NAME -

ROLL N -

TEST N. -

SUBJECT - Full syllabus
paper - I)

total marks=251

good in theory and presentation and in numerical

Q-1 (a) Steady, 2D flow

$$u = 1.85 + 2.33x + 0.656y$$

$$v = 0.754 - 2.18x - 2.33y$$

Vorticity Ω = curl of $\vec{V}$

$$\Omega = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

$$\frac{\partial v}{dx} = -2.18 \quad , \quad \frac{\partial u}{\partial y} = 0.656$$

Vorticity $\Omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$

$$= -2.18 - 0.656$$

$$= \underline{2.836} \quad \text{Ans.}$$

rate of volumetric dilatation = $\varepsilon_{xx} + \varepsilon_{yy} + \varepsilon_{zz}$

$$= \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}$$

$$= 2.33 + (-2.33) + 0 = \underline{\underline{0}}.$$

Shear strain = $\varepsilon_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$

$$= -2.18 + 0.656$$

$$= -1.54$$

Since $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$ [FLOW IS INCOMPRESSIBLE]

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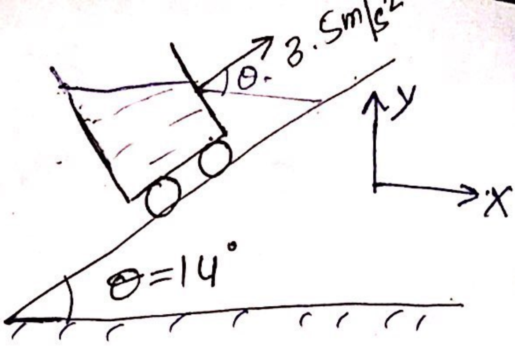

$$\tan\alpha_1 = \left(\frac{a_x}{a_y + g}\right).$$

$$\tan\alpha_1 = \left(\frac{3.5\cos\theta}{3.5\sin\theta + g}\right)$$

$$\alpha_1 = \tan^{-1}\left[\frac{3.5\cos 14}{3.5\sin 14 + 9.81}\right]$$

$$\underline{\alpha = 17.675^\circ} \quad \underline{\text{Ans}}$$

<u>Case – II</u>.

$$\tan\alpha = \left(\frac{3.5\cos\theta}{g - 3.5\sin\theta}\right).$$

10

$$\underline{\alpha = 20.75^\circ}$$

Q-1 (b) sum of All heat Transfer for a cycle

$= -170$ kJ

$N = 100$ cycle/min.

Process	Q(kJ/min)	W(kJ/min)	ΔE (kJ/min)
a – b	0	2170	– 2170
b – c	21000	0	21000
c – d	–2100	34500	–36600
d – a	–35900	– 53670	17770

good

Applying I law of Thermodynamics for process a-b.

$$Q_{a-b} = W_{a-b} + \Delta E_{a-b}$$
$$0 = W_{a-b} + \Delta E_{a-b}$$
$$0 = 2170 + \Delta E_{ab} \Rightarrow \Delta E_{ab} = -2170 \text{ KJ/min}$$

App I law of TD for b-c.

$$Q_{b-c} = W_{b-c} + \Delta E_{b-c}$$
$$2100 = 0 + \Delta E_{b-c} \Rightarrow \Delta E_{bc} = 2100 \ \frac{KJ}{min}$$

App I law of TD for c-d.

$$Q_{c-d} = W_{c-d} + \Delta E_{c-d}$$
$$-2100 = W_{c-d} + (-36600)$$
$$W_{c-d} = 34500 \text{ KJ/min.}$$

Given.

$$\Sigma Q = -170 \times 100 \text{ KJ/min.}$$
$$Q_{a-b} + Q_{b-c} + Q_{c-d} + Q_{d-a} = -17000 \text{ KJ/min}$$
$$0 + 21000 - 2100 + Q_{d-a} = -17000.$$
$$Q_{d-a} = -35900 \text{ KJ/min}.$$

for cycle $\Delta E_{cycle} = 0$.

$$\Delta E_{a-b} + \Delta E_{b-c} + \Delta E_{c-d} + \Delta E_{d-a} = 0$$
$$-2170 + 21000 - 36600 + \Delta E_{d-a} = 0$$
$$\Delta E_{d-a} = 17770 \text{ KJ/min}.$$

Apply 1st law of TD for d-a.

$$Q_{d-a} = W_{d-a} + \Delta E_{d-a}$$
$$-35900 = W_{d-a} + 17770 \qquad W_{d-a} = -53670$$

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12 $P = W_{a-b} + W_{b-c} + W_{c-d} + W_{d-a}$

$= 2170 + 0 + 34500 - 53670$

$= -17000 \text{ KJ/min}$.

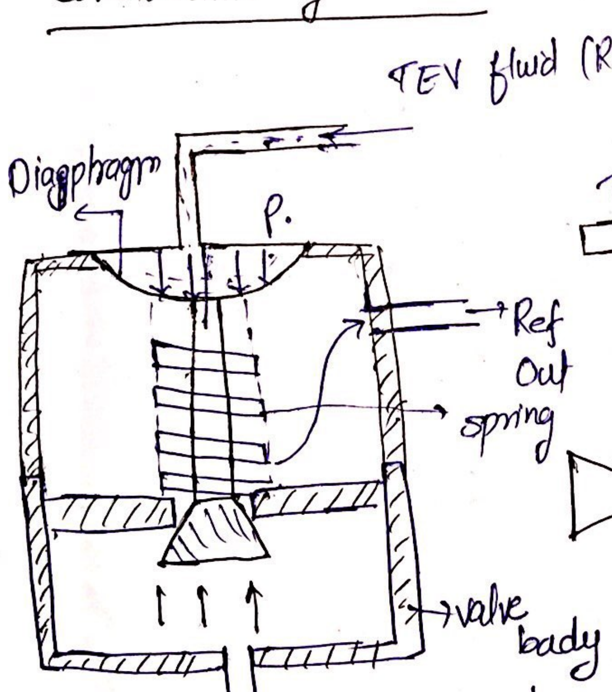
$= -283.33$ KW [Work input]

Q-1 (c)

Thermostatic expansion valve :- (TEV)

- Thermostatic expansion valve is used to control the degree of superheat in the evaporator
- Controlling of degree of superheat is important & slightly superheated refrigerant is prefered to enter into the compressor. thermostatic expansion valve ensures that no liquid refrigerant entry at compressor.
- Liquid Refrigerant can flush of the lubricant & can damage the valves of compressor.

Construction of TEV :-



TEV

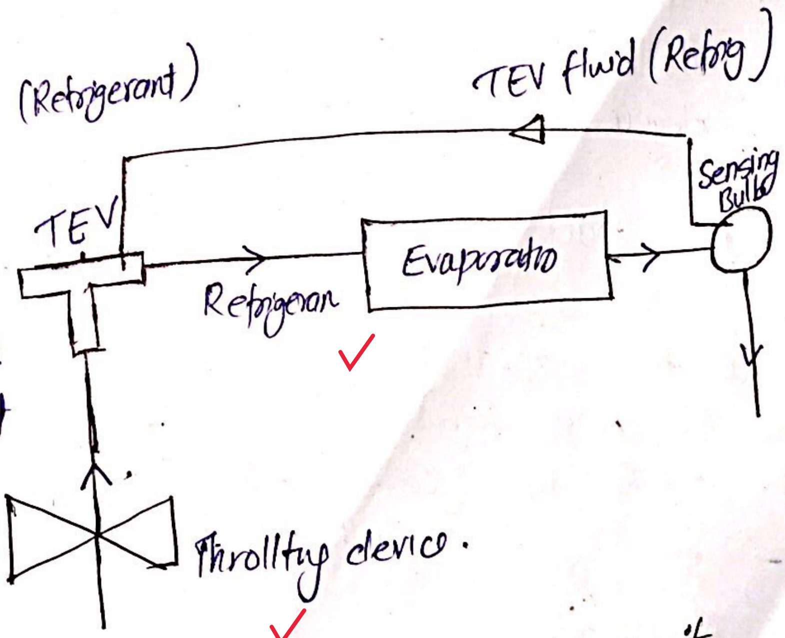


fig 1: Refrigerant circuit

TEV Consist of a secondary Refrigerant which apply Pressure at diaphragm. a spring is also their attached to the valve.

Sensing bulb is provided at the exit of evaporator & the thin piping for Refrigerant flow back to the TEV.

WORKING :

As Load increases

- As load increase, the degree of superheat increase at the evaporator side. due to increase of superheat, outlet Temp of evaporator increase.
- The secondary fluid (situated at sensing bulb) sense this increment in Temp. Heat Transfer increase @ sensing bulb. due to which boiling will occur of the TEV fluid.

→ pressure is increase as a result of boiling of TEV fluid, the pressure is applied to the diaphragm.

→ due to this the valve opening will take place, hence the Refrigerant flow rate increase. & consequently the degree of superheat decrease.

As load Falls (decrease) :-

- As the load decrease, the degree of superheat decrease at the evaporator side hence outlet Temp decrease
- At sensing bulb Less boiling of TEV fluid is there.

→ due to this, Low pressure at the TEV Refrigerant

11 → this low pressure (Reduction in pressure) lead to partial closing of valve

good

→ Consequently Refrigerant flow decrease & again degree of superheat become constant.

Q-1 (d) Grashof Number :-

Grashof's number is a dimensionless Number which is used to study the Natural convetion heat Transfer.

$$Gr = \frac{g \beta \Delta T L_c^3}{\nu^2}$$

$\beta = \frac{2}{T_1 + T_2}$

L_c - char. length

$\nu \to$ kinem. viscosity

Grashof's number is the Ratio of Buoyancy force to the viscous force. Grashof's number compares that which effect is dominating among the Buoyant force and the viscous force in the natural convection.

~~It also indicate that~~

Comparision of Grashof number to Reynolds No

$$Re.No = \frac{\text{inertia force}}{\text{viscous force}} = \frac{\rho V L}{\mu}.$$

$$Gr. = \frac{\text{Buoyancy force}}{\text{viscous force}} = \frac{g \beta \Delta T L_c^3}{\nu^2}$$

- Reynolds number is Generally used in the force convection heat Transfer where as the Grashof number is used for the natural Convection heat transfer

- ~~higher~~ Reynolds number is Generally deal with the incompressible fluids in heat Transfer phenomenon where as in Natural convection density difference is main cause of the bulk motion of the flow

10

give relation (gr/re2) >1,<1

- Inertia force in Reynolds number is related to the pre given velocities where as the buoyancy force in Grashof No is due to the Temperature gradient caused density difference.

Q-1 (e)

① Spark Timing -(Retard)

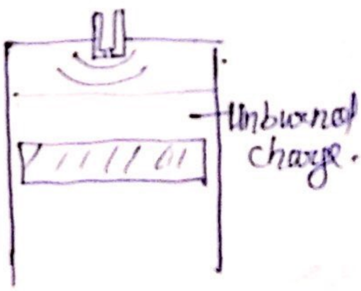
To avoid the knocking Tendency in the SI Engine the spark timing should be Retarded because. due to this maximum pressure in the cycle is reduced as a result max^m Temp also reduce and there will be less chance of pre ignition (knocking) take place. and hence to avoid the knocking in the SI Engine Spark retardation is done.

② Engine speed: (increase)

as Engine speed increases, the Turbulence inside the cylinder increase, as a result the heat Transfer is also increase [due to the fact that convective heat Transfer coeff is high for high Turbulence (Turbulent flow)]. due to the increment in heat Transfer, the hotspot Temperature reduces and hence there will be less possibility to ignition of charge from that hotspot and hence the chance of the knocking will decrease in the SI Engine.

③ Distance of flame Travel:- (Low)

As the first flame front is Generated there will be the expansion of burnt charge due to ~~which~~ this end charge will compress and rise its Temperature. Secondly, the heat Transfer will also be taking place to the



End charge, due to these Reason the Temperature of end charge is increase. if the Distance of flame Travel is high & the end charge will have sufficient time to ignite itself and hence another flame front is Generated which Leads to knocking, so to avoid knocking Distance of flame Travel should be less.

(iv) Mixture inlet Temperature :- (Low)

Mixture inlet temperature should kept Low. because if it is high the end charge & hot spot Temp will also high. which Leads to the pre ignition of the charge and hence this cause the knocking in the SI Engine. so to avoid it, it is preferred in SI Engine to enter low Temp mixture in the Cylinder of Engine.

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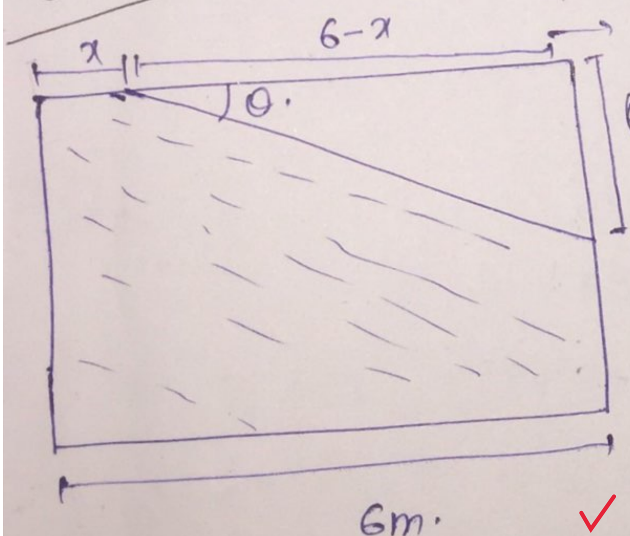
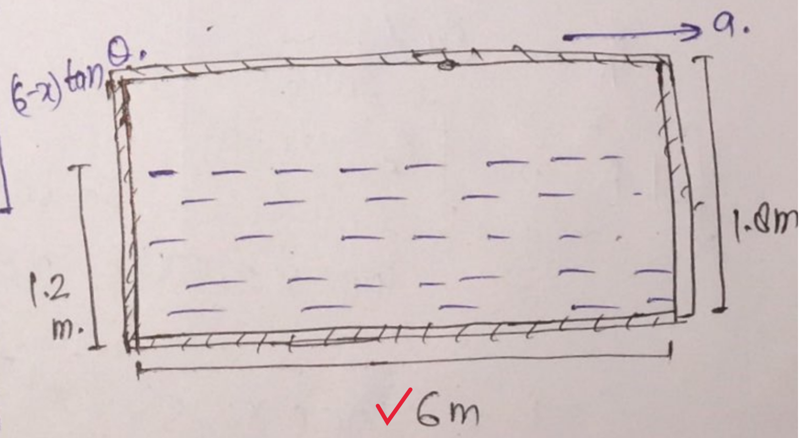
Q-2a $a = 2.5\ m/s^2$





$$\tan\theta = \frac{a}{g} = \frac{2.5}{9.81}$$

$$\theta = 14.297°$$

Applying mass conservation

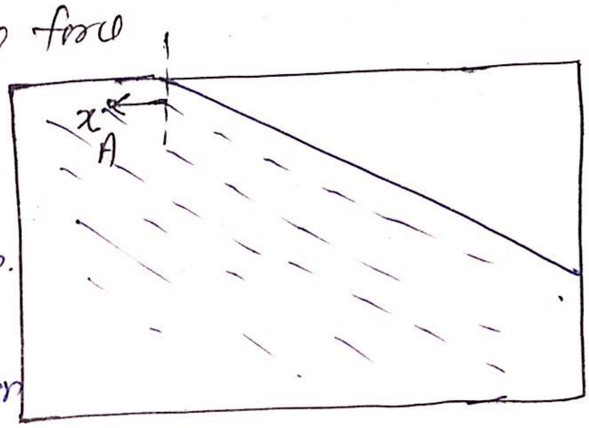
Initial empty Tank volume = final empty tank Volm

$0.6 \times 6 = \frac{1}{2} \times (6-x)(6-x) \tan 14.297$

$7.2 = (6-x)^2 \tan 14.297$

$x = 0.6046\,m$

Calculation of Total Pressure force @ upper wall



Let $P_A = \rho a . x + P_{atm}$.

P_{atm} effect is not taken since it is working on both side.

$P_A = \rho a x$.

$\int dF = \int_0^{0.6046} P_A \cdot dx \cdot w$

$= 1000 \times 2.5 \times 1 \int_0^{0.6046} x\,dx$.

$F = 1000 \times 2.5 \left[\frac{x^2}{2}\right]_0^{0.6046}$

$F = 585.84N$. Ans

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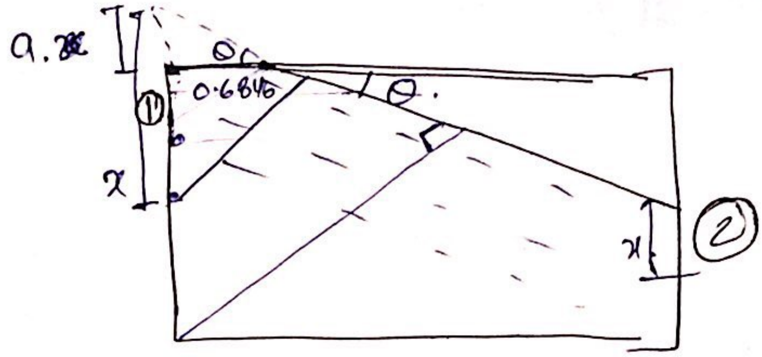
Pressure at side 1.



$$\tan\theta = \frac{a}{0.6846}$$

$$\underline{a = 0.17446\,m}.$$

7

$$P_x = \rho g x.$$

$$dF = \int \rho g x.\, dx.\, w = 9810 \times 1 \int_{0.6046}^{\cancel{0.6}\,2.4046} x\, dx.$$

$$= \underline{27.98\ kN}.$$

Pressure force at front & back surface.

check solution

Pressure force at surface 2.

$$dF = \rho g x\, w.\, dx.$$

$$= 9810 \times 1 \left[\frac{x^2}{2}\right]_0^{1.3545}$$

$$= \underline{9\,kN}.$$

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Q-2 (b) Given. Cross flow H.E.

No of Tubes $n = 30,000$

No of passes $p = 2$

$D = 25\,mm$

Steam cond. outer. $h_o = 11000\ W/m^2K$.

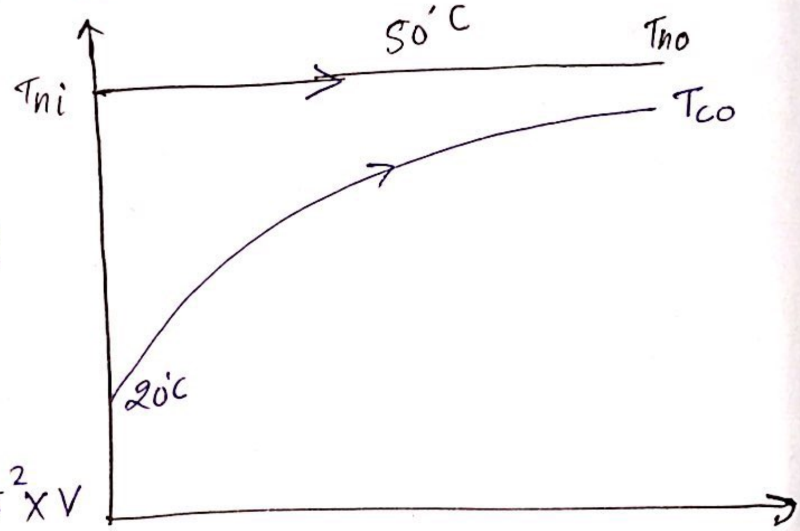
H.T rate $q = 2 \times 10^9\ W$

$\dot{m}_c = 3 \times 10^4\ kg/s$

flow rate / tube $= 1\ kg/s$

$T_{ci} = 20^\circ C$

$T_{sat} = 50^\circ C$



for 1 Tube

$m = 1\ kg/s = \rho\, a . V.$

$1 = 997 \times \frac{\pi}{4} \times 0.025^2 \times V$

$V = 2.0433\ m/s$

Reynolds no for pipe

$$Re = \frac{\rho V D}{\mu} = \frac{997 \times 2.0433 \times 0.025}{855 \times 10^{-6}}$$

$= 59566.377$ (Turbulent flow

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4} \quad [\text{for water heating}]$$

$$= 0.023 \times (59566.377)^{0.8} \times (5.83)^{0.4}$$

$$Nu = 307.607$$

$$\frac{h \times 0.025}{0.613} = 307.607$$

$$\underline{h_i = 7542.523\ W/m^2K}$$

Total heat tran. Coeff. (Convection)

$$\frac{1}{U} = \frac{1}{11000} + \frac{1}{7542.523}$$

$$\underline{U = 4474.4586\ W/m^2K}.$$

Applying energy Balance.

Heat supplied to cold water = heat transfer.

$$m_c\, C_p\, \Delta T_w = q$$

$$3 \times 10^4 \times 4179 \times [T_{co} - 20] = 2 \times 10^9$$

$$\underline{T_{co} = 35.9527^\circ}. \quad \underline{Ans}$$

effectiveness

$$\epsilon = \frac{35.9527 - 20}{50 - 20} = \underline{0.532}.$$

$\epsilon \rightarrow$ correspondiling NTU = 0.759.

16 $$0.759 = \frac{U.A}{C_{min}} = \frac{4474.4586 \times A}{4179 \times 1}$$

$$A = 0.93396 \quad [\text{for 1 Tube}]$$

$$\pi \times D L \times p = 0.93396$$

$$\pi \times 0.025 \times L \times 2 = 0.93396 \qquad \boxed{L = 5.945\,m}\ \underline{Ans}$$

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Q-2 (c)

Engine-1.

$V_s = 3300\ cc,$

$P_{b,mef} = 9.3\ bar$

$N = 4500\ rpm$

$r = 8.2$

eff. Ratio = 0.5

$\eta_{Mech} = 0.9$

Mass of Engine $M = 200\ kg$

Engine-2.

$V_s = 3300\ cc,$

$P_{b,mef} = 12\ bar.$

$N = 4500\ rpm.$

$r = 5.5$

eff. Ratio = 0.5

$\eta_{Mech} = 0.92$

engine mass $M = \cancel{200}\ 220\ kg$

Sol^n.

$$\frac{M_I + m_{f_I} t}{BP_I} = \frac{M_{II} + m_{f_{II}} . t}{BP_2} \quad \text{--- (1)}$$

$$BP_I = P_{b,mef} . \dot{V}s . \frac{NK}{120} = \frac{930 \times 3300 \times 10^{-6} \times 4500}{120}$$

$$= \underline{115.0875\ kW}.$$

$$BP_{II} = P_{b,mef} \cdot \frac{V_s N K}{120} = \frac{1200 \times 3300 \times 10^{-6} \times 4500}{120}$$

$$= \underline{148.2\ kW}.$$

Cycle eff. for Engine I:

$$\eta_I = 1 - \frac{1}{8.2^{0.4}} = \underline{56.9\%}.$$

$$\text{eff ratio} = \frac{\eta_{i,th.}\ (\text{Indic. thermal})}{\eta_{cycle}.}$$

$$0.5 = \frac{\eta_{ith}}{0.569}$$

$$\eta_{ith} = 0.2045\%.$$

$$\eta_{bth} = \eta_{ith.} \eta_{Mech} = 0.2045 \times$$

$$\eta_{b\,th.} = 0.25605 = \frac{B.P}{m_f \cdot CV}.$$

$$0.25605 = \frac{115.0875}{m_f \cdot 44000} \qquad \underline{m_{f,I} = 0.01021\ kg/s}$$

<u>for Engine-2</u>.

$$\eta_{II} = 1 - \frac{1}{5.5^{0.4}} = 0.4943$$

$$\eta_{ith} = 0.4943 \times \text{eff ratio} = 0.2472$$

$$\eta_{b,th} = 0.2472 \times \eta_{Mech} = \underline{0.22739}. = \frac{BP_{II}}{m_{f_{II}} \cdot CV}$$

$$0.22739 = \frac{148.2}{m_{f_{II}} \times 44000} \Rightarrow \underline{m_{f_{II}} = 0.01481\ kg/s}$$

<u>Now eqn (1).</u>

$$\frac{200 + 0.01021 \times t}{115.0875} = \frac{220 * 0.01481 \times t}{148.2}$$

$$t = 22583.43\ sec = \underline{6.273\ hours}.$$

$$bsfc_I = \frac{\cancel{115.0875}}{} \quad \frac{0.01021}{115.0875} \times 3600$$

20

good $= 0.31937 \ Kg/Kwhr$

$$bsfc_{II} = \frac{0.01481}{148.2} \times 3600 = 0.3597 \frac{kg}{Kwhr}$$

* Economically engine I has less bsfc hence it is ~~having~~ more fuel economic.
* Engine two is used for high power application.

Q- 3(a)

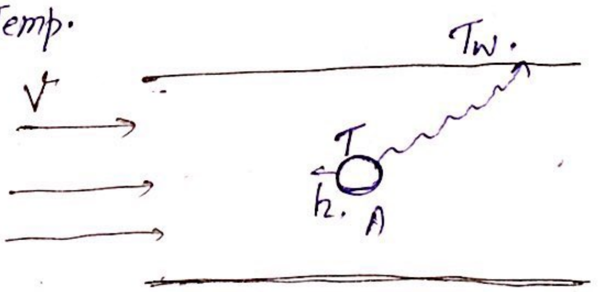
(i) Radiation Effect on Temperature Measurement device

Tg - inlet gas Temp

$T_w \rightarrow$ wall Temp. $\quad$ $V \rightarrow$ Gas velocity

$h \rightarrow$ Conv. H.T of Thermo couple

$T \rightarrow$ thermocouple Temp.



→ As the high Temp Tg gases flow through the duct the Temp of thermocouple start increasing.

→ ~~but~~ the Temp increase to the convection heat Transfer b/w the Gas and thermocouple

→ at steady state the Temp of thermocouple become constant but always lower than that of the gas Temperature.

→ Because the thermocouple simultaneously loosing the heat to wall, through Radiation. this Radiated energy gained by the thermocouple by the convection heat Transfer Coeff.

read from solution also

→ Due to this, there will always be an error in estimation of the Gas Temperature.

at the steady state condition

heat gain through convection = Radiated heat to wall

$$\underline{h \cdot A [T_g - T] = \sigma \epsilon A [T^4 - T_w^4]}.$$

The error in measurement of Gas Temp.

$$\underline{\text{error} = (T_g - T)}.$$

<u>To reduce error</u>

- increase in convective heat Transfer.
- Reduce radiating effect by reducing emissivity.

(ii)

$T_w = 500\,K$

$T = 850\,K.$

$\epsilon = 0.6$

13

$h = 60\ W/m^2K.$

<u>for actual Temp</u>.

Applying energy balance

$$hA[T_g - T] = \sigma \epsilon A[T^4 - T_w^4]$$

$$60[T_g - 850] = 5.67\times10^{-8} \times 0.6 [850^4 - 500^4]$$

$$60[T_g - 850] = 15632.4$$

$$T_g - 850 = 260.54$$

$$\underline{T_g = 1110.54K}$$

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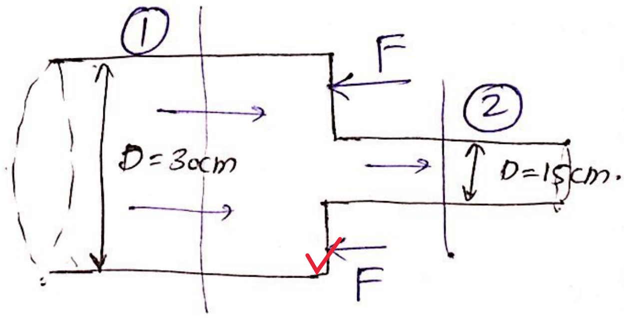
3 (b) (i)



For 30cm dia pipe

$\beta_1 = 1.3$

$\alpha_1 = 1.9$

for 15cm dia pipe

$\beta_2 = 1.05$

$\alpha_2 = 1.15$

$P_2 = 15 kPa.$

$V_2 = 6m/s$ [mean]

<u>mean velocity @ pipe 1</u>

$$A_1 V_1 = A_2 V_2$$

$$\frac{\pi}{4} \times 30^2 \times V_1 = \frac{\pi}{4} \times 15^2 \times 6$$

$$\underline{V_1 = 1.5 \, m/s}$$

<u>Applying B.E^n @ ① & ②</u>

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + \cancel{z_2}$$

$$\frac{P_1}{\cancel{\rho g}} + 1.9 \times \frac{1.5^2}{\cancel{2 \times 9.81}} + 0 = \frac{15 \times 10^3}{\cancel{\rho g}} + 1.15 \times \frac{6^2}{\cancel{2 \times 9.81}}$$

$$\underline{P_1 = 33.5625 \, kPa}$$

~~$P_1 A_1$~~ <u>Applying Momentum eq^n</u>

$$P_1 A_1 - F - P_2 A_2 = m V_2 \beta_2 - m V_1 \beta_1$$

$$33.5625 \times 10^3 \times \frac{\pi}{4} \times 0.3^2 - F - 15 \times 10^3 \times \frac{\pi}{4} \times 0.15^2$$

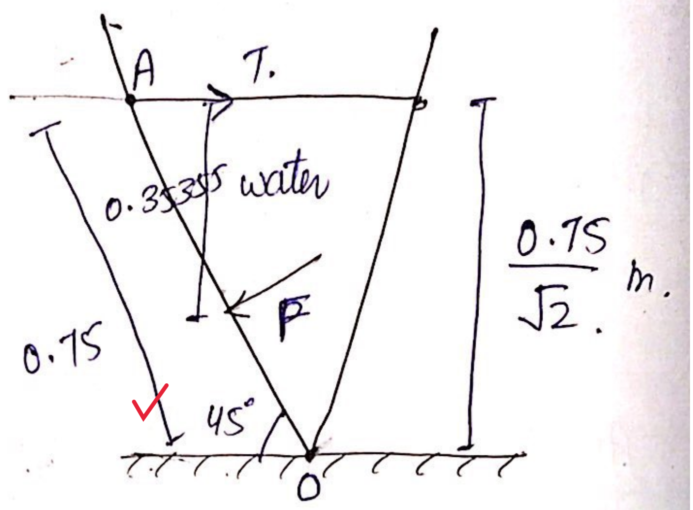
$$= 1000 \times \frac{\pi}{4} \times 0.3^2 \times 1.5 \left[6 \times 1.05 - 1.5 \times 1.3 \right]$$

$$2107.321 - F = 461.225$$

$$\underline{F = 1646.096 \, N}$$

3b (ii)

Force acting on the Trough



$F = w.A\bar{x}$

$= 9810 \times 0.75 \times 6 \times \frac{0.75}{\sqrt{2} \times 2}$

$F = 11705.71\ N$

$h = \bar{x} + \frac{I_{aa} \sin^2\theta}{Ax}$

$= \frac{0.75}{2\sqrt{2}} + \frac{0.75^3 \times 6 \times 2\sqrt{2}\ \sin^2(45)}{12 \times (0.75 \times 6) \times 0.75}$

15

$h. = 0.35355\,m$ from point A

good

$\Sigma M_o = 0$

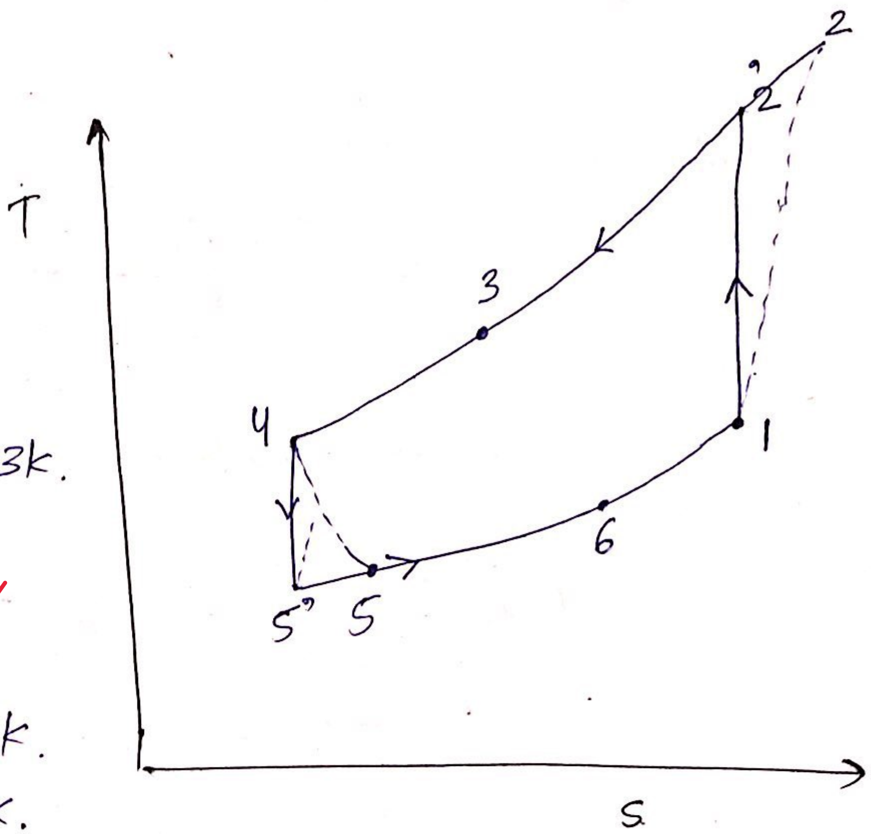
$T \times \frac{0.75}{\sqrt{2}} = F \times \left[\frac{0.75}{\sqrt{2}} - 0.35355\right] \sqrt{2}.$

$= \frac{11.705 \left[\frac{0.75}{\sqrt{2}} - 0.35355\right] \times 2}{0.75}$

$T = 5.517\ kN$

Q- 3 (c)

Given.



$r_p = 5$

$T_1 = 0^\circ C = 273K.$

$P_1 = 100 kPa.$

$T_5 = -80^\circ C$

$= 193K.$

$T_3 = 35^\circ C = 308K.$

$m = 0.4 kg/s$, $\eta_c = 0.80$, $\eta_T = 0.85$

$$\frac{T_2'}{T_2} = r_p^{\frac{\gamma-1}{\gamma}} \Rightarrow T_2' = 273 \times 5^{0.4/1.4} = 432.382 K$$

$$\frac{T_2' - T_1}{T_2 - T_1} = 0.8 \quad , \quad \frac{432.382 - 273}{T - 273} = 0.8$$

$$\underline{T_2 = 472.227 K}.$$

$$\eta_T = \frac{T_4 - T_5}{T_4 - T_5'} \Rightarrow 0.85 = \frac{T_4 - 193}{T_4 - T_5'}.$$

$$0.85 T_4 - 0.85 T_5' = T_4 - 193$$

$$0.15 T_4 + 0.85 T_5' = 193 \quad \text{—(1)}$$

$$\frac{T_4}{T_5'} = 5^{0.4/1.4} = 1.5838 \quad \text{—(2)}$$

by Solving $\underline{T_4 = 281.06\ K}$

effectiveness of Regen.

$$\epsilon = \frac{T_3 - T_4}{T_3 - T_6} \quad \text{—— (2)}$$

Applying energy balance @ Regenerator.

$$\cancel{m}\cancel{C_p}[T_3 - T_4] = \cancel{m}\cancel{C_p}[T_1 - T_6]$$

$$308 - 281.06 = 273 - T_6$$

$$\underline{T_6 = 246.06\ K}.$$

putting in eq^n (2)

$$\epsilon = \frac{308 - 281.06}{308 - 246.06} = \underline{0.4349}.$$

(ii) Rate of heat removal

$$= m[h_6 - h_5]$$

$$= 0.4[C_p \times T_6 - C_p T_5]$$

$$= 0.4 \times 1.005[246.06 - 193]$$

$$= \underline{21.33\ kW}.$$

15

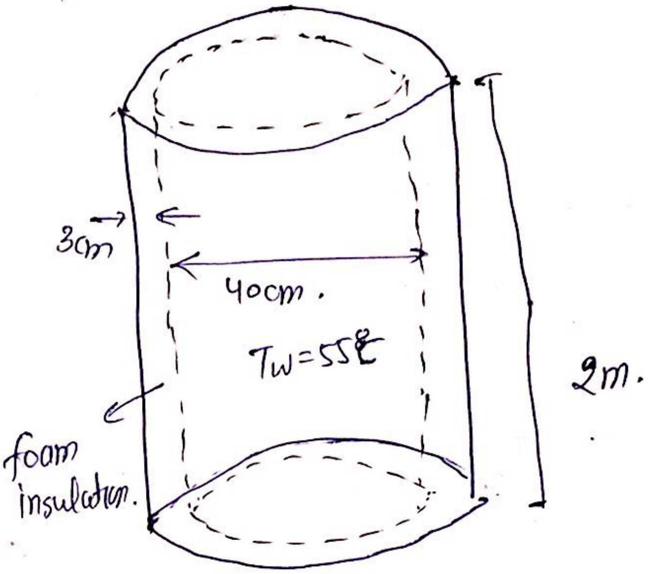
$$COP = \frac{R.E}{W_{I/P}} = \frac{h_6 - h_5}{(h_2 - h_1) - (h_4 - h_5)} = \frac{T_6 - T_5}{(T_2 - T_1) - (T_4 - T_5)}$$

$$= \frac{(246.06 - 193)}{(472.227 - 273) - (281.06 - 193)} = \underline{\underline{0.4773}}\ \text{Ans}.$$

Q 3(d)

Assumption.

- Steady state operation
- heat Transfer Through ends are neglected.



Heat Transfer circuit

$T_o = 27°C$ — $\frac{1}{h_o A_o}$ — $\frac{\ln r_2/r_1}{2\pi K L}$ — $\frac{1}{h_i A_i}$ — $T_{in} = 55°C$

$$\frac{1}{(hA)_{net}} = \frac{1}{h_o A_o} + \frac{\ln(r_2/r_1)}{2\pi K L} + \frac{1}{h_i \cdot A_i}$$

$$= \frac{1}{12 \times \pi \times 0.46 \times 2} + \frac{\ln(23/20)}{2\pi \times 0.03 \times 2} + \frac{1}{50 \times \pi \times 0.4 \times 2}$$

$$\underline{(hA)_{net} = 2.4538 \ W/m^2k}.$$

$$Q = (hA)_{net} \ \Delta T = 2.4538 \times 28$$

$$= 68.7064 \ \underline{W}.$$

$$= 0.0687064 \ KW$$

Q: $= \cancel{2.47343 \ KWhr}$

energy lost /year $= 0.0687064 \times 24 \times 365$ KWhr

$= 601.868$ KWhr/year

Cost of lost energy $= 601.868 \times 0.08$

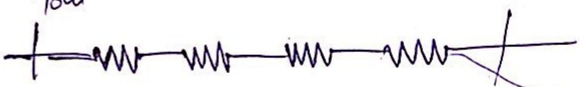
$= 48.15$ \$ /year

fraction of hot water energy of the household that is due to heat loss $= \dfrac{48.15}{200} = \underline{17.196\%}$

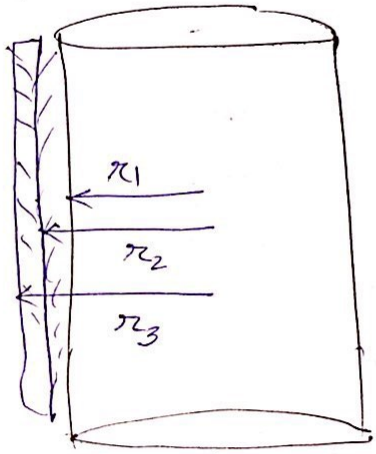
$= \underline{0.17196}$

<u>Case–II</u>

$T_{out} = 27^\circ C$ $\quad T_i = 55^\circ C$



$\dfrac{1}{h_o A_o}$ $\quad \dfrac{\ln(r_3/r_2)}{2\pi K_{fibre} L} + \dfrac{\ln(r_2/r_1)}{2\pi K_{foam}} + \dfrac{1}{h_i A_i}$



$$\frac{1}{(hA)_{net}} = \frac{1}{12 \times \pi \times 0.52 \times 2} + \frac{\ln 54/46}{2\pi \times 0.035 \times 2} + \frac{\ln(46/40)}{2\pi \times 0.03 \times 2} + \frac{1}{50 \times \pi \times 0.4 \times 2}$$

$= 1.4642$

Heat lost $Q = (hA)_{ne} \Delta T$

$= 1.4642 \times (28) \simeq \underline{41 \text{ W}}$.

energy saved $= 68.7064 - 41$

$= 27.7064$ W check solution

10

$= \underline{0.0277 \text{ Kwhr}}$

$[0.0277 \times T] \times 0.08 = 30$

$\underline{T = 13537.9 \text{ hours}}$

5 (a)

speed $N = 12500$ rpm

$\dot{m} = 15$ Kg/s

Press. ratio $r = 4$

isen. eff $\eta_c = 75\%$.

Slip factor $\mu = 0.9$

Flow coeff of Impeller $\phi = 0.3$

$D_1 = 0.15m$.

~~V_f~~ $V_{axial} = 150 m/s$

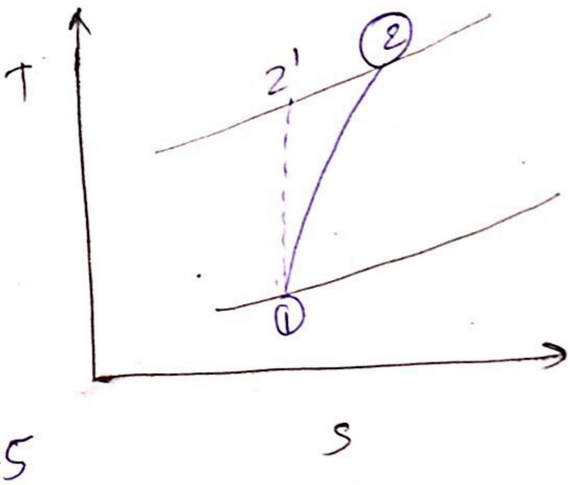
$T_{01} = 295K$.

$P_{01} = 1.0$ bar.

$T'_{2,0} = T_{1,0} r_p^{\frac{\gamma-1}{\gamma}}$

$T'_{2,0} = 295 \times 4^{\frac{0.4}{1.4}}$

$= 438.3683K$.



$$\frac{T_{2'0} - T_{1,0}}{T_{20} - T_{1,0}} = 0.75$$

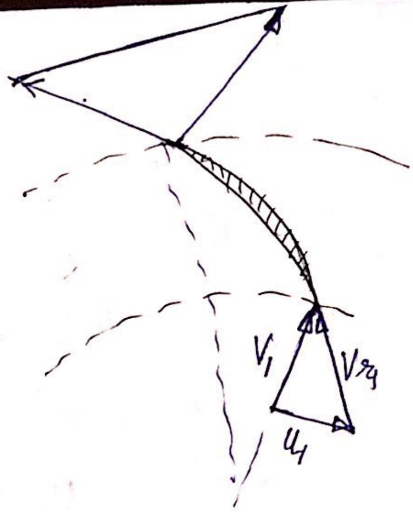
$$\frac{438.3683 - 295}{T_{2,0} - 295} = 0.75$$

$\underline{T_{2,0} = 486.157K}$.

Work done/Kg of air $= C_p [T_{2,0} - T_{1,0}]$

$= 1.005 [486.157 - 295]$

$= 192.112$ KJ/kg



$WD/kg = \mu \phi u^2$

$192.112 \times 10^3 = 0.3 \times 0.9 \times u^2$

$u = 843.52 \ m/s.$

$= \dfrac{\pi \times D \times 12500}{60} = 843.52$

3

read from solution

$\underline{D = 1.288 m}$ ×

$WD/s = 192.112 \times 15 \doteq \underline{2.881 \ MW}$. ×

5(b) Head $H = 80 m$

$N = 300 \ rpm.$

$P = 125 kW$

$\eta_o = 85\%$. ✓

$K_u = 0.45 = \dfrac{u}{\sqrt{2gH}}.$ ✓

$C_v = 0.98$

$\eta_o = \dfrac{P \text{ (shaft Power)}}{\rho g H Q}$ ✓

$0.85 = \dfrac{125 \times 10^3}{9810 \times 80 \times Q}$ ✓

$Q = 0.18730 \ m^3/s$

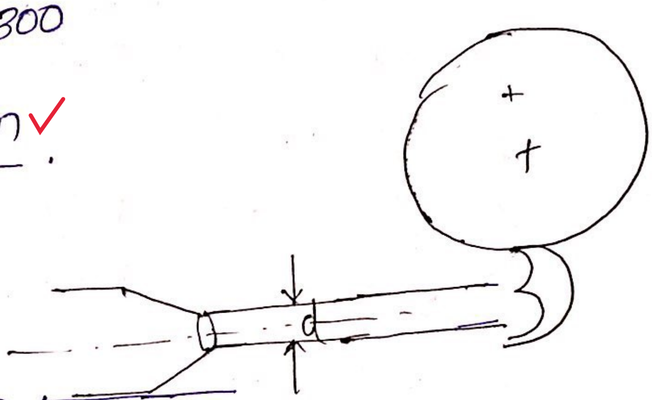
$Ku = \frac{u}{\sqrt{2gH}} \Rightarrow 0.45 = \frac{u}{\sqrt{2 \times 9.81 \times 80}}$

$u = 17.828 \ m/s$

$17.828 = \frac{\pi D N}{60}$

$D = \frac{17.828 \times 60}{\pi \times 300}$

$\underline{D = 1.135 m}$



$Q = \frac{\pi}{4} d^2 \times V$

$0.18730 = \frac{\pi}{4} d^2 \times 0.98 \sqrt{2 \times 9.81 \times 80}$

$d = 0.078389 \ m$

Jet Ratio $= \frac{D}{d} = \frac{1.135}{0.078389} = \underline{14.48}$

12 No of (Buckets) Vanes $= \frac{m}{2} + 15 = \frac{14.48}{2} + 15 = 22.239$

$= \underline{24 \text{ Vanes}}$

even no of ~~Blades~~ Buckets are provided for balancing.

width of blade $= 5d = 5 \times 0.078389$

$= \underline{0.4m}$

5 (c)

Boiler Mountings

- Boiler mountings are the devices which is used for the safety purpose for a boiler. These devices are Generally ~~sto~~ indicates the condition of the boiler where as some of them will fail to save the boiler, called fail safe design.
- These device prevents excessive pressure, (or) excessive heating in the boiler and hence used to avoid the catastrophic failure of the boiler.

Eg: (1) Pressure Guage
(2) Liquid Level Indicator
(3) feed check valve
(4) ~~boiler~~ fusible plug.
(5) Stop valve

(1) **Pressure Guage**

these are the Guages, measure pressure reading and hence these pressure can be seen and these pressure the excessive pressure can be released to avoid the failure of tank (or) drum.

(2) **Liquid level Indicator:**

It ensures that give the reading, how much liq. is present. ~~time~~ min^m liquid to avoid overheating of liquid due to this pressure may rise will be high & failure may take place.

(3) **feed check valve:**

these valves are use the check the feed of the fluid in the drum. proper feeding is required to avoid the failure of the boiler.

Fusible plug :-

These are made up of brass and work as a fail safe design. when Temp is increase beyond a certain limit the fusible plug (having less melting Temp than other part) melt itself & release the pressure to avoid the catastrophic failure of boiler.

Boiler Accessories :-

Boiler Accessories are the devices which are used to inhance the performance of heat addition process & consequently these increase the performance of the cycle. due to these, the efficiency of the cycle is increase.

Eg ① Reheater
② Superheater.
③ economizer.
④ Air preheater.
⑤ steam Tap
⑥ feed water heater

① Reheater :

process of increase the steam Temp which is come out from HP Turbine to the certain Temp.

② Superheater :

process of increase the ~~saturated~~ ~~Temp~~ ~~of the~~ ~~saturated~~ Temp of saturated steam to the some designed superheated value at constant pressure.

③ Economizer.

process of increase the Temp of subcooled liquid to saturated liquid at constant Pressure. 12

④ Air preheater : preheat the air before ~~send~~ send to the Combustion chamber.

5 (d)

borewell depth $H = 25 m$ ✓

No of modules $N = 24$

Each module $9 \times 4 = 36$ [Multicrystalline silicon solar cell]

cell size $= 125 \times 125\ mm^2$

$\eta_{cell} = 12\%$ ✓

overall eff $\eta_o = 50\%$

@ Noon $Q = 800\ W/m^2$

$\rho_w = 996\ kg/m^3$

✓

Total Area of solar cell = cell size × module × N

$= 0.125 \times 0.125 \times 36 \times 24$

$= 13.5\ m^2$ ✓

Total energy incident on cell $= 13.5 \times 800$

$= 10800\ W$ ✓

Energy Generated by solar cell $= \eta_{cell} \times 10800$

$E_g = 0.12 \times 10800$ ✓ $= 1296\ W$

12

over all eff $\eta_o = \dfrac{\rho g Q H}{E_g}$

$0.5 = \dfrac{998 \times 9.81 \times Q \times 25}{1296}$

$Q = 2.652 \times 10^{-3}\ m^3/sec = 2.652\ lit/sec$ ✓

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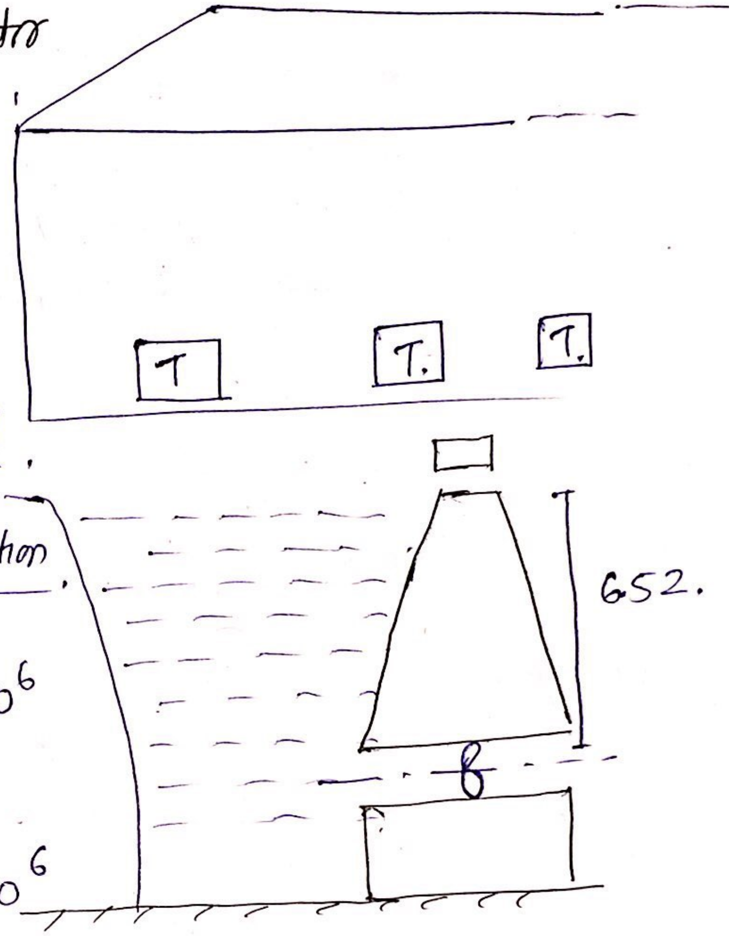
Q- 5 ⓔ

Installed capacity = 2240 MW

No of units = 64 (35 MW/unit)

Head $H = 6.52m$

35 MW @ each Generator



water power available per Turbine $= \frac{35}{0.92}$

$= 38.043$ MW

applying energy conservation

$$\frac{mgh}{5 \times 3600} = 38.043 \times 10^6$$

$$\frac{A \times h \rho g h/2}{3600 \times 5} = 38.043 \times 10^6$$

$$\cancel{\frac{1025 \times Q \times 9.81 \times 6.52}{3600 \times 5 \times 2} = 38.04 \times 10^6}$$

$$\frac{9.81 \times 1025 \times 6.52^2 \times A}{2 \times 3600 \times 5} = 38.043 \times 10^6$$

$A = 3203975.554 \ m^2$ /unit

3

$A \times h = Q \times 5 \times 3600$ $\quad Q = 1160.55 \ m^3/s$

Total surface area $= 3203975.554 \times 64 = 205.05 \ km^2$

Total energy produced $= 2240 \times 10 \times 365 = 8176$ TWhr

7 (a)

overall press. ratio = $r_p = 4$

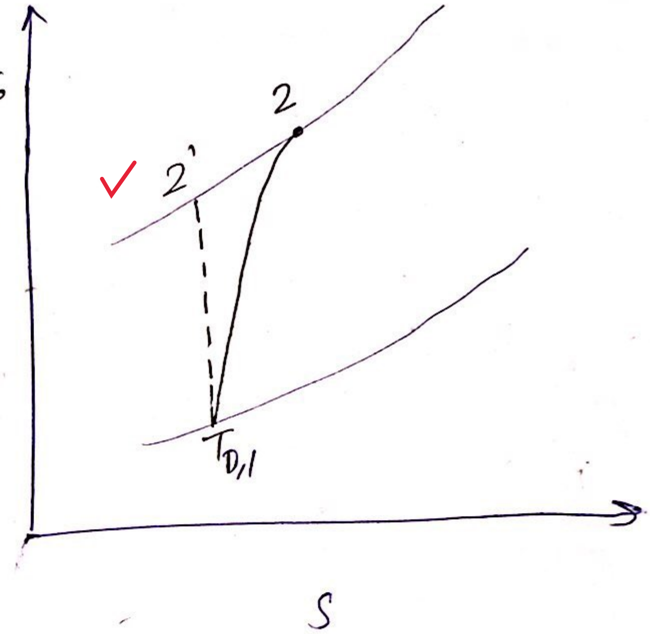
$\eta_{ise} = 0.85$

$T_{0,1} = 290K.$

$\alpha = 10, \ \beta = 45$

$u = 220 \ m/s$

$\phi_W = 0.86$



$T_2' = T_1 \, r_p^{\frac{\gamma-1}{\gamma}}$

$= 290 \times (4)^{\frac{0.4}{1.4}}$

Assuming $\gamma = 1.4$

$\underline{T_2' = 430.9383K}$

$\eta_{is} = \dfrac{T_2' - T_{0,1}}{T_2 - T_{0,1}} \Rightarrow 0.85 = \dfrac{430.9383 - 290}{T_2 - 290}$

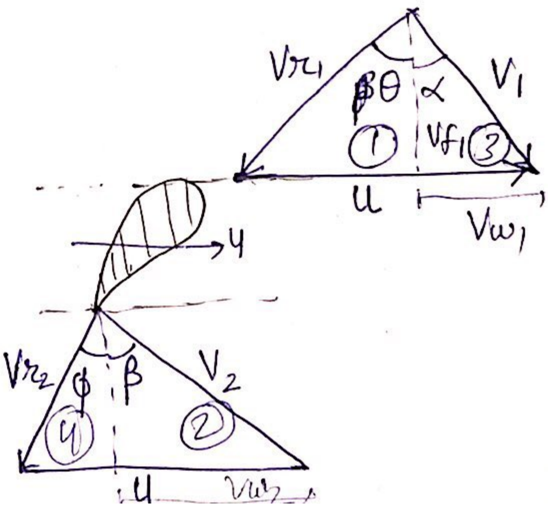
$\underline{T_{0,2} = 455.809K}$

<u>Assuming 50% Reaction stage</u>

$\theta \ \cancel{\phi} = \beta = 45$

$\phi = \alpha = 10°$

$V_1 = Vr_2, \ V_2 = Vr_1$



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$$C_p [T_{0,2} - T_{0,1}] = n . \phi_w [V_{w_2} - V_{w_1}] u \quad \text{--- (1)}$$

$$\tan\alpha + \tan\theta = \frac{u}{V_{f_1}}$$

$$\tan 10 + \tan 45 = \frac{220}{V_{f_1}}$$

$$\underline{V_f = 187.022 \text{ m/s}} = V_{f_2}$$

In Triangle (3)

$$\tan\alpha = \frac{V_{w1}}{V_{f_1}} \qquad V_{w_1} = V_{f_1} \tan\alpha$$

Similarly $V_{w_2} = V_{f_2} \tan\beta$.

putting in eq^n (1)

$$C_p [T_{0,2} - T_{0,1}] = n \phi_w [V_f \tan\beta - V_f \tan\alpha] u.$$

$$\frac{\gamma R}{\gamma - 1} [T_{0,2} - T_{0,1}] = n \phi_w [V_f (\tan\beta - \tan\alpha) u]$$

$$\frac{1.4 \times 284.6}{0.4} \times [458.809 - 290] = n \times 0.86 [187.022 \times 220 \times [\tan 45 - \tan 10]]$$

$$168150.645 = n \times 29145.31$$

$$n = 5.77 \simeq \underline{6 \text{ stages}}.$$

Polytropic eff :-

$$T_2 = T_1 r_p^{\frac{n-1}{n}}.$$

$$458.809 = 290 \times 4^{\frac{n-1}{n}}.$$

$$\frac{n-1}{n} \ln 4 = \ln\left(\frac{458.809}{290}\right)$$

Scanned with CamScanner

$$\frac{n-1}{n} = 0.33092 \qquad \underline{n = 1.4945}$$

Polytropic efficiency

$$\eta_p = \frac{\gamma-1}{\gamma} \cdot \frac{n}{n-1}$$

$$= \frac{1.4-1}{1.4} \cdot \frac{1.4945}{1.4945-1} = \underline{0.86350}$$

$$= \underline{86.35\%}$$

relative velocity @ inlet

$$\cos\theta = \frac{V_f}{V_{r_1}}$$

$$\cos 45 = \frac{187.022}{V_{r_1}}$$

$$\underline{V_{r_1} = 264.49 \text{ m/s}}$$

$$V_1 = \frac{V_f}{\cos 10}$$

$$= 189.9 \text{ m/s}$$

@ inlet

$$\cancel{\frac{T_{01}}{T_1}} = \cancel{V_1} \quad T_{01} = T_1 + \frac{V_1^2}{2 \times C_p}$$

$$290 = T_1 + \frac{189.9^2}{2 \times \frac{1.4 \times 284.6}{0.4}}$$

$$\underline{T_1 = 271.898}$$

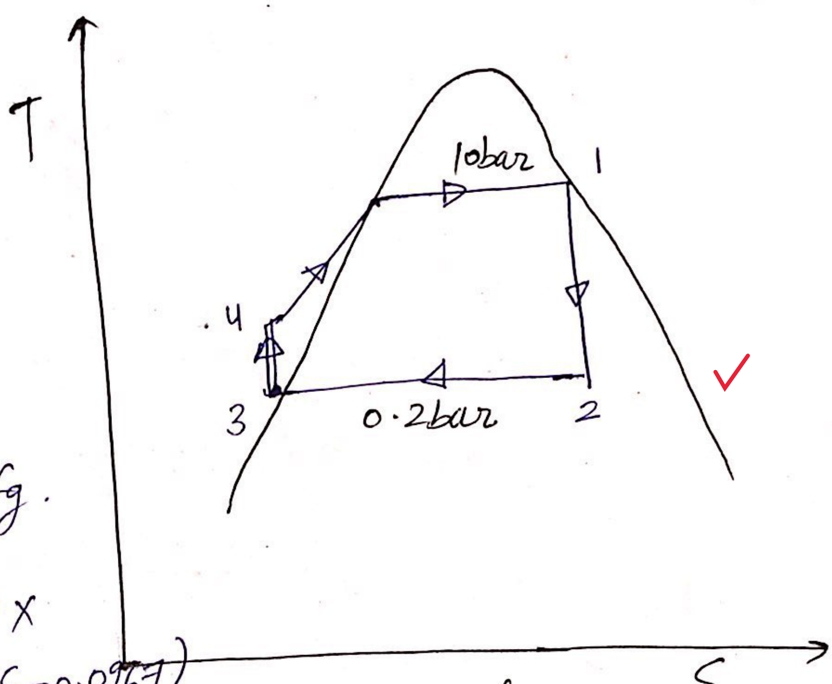
20

$$C = \sqrt{\gamma R T} = 329.142$$

$$M_r = \frac{V_{r_1}}{C} = \frac{264.49}{329.142} = \underline{0.803}$$

7 (b)

for Mercury cycle



Mercury cycle.

$h_1 = 363$ KJ/kg

$S_1 = S_2$

$0.5167 = S_3 + x\, S_{fg}$.

$0.5167 = 0.0967 + x \times (0.6385 - 0.0967)$

$x = 0.7752$

$h_2 = h_3 + x.\, h_{fg} = 38.35 + 0.7752 \times (336.55 - 38.55$

$h_2 = 269.514$ KJ/kg.

$h_3 = 38.35$ KJ/kg

pump work $= v\,dp = 77.4 \times 10^{-6} \times [10 - 0.2] \times 100$

$= 0.0758$.

$h_4 = h_3 + W_p = 38.425$ KJ/kg

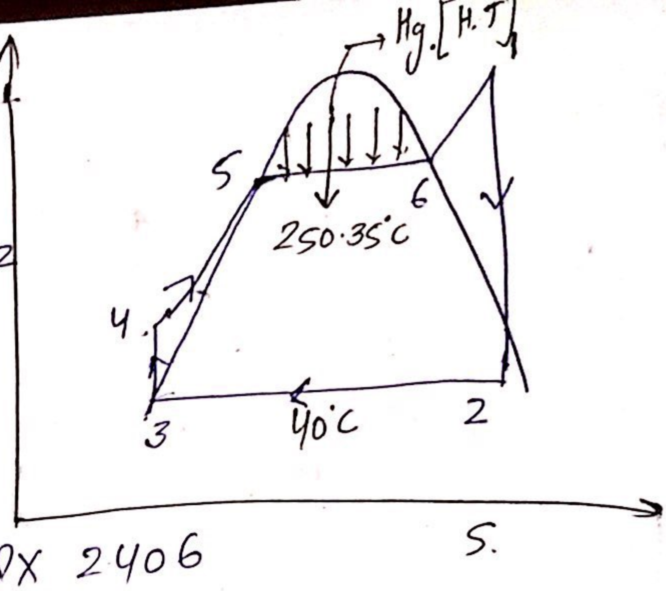
for steam cycle

$h_1 = 3214.5$ KJ/kg

$h_5 = 1087.4$ KJ/kg

$h_6 = 2800.8$ KJ/kg

$h_3 = 167.53$ KJ/kg



$S_1 = S_2$

$6.7714 = 0.5724 + x\,7.6832$

$x = 0.8068$

$h_2 = h_3 + x.h_{fg}$

$= 167.53 + 0.8068 \times 2406$

$= 2108.99$ KJ/kg.

$W_p = 0.001008 \times [4000 - 7.3851]$

$= 4.024$ KJ/kg.

$h_4 = h_3 + W_p = 171.554$ KJ/kg.

* Assuming mass flow rate of water = 1 kg/s

Heat rejected by Hg cycle = Heat gained by steam cycle

$$\left[m_{Hg}\left[h_2 - h_3\right]\right]_{Hg} = \left[1 \times \left[h_6 - h_5\right]\right]_{steam}$$

$$m_{Hg}\left[269.514 - 38.35\right] = \left[2800.8 - 1087.4\right]$$

$m_{Hg} = 7.412$ Kg/Kg of steam <u>Ans</u>

Work O/P of Hg cycle

$$(WD)_{Hg} = W_T - W_p$$

$$= m_{Hg}\left[\left[h_1 - h_2\right] - W_p\right]$$

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$= 7.412[(363 - 269.514) - 0.0758]$

$= 692.356$ KJ/kg of steam

Heat supplied @ Hg cycle.

$[Q_s]_{Hg} = m[h_1 - h_4] = 7.412 \times [363 - 38.425]$

$= 2405.75$ KJ/kg.

work O/P for steam cycle

$(WD)_{steam} = [h_1 - h_2] - W_P$

$= 3214.5 - 2108.99 - 4.024$

$= 1101.486$ KJ/kg

heat supplied to steam cycle

$Q_s = [h_5 - h_4] + [h_1 - h_6]$

$= (1087.4 - 171.554) + (3214.5 - 2800.8)$

$= 1329.546$ KJ/kg

efficieny $\eta = \frac{\Sigma WD}{\text{Heat supplied}} = \frac{692.356 + 1101.486}{2405.75 + 1329.546}$

$= 0.4802$

$= 48.02\%$.

20

Q-7 (c) Delhi (28.62° N, 77.21° E)

$n = 187$

$L_a = 6$ hour

$$\frac{H_g}{H_o} = a + b\frac{L_a}{L_m} \qquad a = 0.25,\ b = 0.57$$

$\cancel{\phi = 28 + \frac{62}{6}}$

$\phi = 28.62°$

declination

$$\delta = 23.45 \sin\left[\frac{360}{365}(284+n)\right]$$

$$= 23.45 \sin\left[\frac{360}{365}(284+187)\right]$$

$$= \underline{22.698°}$$

$$\omega_s = \cos^{-1}[-\tan\phi \tan\delta]$$

$$= \cos^{-1}[-\tan(28.62)\tan(22.698)]$$

$$= 103.1932$$

mean day length $= \frac{2\omega_s}{15} = \frac{2\times 103.1932}{15}$

$= \underline{13.759 \text{ hours}}$

$$H_o = \int_{t_{SR}}^{t_{SS}} I_n \cos\theta_i \, dt$$

$$= \int_{t_{SR}}^{t_{SS}} I_{sc}\left[1+0.033\cos\left(\frac{360}{365}n\right)\right]\left[\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta\right]dt$$

1 hour ——— 15°

dt ——— $\frac{12}{\pi} d\omega$.

$$H_o = \frac{24}{\pi} I_n \int_0^{\omega s} [\cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta] \, d\omega$$

$$= \frac{24}{\pi} I_n \left[\cos\phi \cos\delta \sin\omega + \omega \sin\phi \sin\delta \right]$$

$$= \frac{24}{\pi} \times 3.6 \left[1367 \left(1 + 0.033 \cos \left(\frac{360}{365} \times 187 \right) \right) \right] \times$$

$$\left[\cos 28.62 \cdot \cos 22.698 \sin 103.1932 + \left(\frac{103.1932 \times \pi}{180} \right) \sin 28.62 \sin 22.698 \right]$$

$$H_o = 36358.277 \, [1.1213]$$

$$= 40768.536 \, \frac{KJ}{m^2\text{-day}}$$

No using modified Angstrom Eq^n

$$\frac{H_g}{H_o} = a + b \frac{L_a}{L_m}$$

$$\frac{H_g}{40768.536} = 0.25 + 0.57 \times \frac{6}{13.759}$$

$$H_g = 20325.747 \, \frac{KJ}{m^2\text{-day}}$$

for diffuse Radiation

$$\frac{H_d}{H_g} = 1.354 - 1.57 \left[\frac{H_g}{H_o} \right]$$

$$\frac{H_d}{20325.747} = 1.354 - 1.57\left[\frac{20325.747}{40768.536}\right]$$

$$\boxed{H_d = 11611.157 \ \frac{KJ}{m^2\text{-}day}} \quad \underline{Ans}$$

$$H_g = H_b + H_d$$

good

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$$20325.747 = 11611.157 + H_b.$$

$$\boxed{H_b = 8714.59 \ \frac{KJ}{m^2\text{-}day}} \quad \underline{Ans}.$$