Q-1 @ Given:

Total mass of the vehicle $M = 1000\ kg$

Moment of In. of each wheel $I_W = 0.5\ kg\text{-}m^2$

wheel Rad. $R_W = 0.35\ m$

$W_W \rightarrow$ wheel rot^n velocity

M.O.I of engine & Transmitting sys $I_e = 2.5\ kg\ m^2$

engine. Rot^n velo. $W_e = 5\ \omega_W$

speed $V = 100\ km/h = \underline{27.778\ m/s}$.

$a = 0.5g.$

Sol^n. Assuming – Car deaccelerated to zero velocity

angular velocity of wheel $\omega_W = \dfrac{V}{R_W} = \dfrac{27.778}{0.35}$

$= 79.365\ rad/s$

Angular velo. of engine $\omega_E = 396.828\ rad/s$

① Energy Associated with ~~the~~ vehicle mass = K.E

$= \frac{1}{2} M V^2$

$= 385.808\ KJ$

② Energy Associated with engine $= \frac{1}{2} I_E \omega_E^2$

$= \frac{1}{2} \times 2.5 \times 396.828^2$

$= 196.840\ KJ$

③ Energy associ with wheels $= 4\left(\frac{1}{2} I_w \omega_w^2\right) = 4 \times \left[\frac{1}{2} \times 0.5 \times 79.365\right.$

$= 6.298\ KJ$

Total energy Associated with vehicle = ~~385.808~~

$= 385.808 + 196.840 + 6.298$

$= 588.946$ KJ

the energy absorbed by each brake (E_w)

$$= \frac{\text{Total energy}}{\text{No of brakes}} = \frac{588.946}{4}$$

$= 147.2365$ KJ

(11) since car deaccelerated to zero velocity

wheel

$$(\omega_w)_f^2 = (\omega_w)_i^2 + 2\alpha\theta \quad \text{—— (1)}$$

$$\alpha = \frac{a}{R_w} = \frac{0.5g}{0.35} = 14.014 \text{ rad/s}^2$$

putting in eq^n (1)

$$0 = 79.365^2 + 2 \times (-14.014)\theta$$

$$\boxed{\theta = 224.732 \text{ rad}}$$

Torque capacity of each wheel $T_w = \dfrac{E_w}{\theta}$

$$= \frac{147.2365 \times 10^3}{224.732} = 655.164 \text{ N-m}$$

Ans

12 good in presentation

Q-1(b)

① RAM :-

Acronym — Random Access memory

→ It is Volatile memory. (Primary Memory)
→ it Works b/w ROM & processor, the data that need to be processed, first loaded in RAM.
→ Writing speed is faster than ROM.
→ It is of 2 types ① Static RAM ② Dynamic RAM.

② ROM :

→ Read Only Memory
→ It is non volatile, secondary memory.
→ It works as a main memory, data is stored in this Memory of Computer.
→ Its speed is lower than RAM.
→ Once program is write, it can not be changed for further

③ PROM

Acronym - Programmable Read Only memory
→ It is non volatile secondary memory.
→ It works similar to ROM but the ~~addi~~ it has ~~R~~ a feature that it can be

check solution

Programmed ~~Again~~.

→ It is a reusable where an ROM can't be reuse once program is written.

④ EPROM

- Acronym - Erasable programmable Read ~~any~~ only Memory.

→ the program ~~on~~ written on the memory can be erasable. ✓

→ It is a non volatile memory ✓

→ Erasing of program is done by ultra violet rays

→ It take slighty higher time to erase.

⑤ EEPROM

Acronym - Electrically Erasable Programmable Read only memory.

→ It is non volatile Secondary memory

→ In EPROM the problem is, erasing time is much high, to overcome this erasing is done with the help of electric pulses

→ This method is faster. ✓

→ time taken for erasing is less Compared to EPROM

→ 7

Q-1 (C)

Point $^{B}P = (5, 3, 4)^T$

(i) $R_x(90°)$ (ii) Trans $(5, 3, 6)$ (iii) $R_z(90°)$

then new orientation is given by

$$^{B}P_{new} = R_z(90).\ Trans(5,3,6)\ R_x(90)\ .\ ^{B}P$$

$$= \underbrace{\begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{C} \underbrace{\begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{A} \begin{bmatrix} 5 \\ 3 \\ 4 \\ 1 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 5 \\ 3 \\ 4 \\ 1 \end{bmatrix} = \begin{bmatrix} 1\times5+0\times3+0\times4+0\times1 \\ 0+0+(-1\times4)+0 \\ 0+1\times3+0+0 \\ 0+0+0+1\times1 \end{bmatrix} = \begin{bmatrix} 5 \\ -4 \\ 3 \\ 1 \end{bmatrix}$$

$$B = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 5 \\ -4 \\ 3 \\ 1 \end{bmatrix} = \begin{bmatrix} 1\times5+0(-4)+0\times3+5\times1 \\ 0+1(-4)+0+3\times1 \\ 0+0+1\times3+6\times1 \\ 0+0+0+1\times1 \end{bmatrix} = \begin{bmatrix} 10 \\ -1 \\ 9 \\ 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 10 \\ -1 \\ 9 \\ 1 \end{bmatrix} = \begin{bmatrix} 0\times10+(-1\times-1)+0\times9 & 0\times1 \\ 1\times10 & 0 & 0 & 0 \\ 0 & 0 & 1\times9 & 0 \\ 0 & 0 & 0 & 1\times1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 \\ 10 \\ 9 \\ 1 \end{bmatrix}$$

12

$^{B}P_{new} = [1 \quad 10 \quad 9]^T$ Ans

1 (d) Performance specification of Good Control system

(1) Controllability :

→ the control system should be controllable while operating

→ If the state variables of required ouput is achieved by a finite amount of input variables & finite amount of time, then the system is said to be controllable.

(2) Observable :-

- It is also a required property to Identify whether the control system is working as per requrement
- If the state variables of any control system is easily Identifiable ~~so that~~ using finite no. of Input, it is termed as the system is observable.

(3) ~~Fast~~ Fast Response : (fast Response)
- Controll- system should Respond fastly to the disturbance
- If there is change in input state variable, the control system is required to produce extra current fastly to get the desired ~~output~~ o/p.

(4) ~~Flexibility~~ Flexibility :
- the control system should be flexible to Reprogram and Change its output state variable as per the requrement

8

read from solution also

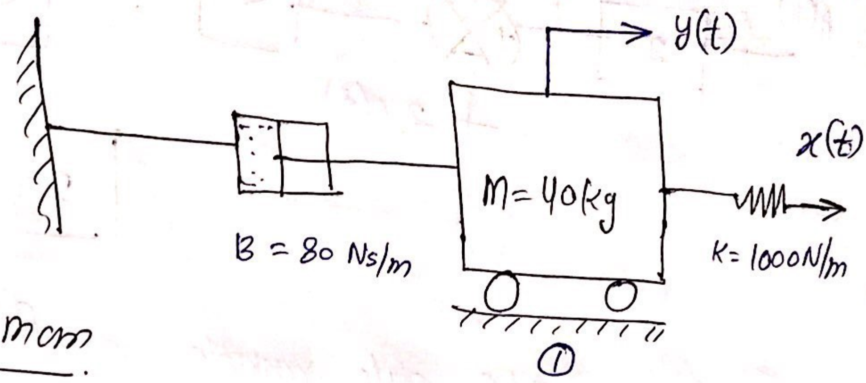
Scanned with CamScanner

Q-1 (e)

Assumption

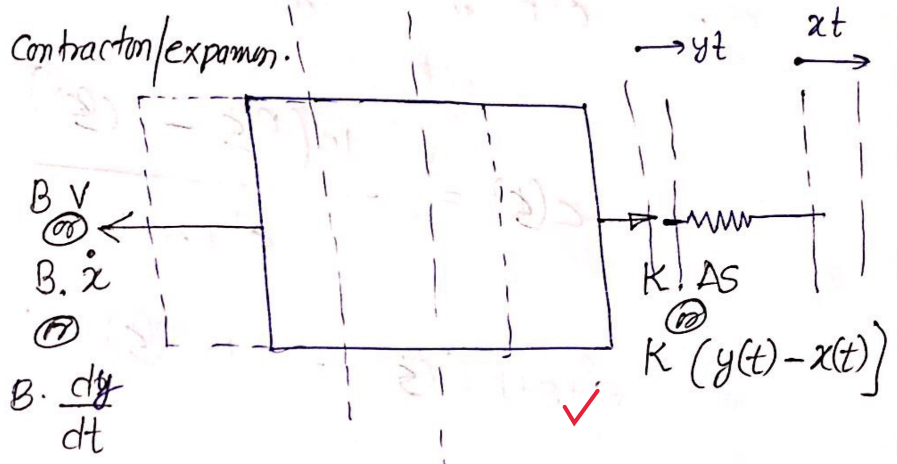
→ No friction on the surface ①

→ spring is linear



~~Using~~ FBD of mass

AS- spring contraction/expansion.



Applying D' Alemberts law

$$F_{spring} + F_{damper} + F_{inertia} = 0$$

$$K(y(t) - x(t)) + B.\frac{dy}{dt} + m.a = 0$$

$$\boxed{m.\frac{d^2y}{dt^2} + B.\frac{dy}{dt} + Ky(t) = K x(t)} \quad \left(a = \frac{d^2y}{dt^2}\right)$$

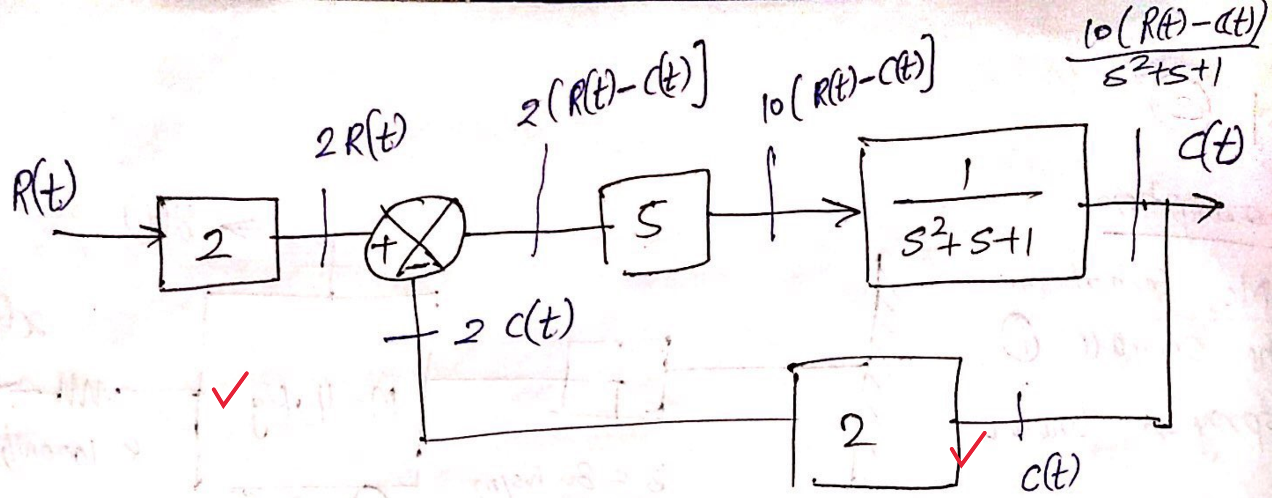
$m = 40kg$, $B = 80$ Ns/m, $K = 1000$

putting.

$$40\frac{d^2y}{dt^2} + 80\frac{dy}{dt} + 1000(y(t)) = 1000\, x(t)$$

dividing by 40

$$\boxed{\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 25y = 25x}$$



Assuming I/P state variable $= R(s)$

" O/P " " $= C(s)$

$$C(s) = \frac{10(R(s) - C(s))}{s^2+s+1}$$

$$s^2+s+1\,(C(s)) = 10\,R(s) - 10\,C(s)$$

$$(s^2+s+11)\,C(s) = 10\,R(s) \quad \text{— ①}$$

Transfer fuction is $= \dfrac{\text{Laplace of O/P}}{\text{Laplace of I/P}}$

12

Ans $$\boxed{\frac{C(s)}{R(s)} = \frac{10}{s^2+s+11}}$$

good

Q-3 (a)

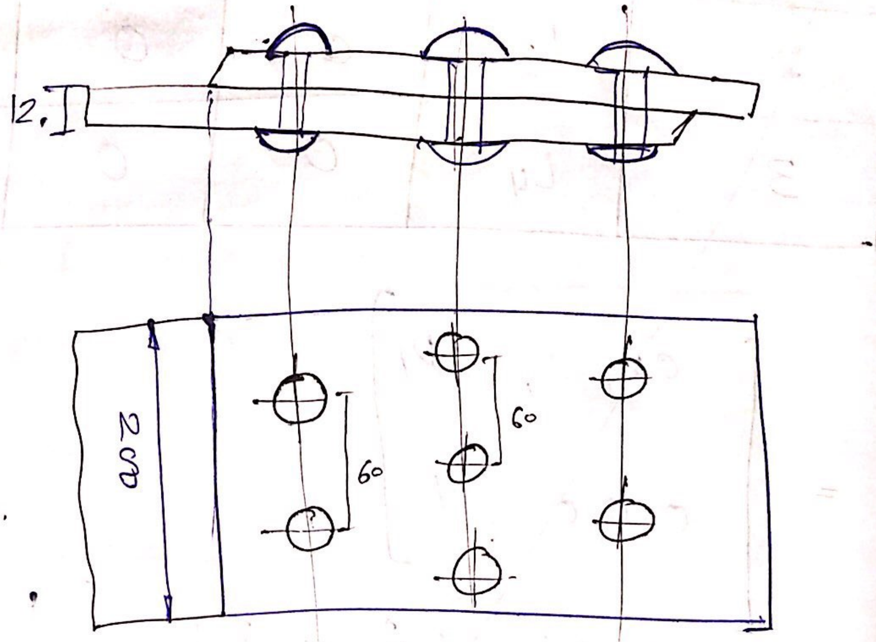
$d = 20mm$

pitch $w = 60mm$

$\sigma = 200\ MPa$

$\tau = 150\ MPa.$

$\sigma_p = 300\ MPa.$



① strength in shear of each rivet

$$(F_s)_1 = nk \cdot \frac{\pi}{4} d^2 \tau.$$

$$= 1 \times \frac{\pi}{4} \times 20^2 \times 150$$

$$= 47.123\ kN$$

② Crushing streng of each rivet

$$(F_c)_1 = \pi d t \sigma_p = \pi \times 20 \times 12 \times 300$$

$$= 226.194\ kN$$

③ Tearing strength of plate @ outer row

$$F_{t_1} = (b - n.d_h)\, t\, \sigma_t = (200 - 2 \times 20) \times 12 \times 200$$

$$= 384\ kN$$

strength of plate at middle row

$$F_{t_2} = (\cancel{b} - 3d_n) \times 12 \times 200 + \text{strenght of outer rivet}$$

$$= (200 - 60) \times 12 \times 200 + 2 \times 47.123$$

$$= \underline{336.094 \ KN}$$

strength of Rivetted Joint

$$F = Min\left[n \times F_{s_i} ; n \times F_{c_1} , F_{t_1} , F_{t_2} \right]$$

$$= Min\left[\cancel{7} \times 47.123 , 7 \times 226.194 , 384 , 336.094 \right.$$

$$= \underline{329.861} \ N.$$

strength of rivet > tensile force Applied.

→ If ~~xxx~~ strength would be lower than Induce stress So, we will prefer double cover to inhance shear strength

→ but ~~#~~ in this case it is not required.

20

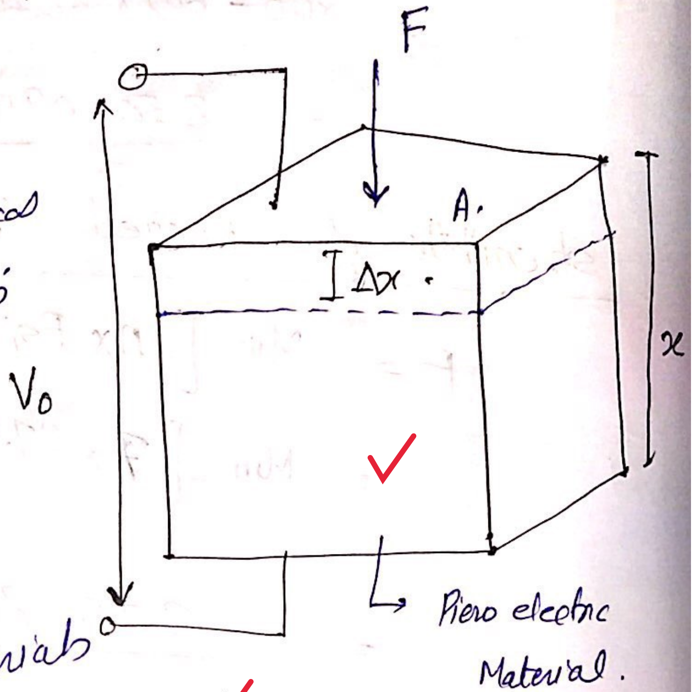
good

Q-3(b)

(1) Piezoelectric Transducers

→ piezoectric Transducers are the Transducers which Generate the output Voltage when mechanical stress (or) deformation is taken place.

Eg: Quartz



principle of operation :-

→ piezo electric type of materials are those on which if the normal stress is applied & then they get deformed and corresponding to it the output voltage is Generated.

→ This output voltage is generated to the change in orientation of the intermolecular structure.

→ The output voltage is directionly proportional to the change in dimensions.

$$V_{out} \propto \Delta x$$

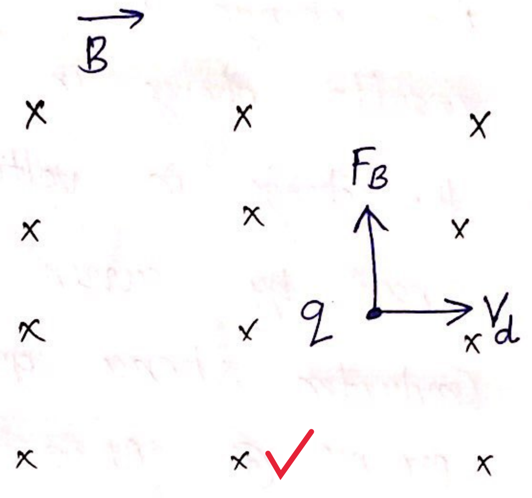
$$\boxed{V_{out} = K_p . \Delta x}$$

K_p → proportionality constant

(11) Hall effect transducer :- Proximity sensor

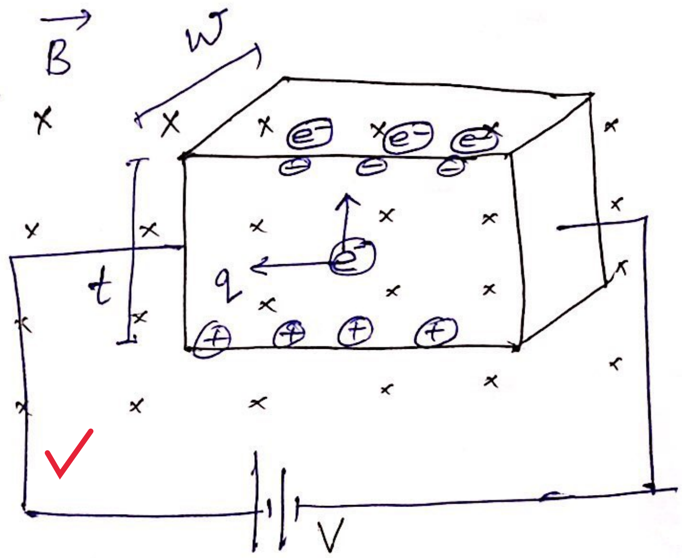
→ Give presence of Magnetic fie

Hall effect :-



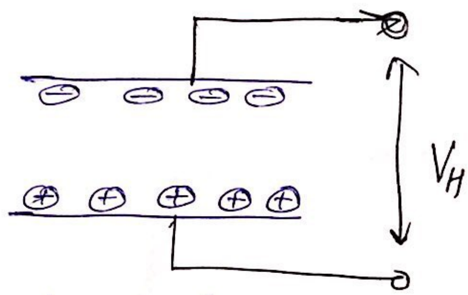
- When a charge particle in current carrying conductor placed normally to the magnetic field. Magnetic field apply a force on it perpendicular to field and direction of flow of charge.

Principle of working :-



→ In the current carrying conductor placed in the perpendicular Magnetic field charge particles (e⁻) flows in the conductor

→ Magnetic field apply a Magnetic force on the charged particles & then they accumulate on the upper side surface as shown in the figure



→ the lower side is termed into +ve charge & consequently voltage is Generated called Hall voltage

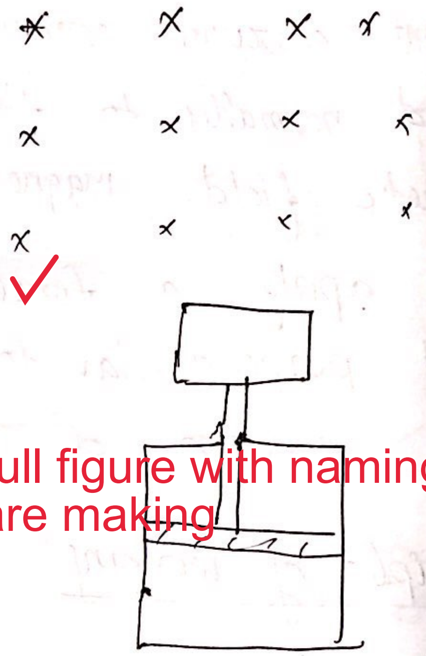
Hall Voltage $\boxed{V_H = K_H \cdot \frac{IB}{w}}$

B → ⊥ʳ mag field
I → Current in cond.
w → width.

~~Hall~~ ~~Mag~~

→ As change in Magnetic field occurs, it results change in hall voltage

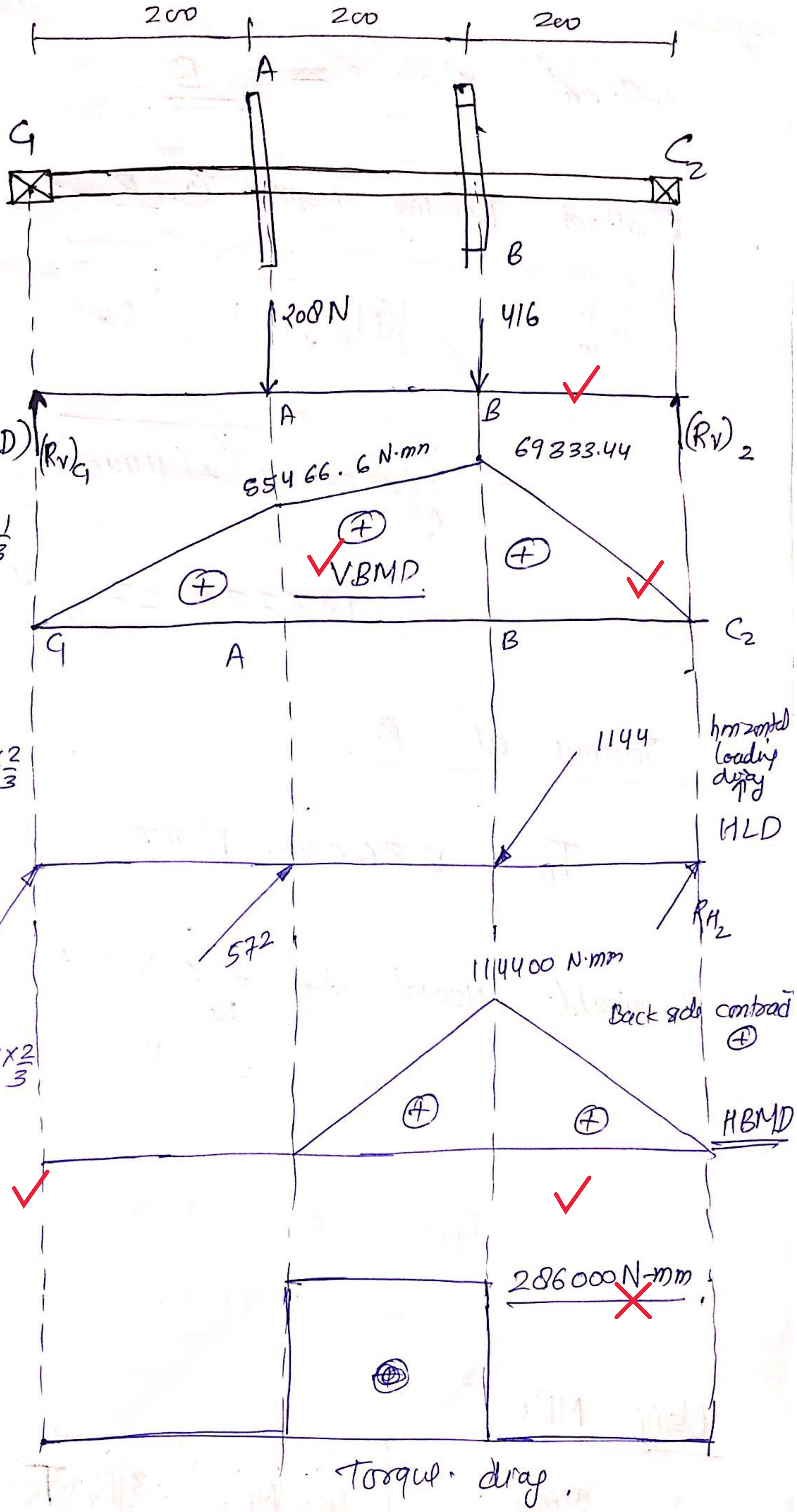
→ the change in voltage is sensed by current carryg Conductor & hence give the presence or Absence of any object.



make full figure with naming if you are making

17

Q-3 (c)



Vertical loading diagram (VLD)

$$(R_V)_{C_1} = \frac{208 \times 2}{3} + \frac{416 \times 1}{3}$$

$$(R_V)_{C_1} = 277.33$$

$$(R_V)_2 = \frac{208 \times 1}{3} + \frac{416 \times 2}{3}$$

$$= 346.667$$

$$R_{H_1} = \frac{1144 \times 1}{3} - \frac{572 \times 2}{3}$$

$$= 0$$

$$R_{H_2} = 572$$

Critical X/SC $\Rightarrow$ B.

Resultant Bending Moment @ B

$$(M_R)_B = \sqrt{[(M_B)_V]^2 + [(M_B)_H]^2}$$

$$= \sqrt{(69833.44)^2 + (114400)^2}$$

$$= 183770.27 \text{ N.mm}$$

Torque at B.

$$T_B = 286000. \text{ N-mm}.$$

Permissible Normal stress $= \underset{Min}{[}0.3\, S_{yt}$ or $0.18\, S_{ut}]$

$$\sigma_{per} = 111.6 \text{ MPa}$$

$$\tau_{per} = 0.75 \times \sigma_{per}$$

$$= 0.75 \times 111.6 = 87.7 \text{ MPa}.$$

Using MDET

$$M_e \; \cancel{\sigma_{per}} = \sqrt{[K_b (M_R)_B]^2 + \frac{3}{4}[K_t (T_R)]^2}$$

$$M_e = \sqrt{(2 \times 133770.27)^2 + \frac{3}{4}(1.5 \times 206000)^2}$$

$$= 505508.173 \ N \cdot mm$$

$$\sigma_{per} = \frac{32 M_e}{\pi d^3}$$

do not make silly mistake
(in torque)

$$111.6 = \frac{32 \times 505508.173}{\pi d^3}$$

$$\boxed{d = 35.868 \ mm.}$$

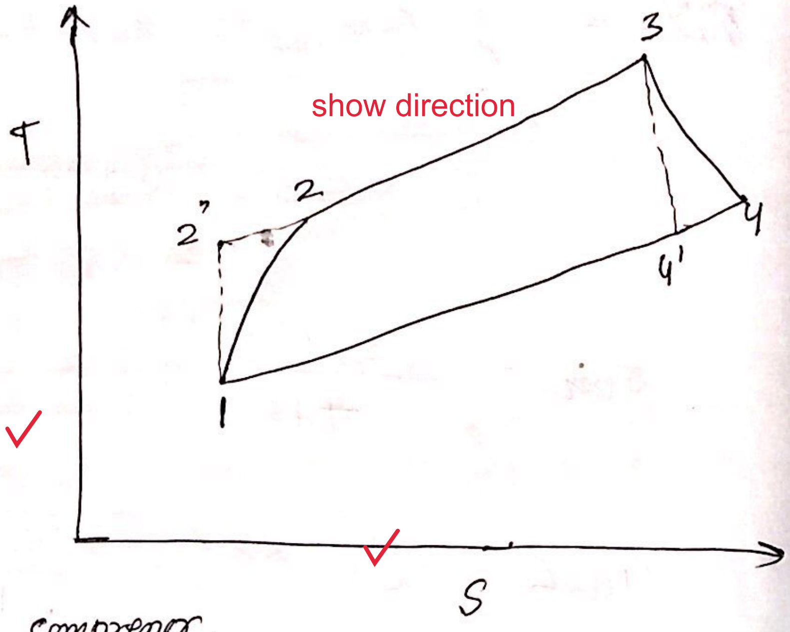
Selecting next higher number in series of 5

$$\boxed{d = 40 \ mm}$$

Type text here

10

5 (a)



Assuming 1, 2, 3, 4

Actual cycle.

$\eta_T \to$ isent. eff of Turbine

$\eta_c \to$ isent eff of compressor.

Let $r \to$ be the optimum compression ratio

Let $T_{min} = T_1$ & $T_{max} = T_3 \to$ fix.

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

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

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

$$\frac{T_1 r^{\frac{\gamma-1}{\gamma}} - T_1}{T_2 - T_1} = \eta_c$$

$$T_2 = \frac{T_1\left(r^{\frac{\gamma-1}{\gamma}} - 1\right)}{\eta_c} + T_1$$

Similarly

$$T_4' = \frac{T_3}{r^{\frac{\gamma-1}{\gamma}}}$$

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

$$\eta_T = \left(\frac{T_3 - T_4}{T_3\left(1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}\right)}\right)$$

$$T_4 = T_3 - \eta_T T_3 \left(1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}\right)$$

$$T_4 = T_3\left[1 - \eta_T\left(1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}\right)\right]$$

Work done $WD/kg = W_T - W_C$

$$= C_p\left[(T_3 - T_4)\right] - C_p\left[T_2 - T_1\right]$$

$$= C_p\left[\cancel{T_3} - \cancel{T_3}\left[1 - \eta_T\left(1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}\right)\right] - \frac{T_1\left(r^{\frac{\gamma-1}{\gamma}} - 1\right)}{\eta_C} \cancel{-T_1} + \cancel{T_1}\right]$$

$$= C_p\left[\eta_T\left(1 - \frac{1}{r^{\frac{\gamma-1}{\gamma}}}\right)T_3 - \frac{T_1\left(r^{\frac{\gamma-1}{\gamma}} - 1\right)}{\eta_C}\right]$$

$$\frac{dWD}{dr} = C_p\left[\eta_T T_3\left(0 - \frac{(1-\gamma)}{\gamma\, r^{\frac{2\gamma-1}{\gamma}}}\right) - \frac{T_1}{\eta_C}\left(\frac{\gamma-1}{\gamma} r^{\frac{-1}{\gamma}}\right)\right] = 0$$

$$\eta_T T_3 \cancel{\left(\frac{\gamma-1}{\gamma}\right)} \frac{1}{r^{\frac{2\gamma-1}{\gamma}}} = \cancel{\left(\frac{\gamma-1}{\gamma}\right)} \frac{T_1}{\eta_C} r^{\frac{-1}{\gamma}}$$

$$\eta_T \eta_C \frac{T_3}{T_1} = r^{2\left(\frac{\gamma-1}{\gamma}\right)}$$

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$$\cancel{r = \left(\frac{T_3}{T_1}\eta_T \eta_C\right)^{\frac{\gamma-1}{2\gamma}}}$$

$$\boxed{r = \left(\frac{T_3}{T_1}\eta_T \eta_C\right)^{\frac{\gamma}{2(\gamma-1)}}}$$

$$\boxed{r = \left(\frac{T_{max}}{T_{min}}\eta_T \eta_C\right)^{\frac{\gamma}{2(\gamma-1)}}}$$

$\frac{T_{max}}{T_{min}} = 3$ $\quad \gamma = 1.67$ $\quad \eta_T = 0.9, \; \eta_C = 0.8$

12 $$r = \left(3 \times 0.9 \times 0.8\right)^{\frac{1.67}{2(1.67-1)}}$$

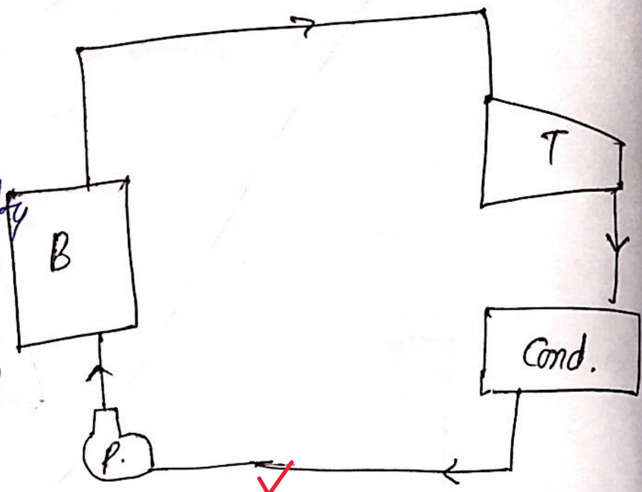
$$\boxed{r = 2.611}$$

5 (c)

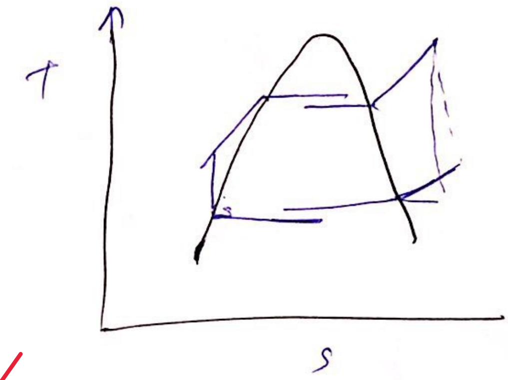
Internally & Externally Irreversible cycle

(1) Internally Irreversible Rankine cycle

- Let us assume a Rankine cycle as shown in this diag.



- the Internally irreversibility is occur due to the frictional effect of working substance in the Rankine cycle.



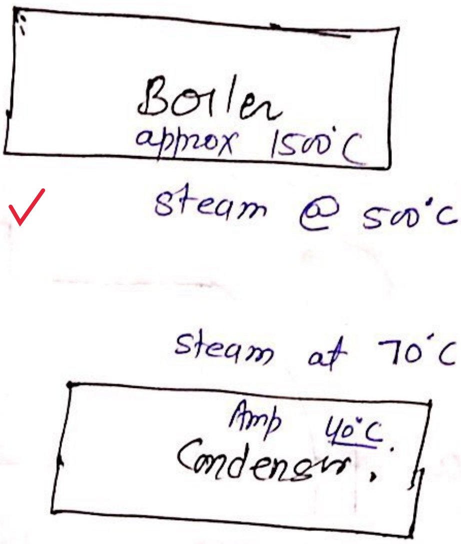
→ The Pressure loss in pipe lines and non isentropic processes are taken place in the Turbine, & pump.

→ the Pressure losses and frictional irreversibility can be observed in Internally irreversible ~~cause~~ Rankine cycle.

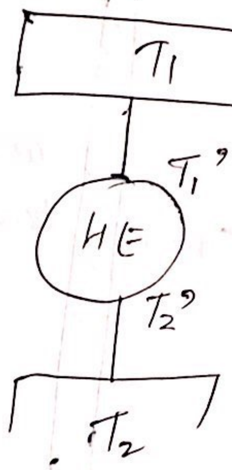
(2) Externally Reversible Rankine cycle

the external irreversibility occur due to the Temperature gradient occur at system boundary.

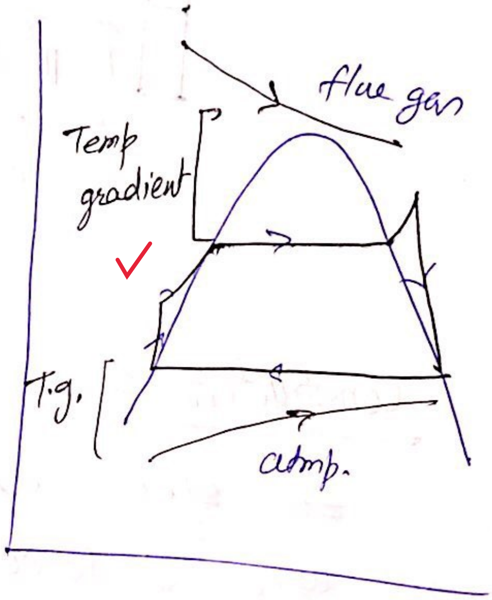
→ Let us consider, a boiler furnace. The Temp of Boiler furnace is at degree of 1500°C, where as water temp in boiler is 500°C due to the finite Temperature Gradient the irreversibility occurs at the Boiler.



→ Also, since the process will not be isothermal ~~throuout~~ throughout it also leads to irreversible head addition



→ Temp gradient is also their at the condenser leads to Internal irreversiblity.



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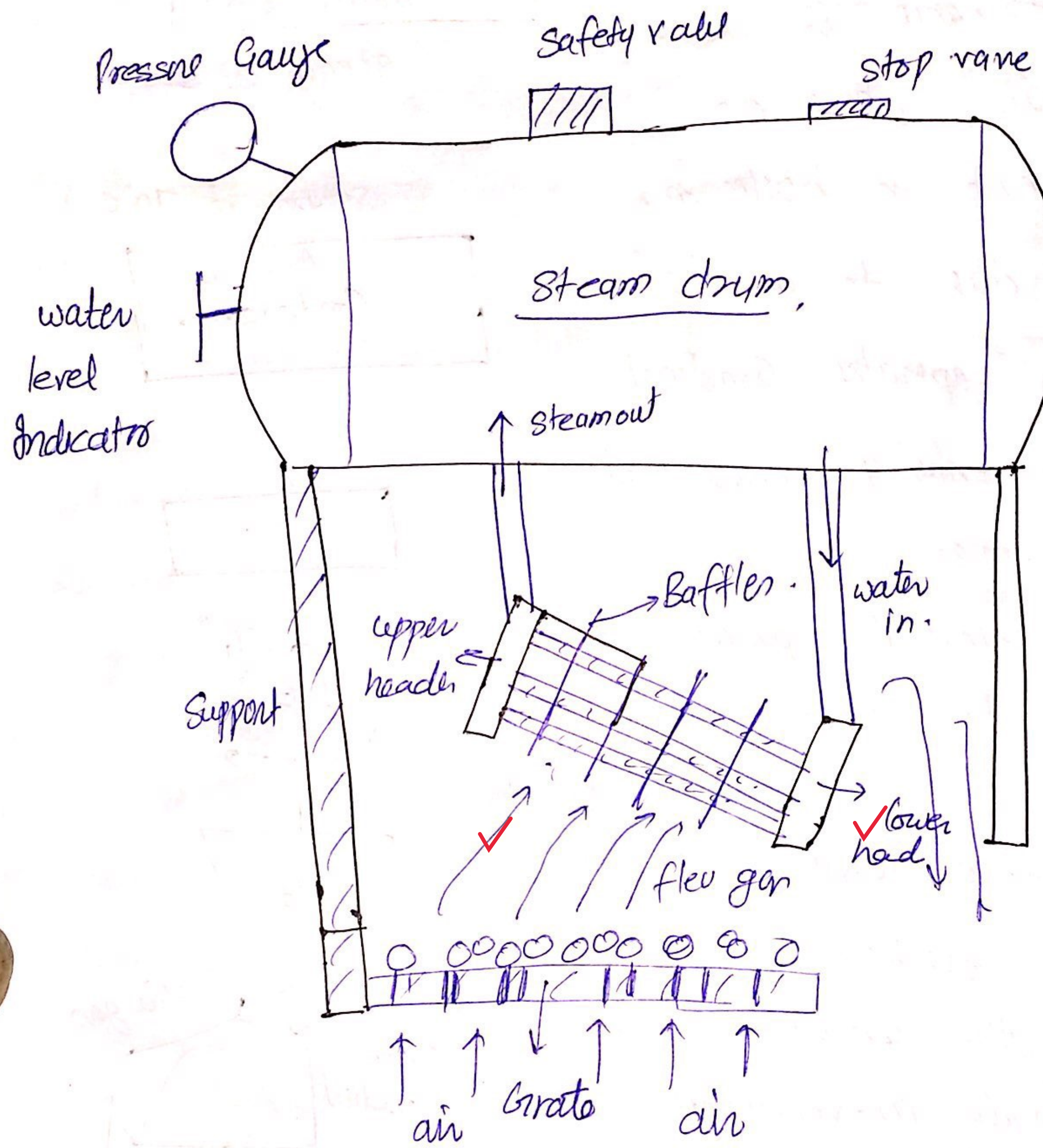
Q-5(d) Babcock Wilcox Boiler



→ Construction :-

→ ~~Steo~~ steel drum containing water.

→ upper & lower headers are situated at tube ends

→ water tubes are inclined at 15° from horizontal

→ Grate is situated below Tubes

→ Externally fired. boiler. (water tube)

Working :-

→ Steam drum consist of steam & water.

→ water come to lower header & flows through the Tubes

→ since as water converted. into steam, it density reduces & it lefted to the upper header due to density diff.

→ now steam sent back to the drum.

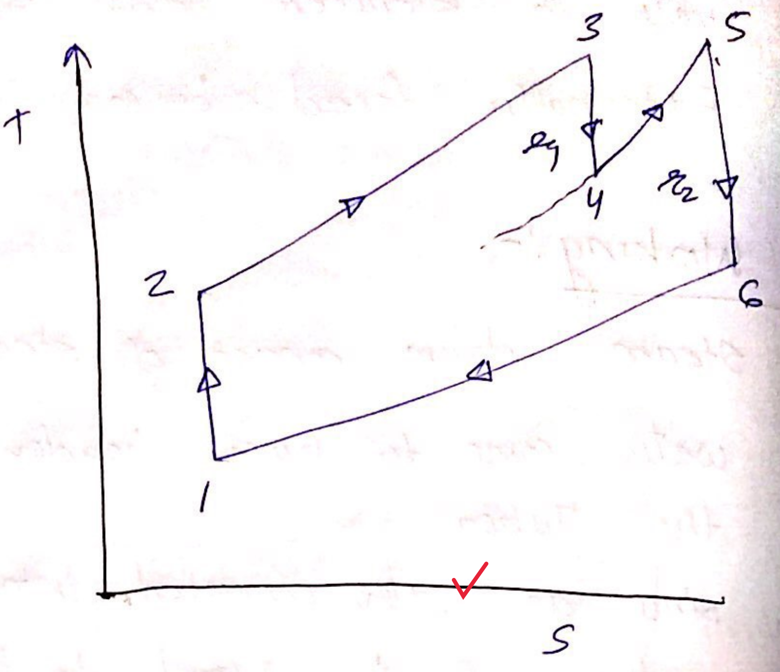
→ Baffles are used to inhance the heat Transfer rate.

→ Now steam is sent to the superheater to super heat it

→ the flow of water in Tubes occur natrally means no external flow is requred to maintain flow hence It is called Natural circulation.

8

Q- 5 (e)



$r \rightarrow$ overall p ratio.

$T_1 = T_{min}$

$T_3 = T_5 = T_{max}$.

$$\frac{T_2}{T_1} = r^{\frac{\gamma-1}{\gamma}}$$

$$\underline{T_2 = T_1 r^{\frac{\gamma-1}{\gamma}}}$$

P. ratio Let for first stage $= r_1$

Pratio for second stage $= r_2$

$$r_1 \times r_2 = r \quad \text{—— (1)}$$

WD of Turbine

$$= C_p\left[(T_3 - T_4) + (T_5 - T_6)\right]$$

$$WD = C_p\left[\left(T_3 - \frac{T_3}{r_1^{\frac{\gamma-1}{\gamma}}}\right) + \left(T_5 - \frac{T_5}{r_2^{\frac{\gamma-1}{\gamma}}}\right)\right] \quad \text{—— (2)}$$

for max^m W_T $\left(r_2 = \frac{r}{r_1}\right)$

putting in (2)

$$C_p\left[T_3\left(1 - \frac{1}{r^{\gamma-1}}\right) + T_5\left(1 - \left(\frac{r_1}{r}\right)^{\frac{\gamma-1}{\gamma}}\right)\right.$$

$$\frac{dWD}{dr_1} = 0$$

$$r_1 = \sqrt{r} = r_2$$

For max^m work o/p $= r_1 = r_2 = \sqrt{r}$

$$(WD)_{net} = W_T - W_C$$

$$= C_p\left[(T_3 - T_4) + (\overset{=T_3}{T_5} - T_6)\right] - C_p\left[(T_2 - T_1)\right]$$

$$WD = C_p\left[2T_3 - \underline{T_4} - \underline{T_6} + \underline{T_2} + T_1\right] \text{ --- } (3)$$

$$= \cancel{C_p\left[2T_3\right]} \qquad T_4 = \frac{T_3}{(\sqrt{r})^{\frac{\gamma-1}{\gamma}}} \qquad T_4 = \frac{T_3}{r^{\frac{\gamma-1}{2\gamma}}}$$

$$T_6 = \frac{T_3}{r^{\frac{\gamma-1}{2\gamma}}}$$

$$WD = C_p\left[2T_3 - \frac{2T_3}{r^{\frac{\gamma-1}{2\gamma}}} - T_1 r^{\frac{\gamma-1}{\gamma}} + T_1\right]$$

$$\frac{dWD}{dr} = C_p\left[0 + \left(\frac{\cancel{\gamma-1}}{\cancel{2\gamma}}\right)\frac{\cancel{2}T_3}{r^{\frac{3\gamma-1}{2\gamma}}} - T_1\left(\frac{\cancel{\gamma-1}}{\cancel{\gamma}}\right) r^{-\frac{1}{\gamma}}\right] = 0$$

$$\frac{T_3}{r^{\frac{3\gamma-1}{2\gamma}}} = T_1 \, r^{-\frac{1}{\gamma}}$$

$$\frac{T_3}{T_1} = r^{\left(\frac{3\gamma-3}{2\gamma} = \frac{3}{2}\frac{\gamma-1}{\gamma}\right)}$$

$$\boxed{(r)^{\frac{\gamma-1}{\gamma}} = \left(\frac{T_3}{T_1}\right)^{2/3}}$$

H.P.

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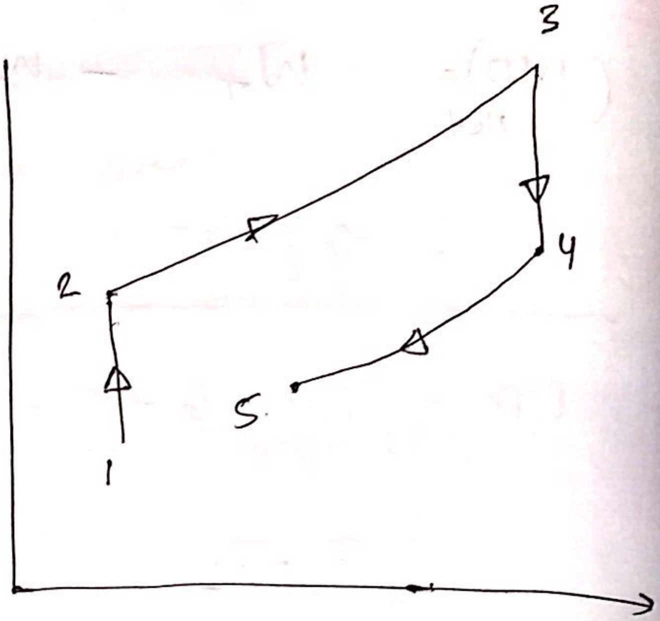
good

6(a)

$P_{o/p} = 100\ MW$

$\dot{m}_{gas} = kg/s$, $\dot{m}_{vap}\ kg/s$



$T_1 = 300K,\ P_1 = 1bar$

$r = 14$

$T_3 = 1700K.$

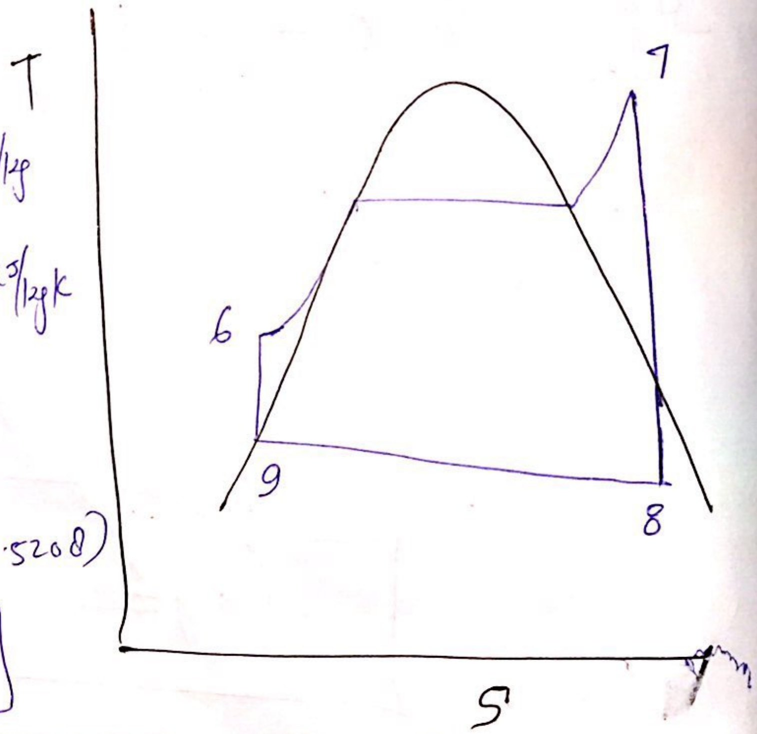
$T_5 = 400K.$

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

$= 300 \times 14^{\frac{0.4}{1.4}}$

$= \underline{637.656K}.$

$T_4 = \frac{1700}{14^{0.4/1.4}} = \underline{799.80K}.$



$h_7 = 3423.1\ kJ/kg$

$S_7 = 6.8826\ kJ/kgK$

$S_7 = S_8$

$6.8826 = 0.5208 + x(8.3291 - 0.5208)$

$\boxed{x = 0.8147}$

~~In Heat Recovery Generator~~ :-

$h_8 = 151.4934 + 0.8147(2566.667 - 151.4934)$

$h_8 = 2119.135$ KJ/kg

$h_9 = 151.4934$ KJ/kg

pump work $W_p = -\nu dp = 0.001006(6000 - 6)$

$= 6.03$ KJ/kg.

$h_6 = \underline{157.5233 \text{ KJ/kg}}$

In heat Recovery Generator

Subcooled ~~Saturated~~ water at pressure 60 bar & enthalpy 157.523 enter into it & it is heated by flue gases Leaving Turbine at 799.80 K and Leaves Recovery Generator to 400 K.

where as steam leaves Recovery Generator at 500°C. using counter flow heat exchanger.

$W_{net} = W_{gas} + W_{steam}$

$W_{gas} = m_{gas}[C_p(T_3 - T_4) - C_p(T_2 - T_1)]$

$= m_{gas}[1.005(1100 - 799.8) - 1.005(637.656 - 300)]$

$= m_{gas} \cdot 565.356$ KW

$W_{steam} = m_{vap}[h_7 - h_8 - W_p]$

$= m_{vap}[3423.1 - 2119.135 - 6.03]$

$= m_{vap} \cdot 1297.935$ KW

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~~In Heat Recovery Generator~~ :-

$h_8 = 151.4934 + 0.8147 (2566.667 - 151.4934)$

$h_8 = 2119.135$ kJ/kg

$h_9 = 151.4934$ kJ/kg

pump work $W_p = -v\,dp = 0.001006 (6000 - 6)$

$= 6.03$ kJ/kg.

$h_6 = \underline{157.5233 \text{ kJ/kg}}$

In heat Recovery Generator

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$= m_{gas} [1.005 (1700 - 799.8) - 1.005 (637.656 - 300)]$

$= m_{gas} \cdot 565.356$ kW

$W_{steam} = \dot{m}_{vap} [h_7 - h_8 - W_p]$

$= m_{vap} [3423.1 - 2119.135 - 6.03]$

$= m_{vap} \cdot 1297.935$ kW

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$$W_{net} = P_{o/p} = 100\times10^3 = m_{gas}(565.356) + m_v\,1297.935 \quad \text{--- (1)}$$

Applying energy balance at Heat Recovery Gen

$$m_{gas}[T_4 - T_5] = m_{vap}[h_7 - h_6]$$

$$m_{gas}[799.8 - 400] = m_{vap}[3423.1 - 157.5233]$$

$$\boxed{399.8\, m_{gas} = 3265.576\, m_{vap}} \quad \text{--- (2)}$$

Solving (1) & (2)

$$\boxed{\begin{aligned} m_{gas} &= 138.07 \text{ kg/s} \\ m_{vap} &= 16.9039 \text{ kg/s} \end{aligned}}$$

Ans

thermal eff

$$\eta = \frac{WD}{Q_s}$$

$$= \frac{100\times10^3}{138.07(1.005(1700-300))}$$

$$= 0.5147 = 51.47\%$$

(iv) mass flow rate of cooling water m_w

$$m_{vap}[h_8 - h_9] = m_w\, c_{pw}\, \Delta T$$

$$16.9039(2119.135 - 151.4934) = m_w \times 4.187 \times 25$$

$$\boxed{m_w = 317.753 \text{ kg/s}}$$

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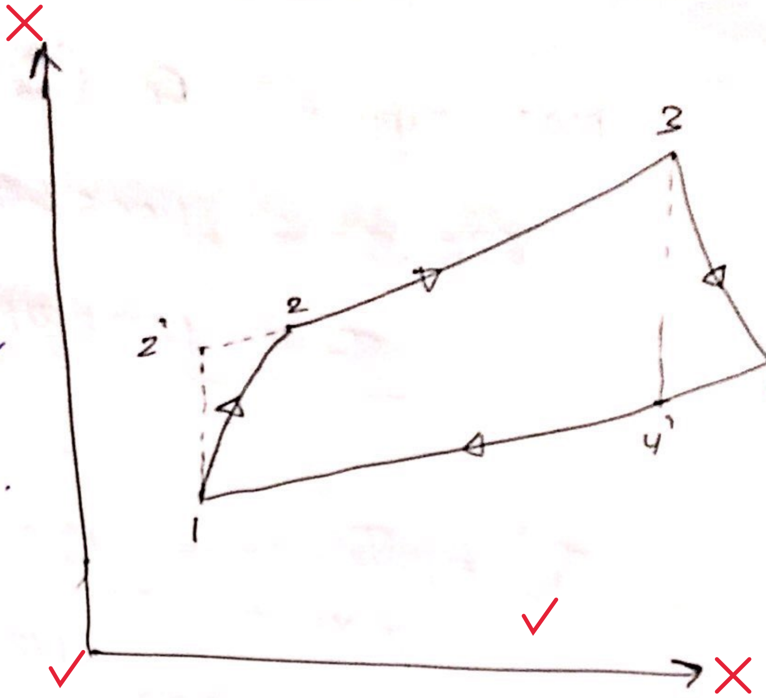
6 (b)

Assumption

→ Air is working subs

→ perfect Gas Behaviour of air

→ c_p, c_v, γ → const.



Given.

$T_1 = 310$ K

$P_1 = 101$ kPa

Comp^n rat $r = 12$

heat added $Q_s = 695.3$ kJ/kg

isent. effiuen. $\eta_c = 0.84$, $\eta_T = 0.87$

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

$$T_2' = 310 \times (12)^{\frac{0.4}{1.4}}$$

$$\underline{T_2' = 630.52 \text{ K}}.$$

effect of η_c.

$$\eta_c = \frac{T_2' - T_1}{\cancel{B}\, T_2 - T_1}$$

$$0.84 = \frac{630.52 - 310}{T_2 - 310}$$

$$\underline{T_2 = 691.571 \text{ K}}.$$

$$\text{heat supp} = C_{pa}(T_3 - T_2)$$

$$695.3 = 1.005(T_3 - 691.571)$$

$$\underline{T_3 = 1383.412\,K}$$

$$T_4' = \frac{T_3}{r^{\frac{\gamma-1}{\gamma}}} = \frac{1383.412}{(12)^{\frac{0.4}{1.4}}}$$

$$T_4' = 680.164\ K$$

$$\eta_T = \frac{T_3 - T_4}{T_3 - T_4'} = \frac{1383.412 - T_4}{1383.412 - 680.164} = 0.87$$

$$\boxed{T_4 = 771.586}\ K$$

① Power @ I/P to compr

$$W_c/kg = C_p[T_2 - T_1]$$

$$= 1.005[691.571 - 310]$$

$$= 382.47\ kJ/kg$$

$$W_c/sec = 100 \times (382.47) = \underline{35.247\,MW}$$

② Temp @ exit of Turbine $T_3 = \underline{1383.412\,K}$

③ $$\eta_{th} = \frac{W_T - W_c}{Q_s} = \frac{C_p[(1383.412 - 771.586)] - 3}{695.3}$$

$$= 0.3342 \quad \underline{= 33.42}$$

(iv) Entropy change in comp.

20

$$\Delta S_{1-2} = m_a\left[C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1} \right]$$

$$= 100\left[1.005 \ln\left(\frac{691.571}{310}\right) - 0.287 \ln(12) \right]$$

$$= \underline{9.323 \checkmark \ KW/K}.$$

Q-6 (c)

$$\frac{81.9}{12} C + \frac{4.9}{1} H + \frac{6}{16} O + \frac{2.3}{14} N$$

$$+ X\left[O_2 + \frac{79}{21} N_2 \right] \longrightarrow A CO_2 + B H_2O$$

$$+ C N_2$$

C - Balance.

$$\frac{81.9}{12} = A \qquad \boxed{A = 6.825}.$$

×

H- Balance 4.9 ✗ $= 2B$ $\boxed{B = 2.45}$

47

O- Balance.

$$\frac{6}{16} + 2X = 2 \times 6.825$$

$$\boxed{X = 6.6375}$$ ✗

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N. Balance

$$\frac{2.3}{14} + 2 \times \frac{79}{21} \times 6.6375 = 2C$$

$$\boxed{C = 25.051}$$

eq^n. Stoich. :

$$\frac{81.9}{12} C + 4.9H + \frac{6}{16} O + \frac{2.3}{14} N + 6.6375\left[O_2 + \frac{79}{21} N_2\right]$$

$$\longrightarrow 6.825 CO_2 + 2.45 H_2O + 25.051 N_2$$

$$(A/F)_{stoich} = \frac{6.6375\left[32 + \frac{79}{21} \times 28\right]}{100}$$

$$= 9.115$$

When 25% excess air supplied.

$$\frac{81.9}{12} C + 4.9H + \frac{6}{16} O + \frac{2.3}{14} N + 8.2968\left(O_2 + \frac{79}{21} N_2\right)$$

$$\longrightarrow 6.825 CO_2 + 2.45 H_2O + 1.6593 O_2 + 31.2939 N_2$$

Analysis of dry product

×

Component	Moles in exhaust	% of Moles
CO_2	6.825	$\frac{6.825}{6.825+1.6593+31.2939} \times 100 = 17.15\%$
O_2	1.6593	$\frac{1.6593}{6.825+1.6593+31.2939} \times 100 = 4.17\%$
N_2	31.2939	78.68%

×

8

dry product = 2.45 H_2O

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$$= \frac{2.45}{2.45 + 6.825 + 1.6593 + 31.2939}$$

$$= 5.8\%$$

check calculation

wet analysis?

check solution

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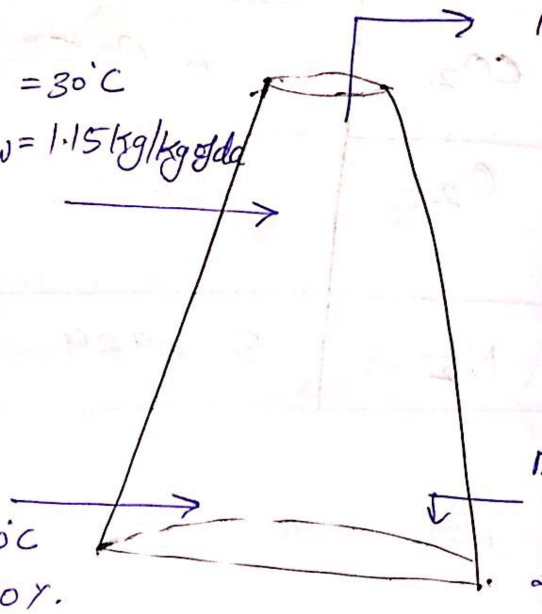
Q- 7@

Cooling Tower

Assuming mass flow rate of air inlet to cooling Tower = 1 kg/sec



at inlet of air.

$$P_{s_1} = 2.3392 \text{ kPa}$$

$$\phi = 0.60 = \frac{P_{v_1}}{P_{s_1}}$$

$$P_{v_1} = 1.40352 \text{ kPa}$$

$$\omega_1 = 0.622 \frac{P_{v_1}}{P_t - P_{v_1}} = 0.622 \frac{1.40352}{101.3 - 1.40352}$$

$$= 0.00873 \text{ kg/kg of d.a.}$$

at outlet of air.

$$P_{s_2} = 4.2469 \text{ kPa.}$$

$$P_{v_2} = \phi_2 P_{s_2} = 0.9 \times 4.2469 = 3.8222 \text{ kPa}$$

$$\omega_2 = 0.622 \frac{P_{v_2}}{P_t - P_{v_2}} = 0.622 \frac{3.8222}{101.3 - 3.822}$$

$$= 0.024389 \text{ kg/kg of}$$

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Enthalpy of entering air

$$h_i = 1.005t_1 + \omega_1[2500 + 1.88t_1]$$
$$= 1.005 \times 20 + 0.00873[2500 + 1.88 \times 20]$$
$$= 42.253 \text{ kJ/kg of da.}$$

exit

$$h_2 = 1.005t_2 + \omega_2(2500 + 1.88t_2)$$
$$= 1.005 \times 30 + 0.024389(2500 + 1.88 \times 30)$$
$$= 92.498 \text{ kJ/kg of da.}$$

applying energy balance:

$$m_w[c_p(T_{1w} - T_{2w})] = m_a[h_2 - h_1]$$

$$\Rightarrow \cancel{m_w[1 \times 1.5 \times 4.187(T_{2w} - 30)]}$$

$$= 1.15 \times 4.187(30 - T_{2w}) = 1[92.498 - 42.253]$$

$$T_{2w} = 19.565^\circ \text{ Ans}$$

fraction of water evaporated $= \dot{m}_a[\omega_2 - \omega_1]$

$$= 0.024389 - 0.00873$$

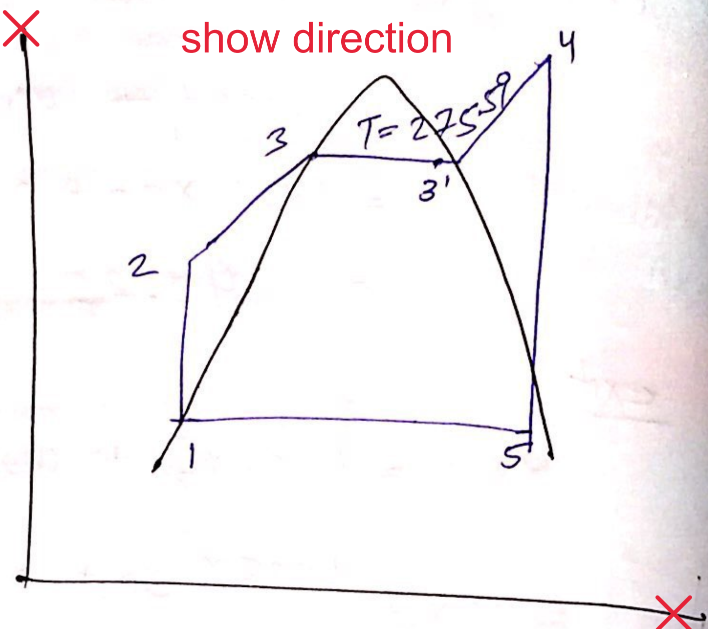
$$= 15.659 \text{ gm/kg of da}$$

Ans

20

$$\text{Range of cooling Tower} = T_{w1} - T_{wo}$$
$$= 30 - 19.565$$
$$= 10.435^\circ C$$

Q-7(b)



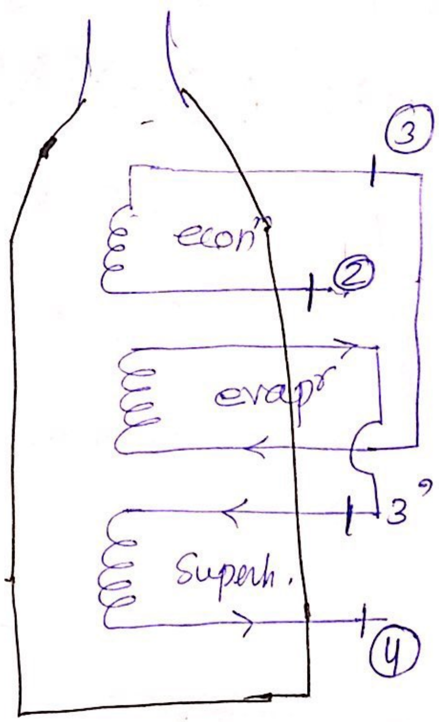
$T_2 = 140^\circ C$

$T_4 = 450^\circ C$ @ 60 bar

~~$T_{3'} = 250^\circ C$~~

evap. rate $= \dfrac{8.5 \text{ kg of steam}}{\text{kg of coal}}$

$A/F = 15$



Steam produced / kg of coal

$= 8.5$ kg.

Heat transfer at economiser.

$Q_E = m_s [h_3 - h_2]$

$= \cancel{8.5}[$

$h_3 = 1213.8$ kJ/kg K.

$Q_E = 8.5 [1213.8 - (1213.8 - c_p (275.59 - 140))$

$= 8.5 \times [4.187 \times (275.59 - 140)]$

$= \underline{4.825 \text{ MJoule/ kg of coal}}$

Heat Added in super heater

$h_{3'} = h_3 + x \cdot h_{fg}$

$= 1213.8 + 0.98(1570.9)$

$= 2753.282 \text{ KJ/kg}.$

$h_4 = 3302.9 \text{ KJ/kg}$

$Q_{super} = m_s [h_4 - h_3']$

$= 8.5 [3302.9 - 2753.282]$

$= 4.671 \text{ MJ/kg of Coal}$

$A/F = 15 \quad \therefore m_f = 1 \text{ kg}$

$m_a = 15 \text{ kg/kg of coal}.$

heat sup. @ air preheater

$Q = m_a c_{p_a} \Delta T = 15 \times 1.005 (250 - 25)$

$= 3.391 \text{ MJ/kg of coal}.$

Total heat Added $= m_s [h_4 - h_2]$

$= 8.5 [3302.9 - 646.08]$

$= \underline{22582.93} \text{ KJ/kg of coal}.$

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η eff of steam Gen.

$$\eta_{s.g} = \frac{22502.93}{25.2\times10^3} = 0.8961$$

$$= 89.61\%$$

% heat Added in econ^{r}

$$Q_E\% = \frac{4.825}{22.502} = 21.366\%$$

$$Q_{sup} = \frac{4.671}{22.502} = 20.68\%$$

18 $Q_{boiler} = 100 - 21.366 - 20.68$

$$= 57.954\%$$

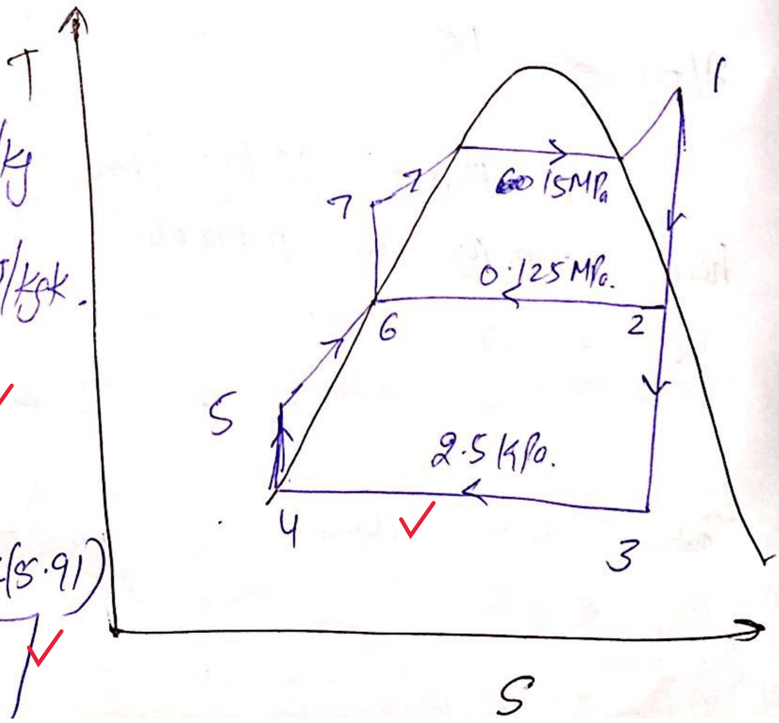
Q-7 (c)

Regenerative Rankine cycle.

from steam Tables.

$h_1 = 3583.1$ KJ/kg

$S_1 = 6.6796$ KJ/kgK.



$S_2 = S_1$

$6.6796 = 1.3741 + x(5.91)$

$$\boxed{x_2 = 0.8977}$$

$h_2 = 444.36 + 0.8977(2240.6)$

$= 2455.74$ KJ/kg

$h_6 = 444.36$ KJ/kg

for h_3,

$S_1 = S_3$

$6.6796 = 0.3118 + x_3(8.3302)$

$\boxed{x_3 = 0.7644}$

$\boxed{h_4 = 88.424}$ KJ/kg K

$h_3 = 88.424 + 0.7644(2451.0)$

$h_3 = 1961.968$ KJ/kg

pump ①. $W_{P_1} = v_4\, dP = 0.001002(125 - 2.5)$

$= 0.12274$ KJ/kg

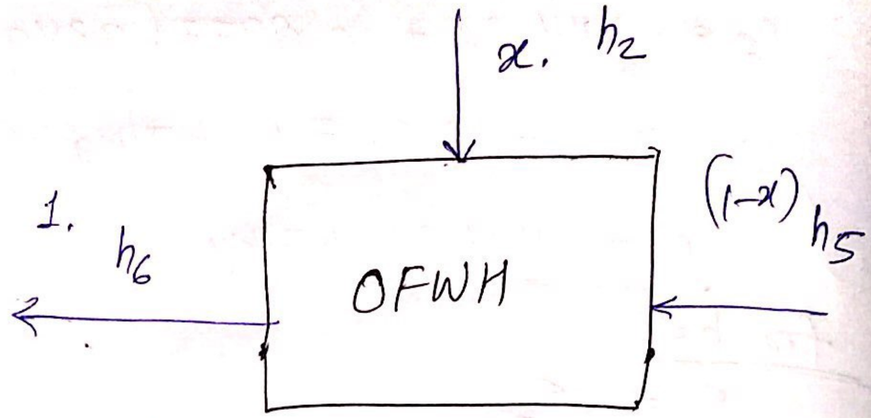
$h_5 = W_{P_1} + h_4 = 88.546$

pump ② $W_{P_2} = 0.001048 \times [15000 - 125]$

$= 15.589$ KJ/kg

$h_7 = 444.36 + 15.589 = 459.95$ KJ/kg

Let us assume x mass is taken out from turbine.



Applying energy balance

$$x h_2 + (1-x) h_5 = h_6$$

$$x(2455.74) + (1-x)\,88.546 = 444.36$$

(ii) $\boxed{x = 0.1503}$ kg. Ans

$$(WD)_{net} = 1(h_1 - h_2) + (1 - 0.1503)\left[h_2 - h_3 - W_{p_1}\right] - W_{p_2}$$

$$= (3583.1 - 2455.74) + 0.8497(2455.74 - 1961.960 - 0.12274) - 15.589$$

$$\boxed{(WD)_{net} = 1531.224 \text{ KJ/kg}}$$ Ans.

(II) part?

(3) heat Transfer by boiler.

$$Q_b = h_1 - h_7 = 3583.1 - 459.95$$

15

$$= 3123.15 \text{ KJ/kg}$$

$$\eta = \frac{WD}{Q_b} = \frac{1531.224}{3123.15} = 0.4902 = 49.02\%$$

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