NAME -

ROLL N -

TEST - 10

SUB - FULL SYLLABUS

paper - 1

Total marks-234

Very good performance.

Keep practicing.

Q-1 (a)

(i) Impracticalities of Carnot Vapour Cycle :-

assuming a Carnot vapour cycle as shown in fig

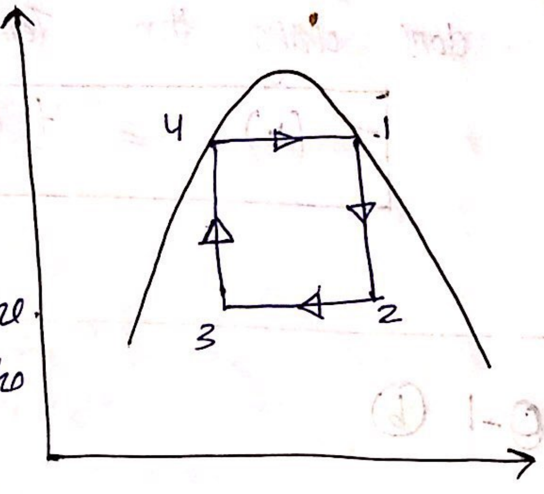


Fig: Vapour carnot cycle.

→ Process 1-2 : In this process saturated steam expands in Turbine. since expansion is occurring in the wet Region, the liquid particle can damage the Turbine blade. when high energy particle (wet) collide with Turbine blades so there is a possibility of erosion of metal consequently turbine can be damaged.

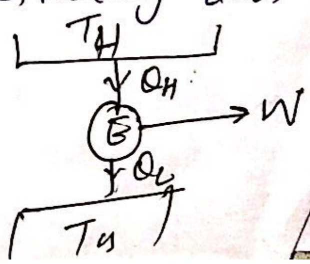
→ Process -3-4 - since at state 3, both liquid and vapour are present hence there is no ~~device~~ device available which can increase the pressure of liquid, & Dry steam mixture. so it is also an impractibility of carnot cycle.

(ii) Statements of carnot principle :-

* Carnot principle state that :—
All the engines interacting same thermal reservoirs (T_H & T_L) are less efficient than Carnot Engine (Reversible Engine). hence carnot engine have highest efficiency than all the Engines interacting with same Temp reservoirs.

* all the carnot engines interacting with same thermal reservoirs will be same efficient & efficiency does not depend on working substance.

$$\boxed{\eta = 1 - \frac{T_L}{T_H}}$$



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(III) Thermodynamic Temperature scale :-

It is the absolute temperature scale measured in Kelvin. all the thermodynamic ~~cal~~ calculations are done using this Temp.

$$\boxed{T\,(K) = t\,(^\circ C) + 273.15}$$

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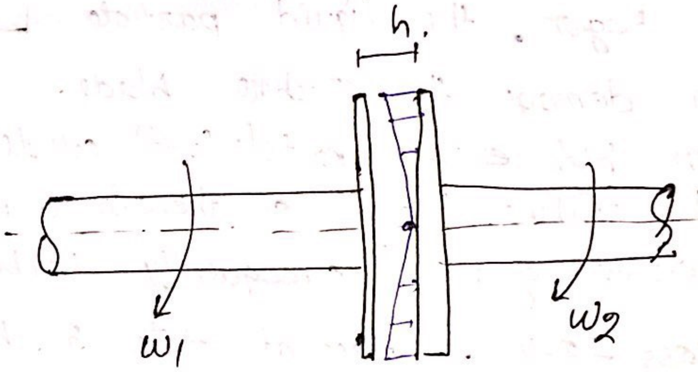
Q-1 (b)



$d = 152.4$ mm

$h = 5.08$ mm

$N = 1200$ rpm.

$T = 0.004$

Torque Transmitted $T = \int_0^{d/2} dF \cdot r$

$$= \int \tau_r \, 2\pi r\, dr \cdot r$$

$$= \frac{\mu(\omega_1 - \omega_2) r}{h} \, 2\pi r\, dr \cdot r$$

$$= \frac{\mu(\omega_1-\omega_2)\, 2\pi}{h} \int_0^{d/2} r^3\, dr$$

$$= \frac{2\pi \mu(\omega_1 - \omega_2)\left[r^4\right]_0^{d/2}}{4h}$$

$$\boxed{T = \frac{\pi \mu (\omega_1 - \omega_2)\, d^4}{32h}}$$

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$$\frac{32Th}{\pi \mu d^4} = \omega_1 - \omega_2$$

$$\boxed{\omega_2 = \omega_1 - \frac{32Th}{\pi \mu d^4}} \quad \text{— (1)}$$

$$\% \text{ slip} = \frac{\omega_1 - \omega_2}{\omega_1} \times 100$$

$$\% \text{ slip} = \frac{\cancel{\omega_1} - \cancel{\omega_1} + \frac{32Th}{\pi \mu d^4}}{\omega_1} \times 100$$

$$\boxed{\% S = \frac{32Th}{\pi \mu d^4 \omega_1} \times 100}$$

$$\% S = \frac{32 \times 0.004 \times 5.08 \times 10^{-3}}{\pi \times 0.4 \times (152.4 \times 10^{-3})^4 \times \left(\frac{120 \times 2\pi}{60}\right)} \times 100$$

$$= 7.633\ \%$$

using eq^n (1)

$$\omega_2 = \omega_1 - \frac{32Th}{\pi \mu d^4}$$

$$= \frac{120 \times 2\pi}{60} - \frac{32 \times 0.004 \times 5.08 \times 10^{-3}}{\pi \times 0.4\ (152.4 \times 10^{-3})^4}$$

$$= 11.607 \text{ rad/s.}$$

eff of fluid drive

$$\eta_{fd} = \frac{P_{o/p}}{P_{I/p}} = \frac{\cancel{T} \cdot \omega_{out}}{\cancel{T} \cdot \omega_{input}} = \frac{11.607}{4\pi} = 0.9236$$

$= 92.36\%$

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Q-1 ©

Lumped System Analysis :-

* In Lumped system Analysis, we assume that a body on which lumped system Analysis is done having no Temperature gradient is present inside the body.
* In this analysis, we consider that the internal conductive Resistance of the body is very less compared to that body. the external convective Resistance of that body.

For lumped system Analysis to be Applicable

$$\underline{\text{Biot No} < 0.1}$$

$$\text{Biot No} = \frac{\text{Internal Conductive Resistance}}{\text{External Convective Resistance}}$$

$$= \frac{S/KA}{1/hA}$$

$$\boxed{Bi = \frac{hs}{K_{solid}}}$$

Physical significance of Biot No :-

→ Biot No is used to determine whether the analysis of the system is done ~~bas~~ assuming lumped system analysis.

→ with consideration of Biot No the internal Temperature Gradients are observed with in body. & compare the Result of convective coeff of at the outer body of the system under consideration

Physical significance of fourier No :

- Fourier No is the Ratio of heat conduction to that of the heat storage.
- It is dimension less parameter which measure time.

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Fourier No. $F_o = \dfrac{\text{Rate of Heat Conduct}^n}{\text{Rate of heat storage}}$.

$$\boxed{F_o = \frac{\alpha t}{S^2}} \qquad \alpha = \frac{K}{\rho c_p}.$$

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$\alpha \rightarrow$ thermal diffusivity

$\rho \rightarrow$ density of material

$c_p \rightarrow$ specific heat

$t \rightarrow$ time

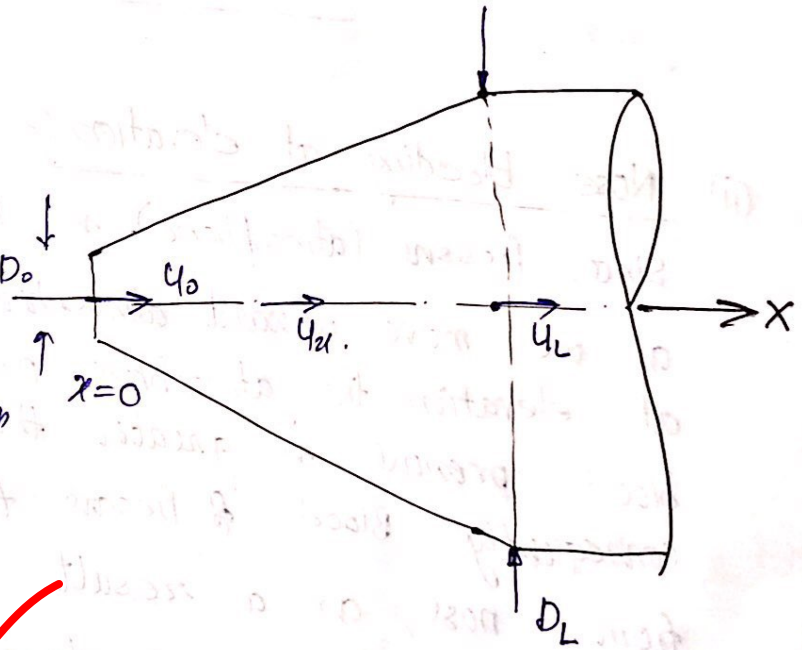
$S \rightarrow (V/A)$

Q-1 (d)

$u(x) = a + b x^2$

$u_o = 24.3 \; m/s$

$u_L = 16.8 \; m/s.$



applying boundary condition

(i) at $x = 0$, $u = u_o$

$u_o = a + b(0)$

$$\boxed{a = 24.3}$$

(ii) at $x = L$, $u = u_L = 16.8 \; m/s$

$16.8 = 24.3 + b.(1.56)^2$ $\qquad$ $b = -3.0818$

$u(x) = 24.3 - 3.0818x^2$ —— (1)

Fluid Acceleration along centreline:

$$a_x = \frac{D\vec{u}}{Dt} = \left[u\frac{\partial u}{\partial x} + \cancel{v\frac{\partial u}{\partial y}}^{0} + \cancel{w\frac{\partial u}{\partial z}}^{0} + \cancel{\frac{\partial s}{\partial t}}^{0}\right]$$

$$= u\frac{\partial u}{\partial x} = (24.3 - 3.0818x^2)(-2\times 3.0818x)$$

$$\boxed{a_x = 18.995x^3 - 149.775x.} \quad m/s^2$$

$$a_{x=1} = 18.995(1)^3 - 149.775\times 1.$$

$$= \underline{-130.78 \ m/s^2} \ (\text{deacceleration})$$

(ii) Nose bleeding at elevation:-

Since, Pressure (atmospheric) is maximum at the sea level as we move upward atmospheric pressure decreases. Hence at elevation the atmospheric pressure reduces and the blood pressure is greater than atmp pressure consequently Blood ~~P~~ Pressure forced the blood out from nose, as a result nose bleeding will occur.

Shortness of Breath at elevation:

Oxygen level is max^m in air at the sea level as we move upward oxygen level decreases as a result when a person breath at the high altitude & it can not able to get sufficient oxygen, so due to this breath rate increases & become short.

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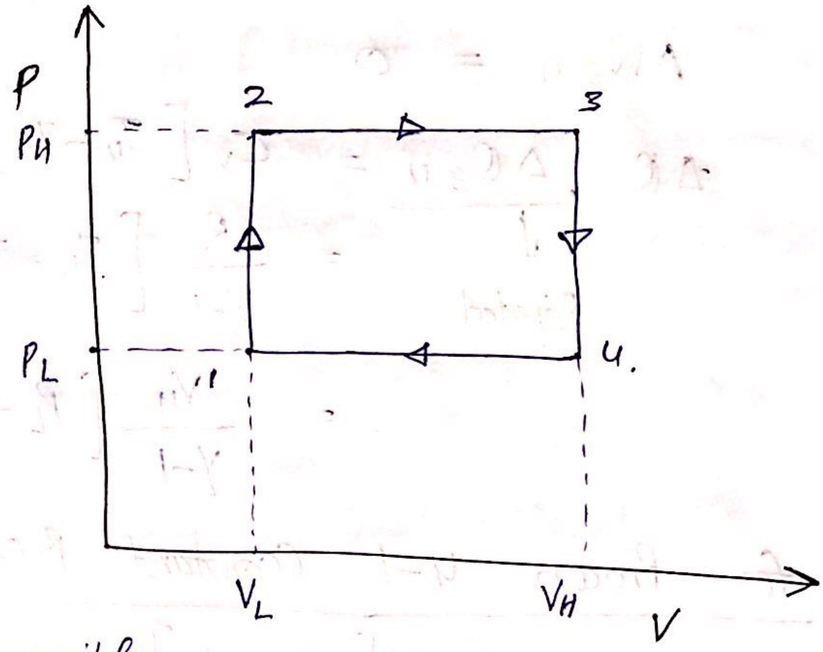
Q-1 (e)



Assumption

→ Air is a working substance, which is assumed to be Ideal Gas

→ C_p, C_v & γ values are constants

→ all processes are reversible.

① Process 1-2 (Constant volume Process)

$$\Delta W_{1-2} = 0$$

Applying first law of Thermodynamic.

$$\Delta U_{1-2} = \Delta Q_{1-2} - \overset{\to 0}{\cancel{\Delta W_{1-2}}}$$

$$\underbrace{\Delta Q_{1-2}}_{\text{Heatsup}} = C_v\left[T_2 - T_1\right] = \frac{R}{\gamma-1}\left[T_2 - T_1\right] =$$

$$\Delta Q_{1-2} = \frac{P_H V_L - P_L V_L}{\gamma-1} = \frac{V_L\left(P_H - P_L\right)}{\gamma-1}$$

② Process 2-3 (Constant Pressure Process)

$$\Delta W_{2-3} = P_H\left[V_H - V_L\right]$$

$$\underbrace{\Delta Q_{2-3}}_{\text{heatsup.}} = C_p\left[T_3 - T_2\right] = \frac{\gamma}{\gamma-1}\left[RT_3 - RT_2\right] = \frac{\gamma}{\gamma-1}\left[P_H V_H - P\right.$$

$$= \frac{\gamma}{\gamma-1} P_H\left[V_H - V_L\right]$$

$$\cancel{\Delta U_{2-3} = \Delta Q_{2-3} - \Delta W_{2-3}}$$

for process 3-4 (constant volume)

$$\Delta W_{3-4} = 0$$

$$\underbrace{\Delta Q_{3-4}}_{\text{Rejected}} = C_v [T_4 - T_3]$$

$$= \frac{R}{\gamma-1}[T_4 - T_3] = \frac{1}{\gamma-1}[P_L V_H - P_H V_H]$$

$$= \frac{V_H}{\gamma-1}[P_L - P_H] \quad \text{(Heat Rejected)}$$

for Process 4-1 (constant pressure):

$$\Delta W_{4-1} = P_L [V_L - V_H]$$

$$\Delta Q_{4-1} = \frac{\gamma}{\gamma-1} P_L [V_L - V_H] \quad \text{(Heat Rejected)} \quad [\because V_L < V_H]$$

Efficiency

$$\eta = \frac{\Sigma \text{(Work done)}}{\text{Heat supplied.}}$$

$$= \frac{P_H(V_H - V_L) + P_L(V_L - V_H)}{V_L \frac{(P_H - P_L)}{\gamma-1} + \frac{\gamma}{\gamma-1} P_H [V_H - V_L]}$$

$$= \frac{P_H V_H - P_H V_L + P_L V_L - P_L V_H}{V_L \frac{(P_H - P_L)}{\gamma-1} + \frac{\gamma}{\gamma-1} P_H [V_H - V_L]}$$

$$= \frac{(V_H - V_L)(P_H - P_L)(\gamma-1)}{V_L(P_H - P_L) + \gamma P_H [V_H - V_L]}$$

dividing by $(V_H - V_L,\ P_H - P_L)$

$$\boxed{\eta = \frac{\gamma-1}{\left(\frac{\gamma P_H}{P_H - P_L}\right) + \left(\frac{V_L}{V_H - V_L}\right)}} \quad \text{H.P}$$

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Q- 2ⓐ Moment of Iner. of F.W $I = 0.54\ kg\text{-}m^2$

speed $N = 3000$ rpm , $\omega = \frac{2\pi \times 3000}{60}$

Temp $T = 15°C$ $= 314.1592$ rad/s

water equvelent mass $\dot{m}_w = 2kg$

Sol^n. when flywheel come to rest $\omega_{final} = 0$

Change in kinetic energy of flywheel

$$\Delta E = \frac{1}{2} I (\omega_i^2 - \omega_f^2)$$

$$= \frac{1}{2} \times 0.54 \left[314.1592^2 - 0^2 \right]$$

$$= 26.64\cancel{8}\ KJ$$

this energy is converted into heat energy or the energy dissipates on frictional heat

$$Q_f = \Delta E = 26.648 KJ$$

$$= m_w C_{pw} \Delta T_{bearing} = 26.640$$

$$2 \times 4.187\ \Delta T_{bearing} = 26.640$$

rise in Temp of bearing. $\boxed{\Delta T_{bearing} = 3.182\ °C}$

Initial Temp of bearing $= 15°C = 288 K.$

final " " $= 18.\cancel{8}182°C = \underline{291.182 K}$

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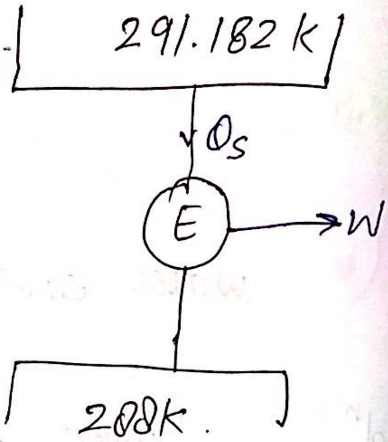
For that dissipated heat to convert into work

Assume a carnot engine which extract heat from bearing & convert it into useful work.



$$Q_S = \Delta E = 26.648K.$$

efficiency of cycle

$$\eta_{carnot} = 1 - \frac{T_L}{T_H}$$

$$= 1 - \frac{288}{291.182} = \underline{0.01092}.$$

$$(W)_{max} = \eta_{carnot} \times Q_s$$

$$= 0.01092 \times 26.648$$

$$= 0.29099 \text{ KJ}$$

$$= \underline{290.99 \text{ Joules}}.$$

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Please refer solution

Initial kinetic energy $= \frac{1}{2} I\omega_2^2 = 26.648$ KJ.

final " " $= (W)_{max} = 290.99$ J.

Unavailable kinetic energy $= E_{initial} - E_{final}$

$$= 26.648 - 0.29099$$

$$= \underline{26.357 \text{ KJ}}.$$

final energy $= 290.99 = \frac{1}{2} \times 0.54 . \omega^2$

$\omega = 32.829$ rad/s $= \underline{313.5 \text{ rpm}}$.

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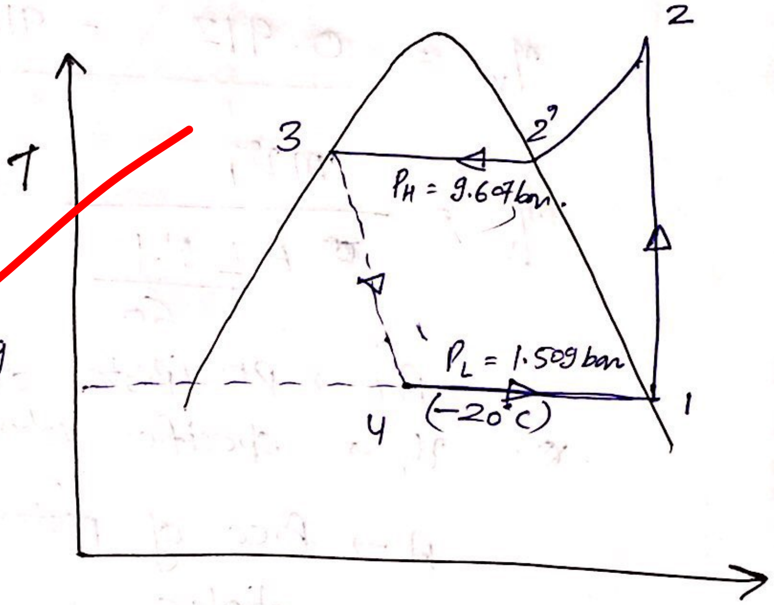
Q-2 (b)

Cooling effect = 50 KW (single cy)

lower Press. P_L = 1.509 bar

higher Press. P_H = 9.607 bar



From Table

$h_1 = 178.61$ KJ/kg

$h_3 = h_4 = 74.53$ KJ/kg

Since process 1−2 is assumed to be isentropic

$$S_1 = S_2 = 0.7082 = 0.682 + 0.747 \ln \frac{T_2}{313}$$

$$\underline{T_2 = 324.17 \text{ K}}.$$

then $h_2 = h_2' + C_{P_{v}}[T_2 - T_2']$

$= 203.05 + 0.747[324.17 - 313]$

$h_2 = \underline{211.394 \text{ KJ/kg}}$

Cooling effect $50 = m[h_1 - h_4]$

$50 = m[178.61 - 74.53]$

mass flow rate $\boxed{m = 0.4804 \text{ kg/s}}$ $= \underline{28.824 \text{ kg/min}}$.

Power Required $= m[h_2 - h_1] = 0.4804 \times [211.394 - 178.61]$

$= \underline{15.749 \text{ KW}}$.

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Volumetric efficiency of compressor

$$\eta_v = 1 + C - C\left[\frac{P_2}{P_1}\right]^{1/n}$$

$$= 1 + 0.02 - 0.02\left[\frac{9.607}{1.509}\right]^{1/1.13}$$

$$\underline{\eta_v = 0.917 = 91.7\%}$$

$$\eta_v = \frac{m v_1}{\frac{A.L\,N.K}{60}}$$

$AL \rightarrow$ PD (Piston displacement)

$v_1 \rightarrow$ specific volume entering Compressor.

$A \rightarrow$ Area of piston.

$L \rightarrow$ stroke

$N \rightarrow$ rpm

$k \rightarrow$ No of cylinder

$$0.917 = \frac{0.4804 \times 0.1088}{PD \times \frac{400}{60} \times 1}$$

Piston displacement

$$\boxed{PD = 8.5497 \times 10^{-3}\ m^3/cycle}$$

$$\boxed{PD = 0.0567\ m^3/sec}$$

$$\boxed{PD = 3.42\ m^3/min}$$

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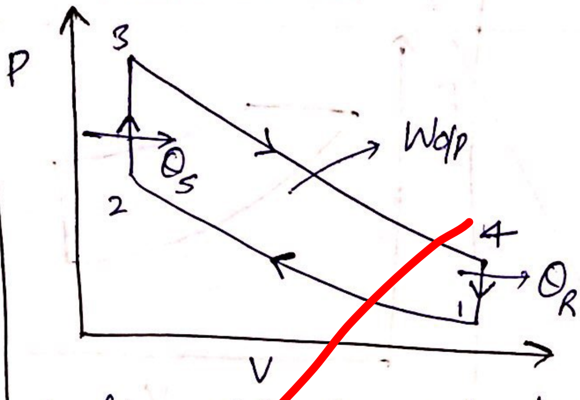
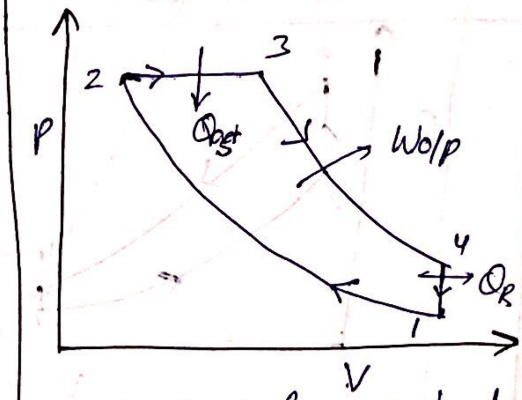
Q-2 (c)

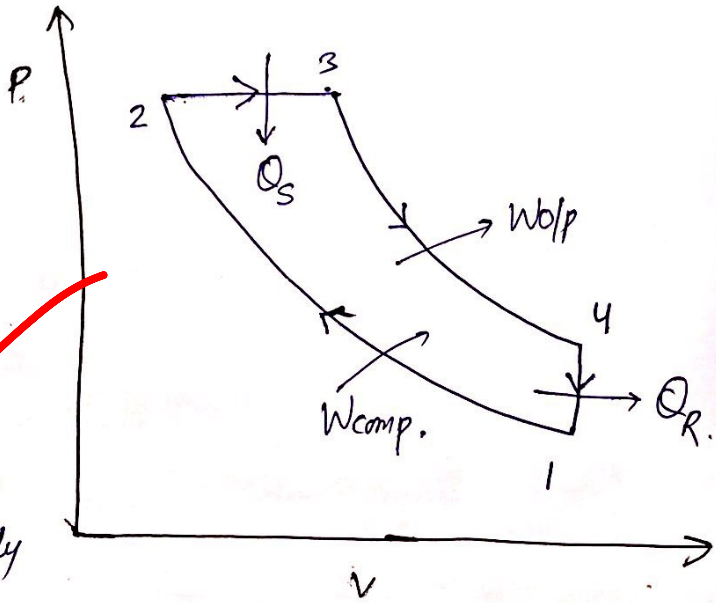
OTTO CYCLE	DIESEL CYCLE
	
* It consist of constant volume heat addition	* Constant Pressure heat addition takes place.
* Compression ratio is less in otto cycle when max^m Temperature is fixed for the cycle.	* Compression ratio is high compared to otto cycle. when max^m Temp is fixed for cycle.
* No work done during the heat addition Process	* work done on piston during heat addition
* spark plug used, (spark ignition)	* fuel injector used, Compression Ignition.

Efficiency of Diesel cycle :

Assumption

* Air is assumed to be working substance
* Air is assumed to be an Ideal Gas
* C_p, C_v, γ will remain constant

Let P, V, T are Pressure Volume & Temp respectively at point 1, 2, 3, 4.



Let $r = \frac{V_1}{V_2}$ = Compression ratio.

$\rho = \frac{V_3}{V_2}$ = cutt off ratio.

eff $\eta_{diesel} = \frac{Q_S - Q_R}{Q_S} = 1 - \frac{Q_R}{Q_S}$ ——— (1)

$\eta_{d} = 1 - \frac{C_v[T_4 - T_1]}{C_p[T_3 - T_2]} = 1 - \frac{T_4 - T_1}{\gamma(T_3 - T_2)}$ ——— (2)

1-2 - Adiabatic + Reversible

$\frac{T_2}{T_1} = r^{\gamma-1}$ $\quad T_2 = T_1 r^{\gamma-1}$ ——— (A)

2-3 constant Pressure

$\frac{V_2}{T_2} = \frac{V_3}{T_3}$ $\Rightarrow T_3 = \rho T_2 \Rightarrow T_3 = \rho r^{\gamma-1} T_1$ (B)

process 3-4 - Isentropic

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

from eqn (B)

$T_4 = T_1 \rho \cancel{r^{\gamma-1}} \frac{\rho^{\gamma-1}}{\cancel{r^{\gamma-1}}}$

$T_4 = T_1 \rho^{\gamma}$ ——— (C)

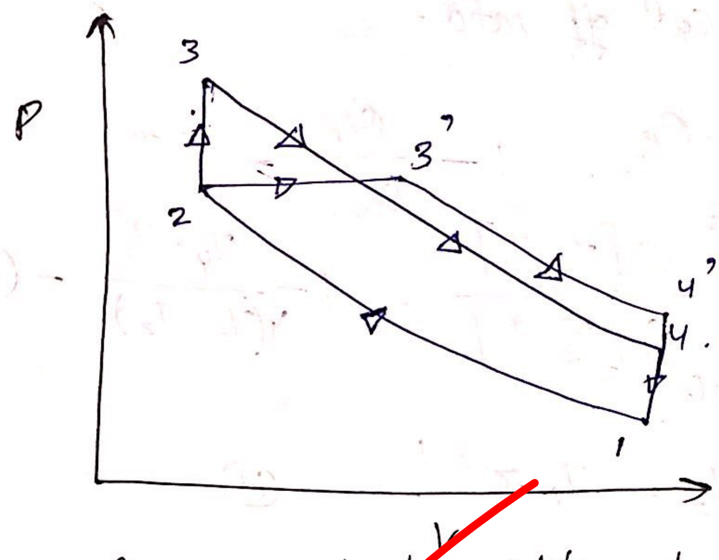
using eqn (A) & (B) & (C) putting in (2)

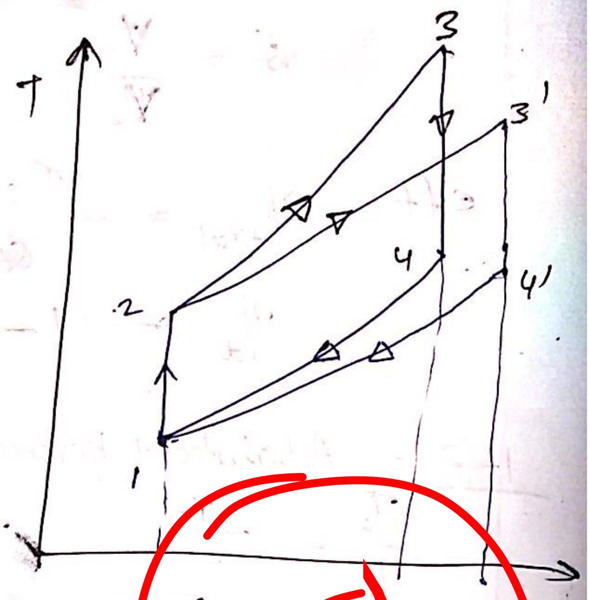
$\eta = 1 - \frac{T_1 \rho^{\gamma} - T_1}{\gamma[\rho r^{\gamma-1} T_1 - T_1 r^{\gamma-1}]}$

$\eta = 1 - \frac{\cancel{T_1}[\rho^{\gamma} - 1]}{\cancel{T_1} r^{\gamma-1} \gamma [\rho - 1]}$

$$\boxed{\eta = 1 - \frac{\rho^{\gamma} - 1}{r^{\gamma-1}\, \gamma\, (\rho - 1)}}$$

Eff. Comparison for same compression Ratio





① Assuming heat addition to be same

As shown in T-s diagram the entropy is more in case of diesel cycle & hence mean Temp of heat Addition is lower consequently the efficiency of diesel cycle is less compared to otto.

Q-4 ⓐ

2 stroke

speed $N = 440\,rpm$

brake load $W = 50\,kg$

imef.p $P_{i,mef} = 3\,bar = 300\,KPa$.

fuel cons. $m_f = 5.4\,Kg/hr$.

$\Delta T_{WJ} = 36^\circ C$

$m_{WJ} = 440\,Kg/hr$.

$A/F = 30$

ex. gas Temp $T_{ex} = 350^\circ C$

$T_a = 17^\circ C$

$P_0 = 76\,cm$ of Hg.

Cy. dia $D = 22\,cm = 0.22\,m$

stroke $L = 25\,cm = 0.25\,m$.

Brake dia $D_b = 1.2\,m$

$CV = 43\,MJ/kg$

$H\% = 15\%$

$R = 0.287$

sp. heat of exh. gas $C_{pex} = 1\ KJ/kg\,K$.

sp. heat of dry steam $C_{ps} = 2\ KJ/kg\,K$

enthalpy of sup. heated steam $h_s = 3180$

Sol^n

Brake Torque $= T = W \cdot \frac{D_b}{2} g$

$= 50 \times 9.81 \times 0.6 = 294.3\ N.m$

$BP = T.\omega = 294.3 \times \frac{2\pi \times 440}{60}$

$= \underline{13.56\ kW}$.

$IP = P_{mef} \times V_s = 300 \times \frac{\pi}{4} \times 0.22^2 \times 0.25 \times \frac{440}{60}$

$= \underline{20.907\ KW}$.

(i) Indicated thermal eff.

$$\eta_{i,th} = \frac{IP}{m_f \cdot CV} = \frac{20.907}{\frac{5.4}{3600} \times 43000} = 0.3241$$

$= \underline{32.41\%}$.

(ii) <u>specific fuel consumption</u>.

brake specific fuel consumption $bsfc = \frac{m_f}{B.P} = \frac{5.4}{13.56} = 0.3982\ \frac{Kg}{KWhr}$.

$= \frac{398.2\,g}{KWhr}$.

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mass flow rate of air $= 30 \times m_f$

$= 30 \times 5.4 = 162$ kg/hr.

$= 0.045$ kg/s.

$P_{atm} = 0.76 \times 13.6 \times 10^3 \times 9.81$

$= \underline{101.396 \text{ kPa}}$.

$P_{atm} \dot{V}_a = \dot{m} RT$

$101.396 \times \dot{V}_a = 0.045 \times 0.287 \times 290$

$\underline{\dot{V}_a = 0.03693 \text{ m}^3/\text{sec}}$.

$\dot{V}_{swept} = \frac{\frac{\pi}{4} D^2 L N K}{60} \simeq 0.06969.$

$\eta_v = \frac{\dot{V}_a}{\dot{V}_s} = \frac{0.03693}{0.06969} \simeq \underline{\simeq 53\%}$

Heat loss in water Jacket

$Q_{WJ} = m_{WJ} C_{pw} . \Delta T_{WJ} = \frac{440}{3600} \times 4.187 \times 36$

$= \underline{18.4228 \text{ KW}}$.

mass of steam at exhaust $= 9 \times \% H \times m_f$

$= 9 \times 0.15 \times \frac{5.4}{3600}$

$= 2.025 \times 10^{-3}$ kg/s.

mass of dry exhaust $= \frac{30 \times 5.4 + 5.4}{3600} - 2.025 \times 10^{-3}$

$m_{ex} = 0.04447$ Kg/s

$Q_{exhaust} = m_{ex} C_{pex} \Delta T = 0.04447 \times 1 \times [350 - 17]$

$= 14.808$ KW

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head added

$$Q_s = \frac{5.4}{3600} \times 43000 = 64.5\ kW.$$

enthalpy of ~~steam~~ moisture (water) at room Temp

$$h_1 = 4.187 \times 17 = 71.179\ kJ/kg$$

$$Q_{steam} = 2.025 \times 10^{-3} [3180 - 71.18]$$

$$= 6.2953\ kJ/kg$$

Heat Balance sheet

Component	Amount (Kw)	%age
Q_s	64.5	100%
B.P	13.56	21.02%
$(Q_{WJ})_{loss}$	18.4228	28.56%
$(Q_{loss})_{dry}$	14.808	22.95%
$(Q_{loss})_{steam}$	6.2953	9.76%
Unaccounted loss	11.4139	17.69%

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Q-4 (b)

$RSH = 20\,kW$

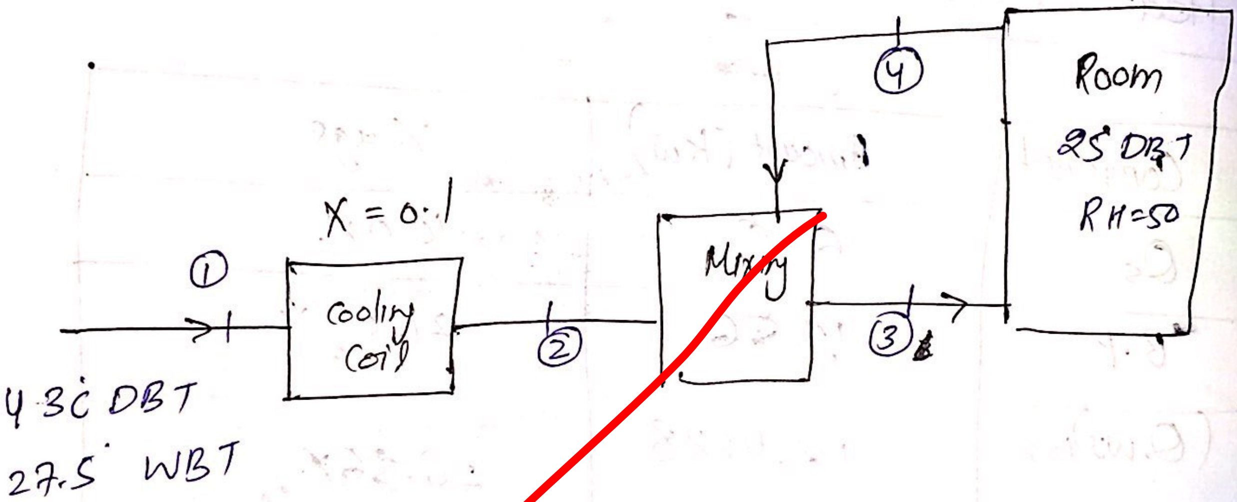
$RLH = 5\,kW$

Inside condition = 25°C DBT, 50% RH.

$X = 0.1$

$$\frac{m_{return}}{m_{fresh}} = 4.$$

Outside condition = 43°C DBT, 27.5°C WB



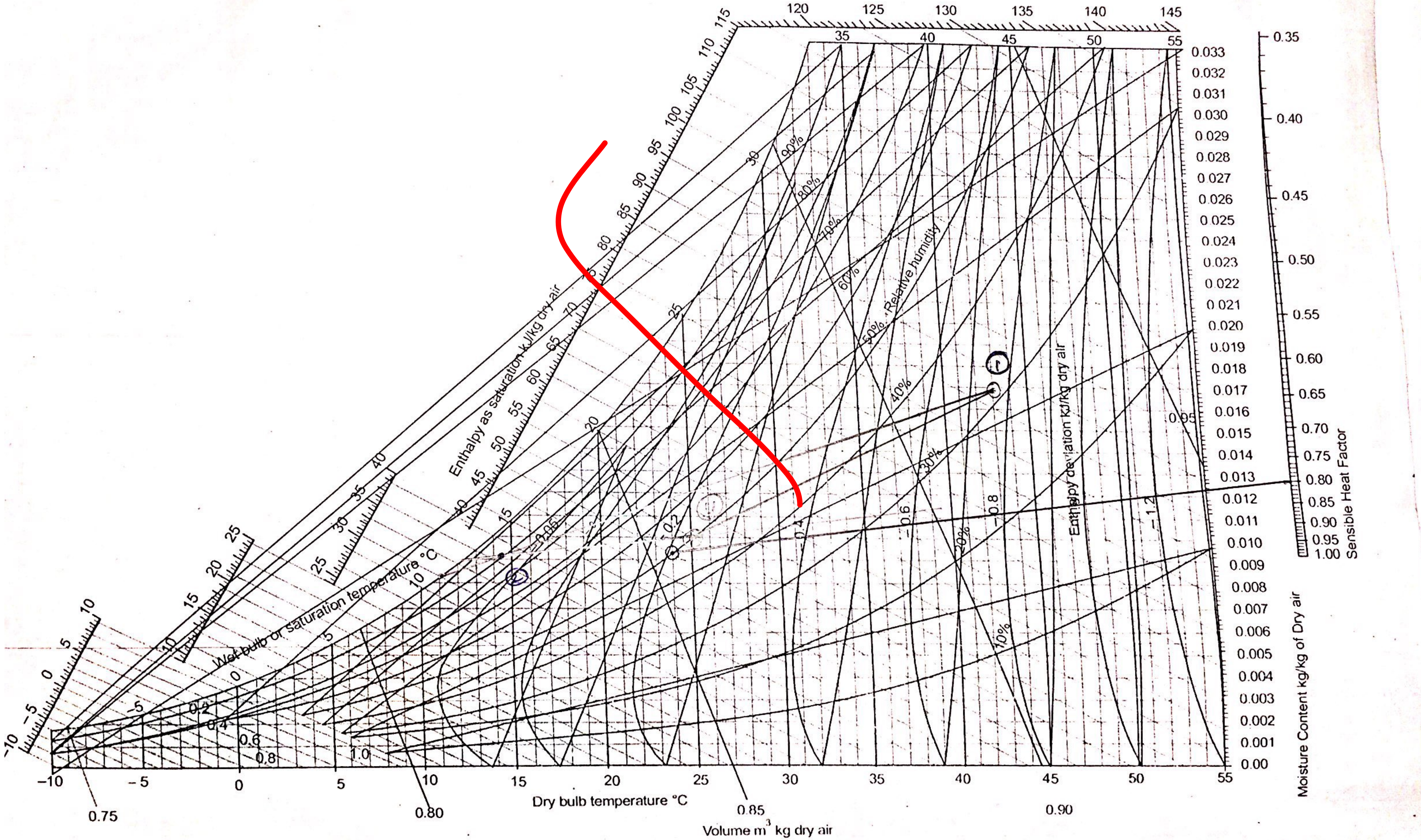
Sensible heat factor $SHF = \dfrac{RSH}{RSH + RLH} = \dfrac{20}{25}$

$= 0.8$

To calculate at state 3.

From psychrometric chart

ADP = 11°C



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Temp of air leaving cooling coil = $14.1 C$

(iii) dehumidification = $m_a(\omega_1 - \omega_2)$

$= m_a[0.017 - 0.008]$

$= 12.010[0.017 - 0.008]$

$LH = 50 \text{ cmm } \Delta W \text{ kW}$

$5 = 50 \text{ cmm } [0.017 - 0.008]$

fresh. cmm = $11.11 \, m^3/min$.

$v = 0.925 \, m^3/kg$

$m = \frac{11.11}{0.925} = 12.01 \text{ kg/min}$.

denumidified air = ~~12.01~~ 0.10809 kg/min.

Total load $= m[h_1 - h_2]$

$= \frac{12.01}{60}[87 - 36.5]$

$= 10.108$ kW Ans.

7

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Q-4 (c)

$K = 6$ (No of cy)

4stroke.

$P_{o/p} = 120\ kW$ @ $N = 1600$ rpm

% of $H = 13\%$ [1% non combustible]

$\eta_v = 0.80$

$\eta_{ith} = 0.40$

$\eta_{Mech} = 0.80$

110% excess air then Required for stoich Rxn.

1 kg of air $\longrightarrow 0.77\ m^3$

O_2 → 23% by mass

O_2 → 21% by volume.

$CV = 43\ MJ/kg$

$C = 86\%$

Assuming the fuel has 100 kg mass.

Component	mass (kg)	(kmole) Moles
C	86	7.1666
H	13	13

Stoichiometric Reaction

$$7.1666\,C + 13\,H + X\left[O_2 + \frac{79}{21}N_2\right] \longrightarrow A\,CO_2 + B\,H_2O + X\,\frac{79}{21}N_2$$

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C- Balance

$$\boxed{7.1666 = A}$$

H- Balance

$$13H = 2B \qquad \boxed{B = 6.5}$$

O- Balance

$$2X = A \times 2 + B$$

$$2X = 7.1666 \times 2 + 6.5$$

$$\boxed{X = 10.4166}$$

Stoichemetric Reaction

$$7.1666C + 13H + 10.41666\left[O_2 + \frac{79}{21}N_2\right] \longrightarrow 7.1666CO_2 + 6.5H_2O + 39.186N_2$$

Actual Reaction

$$7.1666C + 13H + 21.8749\left[O_2 + \frac{79}{21}N_2\right] \longrightarrow 7.1666CO_2 + 6.5H_2O + 11.458O_2 + 82.291N_2$$

Dry exhaust Gas

Component	moles (kmole)	% of mole
CO_2	7.1666	7.10%
O_2	11.458	11.35%
N_2	82.291	81.544%

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$BP = 120\,kW$

$$IP = \frac{BP}{\eta_{Mech}} = \frac{120}{0.8} = 150\,kW$$

$$\eta_{i,th} = \frac{IP}{m_f\,CV} = \frac{150}{m_f \times 43000} = 0.4$$

$$\underline{m_f = 8.7209 \times 10^{-3}\ kg/s}$$

$$A/F = \frac{21.8749\left[32 + \frac{79}{21} \times 28\right]}{7.166 \times 12 + 13 \times 1} = \underline{80.3452 \times 0.99}$$

$$= \underline{80.041}$$

$$m_a = A/F \times m_f = 0.26190\ kg/s$$

$$\rho = \frac{1}{6.77} = 1.2902$$

$$V_a = \frac{0.2619}{1.2987}$$

$$= 0.20166\ m^3/sec$$

$$\eta_{volu} = \frac{V_a}{V_s}$$

swept volume $= V_s = \frac{0.20166}{0.8}$

$$= 0.2520\ m^3/sec$$

$$0.2520 = \frac{\pi}{4} D^2 \times 1.5D \times \frac{6 \times 1600}{120}$$

$$\boxed{D = 0.1388\ m}$$

$$\boxed{L = 0.2082\,m}$$

18

Q-5 (a) $T = 47^\circ C = 320 K$.

S.C current $I_{sc} = 2\ A$

Reverse sat. curr $I_0 = 10.\ n.A = 10^{-8}\ A$

$K = 1.3806 \times 10^{-23}\ m^2 kg\ s^{-2} K^{-1}$

$q = 1.6022 \times 10^{-19}\ C$.

then current can be given as (Junction current)

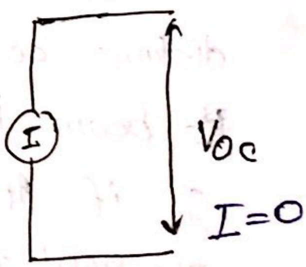
$$I_J = I_0 \left[\exp\left(\frac{qV}{KT}\right) - 1 \right]$$

current in cell $\quad I = I_{sc} - I_0 \left[\exp\left(\frac{qV}{KT}\right) - 1 \right]$ — (1)

open circuit voltage

(a) open circuit $I = 0$ putting in eq^n (1)

$$0 = 2 - 10^{-8} \left[\exp\left(\frac{1.6022 \times 10^{-19} \times V_{oc}}{1.3806 \times 10^{-23} \times 320} \right) - 1 \right]$$



$$e^{36.2659\, V_{oc}} = 2 \times 10^8 + 1$$

$$36.2659\, V_{oc} = \ln(2 \times 10^8 + 1)$$

$$\boxed{V_{oc} = 0.527\ \text{Volt}}$$

Solar Constant :-

- It is the mean value of extraterrestrial Radiation which falls perpendicular to the plate situated at outerside of atmosphere.
- Its value was calculated as $1367\ W/m^2$.

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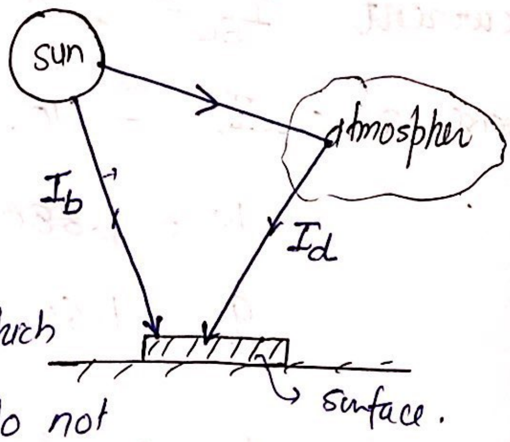
② Global Radiation.

Global Radiation is the summation of Beam Radiation & diffuse Radiation.



I_b – beam Radiation

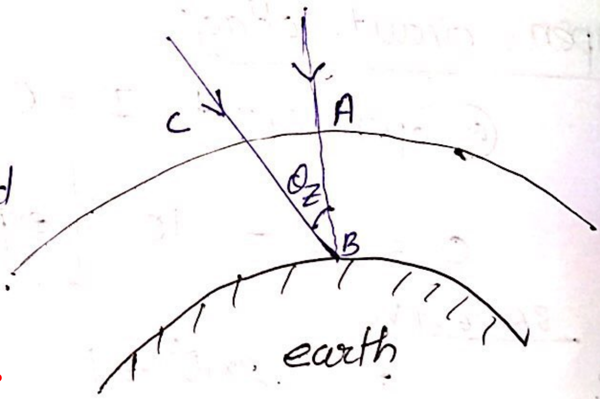
I_d → diffuse Radiation.

Beam Radiation is the Radiation which Incident directly from sun & do not Interact with atmosphere.

where as, diffuse Radiation interact with atmospheric Gases, particulats & then reflected towards the surface

Global Radiat. ← $\boxed{I_g = I_b + I_d.}$

③ Air mass.



Air mass is defined as the distance covered by the inclined ~~Ro~~ beam Radiation to that atm. if It enteres atmpo perpendicularly

air mass $\boxed{m = \frac{CB}{AB}}$

$\boxed{m = \sec\theta_z}$

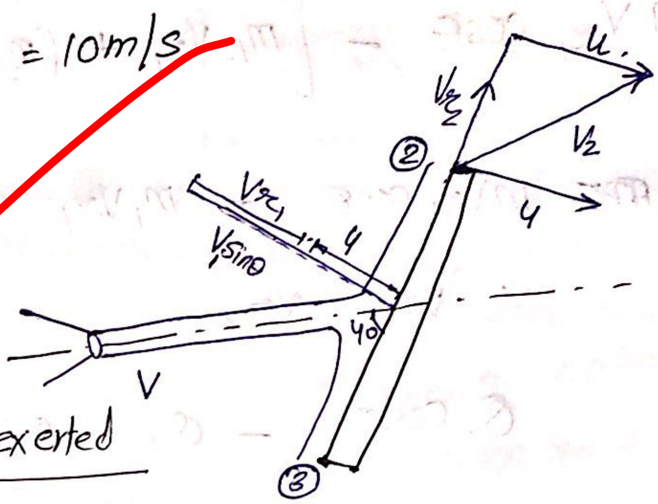
10

5 (b) Area $A = 13\,cm^2 = 13\times10^{-4}\,m^2$

$V = 25\ m/s$

$\theta = 40°$

Plate vel.: $u = 10\,m/s$



(i) Normal force exerted

F_N = Rate of change of momentum in normal direct^n

$$F_N = m\,V_{r_1} - [m_2 V_{r_2} + m_3 V_{r_3}]$$

$$F_N = \rho a\,(V_r)\,V_r$$

$$F_N = \rho a\,(V_1\sin\theta - u)^2$$

$$= 1000\times13\times10^{-4}\,(25\sin40 - 10)^2$$

$$= 47.893\,N$$

142.11 N

(ii) Power = force on Normal direction. u.

$$= 47.893\times10$$

$$= 478.93\,W$$

(iii) $$\eta = \frac{WD/s}{\frac{1}{2}mV_1^2} = \frac{478.93}{\frac{1}{2}\times1000\times13\times10^{-4}\times25^3}$$

$$= 0.0471$$

Refer solution

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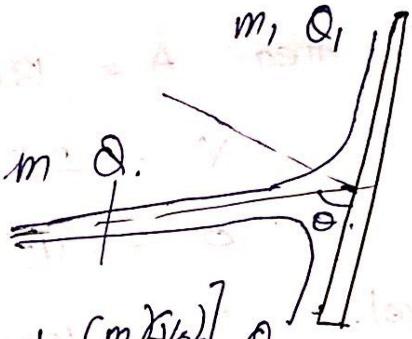

thrust force

$$Q = Q_1 + Q_2 \quad (1)$$

$$F_T = m V_{r_1} \cos\theta - \left[m_1 V_{r_1} + (m_2)(V_{r_2}) \right]$$

$$= m V_{r_1} \cos\theta - m_1 V_{r_1} + m_2 V_{r_2}$$

$$\because V_{r_1} = V_{r_2}$$

$$= Q \cos\theta - Q_1 + Q_2 = 0 \quad (2)$$

eqⁿ (1) + (2)

$$Q[\cos\theta + 1] = 2Q_1$$

$$\boxed{Q_1 = \frac{Q[\cos\theta + 1]}{2}}$$

$$Q_2 = Q - \frac{Q}{2}(\cos\theta + 1)$$

$$= \frac{2Q - Q\cos\theta + Q}{2} = \frac{Q[1 - \cos\theta]}{2}$$

$$\boxed{\frac{Q_1}{Q_2} = \frac{1 + \cos\theta}{1 - \cos\theta}} = \frac{1 + \cos 40}{1 - \cos 40}$$

$$= 7.548$$

3

5 (d)

Comparison b/w Axial Flow compressors & Centrifugal:

Axial Flow Compressors	Centrifugal Compressors
* Axial flow compressors are those on which the flow of fluid is taken place in the axial direction	* Flow of the fluid is taking place in Radial direction (Generally ~~on~~ out-ward flow).
* Compression Ratio per stage is less compared to centrifugal Compressors	* Compression ratio per stage is high compared to axial flow.
* These compressors are preferred for Multistaging	* Multistaging is not Preffered Generally.
* Their volume handling (compressing) Capacity is high compared to that of centrifugal.	* Their Volume handling Capacity is lower than that of axial compr.
* due to high mass flow rate they worked near the chocking Range (mass flow rate ↑↑ & pressure ratio ↓↓)	* they run away from chocked Region & also surging should be avoided.
* high starting torque Required compared to centrifugal comp	* Low starting torque than Axial flow.
* Overall pressure ratio may be high compared to centrifugal Compr. (upto 10)	* Overall pressure ratio is less than Axial flow (upto 4-5).

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Axial flow.	Centrifugal flow
* Isentropic efficiency is slightly higher than centrifugal type (Ranging 87 - 90)	* Isentropic efficiency is slightly lower than Axial flow Ranging (80 - 83%)
* high ~~ment~~ maintenance cost Required.	* Low maintenance cost compared to Axial flow Compr.
* Small frontal area for same compression ratio & volume handing capacity.	* large frontal area for same comp ratio & volume handling.
* Poor performance at the part load condition	* Good performance at the part load condition.

5 (e)

No of cows $N = 4$

$RT = 50$ days

Biogas Yield $= 0.22\ m^3/kg$ of dry matter

Dry matter produced $= 2.5\ kg/day/cow$

% of ~~xxxx~~ dry matl in dung $= 18\%$

$\rho_s = 1090\ kg/m^3$

$\eta_b = 63\%$

$CV = 23\ MJ/m^3$

dry matter produced per day $= 2.5 \times 4$

$= 10$ kg/day.

Cow dung per day $= \frac{10}{\% \text{ of dry matt}} = \frac{10}{0.18}$

$= 55.555$ kg/day

Slurry mass $= 2 \times 55.555$

$= \underline{111.11 \text{ kg/day}}$.

volume of slurry $= 0.1019 \, m^3$

for 50 days slurry volume Required $= 50 \times 0.1019$

$= \underline{5.095 \, m^3}$.

volume of fixed dome biogas digester $= \underline{5.093} \times 1.13$

$= \underline{5.757 \, m^3}$

(ii) Dry matter produced per day $= 10$ kg/day

Biogas produced per day $= 0.22 \times 10$

$= 2.2 \, m^3/\text{day}$

Total heat content associated with biogas per day

$= 2.2 \times 23 = 50.6 \frac{MJ}{day}$

total available thermal energy $= 50.6 \times 0.63$

$= 31.878 \frac{MJ}{day}$

$= \underline{0.3689 \frac{KJ}{sec}}$.

8

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8 (a)

Head $H = 40m$

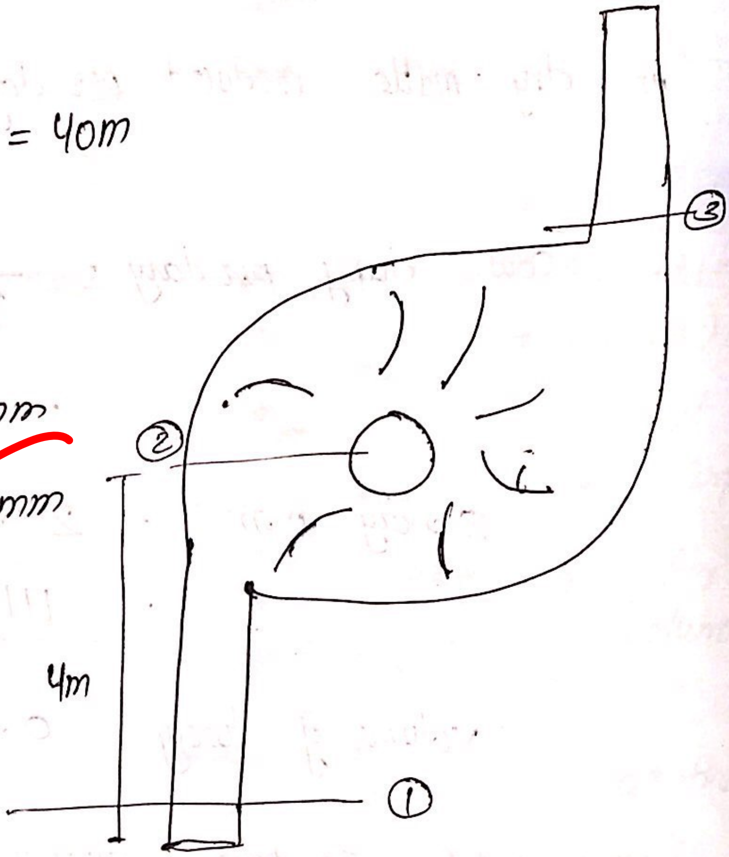
$H_s = 40m$

Suction $D_s = 150mm$

delivery $D_d = 150\ mm$

$(h_f)_s = 2.3\ m$

$(h_f)_d = 7.4\ m$



$D_2 = 0.42\ m$

$B_2 = 25mm = 0.025\ m$

$N_\phi = 1200\ rpm$

$u_2 = \frac{\pi \times 0.42 \times 1200}{60}$

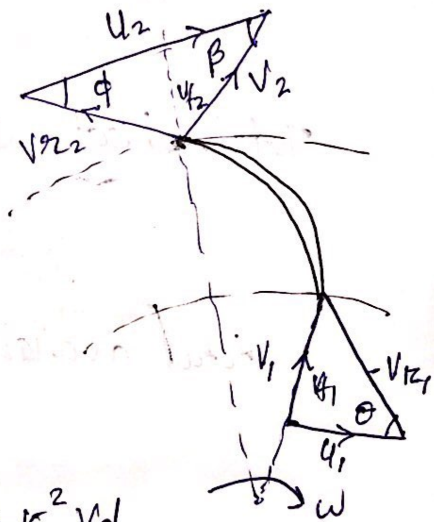
$= 26.389\ m/s$

$\phi = 35'$

$\eta_M = 0.82$

$V_d \rightarrow$ velocity at discharge pipe.

$\eta_0 = 0.72$



$Q = \pi D_2 B_2 Vf_2$

$= \pi \times 0.42 \times 0.025\ Vf_2$

$Q = 0.03298\ Vf_2$ — (1)

also discharge

$Q = \frac{\pi}{4} Dd^2 \cdot Vd = \frac{\pi}{4} \times 0.15^2\ Vd$

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$Q = 0.01767\ V_d$ —— (2)

(1) = (2)

$0.03298\ V_{f_2} = 0.01767\, V_d.$

$$\boxed{V_d = 1.86644\, V_{f_2}} \quad \text{—— (3)}$$

Manometric head $H_m = H_s + (h_f)_s + (h_f)_d + \frac{V_d^2}{2g}$

$$= 40 + 2.3 + 7.4 + \frac{1.8664^2 V_{f_2}^2}{2g}$$

$$H_m = 49.7 + 0.17755\ V_f^2 \quad \text{—— (4)}$$

$$\eta_M = \frac{g H_m}{V_{w_2} u_2.} = \frac{g H_m}{\left(u_2 - \frac{V_{f_2}}{\tan\phi}\right) u_2}$$

$$0.82 = \frac{9.81 \times \left[49.7 + 0.17755\ V_{f_2}^2\right]}{\left(26.389 - \frac{V_{f_2}}{\tan 35}\right) 26.389}$$

$$571.031 - 30.903\ V_{f_2} = 487.557 + 1.7417\ V_f^2$$

$$1.7417\ V_{f_2}^2 + 30.903\ V_{f_2} - 83.474 = 0$$

$$\underline{V_{f_2} = 2.3815 \text{ m/s}.}$$

$Q = 0.03298 \times 2.3815 = 0.0785\ m^3/sec$

$\underline{78.5 \text{ lit/sec}}$

$H_m = 49.7 + 0.17755 \times 2.3815^2 = \underline{50.7069 m}.$

Water power $= \rho g Q H_m =$

$= 9810 \times 0.0785 \times 50.7069$

$= 39.048$ kW

power Req to drive pump $= \frac{39.048}{\eta_0} = \frac{39048}{0.72} = \underline{54.234 kW}$

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Apply B.E^n @ ① & ② (suction side)

$$\cancel{\frac{P_1}{\rho g}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{Z_1}^{0\,[\text{datum}]} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + (h_L)_s.$$

$$0 = \frac{P_2}{\rho g} + \frac{V_d^2}{2g} + Z_2 + (h_L)_s)$$

$$(V_d)_s = (V_d)_d = 1.86644 \times 2.3815 = 4.445 \text{ m/s}$$

$$0 = \frac{P_2}{\rho g} + \frac{4.445^2}{2g} + 4 + 2.3$$

$$\frac{P_2}{\rho g} = -5.293 \text{ m} \; [\text{guage}]$$

$$\simeq 5 \text{ m} \; [\text{absolute}]$$

Pressure at delivery side

$$H_m = \left(\frac{P_d}{\rho g} + \cancel{\frac{V_d^2}{2g}} + \cancel{Z_d}\right) - \left(\frac{P_s}{\rho g} + \cancel{\frac{V_s^2}{2g}} + \cancel{Z_s}\right)$$

$$50.7069 = \frac{P_d}{\rho g} - \frac{P_s}{\rho g}$$

[$V_{d_2} = V_{d_3}$ → ∵ Q & A same]
assuming no change in datum]

$$50.7069 = \frac{P_d}{\rho g} - 5$$

$$\boxed{\frac{P_d}{\rho g} = 55.7069 \text{ m}}$$ Absolute.

Refer solution

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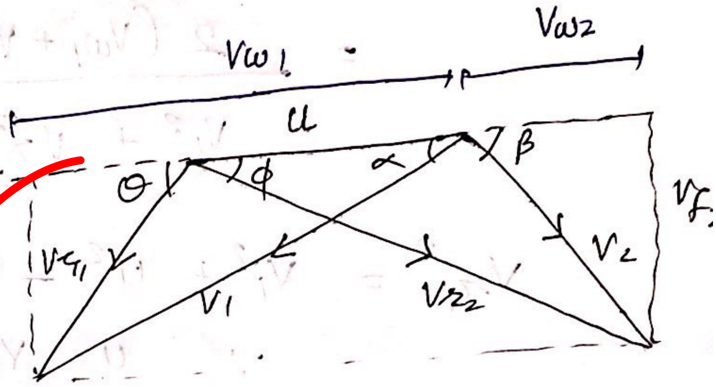
Q-8(b) 50% Reaction stage

$$V_1 = V_{r2}$$
$$V_{r1} = V_2$$

$$\theta = \beta$$
$$\alpha = \phi$$

$\alpha \rightarrow$ nozzle angle.



work done

$$WD/kg = [V_{w1} + V_{w2}] . u .$$

$$WD = (V_1 \cos\alpha + V_{w2})\, u . \quad —(1)$$

$$\therefore \boxed{V_{w2} = V_1 \cos\alpha - u} —(2) \left[\because \theta = \beta,\ V_{r1} = V_2\right]$$

putting in (1)

$$WD = (V_1 \cos\alpha + V_1 \cos\alpha - u)\, u .$$

$$WD = (2V_1 u \cos\alpha - u^2)$$

for max^m work done

$$\frac{dWD}{du} = 0 \Rightarrow \left[2V_1 \cos\alpha - 2u\right] = 0$$

$$u = V_1 \cos\alpha$$

$$\boxed{\frac{u}{V_1} = \cos\alpha} = \rho$$

$$\boxed{\rho = \cos\alpha}$$

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efficiency of Reaction Turbine.

$$\eta = \frac{(V_{w_1} + V_{w_2})\,u}{\frac{1}{2} V_1^2 + \frac{1}{2}\left[V_{r_2}^2 - V_{r_1}^2\right]}$$

$$= \frac{2\,(V_{w_1} + V_{w_2})\,u}{V_1^2 + V_{r_2}^2 - V_{r_1}^2}$$

$$V_{r_1}^2 = V_1^2 + u^2 - 2Vu\cos\alpha.$$

$$\because\ u = V_1 \cos\alpha.$$

$$= V_1^2 + V_1^2\cos^2\alpha - 2V_1^2\cos^2\alpha$$

$$V_{r_1}^2 = V_1^2(1 - \cos^2\alpha)$$

and $V_{r_2}^2 = V_1^2$

$$\eta = \frac{(V_1\cos\alpha + V_1\cos\alpha - u)\,u}{\frac{1}{2}V_1^2 + \frac{1}{2}\left[V_1^2 - (V_1^2(1 - \cos^2\alpha))\right]}$$

$$= \frac{2\left[V_1\cos\alpha\right]V_1\cos\alpha}{V_1^2 + \cancel{V_1^2} - \cancel{V_1^2} + V_1^2\cos^2\alpha}$$

$$\eta = \frac{2V_1^2\cos^2\alpha}{V_1^2(1 + \cos^2\alpha)}$$

$$\boxed{\eta = \frac{2\cos^2\alpha}{1 + \cos^2\alpha}}$$ H.P.

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mean Dia $D_m = 0.5 m$

blade height $h = 0.03 m$

$\theta = 60^\circ$, $\phi = 160^\circ$

$\rho = 2.7 \ kg/m^3$

$N = 3000$ rpm.

$u = \frac{\pi D N}{60} = \frac{\pi \times 0.5 \times 3000}{60} = 78.54 m/s$.

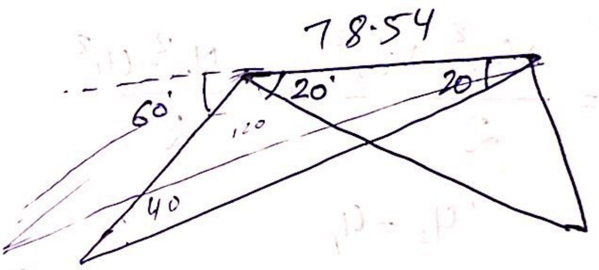
for optimum condition.

$V_1 = \frac{u_1}{\cos\alpha}$

$\alpha = \phi$

$V_1 = \frac{u_1}{\cos\alpha}$

$= \frac{78.54}{\cos 20} = 83.58$.



$V_{r_1} = 41.009$

$V_{r_2} = 105.816$

$\frac{78.54}{\sin 40} = \frac{V_1}{\sin 120}$ $V_1 = 105.816 m/s$.

$V_f = V_1 \sin 20$ $V_f = 36.19 m/s$.

$\dot m = \rho \pi D_m . h . V_f = 2.7 \times \pi \times 0.5 \times 0.03 \times 36.19$

$= 4.604 m/s$.

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$P_{o/p} = m[V_{w_1} + V_{w_2}]u$

$= m[2V_1\cos\alpha - u]u = 4.604[2 \times 105.816 \cos 20 - 78.5]78.5$

$= 43.51 kW$.

$\eta = \frac{2(V_{w_1}+V_{w_2}) \times u}{V_1^2 + V_{r_2}^2 - V_1^2} = 0.915 = 91.5\%$.

8 (c)

Degree of Reaction

degree of Reaction is defined by the enthalpy drop on moving blade divided by enthalpy drop per stage.

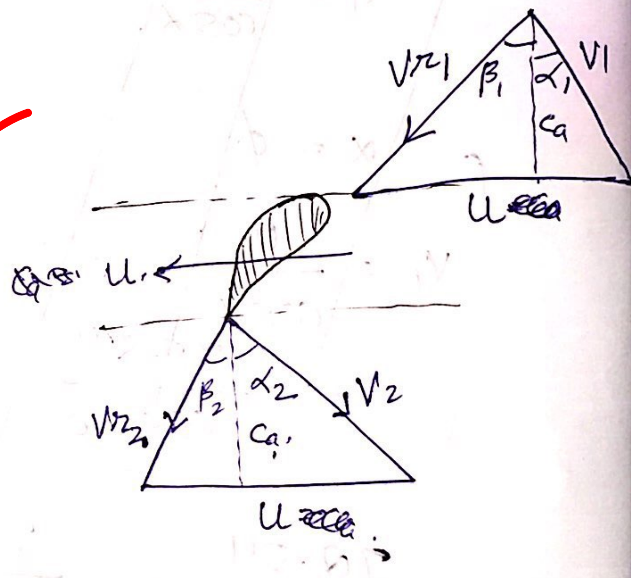
$$\boxed{R = \frac{\Delta h_m}{\Delta h_{stage}}} \quad , \quad \boxed{\Delta h_{stage} = \Delta h_m + \Delta h_{stator}}$$

Let us consider flow through axial compressor

$$\Delta h_m = \frac{V_{r_1}^2 - V_{r_2}^2}{2} + \frac{u_2^2 - u_1^2}{2}$$

$$\because u_2 = u_1$$

$$\Delta h_m = \frac{V_{r_1}^2 - V_{r_2}^2}{2}$$



$$R = \frac{\frac{V_{r_1}^2 - V_{r_2}^2}{2}}{(V_{w_1} + V_{w_2})\,u}$$

$$= \frac{V_{r_1}^2 - V_{r_2}^2}{2u\,[V_{w_1} + V_{w_2}]} = \frac{(C_a \sec\beta_1)^2 - (C_a \sec\beta_2)^2}{2u\,[C_a \tan\alpha_1 + C_a \tan\alpha_2]}$$

$$= \frac{C_a\,[\sec^2\beta_1 - \sec^2\beta_2]}{2u\,[\tan\alpha_2 + \tan\alpha_1]}$$

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we know $\sec^2\theta - 1 = \tan^2\theta$

$\sec^2\theta = 1 + \tan^2\theta$.

$$R = \frac{C_a}{2u}\frac{(\tan^2\beta_1 - \tan^2\beta_2)}{(\tan\alpha_2 + \tan\alpha_1)} \quad \text{—— (1)}$$

$C_a \tan\alpha_1 + C_a \tan\beta_1 = C_a \tan\alpha_2 + C_a \tan\beta_2$

$\tan\alpha_1 + \tan\beta_1 = \tan\alpha_2 + \tan\beta_2$

$\tan\beta_1 - \tan\beta_2 = \tan\alpha_2 - \tan\alpha_1$

$$R = \frac{C_a}{2u}\left[\tan\beta_1 + \tan\beta_2\right]$$

$$= \frac{C_a}{2u}\left[\underline{\tan\beta_1 + \tan\alpha_1} - \tan\alpha_1 + \underline{\tan\beta_2 + \tan\alpha_2} - \tan\alpha_2\right]$$

$$= \frac{C_a}{2u}\left[\frac{u}{C_a} - \tan\alpha_1 + \frac{u}{C_a} - \tan\alpha_2\right]$$

$$= \frac{C_a}{2u}\left[\frac{2u}{C_a} - (\tan\alpha_1 + \tan\alpha_2)\right]$$

$$\boxed{R = 1 - \frac{C_a\left[\tan\alpha_2 + \tan\alpha_1\right]}{2u}}$$

(ii) $N = 5000$ rpm $\quad V_f = 250$ m/s, $D_m = 1m$

$(\Delta T)_{actual} = 20K$.

$$u = \frac{\pi D N}{60} = \frac{\pi \times 1 \times 5000}{60}$$

$\underline{u = 261.8 \text{ m/s}}$.

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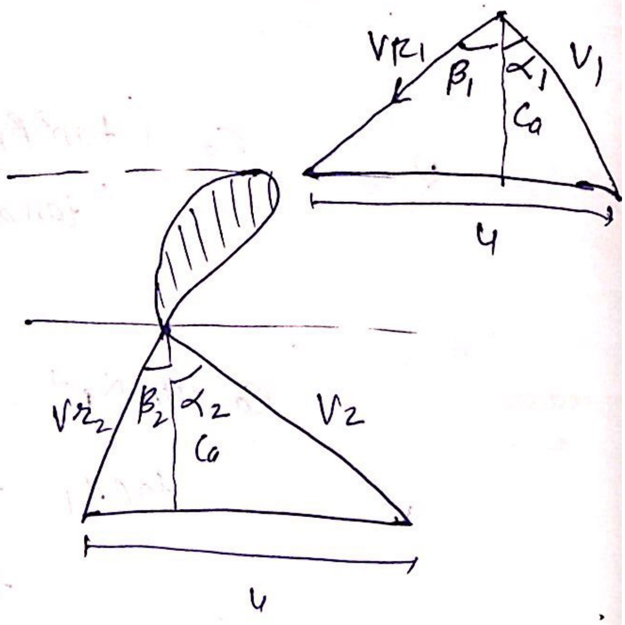
For 50% Reaction stage.

$$\beta_1 = \alpha_2$$

$$\alpha_1 = \beta_2$$



$$\tan\alpha_1 + \tan\beta_1 = \frac{u}{C_a}$$

$$\tan\alpha_1 + \tan\beta_1 = \frac{261.8}{250}$$

$$\tan\alpha_1 + \tan\beta_1 = 1.0472 \quad \text{--- (1)}$$

$$WD = C_p \Delta T = 1.005 \times 20$$

$$= 20.1 \text{ KJ/kg}$$

$$20.1 \times 10^3 = [V_{w_2} - V_{w_1}]\, u$$

$$20.1 \times 10^3 = [C_a \tan\alpha_2 - C_a \tan\alpha_1]\, u.$$

$$20.1 \times 10^3 = [\tan\beta_1 - \tan\alpha_1]\, C_a \times u$$

$$\tan\beta_1 - \tan\alpha_1 = 0.3071 \quad \text{--- (2)}$$

eq^n (1) + (2)

$$\tan\beta_1 = \frac{1.0472 + 0.3071}{2} = 0.6775$$

0.37005

$$\boxed{\begin{aligned}\beta_1 &= \alpha_2 = 34.103 \\ \alpha_1 &= \beta_2 = 20.307^\circ\end{aligned}}$$