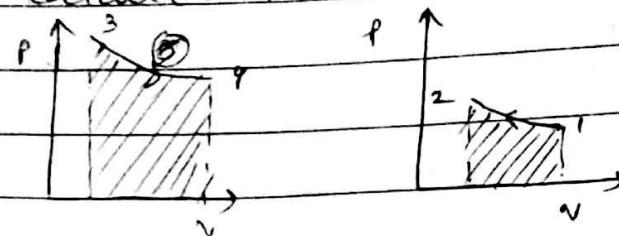
$$Q_1 = 840 \text{ kJ}$$

$$(ii) 3500 \times 10^3 \times \left(\frac{0.18}{1.3}\right)^{1.4} = P'_2$$

$$\therefore 3500 \times 10^3 \times 15.92 = P'_2$$

$$219 \cdot \cancel{55720} \times 10^3 = P'_2$$

To calculate the work done,



$$\begin{aligned}
 \text{(i)} \quad W_{12} &= \frac{P_1 V_1 - P_2 V_2}{\gamma - 1} \quad W_{2-3} = 0 \quad \text{and} \quad W_{4-1} = 0 \\
 &= \frac{1.3 \times 10^5 - 15.2 \times 0.18 \times 10^5}{1.4 - 1} \\
 &= 10^5 \left[1.3 - 2.73 \right] \\
 &= \frac{-1.43 \times 10^5}{0.4} = -3.575 \times 10^5 \text{ J} \\
 &= -392.2 \times 10^3 \text{ J}
 \end{aligned}$$

$$W_{3-4} = \frac{3500 \times 10^3 \times 0.18 - 219 \times 10^3 \times 1.3}{1.4} \\ = + 863.2 \times 10^3 \text{ J}$$

(ii) ~~first law of cyclic processes~~ 1-2-3-4-1

$$\Sigma \mathcal{G} = \Sigma W$$

$$\phi_1 + \phi_2 = w_{12} + w_{3-4}$$

$$840 \times 10^3 + Q_2 = 863.2 \times 10^3 - 392.25 \times 10^3$$

$$840 \times 10^3 + Q_2 = 470.95 \times 10^3$$

$$Q_2 = -369.05 \times 10^3 \text{ J}$$

$$(iii) E_2 - E_1 = Q - W_{1-2} \\ = 392 \cdot 2 \times 10^3 \text{ J}$$

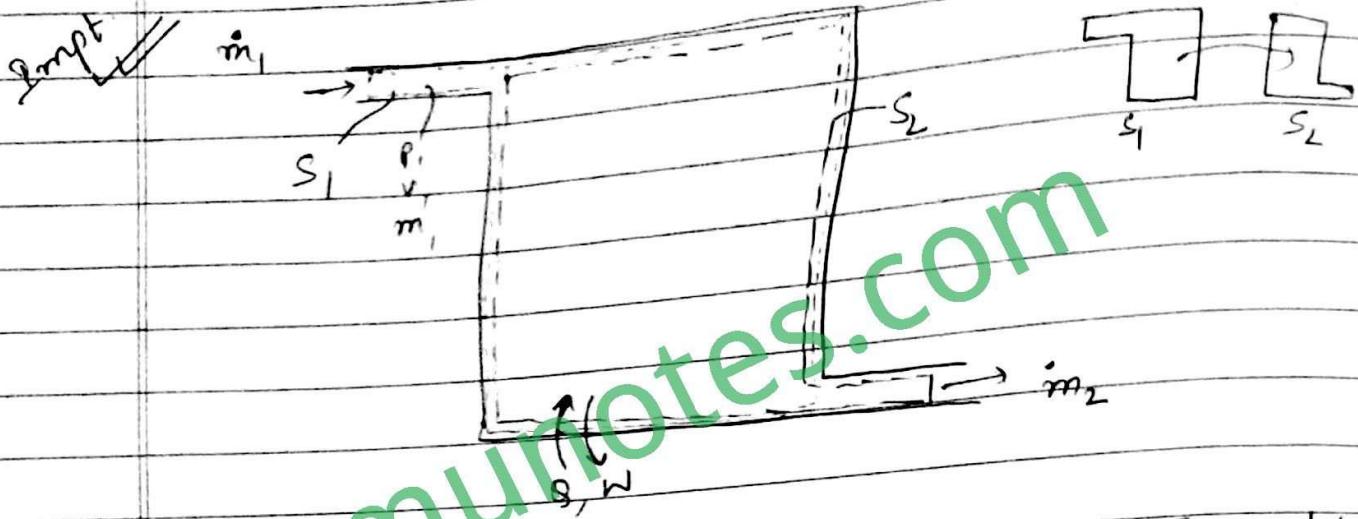
$$E_3 - E_2 = 840 - 0 = 840 \times 10^3 \text{ J}$$

$$E_4 - E_3 = Q - W_{4-3} \\ = 0 - (-863 \times 10^3) = 863 \cdot 2 \times 10^3 \text{ J}$$

$$E_1 - E_4 = -369.05 \text{ kJ}$$

10/09/15

First Law of Thermodynamic for Open Series (Flow Devices)



$$Q - W = \Delta E = E_2 - E_1$$

$\{V_1$ and V_2 are specific vol.

$$W = W_x \quad (\text{Work done})$$

$$= W_x - p_1 V_1 m_1 + p_2 V_2 m_2$$

$$E_1 = e_1 m_1 + E_{cr}$$

$$E_2 = e_2 m_2 + E_{cf}$$

$$E_{cr} = E_{cf} \quad \leftarrow \text{steady flow}$$

$$Q - W_x + p_1 V_1 m_1 - p_2 V_2 m_2 = e_2 m_2 + E_{cf} - e_1 m_1 - E_{cr}$$

$$Q - W_x = (e_2 + p_2 V_2) m_2 - m_1 (e_1 + p_1 V_1)$$

$m_1 = m_2 = m \quad \leftarrow \text{conservation of mass principle}$

$$e = u + \frac{1}{2} V^2 + gH$$

$\downarrow \rightarrow$ velocity

$$Q - W_x = (u_2 + \frac{1}{2} V_2^2 + gH_2 + p_2 V_2) m_2 - m_1 (u_1 + \frac{1}{2} V_1^2 + gH_1 + p_1 V_1)$$

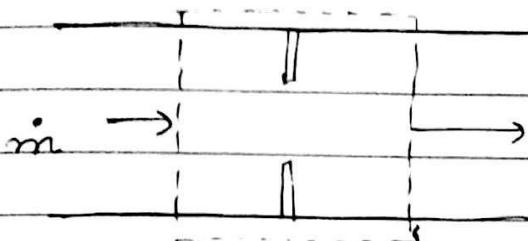
Enthalpy; $h = u + pv$

$$Q - W_x = (h_2 + \frac{1}{2} V_2^2 + gH_2) m_2 - (h_1 + \frac{1}{2} V_1^2 + gH_1) m_1$$

$$\boxed{\frac{Q - W_x}{m} = \Delta(h + \frac{1}{2} V^2 + gH)} \quad \leftarrow \text{steady flow energy eqn (S.F.E.E)}$$

$$\dot{Q} - \dot{W}_x = \sum_{\text{outlet}} (h_2 + \frac{1}{2} V_2^2 + g H_2) - \sum_{\text{inlet}} (h_1 + \frac{1}{2} V_1^2 + g H_1)$$

Throttling Device :



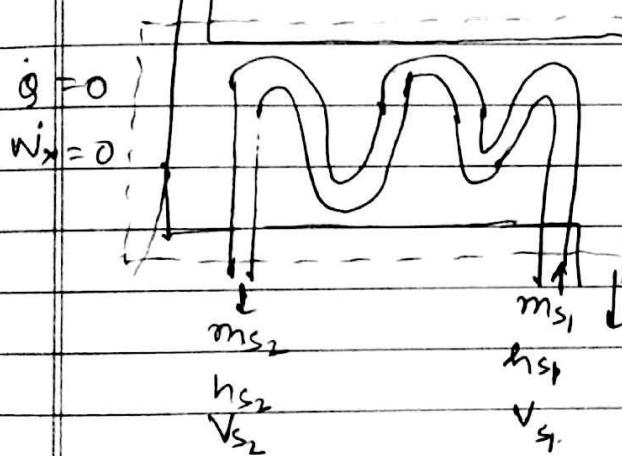
$$\dot{Q} = 0 \quad \dot{W}_x = 0 \quad \Delta Z = 0$$

$$\Delta \frac{1}{2} V^2 = 0$$

$$h_2 = h_1$$

Heat exchanger :

m_w, w, h_w

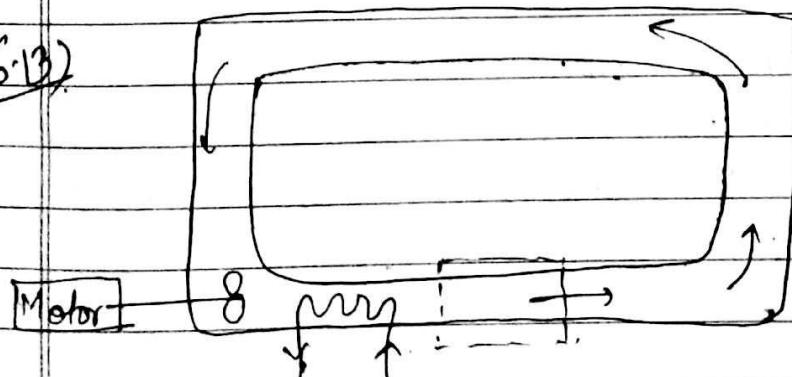


$$\therefore \dot{Q} = (h_{w2} + \frac{1}{2} V_{w2}^2) m_{w2} + (h_{s2} + \frac{1}{2} V_{s2}^2) m_{s2} - (h_w + \frac{1}{2} V_w^2) m_w - (h_s + \frac{1}{2} V_s^2) m_s$$

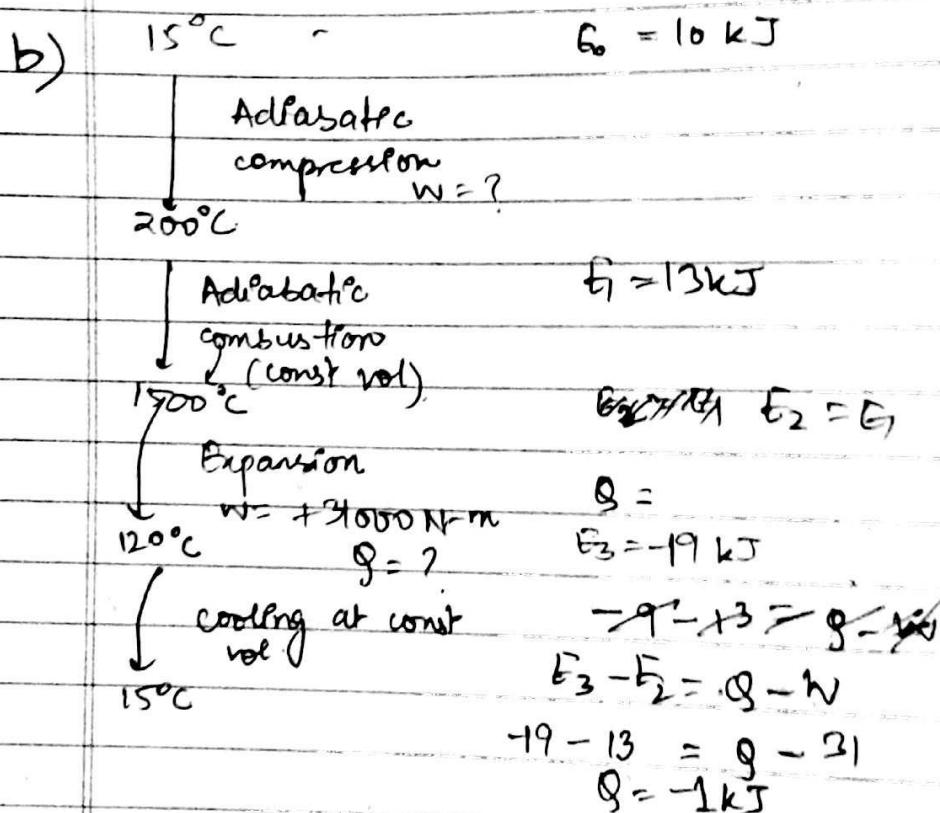
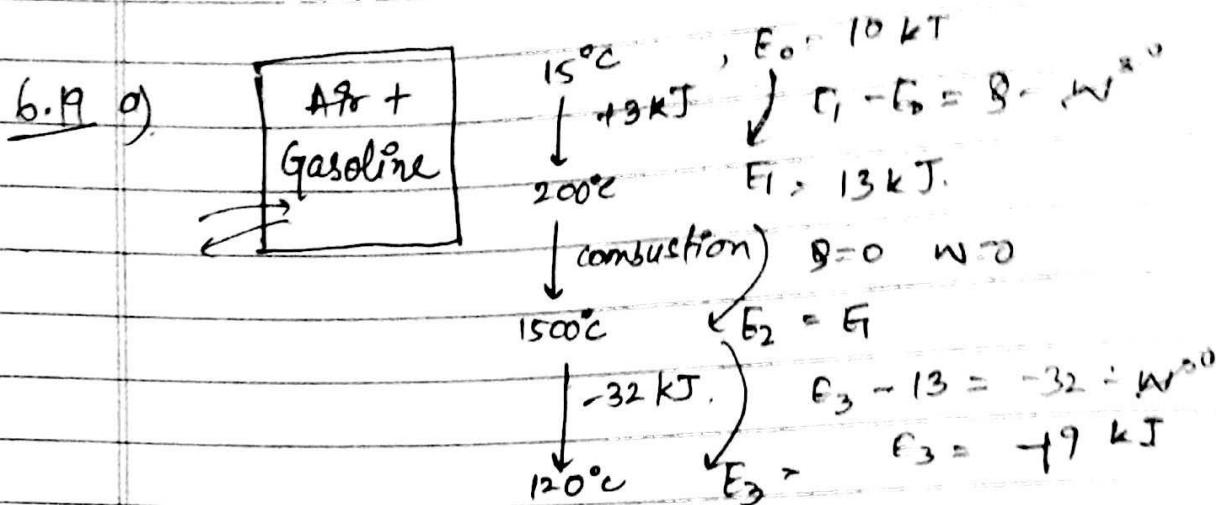
$$\text{or } m_w (\Delta h_w + \frac{1}{2} \Delta V_w^2) + m_s (\Delta h_s + \frac{1}{2} \Delta V_s^2) = 0$$

$$\dot{Q} = m_{w2} (h_{w2} + \frac{1}{2} V_{w2}^2) - m_w (h_w + \frac{1}{2} V_w^2)$$

6.13)



- (i) $\dot{Q} = 0$
- (ii) $W = -ve.$
- (iii) $\Delta E = +ve$
- (iv) $\dot{Q} = 0$

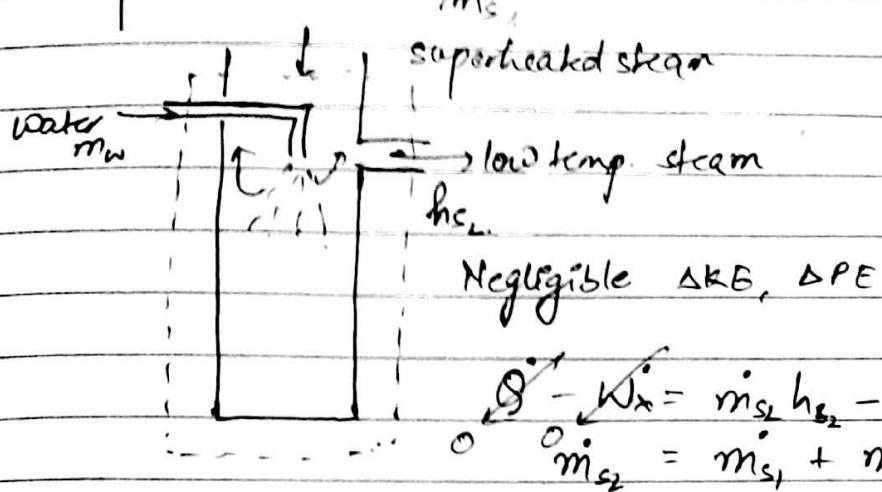


- Q According to first LOT

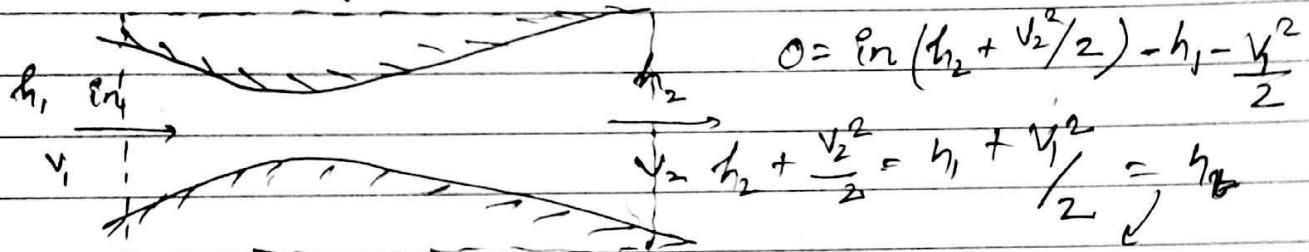
 - (a) TE of a system remains const.
 - (b) " " " during a process remains const
 - (c) enthalpy, entropy & total energy remains const
 - (d) NOT

14/09/15

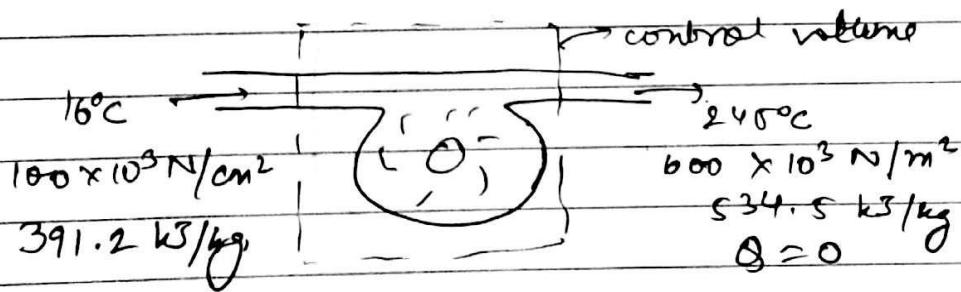
De-superheater:



Adiabatic, convergent divergent nozzle:



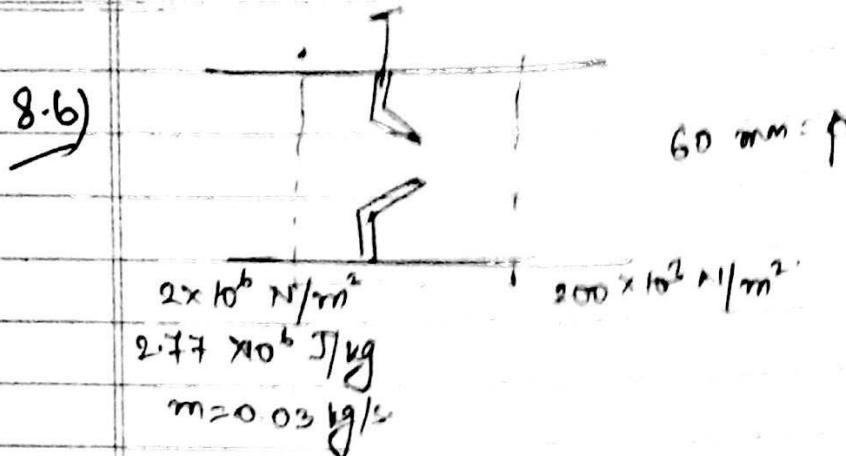
Total enthalpy or
Stagnation enthalpy.

Q8.4)

$$\dot{Q} - W_x = \dot{m} \left[(h_2 + \frac{v_2^2}{2} + g_z z_2) - (h_1 + \frac{v_1^2}{2} + g_z z_1) \right]$$

$$\dot{Q} - W_x = \dot{m} [534.5 - 391.2]$$

$$-W_x = 143.3 \text{ m}$$



$$\dot{Q} - W_1 = \dot{m} [h_1 - h_2]$$

i) $h_1 = h_2$ (throttle as velocity is negligible)
 $\Delta V = 0$

ii) $\rho_1 = 0.98 \text{ m}^3/\text{kg}$ $\rho_2 = 0.9602 \text{ m}^3/\text{kg}$ $0.9602 \text{ m}^3/\text{kg}$

mass flow $\dot{m} = \frac{\rho}{\rho} A_1 V_1$

$$\dot{m} = \rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\boxed{\dot{m} = \frac{A_1 V_1}{\rho_1 V_1} = \frac{A_2 V_2}{\rho_2 V_2}}$$

$$0.03 = \frac{3.14 \times 30 \times 20 \times 10^{-4} \times 10^{-3} \times V_1}{0.98}$$

$$0.03 = \frac{28836.7 \times 10^{-6} \times V_1}{28836.7} \times 10^6 = V_1$$

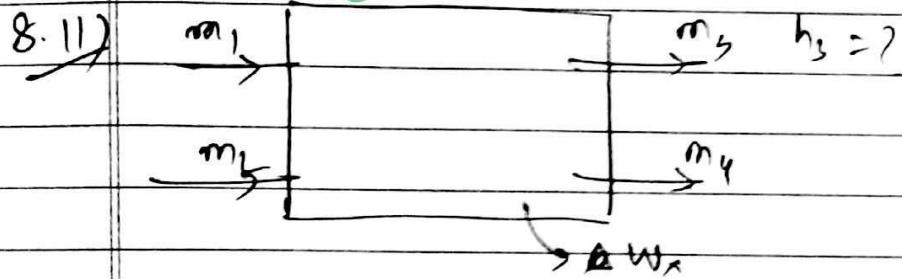
$$1.04 = V_1$$

$$V_2 = \frac{0.03}{2943.13} \times 10^6 \\ = 10.19$$

$$m \left(\frac{V_2^2}{2} - \frac{V_1^2}{2} \right) = \Delta KE$$

$$0.03 \left(\frac{103.83}{2} - \frac{1.0216}{2} \right) = \Delta KE$$

$$1.84 = \Delta KE = 51.3 \text{ J/kg}$$



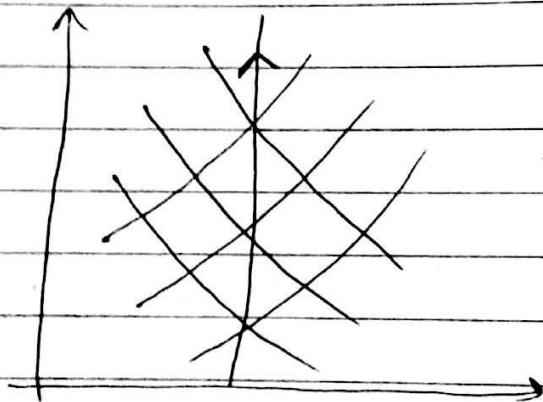
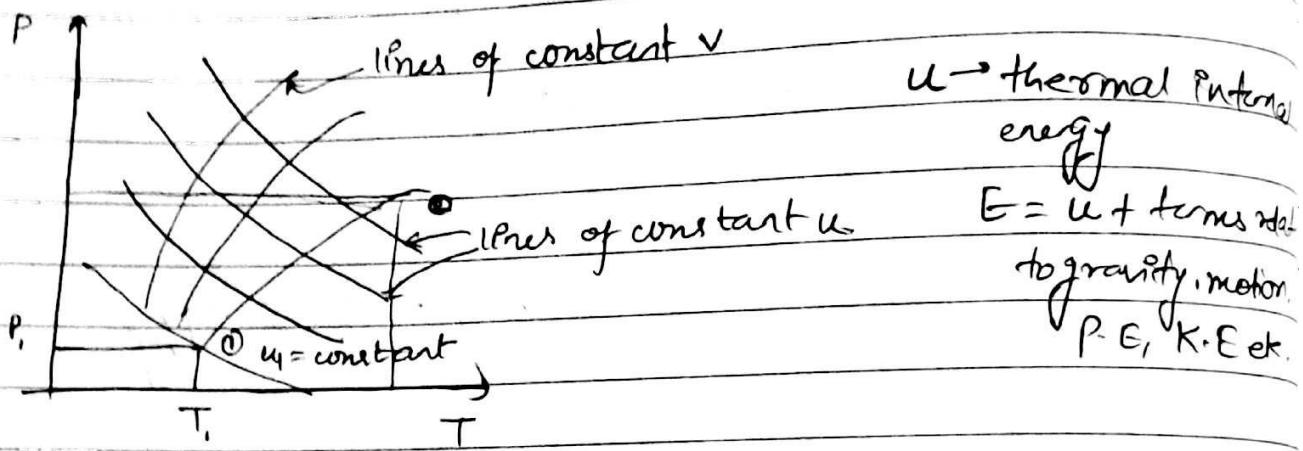
$$-w_x = m_4 \left(h_4 + \frac{V_4^2}{2} \right) + m_3 \left(h_3 + \frac{V_3^2}{2} \right) - m_2 \left(h_2 + \frac{V_2^2}{2} \right) \\ - m_1 \left(h_1 + \frac{V_1^2}{2} \right).$$

Put the values to find answer.

15/09/15

PURE SUBSTANCES

- ↳ Homogenous chemical composition \rightarrow ratio of element should be same.
- ↳ " in " aggregation.
- ↳ Invariable " "



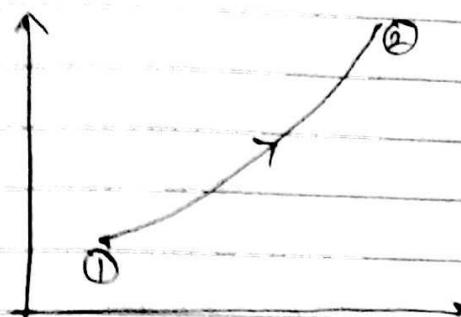
Temp inc. but specific vol also changes therefore internal energy remains const.

Two property rule:

$$z \neq f(x, y)$$

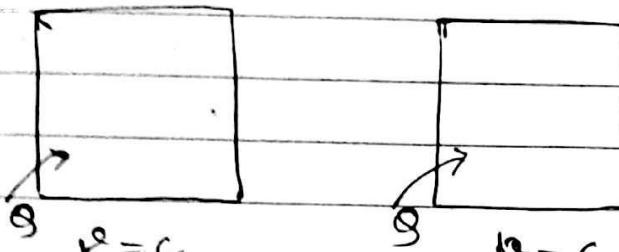
(1) system is in equilibrium

(2) effects of motion, gravity, electricity etc are negligible



$$E = U + KE + PE + \dots$$

$E \approx U$ + heat transactions.



$$C_p > C_v$$

$$C_v = \left(\frac{\delta u}{\delta T} \right)_V$$

$$C_p = \left(\frac{\delta u}{\delta T} \right)_P$$

$$dQ - dW = du$$

$v = \text{const}$

$$dQ = du$$

$$= \left(\frac{\delta u}{\delta T} \right)_V \cdot dT$$

$$C_v = \frac{dQ}{dT} \Big|_V = \left(\frac{\delta u}{\delta T} \right)_V$$

$$dQ - dW = du$$

$$dQ - p \cdot dv = du$$

$$dQ = du + p \cdot dv$$

$$h = u + p \cdot v$$

$$dQ = dh - p \cdot \cancel{dv} - v \cdot \cancel{dp} + p \cdot \cancel{dv}$$

$$C_p = \frac{dQ}{dT} \Big|_P = \left(\frac{\delta h}{\delta T} \right)_P$$

$$dQ = du ; u = f(v, T)$$

$$dQ = \left| \frac{\delta u}{\delta T} \right|_V \cdot dT + \left| \frac{\delta u}{\delta V} \right|_T \cdot dv$$

Q7.4) $m = 0.3 \text{ kg}$ $P = 90 \times 10^3 \text{ N/m}^2$
 $T = 40^\circ \text{C}$ $V = 120 \text{ dm}^3$

$$U = 30.4 \times 10^3 \text{ J} \quad h = ?$$

Q7.5) $dQ - dW = du$

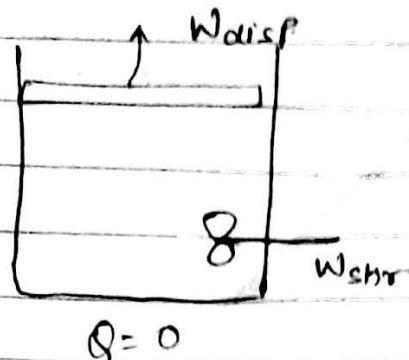
$$dQ - p \cdot dv = du$$

$$dQ = du + p \cdot dv$$

$$= dh - p \cdot \cancel{dv} - v \cdot \cancel{dp} + p \cdot \cancel{dv}$$

$$dQ = dh$$

7.6)



$$dQ - dW = du$$

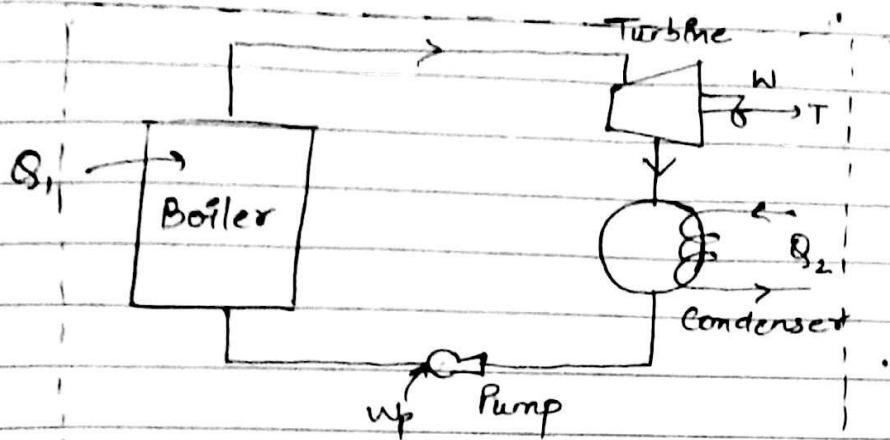
$$0 - (-W_{shtr}) - W_{shp} = dU$$

$$-(-W_{shtr}) - (+pdV) = du$$

$$+W_{shtr} = du + pdV$$

12/10/15

PROPERTIES OF PURE SUBSTANCES



$$Q_1 \rightarrow \text{Boiler} \rightarrow W_T \quad \sum Q = \sum W$$

$$W_P \rightarrow \text{Pump} \rightarrow Q_2$$

$$\begin{array}{c} h_1 \\ | \\ Q_1 \\ | \\ P \\ | \\ h_2 \end{array}$$

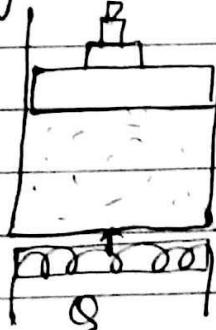
$$\begin{array}{c} T \\ | \\ \text{Condenser} \\ | \\ T \end{array}$$

It is easy to measure the temp and press for the system but not the h_1 and h_2 (enthalpies).

Therefore, the engineers used P, T to determine ' h '.

$$dh(\text{enthalpy}) = \frac{dQ}{dT} \Big|_{\text{const } P}$$

\downarrow weights are added
 \downarrow change \rightarrow
Press \rightarrow



const for process

P_1
 P_2
 P_3
 $T \rightarrow$ variation of
temp is seen

from FLOT;

$$dQ - dW = du.$$

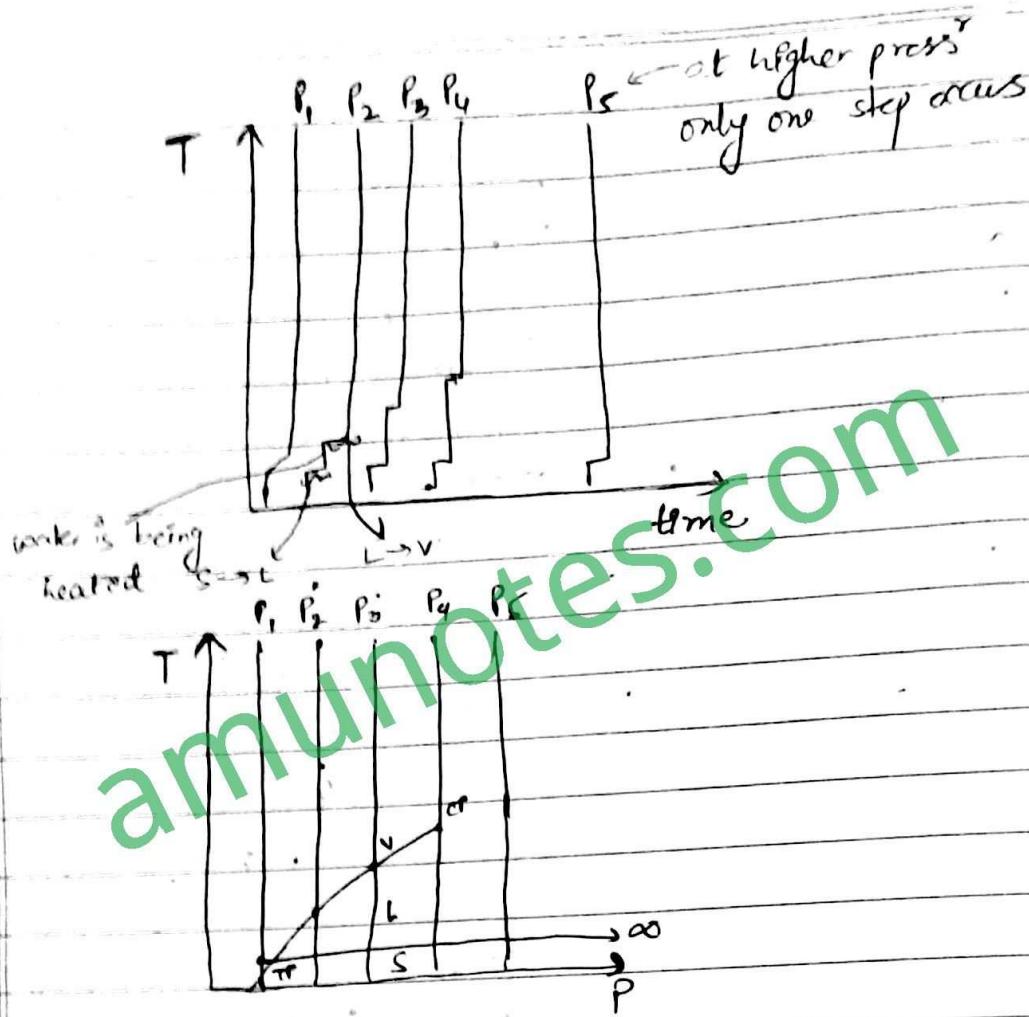
$$dQ - d(PV) = du$$

$$\text{or } dQ = du + pdv + vdp \quad \text{--- (1)}$$

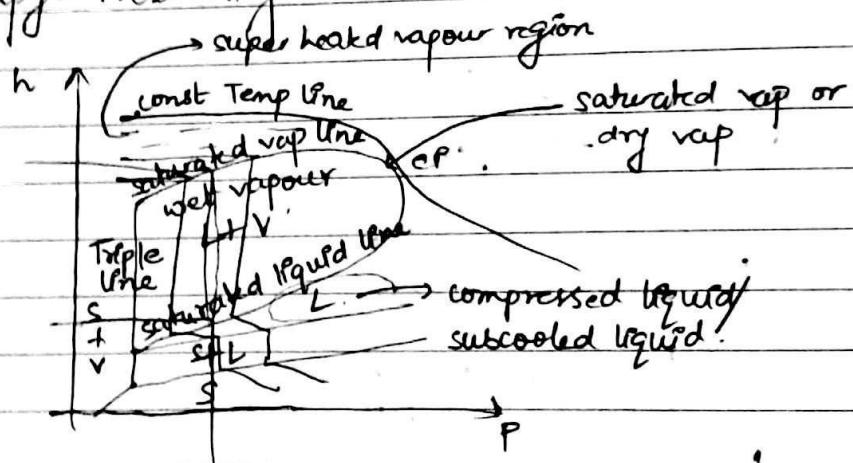
$$dh = d(u + Pv) = du + pdv + vdp \quad \text{--- (2)}$$

$$\text{or } dQ = dh.$$

for $P = \text{const press}$

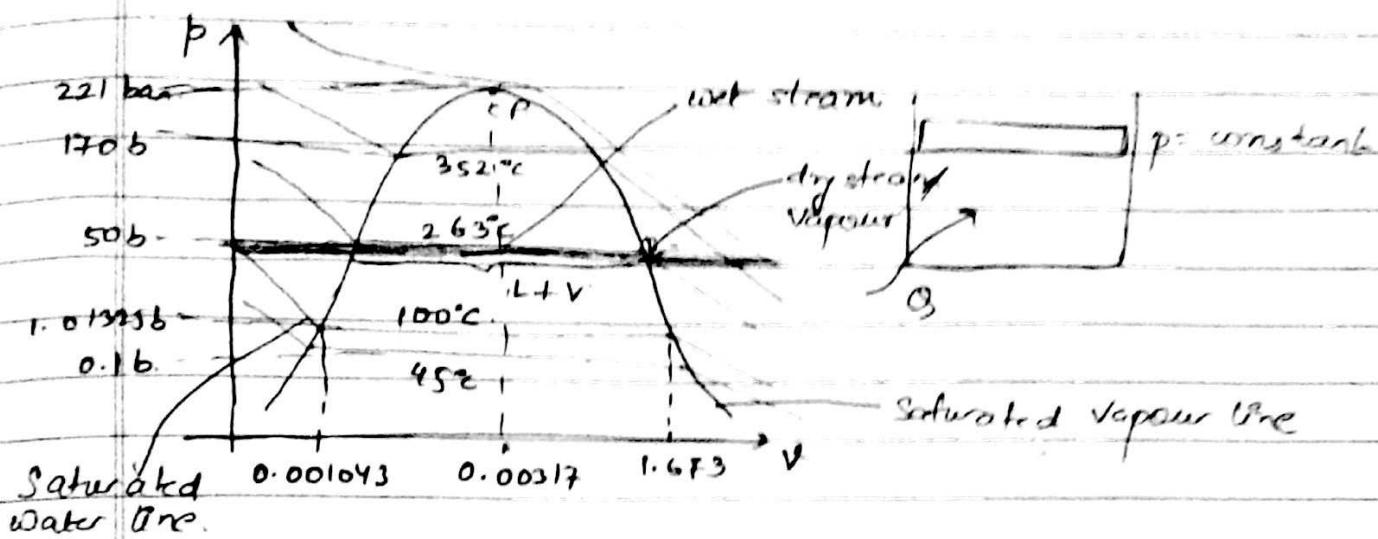


Enthalpy- Press^r diagram :





19/10/15



Dryness fraction:

Ratio of dry vapour in mixture and total mass.

$$x = \frac{m_g}{m_f + m_g} \quad \left\{ m_g = \text{mass of vapour} \right.$$

saturated water \downarrow saturated vap \downarrow $x = 0.4$ (assumed)
 $0 < x < 1$

v	m_g	P
		v_f, v_g
	m_f	

$$v = xv_f + (1-x)v_g$$

sp vol of mixture / u/s same formula used.

Q9.1. $v_g = ?$ $P = 6 \times 10^3 \text{ N/m}^2$

$$P = \frac{6 \times 10^3 \times 1.013}{10^{-5}} = \frac{6.078 \times 10^3 \times 10^{-5}}{10^{-5}} = 6.078 \times 10^{-2}$$

$$= 0.06078$$

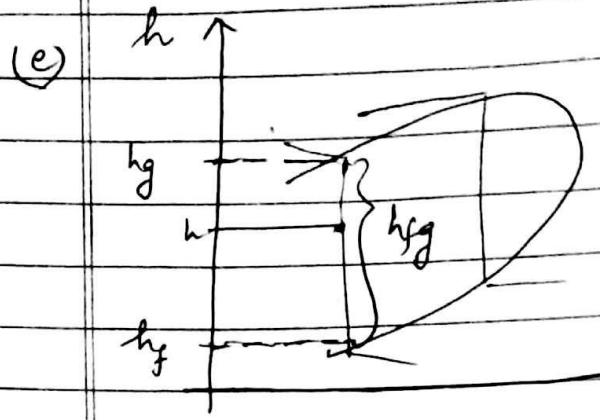
from steam table:

$$v_f = 0.0010064 \text{ m}^3/\text{kg}$$

(b) $T = 200^\circ\text{C}$ from steam table

$$v_g = 0.12716 \text{ m}^3/\text{kg}$$

(c) $T = 100^\circ\text{C}$ $v_f = 0.0010437 \text{ m}^3/\text{kg}$



$$h_{fg} = h_g - h_f$$

$$\begin{aligned} h &= x h_g + (1-x) h_f \\ &= x h_g + h_f - x h_f \\ &= h_f + x h_{fg} \end{aligned}$$

(f) h_{fg} at 6.3 bar

In steam table

At 6 bar, $h_{fg} = 2085.0$

7 bar, $h_{fg} = 2064.9$

$$\frac{h_{fg} - 2085}{2064.9 - 2085} = \frac{6.3 - 6}{7 - 6} = 0.3 \quad (\text{Interpolation})$$

to find out the exact value corresponding to 6.3

$$h_{fg} = 2083.191$$

(g) at $T = 100^\circ\text{C}$, $h_g = 2676^\circ\text{C}$.

(h) $P = 37.5 \text{ bar}, u_f = ? \quad P = \text{at } 40^\circ\text{C}$

at 35°C $u_f = 1045.4$

$u_f = 1082.4$

$u_g = 2602.4$

$u_g = 2601.3$

Interpolating,

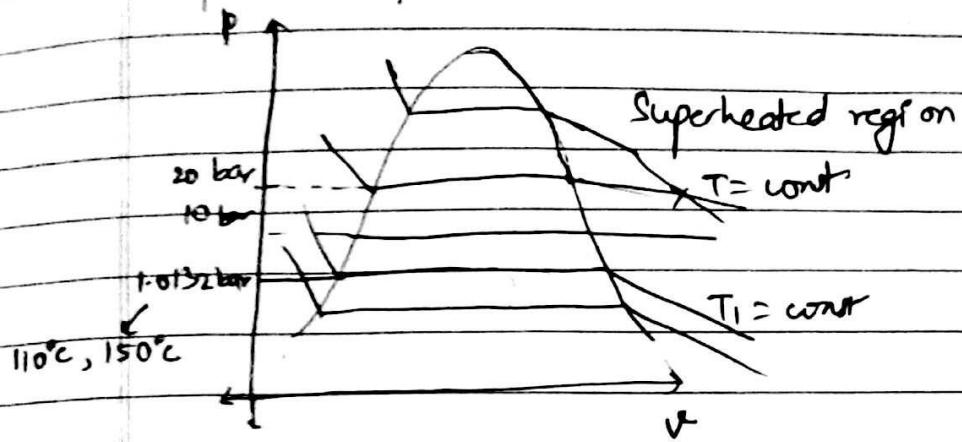
$$\frac{37.5 - 35}{40 - 35} = \frac{u_f - 1045.4}{1082.4 - 1045.4}$$

$$\frac{2.5}{8.2} = \frac{u_f - 1045.4}{37}$$

$$\therefore \frac{18.5 + 1045.4}{2109.3} = \frac{u_f}{u_f} \quad \text{Ans.}$$

20/10/15

Properties of water:



$$\begin{array}{ll} \text{9.1)} & v \\ \text{i)} & h \\ \text{u} & \end{array} \quad p = 4 \text{ bar} \rightarrow T_{\text{sat}} = 143.63^\circ\text{C}$$

$$T = 400^\circ\text{C}$$

$$\Delta T_{\text{sup}} = T - T_{\text{sat}} \quad u = h - pv$$

Degree of superheat

From table 4;

$$v = 0.77250 \quad h = 3273.6 \quad s = 8.1919$$

$$\text{(ii)} \quad P = 70 \text{ bar} \quad h = 2903.0 \times 10^3 \text{ J/kg}$$

$$T = ? \quad v = ?$$

(Table IV).

By interpolation,

$$\frac{2903 - 2839.4}{3018.7 - 2903} = \frac{T - 300}{350 - T}$$

$$\frac{63.6}{115.7} = \frac{T - 300}{350 - T}$$

$$0.549 (350 - T) = T - 300$$

$$192.39 - 0.549 T = T - 300$$

$$492.39 = T + 0.549 T = 1.549 T$$

$$T = 317.87^\circ\text{C}$$

By interpolation again, we'll find sp. vol;

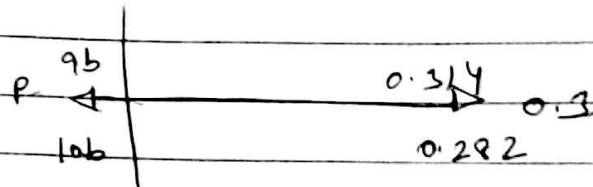
$$\frac{v - 0.029457}{0.035233 - 0.029457} = \frac{2903 - 2839}{3018 - 2839}$$

(k) $T = 350^\circ\text{C}$, $v_{sp} = 0.30 \text{ m}^3/\text{kg}$

Table II,

$$v_g = 0.0087991.$$

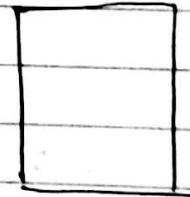
$$P = 1 \quad 350^\circ\text{C}$$



$$\frac{P - 9}{10 - 9} = \frac{0.3 - 0.31440}{-0.31440 + 0.28243}$$

(by interpolation)

9.6 a). $V = 0.58 \text{ m}^3$



$$m = 1 \text{ kg}$$

$$P = 300 \times 10^3 \text{ N/m}^2$$

$$= 3 \text{ bar}$$

$$v, T, x, u, h = ?$$

Ans $v_{sp} = \frac{\text{Tot Vol}}{\text{mass}} = \frac{0.58}{1} = 0.58$

v_{fg}

Table II, at 3 bar

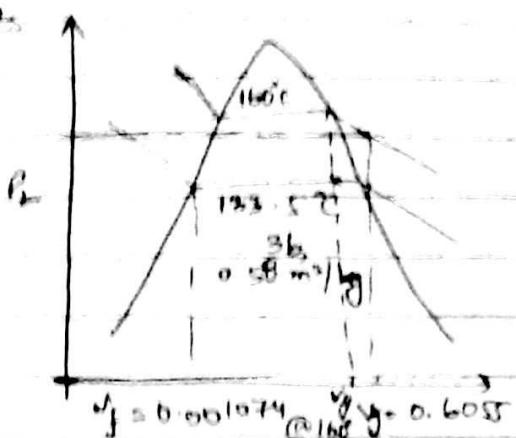
$$v_f = 0.0010735 \text{ and } v_g = 0.60553$$

$$T = 133.54^\circ\text{C}$$

$$v = xv_g + (1-x)v_f$$

$$u = u_f + x u_{fg}$$

$$h = h_f + x h_{fg}$$

26/10/15.

$$\alpha = 0.9511$$

(b) $h_2 = ?$, $\Delta h = ?$, $a_v = ?$ $s = ?$

$$h_2 = u_2 + p_2 v_2$$

from steam table (III).

$$\frac{v_3 - 0.63374}{0.71635 - 0.63374} = \frac{160 - 150}{200 - 150}$$

$$\text{and } \frac{160 - 150}{200 - 150} = \frac{v_4 - 0.47}{0.53 - 0.47}$$

160°C

$$3b \rightarrow 0.65026$$

$$P_2 = ? \quad 0.58$$

$$4b \rightarrow 0.483$$

$$\frac{P_2 - 3}{4 - 3} = \frac{0.58 - 0.65026}{0.483 - 0.65026}$$

$$P_2 = 3.421 \text{ bar}$$

To find out h , we gain interpolate

150°C

180°C

200°C

$$3b \quad 2760 \quad 2781 \quad 2865$$

$$P_2 = 3.412 \quad h_2 = 2778$$

$$4b \quad 2752 \quad 2773 \quad 2860$$

$$h_2 = u_2 + p_2 v_2$$

$$u_2 = 2778 \times 10^3 \left[(3.142) \times 10^5 \times 0.58 \right]$$

$$= 2580 \text{ kJ/kg}$$

From first law of thermodynamics

$$\Delta u = Q_1 = u_2 - u_1$$

P	v_g
3 b	0.605
3.5 b	0.523

$$\frac{P-3}{3.5-3} = \frac{0.58 - 0.605}{0.523 - 0.58}$$

$$\frac{P-3}{0.5} = -\frac{0.02553}{-0.08156}$$

$$P = 3.076 \text{ bar}$$

27/10/15

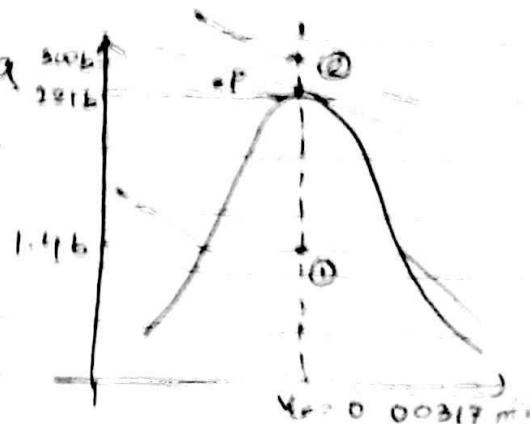
Q7) $m = 1 \text{ kg} = m_f + m_g = 1.4 \text{ ba}$

(a) $\frac{m}{m_f}$

(b) m_{f1}, m_{g1}

(c) $P_2 = 300 \text{ b} \rightarrow T_2 = ?$

(d) Q_{12}



$$V = \delta m = 0.00317 \text{ m}^3$$

$$(b) x = \frac{m_g}{m}$$

$$v = v_f + x(v_g - v_f)$$

$$x = ?$$

$$m_g = x m$$

$$m_f = (1-x)m$$

$$x = 0.00172$$

$$m_g = 0.00172 \text{ kg}$$

$$m_f = 0.99828 \text{ kg}$$

from table IV,

T_2
400°C
0.00283

T_2
500°C
0.00868

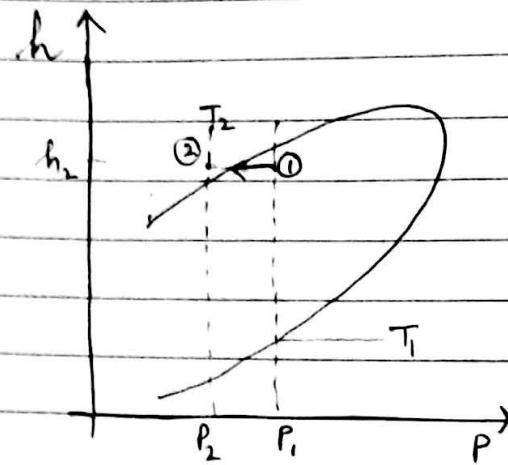
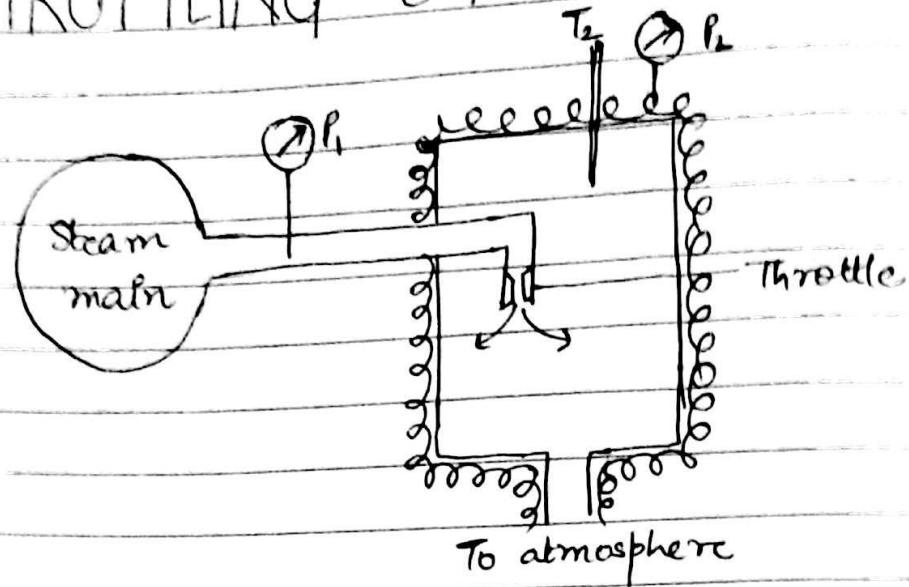
$$\frac{T_2 - 400}{500 - 400} = \frac{0.00317 - 0.00283}{0.00868 - 0.00283}$$

$$T_2 = 405.81$$

$$Q - W = \Delta U$$

$$S = u_2 - u_1$$

THROTTLING CALORIMETER :



Q. 9) $P_1 = 8 \text{ b}$, $P_2 = 1 \text{ b}$, $T_2 = 116^\circ\text{C}$; $x = ?$

$$T = 116^\circ\text{C}$$

Ans:

$$T = 100^\circ\text{C}$$

$$h = 2676.2$$

$$T = 150^\circ\text{C}$$

$$h = 2776.3$$

By interpolation,

$$\frac{150 - 116}{150 - 100} = \frac{h - 2676.2}{2776.3 - 2676.2}$$

$$h_2 = 2708.23 = h_1 = h$$

At 8 bar,

$$h_f = 720.9$$

$$h_{fg1} = 2046.5$$

$$h_g = 2767.5$$

$$h_1 = h_{f1} + 2 h_{fg1}$$

$$9708.23 - 720.9 + x(2046.5)$$

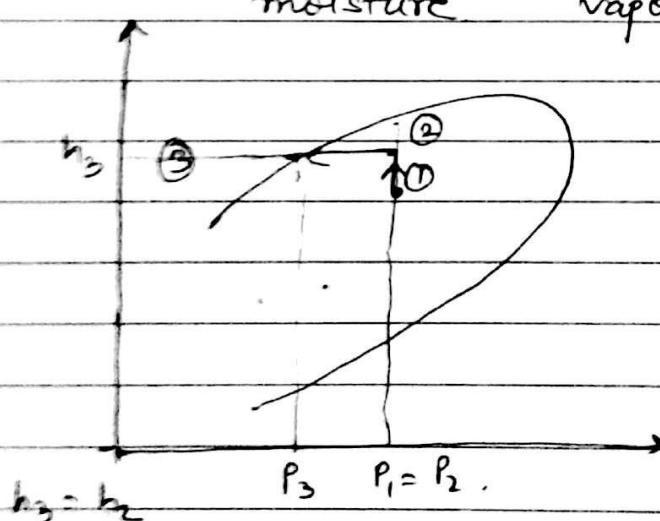
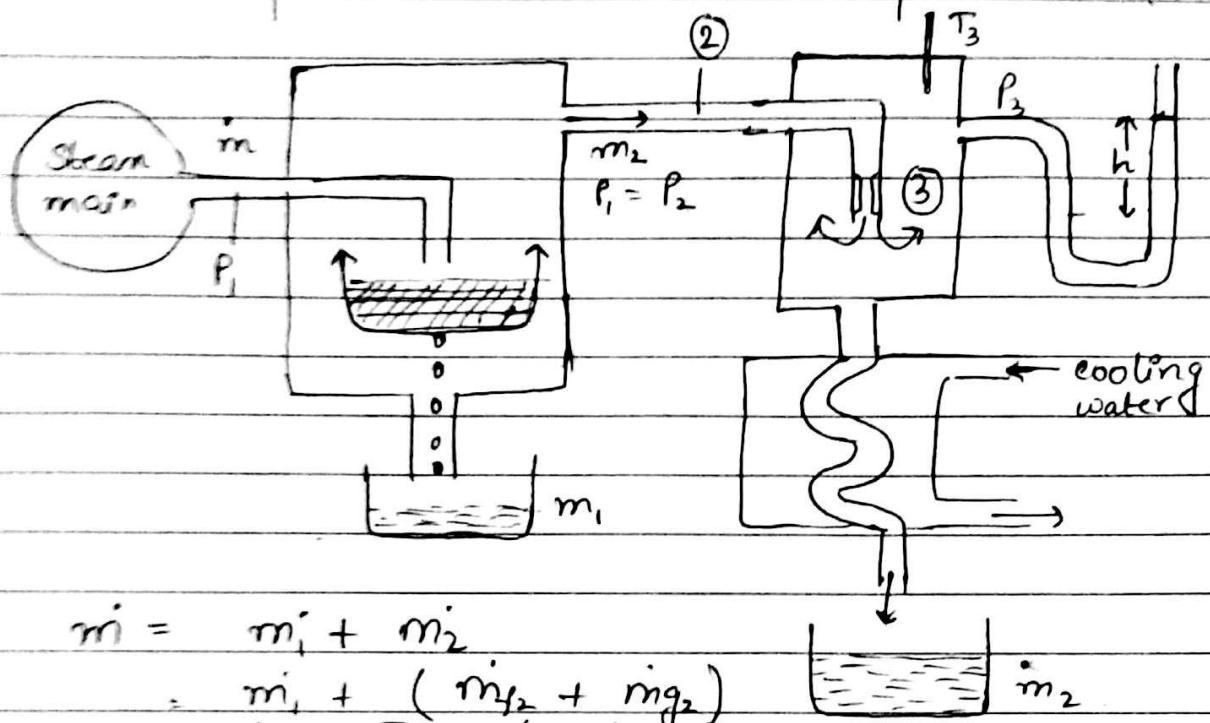
$$\underline{1987.33} = x$$

$$2046.5$$

$$0.971 = x$$

Ay.

SEPARATING AND THROTTLING CALORIMETER



$$x_2 = ? = \frac{m_{g_2}}{m_2}$$

$$x = \frac{m_{g_2}}{m_1 + m_2}$$

29/10/15

From T_3 and $P_3 \rightarrow h_3$ (from separated stream table)
 and $h_2 = h_3$ (throttling process 2-3)

$$h_2 = h_{f2} + x_2 h_{fg2} \text{ (at } P_1 \text{ or } P_2 \text{)} \quad \text{get } x_2$$

$$x_2 = \frac{m_2}{m} \quad \text{or} \quad x = \frac{m_2}{m} = \frac{m_2}{m_1 + m_2} = \frac{m_2}{m_2} \cdot \frac{m_2}{m_1}$$

$$x = x_2 \cdot \frac{m_2}{m}$$

$$\underline{9.10} \quad P_1 = 3.4 \times 10^6 \text{ N/m}^2 \text{ (g)} \quad x = ?$$

$$m_1 = 0.33 \text{ kg}$$

$$m_2 = 4.66 \text{ kg}$$

$$P_3 = 51 \text{ mm water gauge}$$

$$T_3 = 145^\circ\text{C}$$

$$\text{Patm} = 746 \text{ mm of Hg}$$

$$h_3 = 2766 \text{ kJ/kg}$$

(from superheated steam table) and $h_2 = h_3$

$$h_2 = h_{f2} + x_2 h_{fg2} \text{ at } P_1 \text{ and } P_2 \quad (\text{Interpolation})$$

$$\therefore x_2 = 0.98$$

$$x = x_2 \cdot \frac{m_2}{m} = \frac{0.98 \times 4.66}{4.99} = 0.915$$

$$\underline{9.12} \quad D = 280 \text{ m}$$

$$m = 0.02 \text{ kg}$$

$$L = 305 \text{ mm}$$

$$P_1 = 6 \text{ bar}, T_1 = 200^\circ\text{C}$$

$$P_2 = 1.2 \text{ bar}$$

$$P V^n = \text{constant} \quad n = ?, w.D = ?, Q = ?$$

$$V_1 =$$

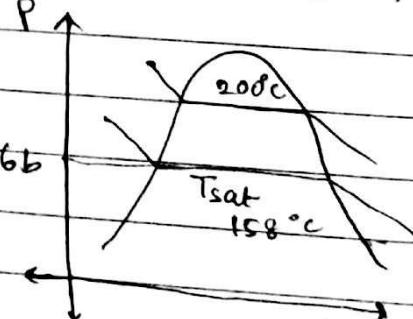
$$V_2 = V_1 + V_{sw}$$

$$V_1 = 0.352 \text{ m}^3/\text{kg}$$

$$Vol = \pi \frac{D^2}{4} L$$

$$= \frac{3.14 \times 280 \times 10^{-3}}{4} \times 305 \times 10^{-3}$$

$$= \frac{75083.680}{4} = 18770.920$$

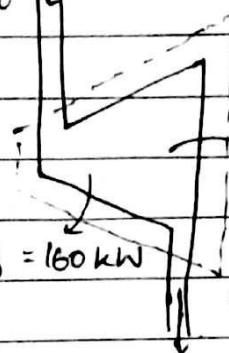


$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n \quad \text{or} \quad \left(\frac{6}{1.2}\right) = \left(\frac{V_2}{V_1}\right)^n \quad n = 1.238$$

$$W.D = \frac{P_1 V_1 - P_2 V_2}{n-1} \quad \text{and} \quad Q-W = u_2 - u_1$$

Saturated Water ~~Steam~~
table @ 1.25, v_2 ~~H_{sat}~~
@ P_1, T_1

9.1b. $v_1 = 0$
 $T_1 = 250^\circ C$
 $T_2 = 20^\circ C$



$$m = 6.1 \text{ kg/s}$$

$$x_2 = ?$$

$$A_2 = ?$$

$$Q = 160 \text{ kW}$$

$$v_2 = 200 \text{ m/s}$$

$$Q - W = h_2 + \frac{v_2^2}{2} - h_1 + \frac{v_1^2}{2}$$

$$-160 \times 10^3 + 3430 = h_2 + \frac{(200)^2}{2} - 2902$$

$$-588.52$$

$$6.1$$

$$-3890.87.87 + 2902 = h_2 + 20000$$

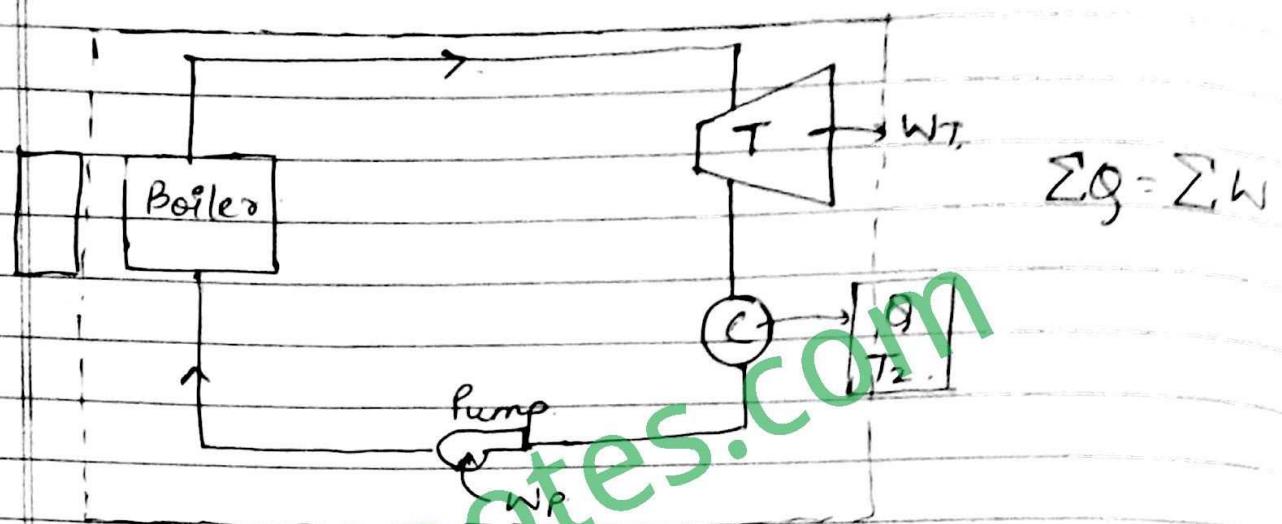
$$h_2 = 20000 + 2902 + 87.87 + 3890.588.52$$

$$= 23490.5$$

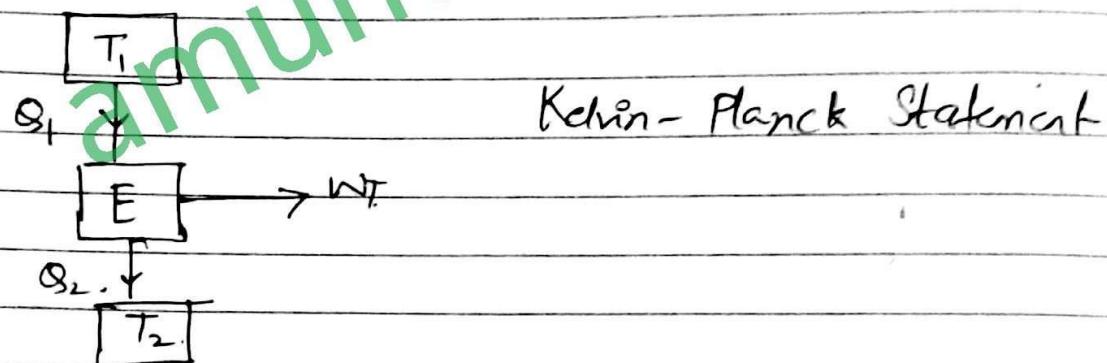
$$x_2 = 0.87 \quad [h_2 = h_f + x_2 h_{fg} @ 0.15b]$$

3/10/15

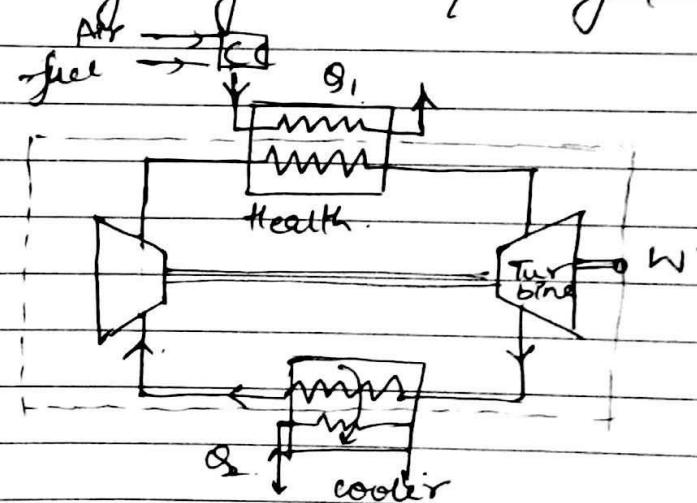
SECOND LAW OF THERMODYNAMICS



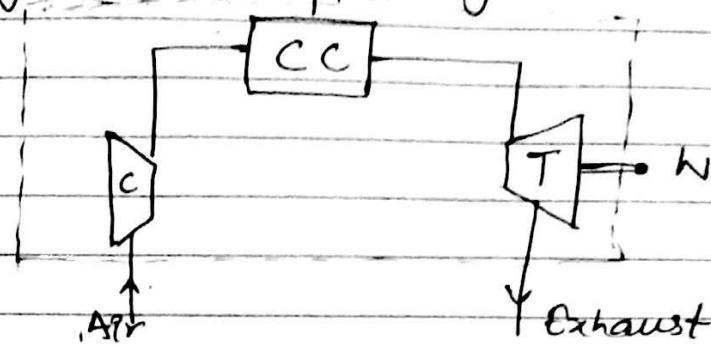
$$\sum Q = \sum W$$



Closed cycle gas-turbine engine :

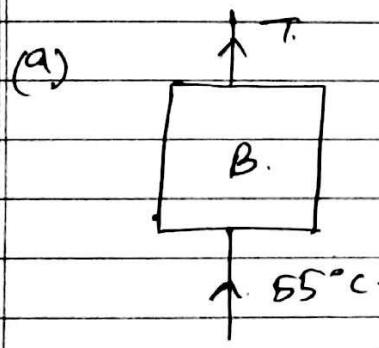
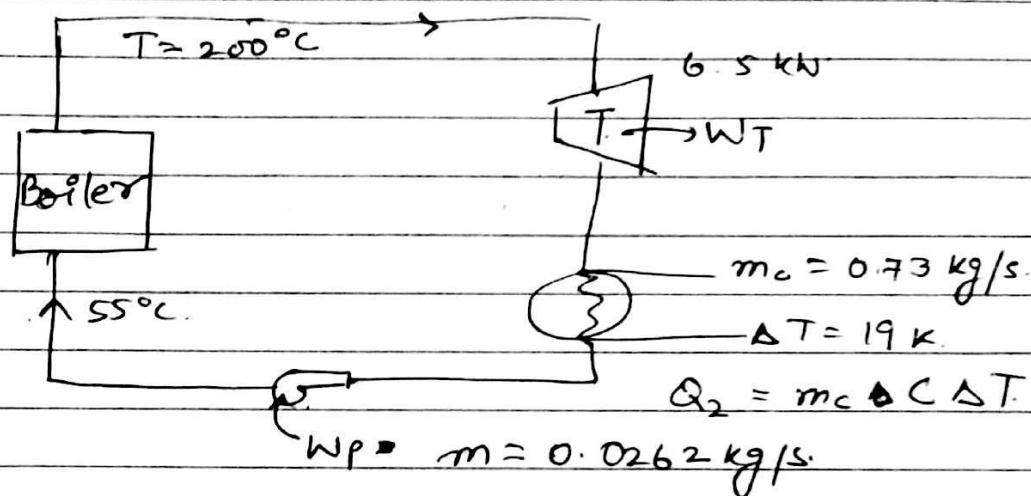


Open-cycle gas-turbine engine:



$$P = 7 \text{ bar}$$

10.4



$$h_1 = h_f @ 55^\circ\text{C}$$

$$h_2 = @ 7b, 200^\circ\text{C}$$

$$Q_1 = m(h_2 - h_1)$$

$$Q_1 = 0.0262(2844.2 - 230.2)$$

$$Q_1 = 68.48 \text{ J}$$

$$(b) W_T = \frac{P}{m} = \frac{\text{Shaft Power}}{m} = \frac{\text{kJ/s}}{\text{kg/s}}$$

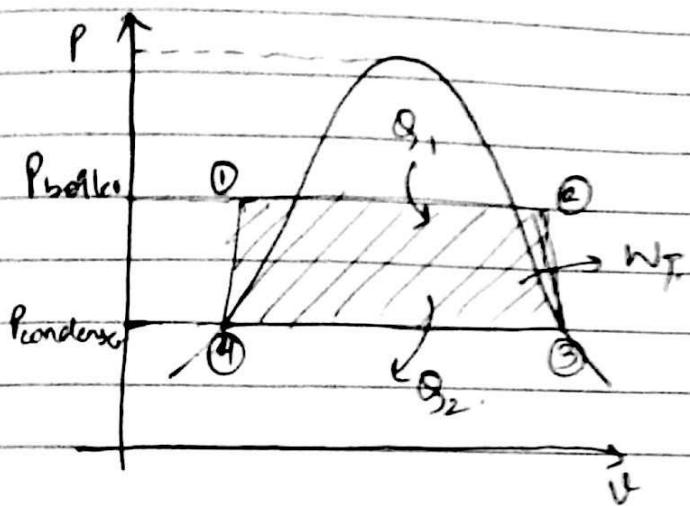
$$W_T = \frac{6.5}{0.0262} = 248.09 \text{ kJ/kg}$$

$$(d) \sum Q = \sum W$$

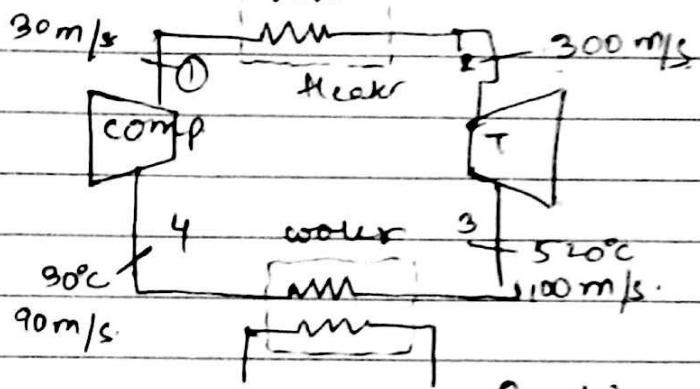
$$Q_1 + Q_2 + Q_{atm} = W_T$$

→ Apply first law on whole system and then apply on each flow device.





$$Q_1 = 642 \text{ kJ/kg}$$

10.5230°C Liquid

$$T_2 = ?$$

$$Q_2 = ?$$

$$\text{heat} = ?$$

$$h = f(T)$$

$$\Delta h = c_p \Delta T$$

SSEE on heater,

$$\frac{Q_1 - W}{m} = \left(h_2 + \frac{v_2^2}{2} - h_1 - \frac{v_1^2}{2} \right)$$

$$642 = h_2 + \frac{(300)^2}{2} - h_1 - \frac{(30)^2}{2}$$

$$h_1 = 990 \cdot 3.$$

$$h_2 = ?$$

$$642 = h_2 + 990 \cdot 3 + 45000 - 990 \cdot 3 - 450$$

$$h_2 = 642 + 990 \cdot 3 + 450 - 45000 \\ = -42917.7 \text{ kJ}$$

$$h_2 = c_p \Delta T$$

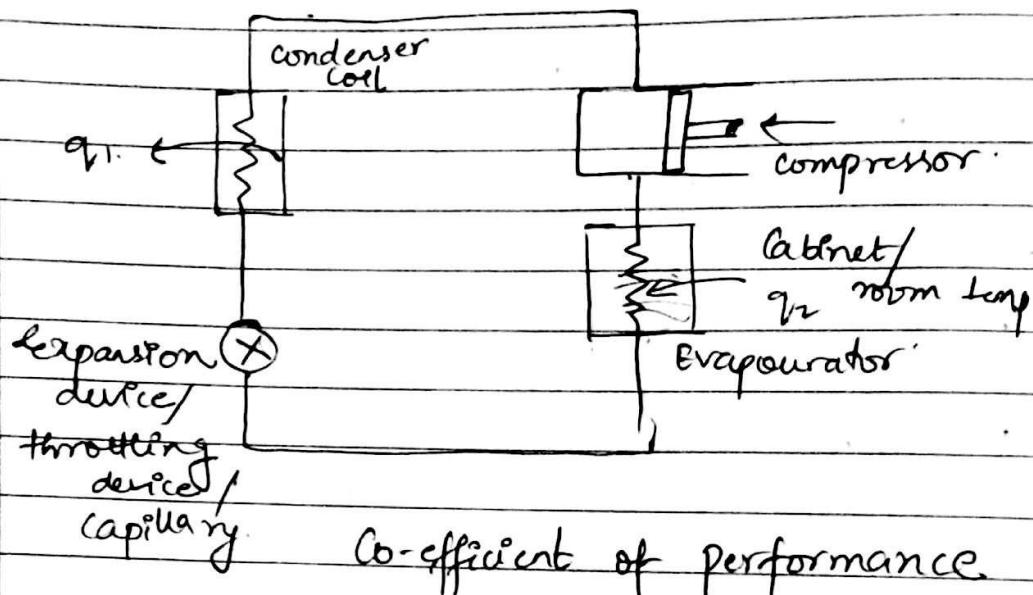
$$-42917.7 = \rho_2 \cdot 1.005 \times 10^3 (T_2 - 230)$$

$$T_2 = 824^\circ\text{C}$$

Applying FLOT on closed system.
 $\sum Q = \sum W$.

$$\eta = \frac{W_{net}}{Q_1}$$

Reversed heat engine: Refrigerator



$$COP = \frac{\text{Desired output}}{\text{Work input}}$$

$$COP_{ref} = \frac{q_2}{w_c}$$

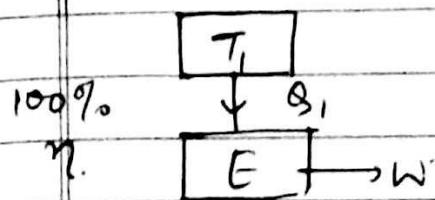
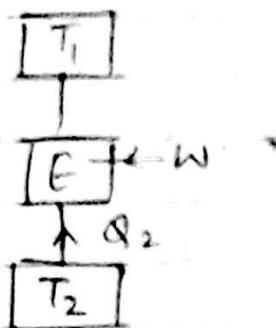
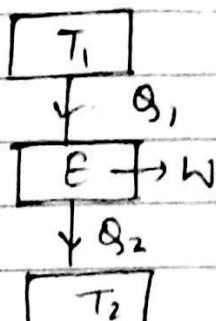
$$COP_{heat pump} = \frac{q_1}{w_c}$$

3/11/15 Second Law:

Kelvin Planck Statement \rightarrow Heat engine

Clausius statement \rightarrow Reversed heat engine

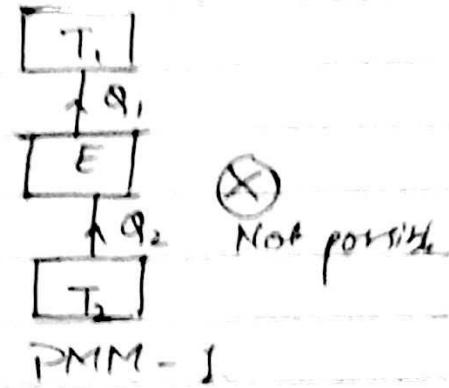
\hookrightarrow not possible to extract heat from lower temp without any extra effort.



(X) Not possible

PMM - 2 \rightarrow (violating 2nd law)

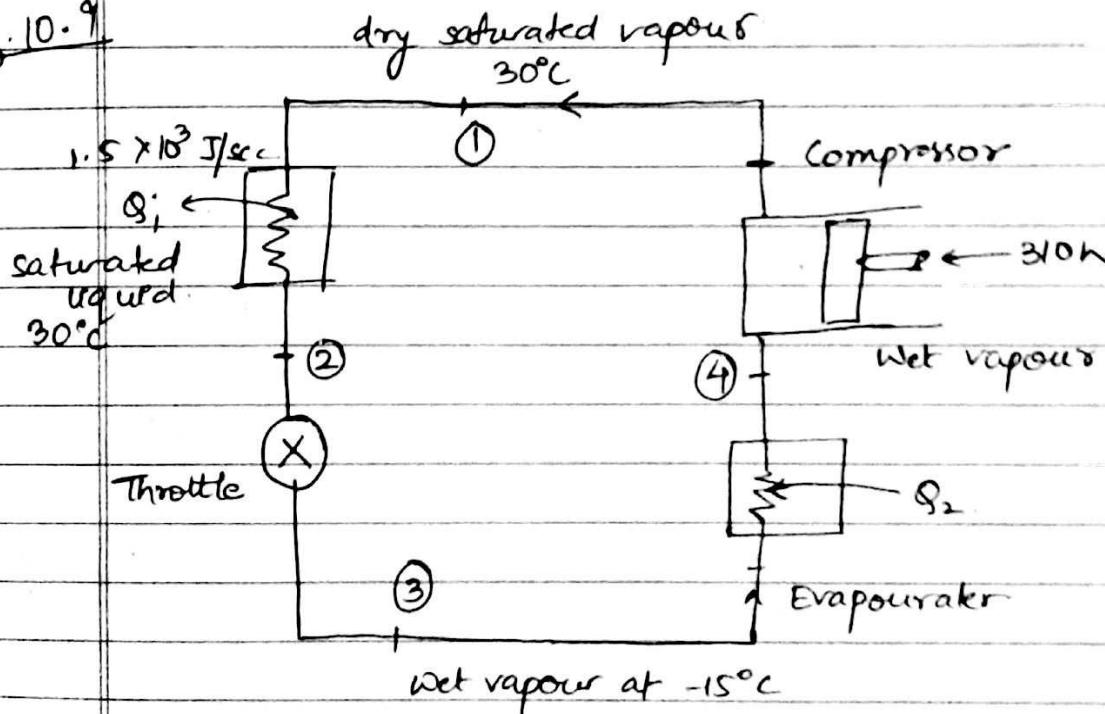
Perpetual motion machine
of second kind.



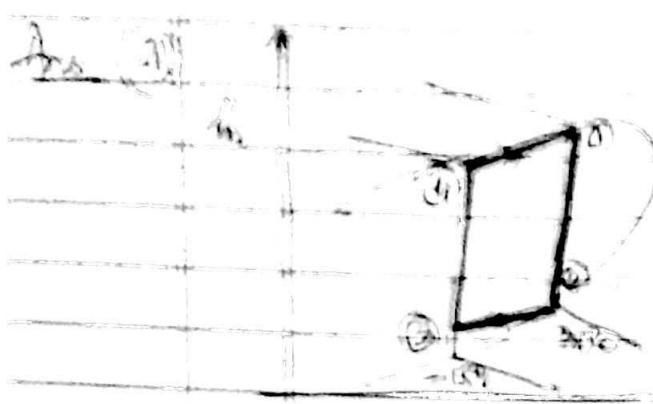
PMM - 1

\therefore Nothing can violate 2nd as well as 1st law of thermo.

Q. 10.9



classmate
Date _____
Page _____



Applying SFEE on condenser,

$$\frac{Q_i}{m} = h_2 - h_1 = h_f @ 30^\circ C - h_{fg}$$

	h_f	h_g
-15°C	223	181
30°C	64.6	199.6

For line 4 for the refrigeration cycle (closed system):

(b)

$$\sum Q = \sum W$$

$$Q_1 + Q_2 = W_c$$

$$-1.5 \times 10^3 + Q_2 = 310 \cdot 0$$

$$Q_2 = -310 + 1.5 \times 10^3 \\ = 1.19 \times 10^3 \text{ J/sec}$$

(c)

$$h_3 = h_2 \left(h_f @ 30^\circ C \right) = 64.6$$

(d) for h_4

SFEE on evaporator,

$$\frac{Q_i}{m} = h_4 - h_3 = \frac{1.19 \times 10^3}{11.12} = h_4 - 64.6$$

$$COP = \frac{Q_i}{W}$$

$$= \frac{1.19 \times 10^3}{310}$$

$$= 3.83 \text{ Am}$$

$$h_4 = 171.80 \text{ J/g}$$

$$x = \text{at } 15^\circ C \therefore h_4 = 171.80 \text{ J/g}$$

$$h_4 = h_f + x(h_g - h_f)$$

$$x = 0.942$$

5/11/15

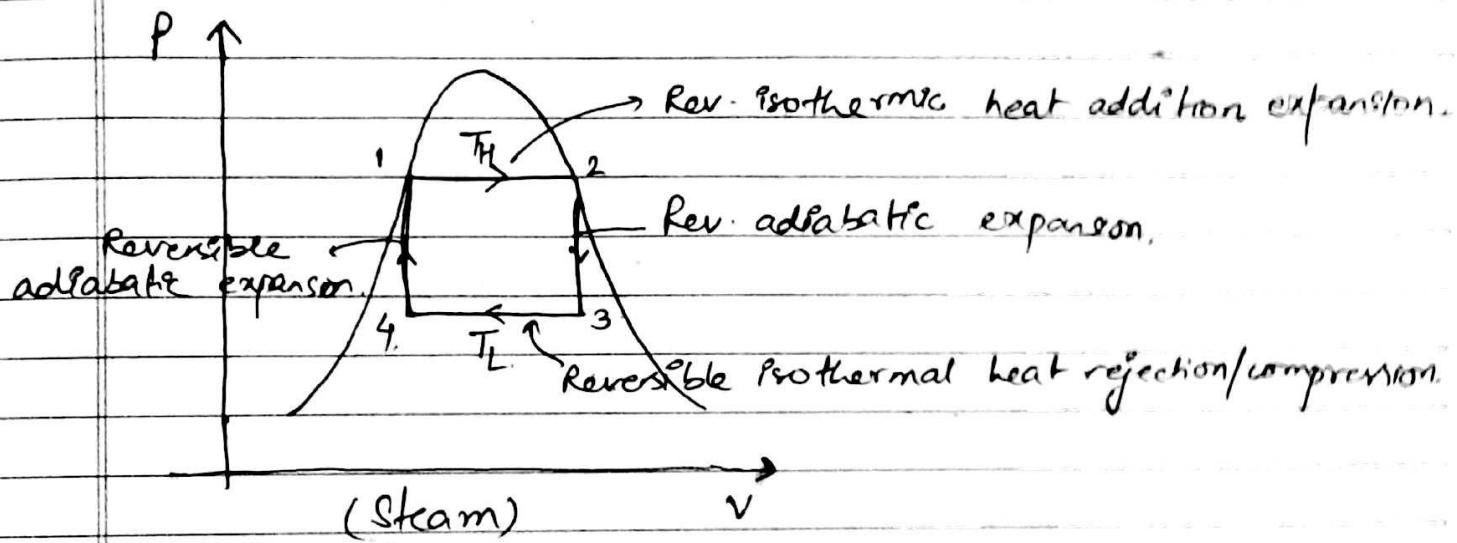
Irreversibilities

↓
Internal

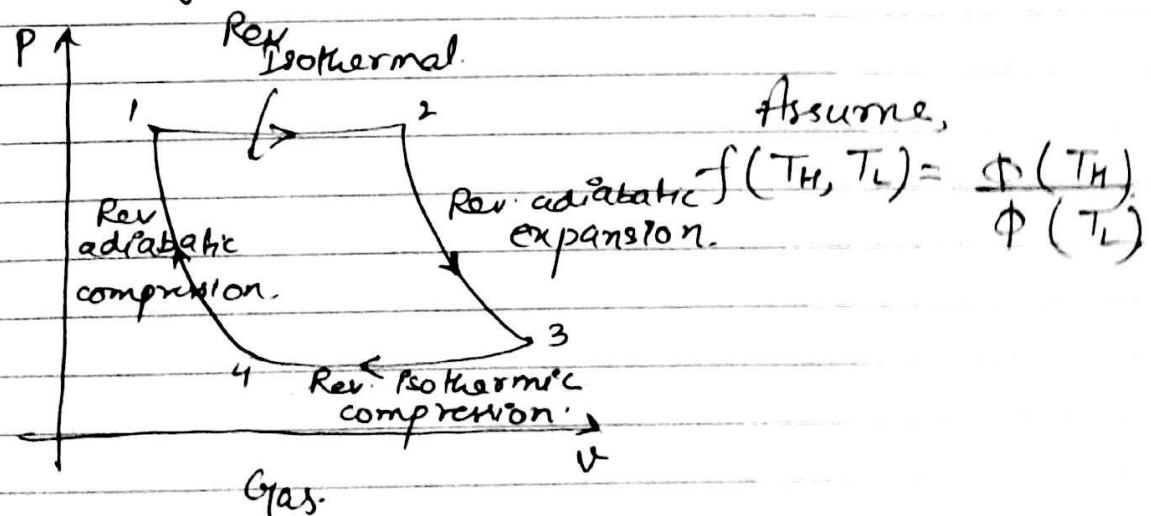
External
↓

Totally reversible process or system.
(Can undergo all types of reversible processes)

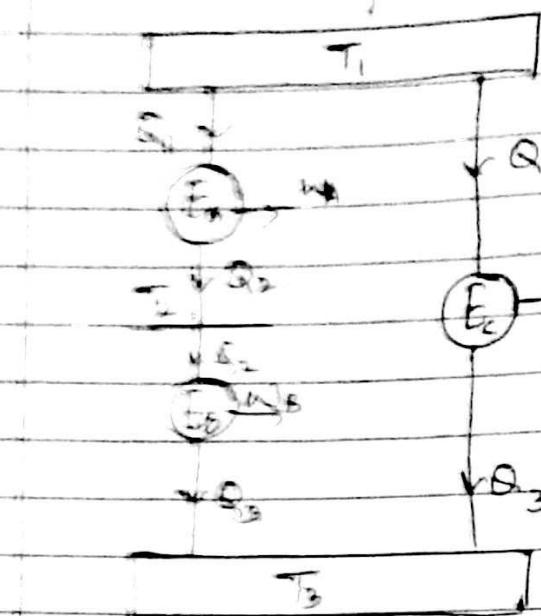
Engine which works on all the reversible processes.



* Carnot cycle



Substitute temperature scale:



$$\eta = g(T_H, T_L)$$

$$\frac{Q_H}{Q_L} = f(T_H, T_L)$$

$$\textcircled{A} \quad \frac{Q_L}{Q_L} = f(T_1, T_2)$$

$$\textcircled{B} \quad \frac{Q_2}{Q_3} = f(T_2, T_3)$$

$$\textcircled{C} \quad \frac{Q_1}{Q_3} = f(T_1, T_3)$$

$$\frac{Q_1}{Q_3} = \frac{Q_1}{Q_2} \cdot \frac{Q_2}{Q_3}$$

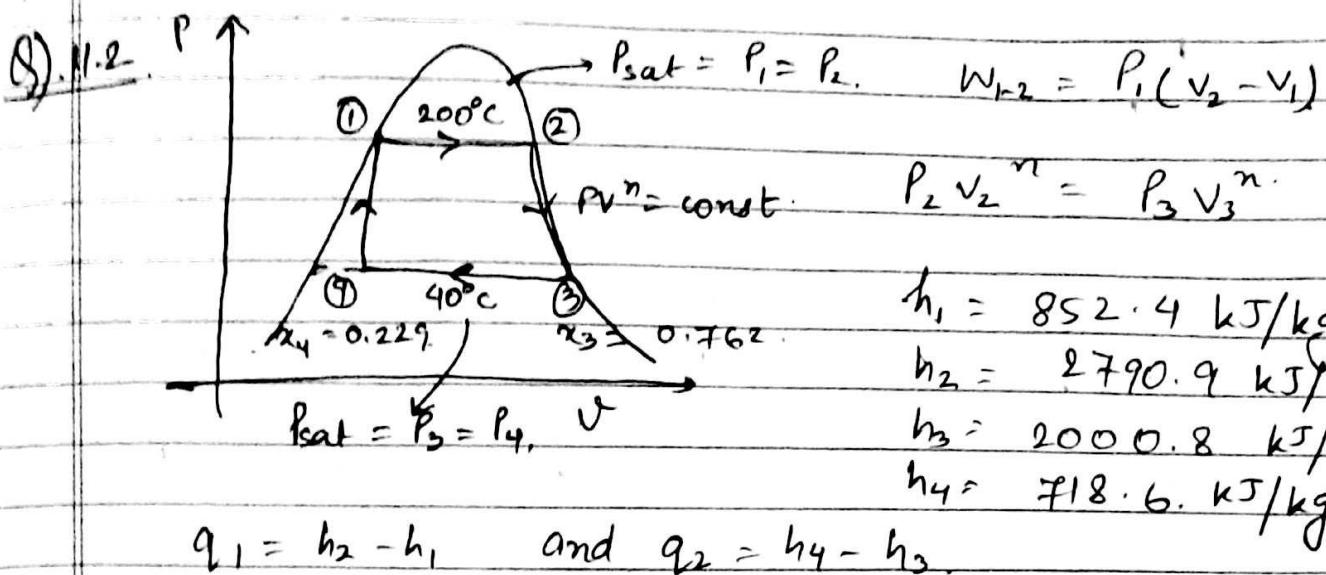
$$f(T_1, T_3) = f(T_1, T_2) \cdot f(T_2, T_3).$$

Zangari (Pg. 303)

Carnot cycle: $\eta_{\text{Carnot}} = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$

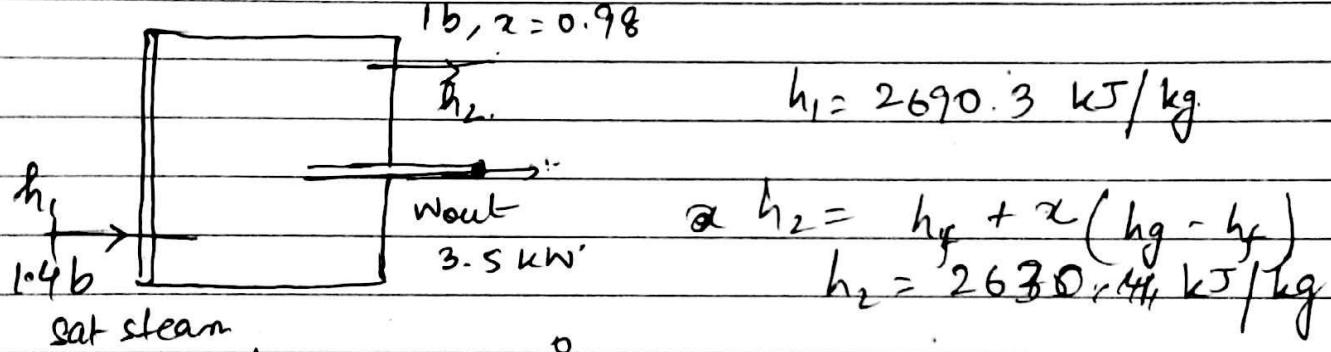
$$\eta_{\text{Carnot}} = \frac{Q_H - Q_L}{Q_H} = \frac{T_H - T_L}{T_H}$$

1/11/15



$$W_{2-3} = \frac{P_2 V_2 - P_3 V_3}{(n-1)} \quad n = 1.12$$

$$\eta_{\text{net}} = \frac{W_{\text{net}}}{Q_1} = \frac{W_{\text{net}}}{q_1} = 93.82\%$$

11.4

$$Q_1 = (h_1 - h_2) m$$

$$= 60 \times 0.058$$

$$= 3.48 \text{ kW}$$

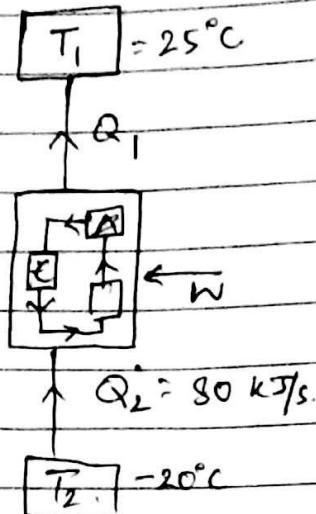
$$\Delta h = h_2 - h_1 = 2630 - 2690$$

$$-W = -60$$

$$W = 60 \text{ kJ} \times 0.058$$

9/11/15

12.3



$$\frac{Q_1}{Q_2} = f(T_1, T_2)$$

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$Q_2 = \frac{T_2}{T_1} \cdot Q_1$$

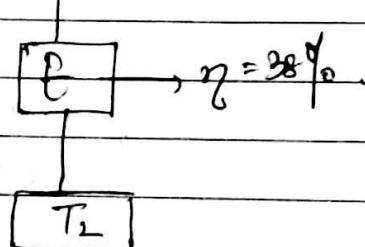
$$W = Q_1 - Q_2 = \frac{Q_1}{Q_2} - 1 = \frac{T_1}{T_2} - 1$$

$$\Rightarrow W = Q_2 \left(\frac{T_1}{T_2} - 1 \right)$$

$$W =$$

12.8

$$T_1 = 145^\circ\text{C}$$



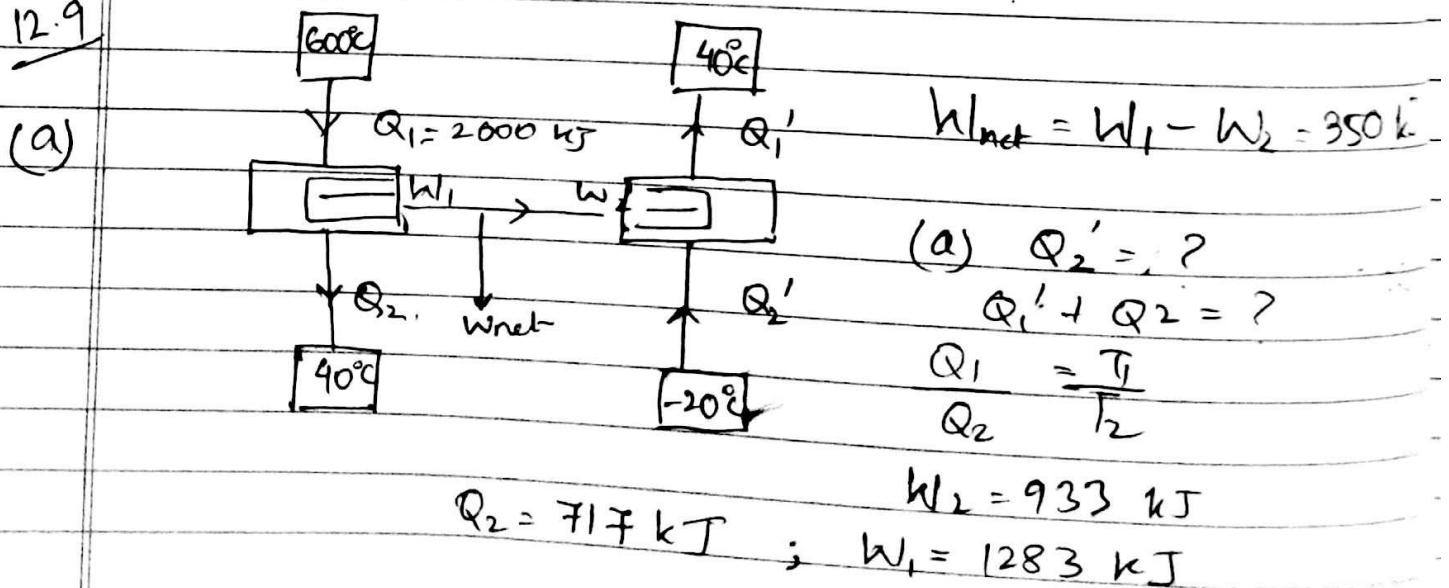
$$\eta = 1 - \frac{T_2}{T_1}$$

$$0.38 = 1 - \frac{T_2}{145}$$

$$T_2 = 259.16 \text{ K}$$

$$= -13.84^\circ\text{C}$$

12.9



$$\frac{S_2'}{S_1} = \frac{S_1'}{S_1' - S_2'} = \frac{T_1}{T_1' - T_2}$$

$$S_1' = 4867 \text{ kJ}$$

Net heat transfer at 40°C will be:

$$Q_1 + Q_2 = 5584 \text{ kJ}$$

(b) Now, efficiency and COP of the engine is 40%.

$$\eta_{\text{eng}} = \left(1 - \frac{T_2}{T_1}\right) \times 0.4 = \frac{W_1}{Q_1}$$

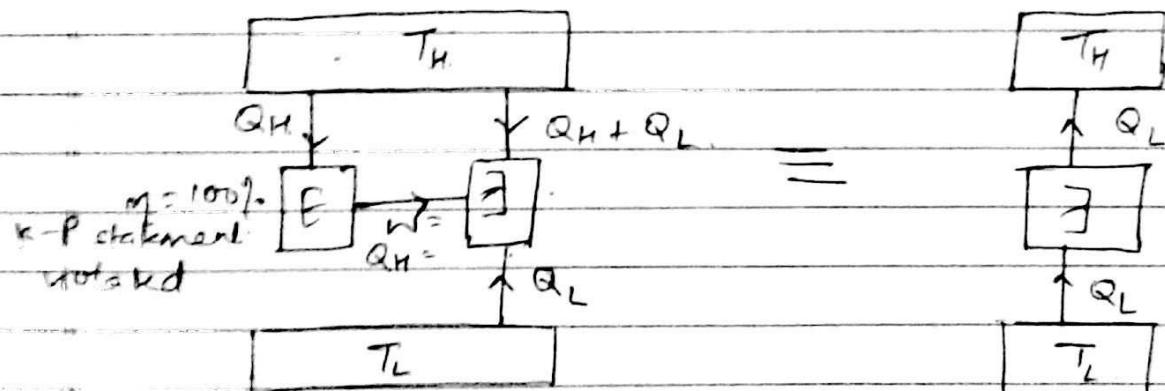
$$\text{COP}_{\text{ref}} = \left(\frac{Q_2}{W_2}\right) = \left(\frac{T_2'}{T_1' - T_2'}\right) \times 0.4$$

$$W_2 = W_1 - W_{\text{ref}}$$

$$W_1 = 513 \text{ kJ}$$

$$W_2 = 163 \text{ kJ}$$

* Equivalence of Kelvin Planck Statement and Clausius Statement* (check from cengel and boles)



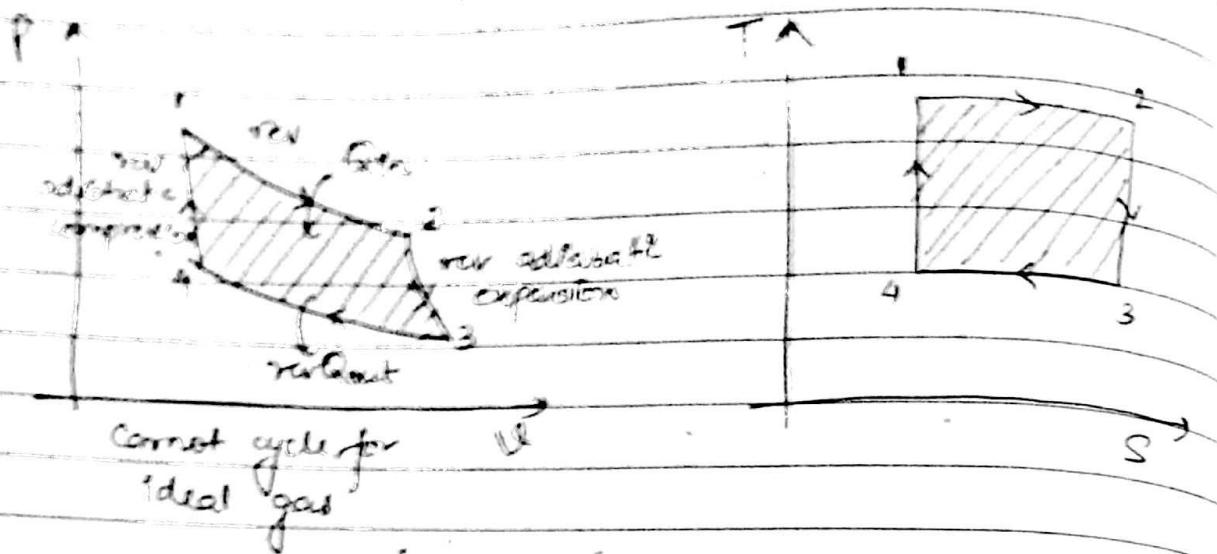
Entropy change:

$$S_2 - S_1 = \frac{dQ}{T} + \text{S generated of irreversibility in a process.}$$

entropy change because taking place because of heat transfer.

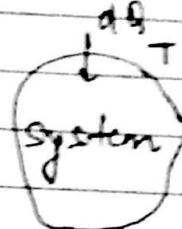
Clausius Statement is violated.

Adiabatic reversible process = Isentropic process



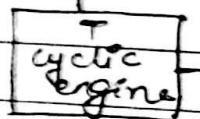
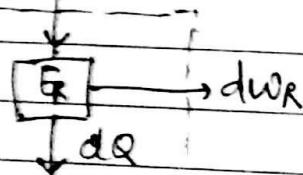
Entropy is a property:

$$\text{Prop: } S_2 - S_1 = \int \frac{dS}{T}$$



Reversible process

STEP 1:



$$\oint (dW_R + dW) \leq 0$$

$$\text{From, } dW_R = \frac{T_0 - T}{\frac{dT}{dQ}}$$

i Otherwise 2nd law would be violated.

$$\Rightarrow \oint \left\{ \frac{(T_0 - T)}{\frac{dT}{dQ}} dQ + dW \right\} \leq 0$$

$$\Rightarrow T_0 \oint \frac{dQ}{dT} \leq 0$$

$$\oint \frac{dQ}{T} \leq 0 \quad (\text{clausius inequality})$$

STEP 2: $\oint \frac{dQ_R}{T} = 0$

$$\int_{B_2 A_1} \frac{dQ_R'}{T} \leq 0 \quad \text{--- ②}$$

$$|A_2 B_1| = \int \frac{dQ_R}{T} \leq 0 \quad \text{--- ①}$$

$$dQ_R' = -dQ_R$$

From eq. ② $\Rightarrow -\oint \frac{dQ_R}{T} \leq 0 \Rightarrow \text{--- ③}$
 can be true only if $\oint \frac{dQ_R}{T} = 0$

STEP 3:

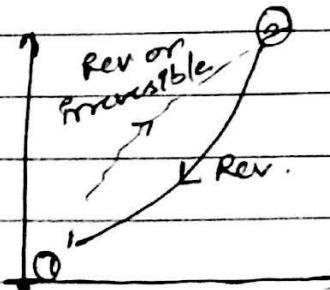
$$\int_A^B \frac{dQ_R}{T} = \int_{1B}^2 \frac{dQ_R}{T}$$

$$\oint \frac{dQ_R}{T} = \int_A^2 \frac{dQ_R}{T} + \int_{2C}^1 \frac{dQ_R}{T} = 0 \quad \text{--- ④}$$

$$\oint \frac{dQ_R}{T} = \int_{1B}^2 \frac{dQ_R}{T} + \int_{2C}^1 \frac{dQ_R}{T} = 0 \quad \text{--- ⑤}$$

from ④ and ⑤

$$\int_A^B \frac{dQ_R}{T} = \int_{1B}^2 \frac{dQ_R}{T} = S_2 - S_1$$

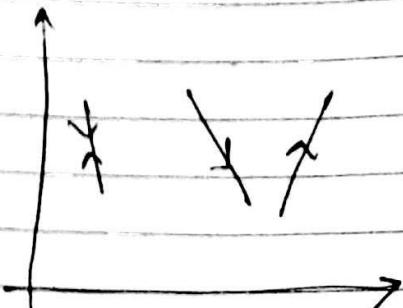


$$\oint \frac{dQ}{T} \leq 0$$

$$\int \frac{dQ}{T} + \int \left(\frac{dQ}{T} \right) \leq 0$$

$$\int \frac{dQ}{T} + (S_2 - S_1) \leq 0$$

$$S_2 - S_1 > \int \frac{dQ}{T}$$



* Pg. 267 and 269
(Spalding and Cole)

* Mollier diagram

$$P_1 V_1 = P_2 V_2$$

$$V_2 = 0.05$$

$$V_1 = 1 m^3$$

$$m = \frac{V_1}{V_2}$$

$$V_1$$

$$V_1 = V_f + x_1 V_{fg} @ 10 \text{ bar} = 0.1847 \text{ m}^3/\text{kg}$$

$$V_2 = \frac{V_1}{m} = 0.9232 \text{ m}^3/\text{kg}$$

$$V_g @ 2 \text{ bar}$$

$V_2 > V_g @ 2 \text{ bar} \Rightarrow$ state (2) is superheated

$$T_1 = T_{\text{sat}} @ 10 \text{ bar}$$

$$T_2 \rightarrow P_2, V_2$$

$$\text{At } 26, 150^\circ\text{C}, v = 0.95954$$

$$\frac{T_2 - 150}{200 - 150} = \frac{1.0804 \text{ m}^3/\text{kg}}{0.9232 - 0.95954}$$

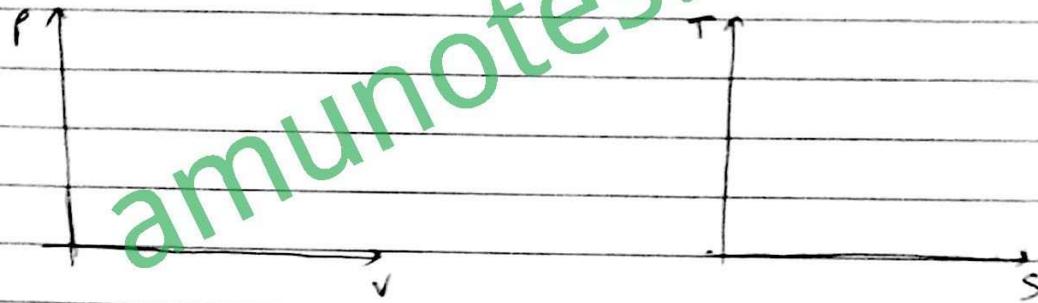
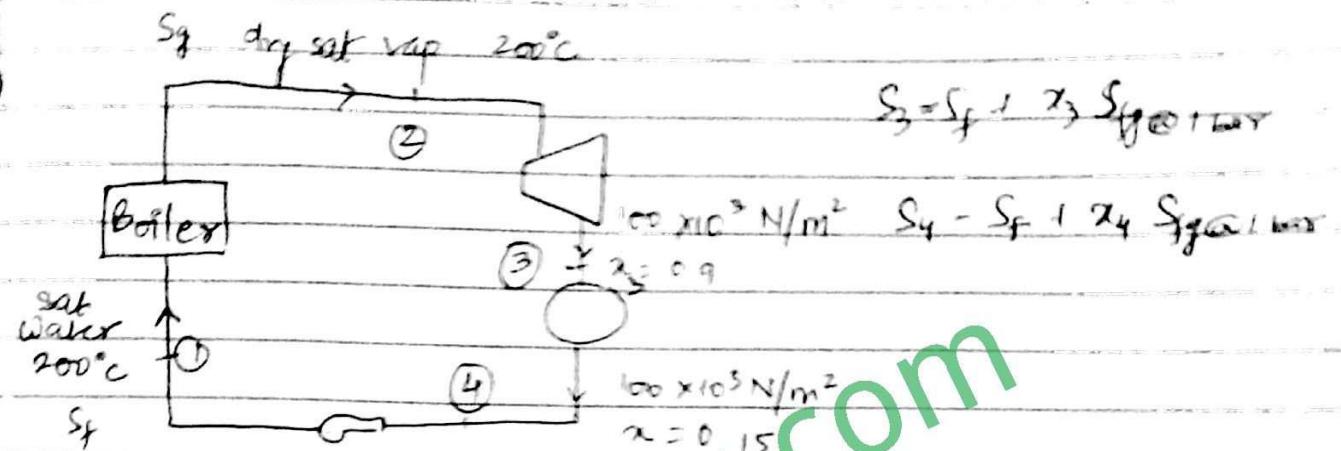
$$\frac{1.0804 - 0.95954}{200 - 150}$$

$$T_2 = 135^\circ\text{C}$$

Work

30/11/15

Q.B.9



$$S_1 = 2.3307 \text{ kJ/kg K}$$

$$\begin{aligned} S_3 &= 1.3 + 0.9 \times 6.0571 \\ &= 1.3 + 5.45 \\ &= 6.75 \end{aligned}$$

$$S_2 = 6.427 \text{ kJ/kg K}$$

$$\begin{aligned} S_4 &= 1.3 + 0.15 \times 6.0571 \\ &= 2.20 \end{aligned}$$

(a) $T = 200^\circ\text{C} = 473 \text{ K}$

$$\delta Q = T dS = T (S_2 - S_1)$$

(b) $\sum \delta Q = \sum \delta W$

$$(c) \oint \frac{dQ}{T} = \int_1^2 \frac{dQ}{T} + \int_2^3 \frac{dQ}{T} + \int_3^4 \frac{dQ}{T} + \int_4^1 \frac{dQ}{T}$$