MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-7 : Full Syllabus Test (Paper-I)

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	17
Q.2	44
Q.3	13
Q.4	—
Section-B	
Q.5	22
Q.6	—
Q.7	38
Q.8	—
Total Marks Obtained	134

Signature of Evaluator .... Cross Checked by ....

Keep up this Consistent effort

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section : A

Q.1 (a) A spherical, thin-walled metallic container is used to store liquid nitrogen at 77 K. The container has a diameter of 0.5 m and is covered with an evacuated, reflective insulation composed of silica powder. The insulation is 25 mm thick, and its outer surface is exposed to ambient air at 300 K. The convection coefficient is known to be 20 W/m^2-K. The heat of vaporization and the density of liquid nitrogen are 2×10^5 J/kg and 804 kg/m^3 respectively.

(i) What is the rate of heat transfer to the liquid nitrogen?

(ii) What is the rate of liquid boil-off (liters/day)?

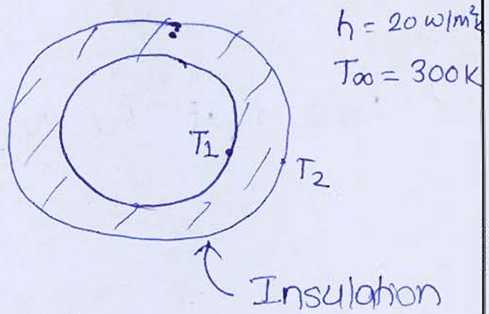
[Take k = 0.0017 for evacuated silica powder at 300 K]

[12 marks]

→ $T_1 = 77\,K$; $D = 0.5\,m$;

$R_1 = 0.25\,m$

$R_2 = R_1 + t = 0.275\,m$;

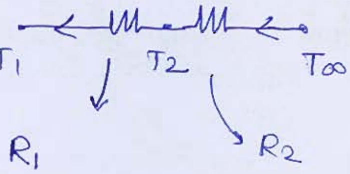


→ Liq. N_2 → ~~h_{fg}~~ $h_v = 2\times10^5\,J/kg$

$\rho = 804\,kg/m^3$.

→ (i) Let inner side temp. of spherical container = $T_1 = 77\,K$.

∴ $R_1 = \dfrac{r_2 - r_1}{4\pi r_1 r_2 k}$ → (sphere)



$R_1 = \dfrac{0.025}{4\pi(0.25)(0.275)\,0.0017}$

as ($T_\infty > T_1$)

∴ $\boxed{R_1 = 17.02\ K/W}$

$R_2 = \dfrac{1}{hA_2} = \dfrac{1}{20 \times 4\pi R_2^2} = \underline{0.0526132\ K/W}$

∴ ~~$T_1 - 1$~~ $Q = \dfrac{T_\infty - T_1}{R_1 + R_2}$ ← Rate of heat transfer to liq. Nitrogen.

∴ $\boxed{Q = \dfrac{300 - 77}{17.02 + 0.0526132} = 13.062\ W}$

In one day, Energy Transfered = $E = Qt$.

$E = 13.062 \times 24 \times 3600 = 1128.544$ kJ

→ ~~mass of Liq. N_2 in container, $M = \rho V$~~

→ amount of Liq. N_2 boil-off ~~$= 804 \times \frac{4}{3}\pi R_1^3$~~

$1128.544 \times 10^3 = m \times h_v$ ~~$= 52.6216$ kg.~~

∴ $m = 5.64$ kg

↳ its vol^m, $V = \frac{m}{\rho} = \frac{5.64}{804} = 7.018$ lit

↑ in one day.

Amount of liq. N_2 boil off

↳ = 7.018 lit/day.

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Q.1 (b) A two-dimensional incompressible flow field is described by equation (a) $V = \left(\frac{C}{r}\right)$; (b) $V = Cr$, in which V is the tangential velocity at a radius r and C is a constant. Determine for each case the circulation (i) around a circle of radius R, (ii) around a closed path formed by the arcs of two circles of radii R_1 and R_2 and the two radius vectors with an angle θ between them. Also calculate the vorticities of the flows described by these equations.

[12 marks]

→ $V = \left(\frac{C}{r}\right)$.

Q.1 (c) An ammonia refrigerator produces 20 tons of ice per day from water at 0°C to ice at 0°C. the condensation and evaporation takes at 20°C and –20°C respectively. The temperature of vapour at the end of isentropic compression is 50°C and there is no under cooling of the liquid. The actual COP is 70% of the theoretical COP. Determine:

(i) The rate of NH_3 circulation.

(ii) The size of single acting compressor when running at 240 rpm assuming $L = D$ and volumetric efficiency of 80%.

Take h_{fg} (fusion of ice) = 335 kJ/kg

Use the properties of NH_3 as listed below:

Temperature (°C)	Enthalpy (kJ/kg)		Entropy (kJ/kgK)	
	h_f	h_g	s_f	s_g
20	274.98	1461.58	1.04341	5.0919
–20	89.72	1419.05	0.3682	5.6204

Specific volume of dry vapour at –20°C = 0.624 m³/kg.

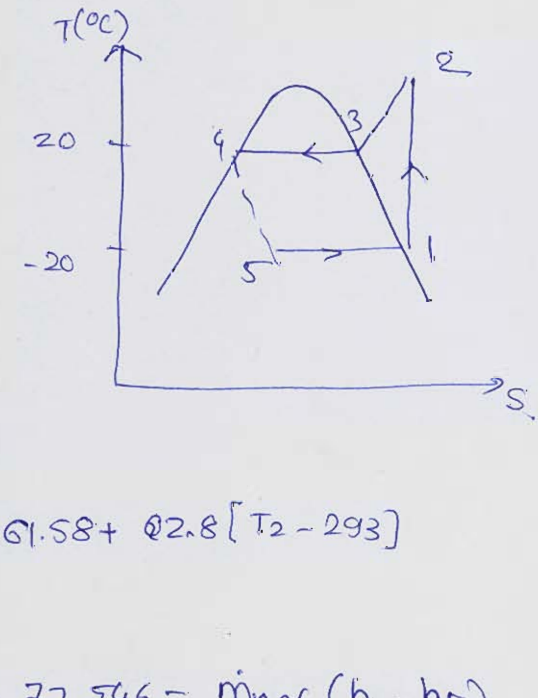
Specific heat of superheated vapour = 2.8 kJ/kgK.

[12 marks]

→ Refrigeration capacity, RC = $\dot{m}_{ice} \times h_{fg} / 24$ hrs.

$= \frac{20 \times 10^3 \times 335}{24 \times 3600} = \underline{\underline{77.546 \text{ kW}}}$

→ $h_1 = 1419.05$, $h_4 = h_5 = 274.98$ } kJ/kg



→ 1→2 → isentropic comp.

$\therefore S_1 = S_2 = 5.6204 = S_3 + C_{pv} \ln\left(\frac{T_2}{T_3}\right)$

$\therefore 5.6204 = 5.0919 + 2.8 \ln\left(\frac{T_2}{293}\right)$

$\therefore \boxed{T_2 = 353.87 \text{ K}}$

$\therefore h_2 = h_3 + C_p[T_2 - T_3] = 1461.58 + 2.8[T_2 - 293]$

$\therefore \boxed{h_2 = 1632 \text{ kJ/kg}}$

→ ∴ Refrig. Capacity = RC = 77.546 = $\dot{m}_{ref}(h_1 - h_5)$

(i) $\therefore \dot{m}_{ref} = \frac{77.546}{1419.05 - 274.98} = 0.06778$ kg/sec

$= 4.067$ kg/min.

rate of NH_3 circulation Ans.

→ (ii) we have, $\eta_v = 0.8 = \dfrac{\dot{m}_{ref} \times v_L}{\frac{\pi}{4} D^2 L \times \frac{N}{60} \times K}$.

$\therefore 0.8 \times \frac{\pi}{4} D^3 \times \frac{240}{60} \times 1 = 0.06778 \times 0.624$

$\therefore \boxed{D = L = 0.25626 m}$

.1 (d) With the help of Maxwell's relation of thermodynamics, prove that Joule-Thomson coefficient, μ_J of a gas is given by the following expression:

$$\mu_J = \left(\frac{\partial T}{\partial p}\right)_h = \frac{T^2}{c_p}\left[\frac{\partial}{\partial T}\left(\frac{v}{T}\right)_p\right]$$

[12 marks]

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Q.1 (e) What are the functional requirements of an injection system? What is the purpose of a fuel injector? Mention the various parts of an injector assembly.

[12 marks]

Q.2 (a) Lubricating oil of specific gravity 0.82 and dynamic viscosity 12.066×10^{-2} N.s/m^2 is pumped at a rate of 0.02 m^3/s through a 0.15 m diameter 300 m long pipe.

Calculate the pressure drop, average shear stress at the wall of the pipe and the power required to maintain the flow:

(i) if the pipe is horizontal;

(ii) if the pipe is inclined at 15 degrees with the horizontal and the flow is

1. in the upward direction,
2. in the downward direction.

Also determine the slope of the pipe and the direction of flow so that the pressure gradient along the pipe is zero.

[20 marks]

→ $\rho = 820$ kg/m^3; $\mu =$

$Q = 0.02$ m^3/s; $D = 0.15$ m; $L = 300$ m;

→ $Q = \frac{\pi}{4} D^2 V$ ∴ velocity through pipe (V)

$0.02 = \frac{\pi}{4} (0.15)^2 V$

$V = 1.13176$ m/s

∴ head loss in pipe, $h_L = \frac{fLV^2}{2gD}$

→ Reynold's no. of flow, $Re = \frac{\rho V D}{\mu} = \frac{820 \times 1.13176 \times 0.15}{12.066 \times 10^{-2}}$

$\therefore$ $\boxed{Re = 1153.717} < 2300$

↳ Flow is Laminar.

$\therefore$ friction factor, $\boxed{f = \frac{64}{Re} = 0.05547}$ $\therefore$ $\boxed{h_L = \frac{fLV^2}{2gD}}$

$\therefore$ $\boxed{h_L = 7.243 m}$

(i) pipe is horizontal :- $(z_1 = z_2)$

Applying Bernoullis equ^n,
bet^n ① & ②

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

$\boxed{V_1 = V_2}$ → same dia. & $\boxed{z_1 = z_2}$

$\therefore$ $\frac{P_1 - P_2}{\rho g} = h_L = 7.243 m$; $\therefore$ Pressure drop $= 7.243 m$
$= 7.243 \times \rho g$
$= \underline{58.264 \ kPa}$

→ $\frac{\Delta P}{L} = \frac{32 \mu V}{D^2} = \left(\frac{\Delta P}{\Delta x}\right) = \frac{32 \times \mu V}{D^2}$

$\therefore$ $\boxed{\frac{\Delta P}{\Delta x} = 194.216}$ ← Pressure drop.

→ Avg. shear stress, $\boxed{\tau_w = -\left(\frac{\partial P}{\partial x}\right) \times \frac{R}{2}}$

↳ −ve → pressure drop.

$\therefore$ $\boxed{\tau_w = 194.216 \times \frac{0.15}{2 \times 2} = 7.2831 \ N/m^2}$

→ Power req. to maintain the flow, $P = \rho Q g h_L$

$P = 820 \times 0.02 \times 9.81 \times 7.243$

$\therefore$ $\boxed{P = 1165.28 \ watt}$

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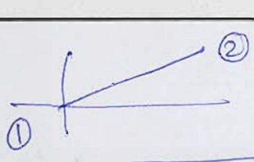
→ pipe → 15° with horizontal

$z \to z_2 - z_1 = L \sin 15^\circ = 77.65\,m.$



→ upward flow, $\frac{P_1 - P_2}{\rho g} = h_L + 77.65$ ∴ Pressure drop $\boxed{\Delta P = 682.8\ kPa}$

∠ ~~Press~~ ~~Eq=~~ $\boxed{\text{Power req.} = \rho Q g (h_L + 77.65) = 13.66\ kW}$

→ downward flow, $\frac{P_1 - P_L}{\rho g} = h_L - 77.65 \Rightarrow \boxed{\Delta P = -566.367\ kPa}$
↳ Pressure increase.

→ no. power is req. to main flow

→ for pressure gradient = 0. in dowward flow.

$0 = h_L \mp L \sin\theta^\circ.$ ∴ ~~L = 7.243~~

∴ $\sin\theta = \frac{h_L}{L} = \frac{7.243}{300}$ → $\boxed{\theta = 1.383^\circ}$
↳ in dowand flow

pressure diff = 0.

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?

Q.2 (b) The steam consumption in a Parson's reaction turbine running at 400 rpm is 5 kg/s. The pressure of the steam at a certain stage is 2 bar, its dryness is 0.96 and the power developed by the stage is 4.4 kW. The discharging blade tip angle is 20° for both fixed and moving blades and the axial velocity of flow is 0.72 of the blade velocity. Calculate the drum diameter and the blade height, assuming the tip leakage as 5 percent and neglect the blade thickness.

Take $v_{g@2\ bar} = 0.8851\ m^3/kg$

[20 marks]

→ $N = 400$ rpm; $\dot{m}_s = 5\,kg/s$;

$P = 2\,bar$; $x_1 = 0.96$; $v_g = 0.8851\ m^3/kg$; ∴ $v_1 = x_1 v_g$
$= 0.849696\ m^3/kg$

∴ $\boxed{\rho_1 = \frac{1}{v_1} = 1.1768915\ kg/m^3}$

→ P.D. = $P = 4.4\,kW$;

→ $\boxed{\theta = 20^\circ}$; $\boxed{V_F = 0.72\,u}$ $D = ?$ $\boxed{H = ?}$

→ we have, mass flow rate, $\dot{m}_s = \rho_1 Q_1$

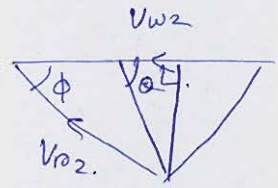
∴ $5 = 1.17689\ (Q_1)$

∴ Discharge = $\boxed{Q_1 = 4.24848\ m^3/sec}$

$[u_1 = u_2 = u]$

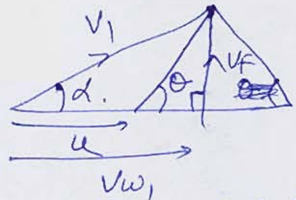
$PD = \dot{m}_s (V_{w1} + V_{w2}) u$

$\therefore \boxed{4400 = 5 (V_{w1} + V_{w2}) u} \quad \ldots (i)$



From velocity Δ,

$\tan\theta = \frac{V_F}{V_{w2}} = \frac{V_F}{V_{w1} - u_1}$



$\therefore V_{w2} = \frac{0.72u}{\tan 20^\circ} = \frac{0.72u}{V_{w1} - u}$

inlet velocity triangle.

→ for parson's Reaction Turbine,

$V_1 = V_{r2}$; & $V_2 = V_{r1}$. $\boxed{\alpha = \phi}$ $\boxed{\theta = B}$

$\therefore \boxed{V_{F1} = V_{F2} = V_F} \quad \therefore \boxed{V_{w2} = V_{w1} - u}$

let $\boxed{V_{w1} = ku}$ $\therefore \boxed{V_{w2} = (k-1)u}$

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Also, $V_{r1} = \frac{V_F}{\sin\theta} = \frac{0.72u}{\sin 20^\circ} = 2.105\,u$

$\boxed{V_{r2} = V_1 = 0.95\,V_{r1} = 2u} = V_1$

~~$V_{r2}\cos\phi =$~~ $V_1^2 = V_{w1}^2 + V_{F1}^2$

$4u^2 = k^2u^2 + 0.72^2u^2$

$\therefore 4 = k^2 + 0.72^2$

$\therefore \boxed{k = 1.86577}$

$\therefore \boxed{V_{w1} = 1.86577\,u}$ $\boxed{V_{w2} = 0.86577\,u}$

$\therefore$ from (i), $\frac{4400}{5} = 2.7315\,u^2$

$\therefore \boxed{u = \text{blade speed} = 17.95\ \text{m/s} = \frac{\pi D N}{60}}$

$\therefore 17.95 = \frac{\pi D (400)}{60}$

$\therefore \boxed{\text{Drum Dia} = D = 0.857\,\text{m}}$

→ we have, Discharge, $Q = \pi D_M H V_F$.

$V_F = 0.72u = 0.72 \times 17.95 = 12.924$ m/s.

$\therefore$ $Q = 4.24848 = \pi \times 0.857 \times H \times 12.924$

$\therefore$ Blade Height, $H = 0.122$ m

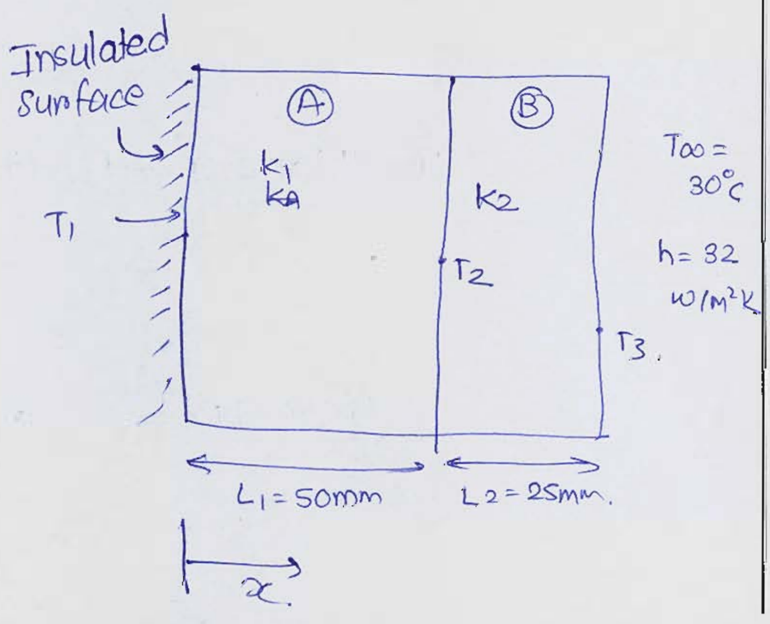
Q.2 (c) An infinite composite slab is made of two layers A and B of different materials. The layer A is 5 cm thick, has thermal conductivity 0.4 (1 + 0.07 *t*) W/mK, where *t* is the temperature in °C, and its exposed surface is insulated (There is a very thin source of heat). The layer *B* is 2.5 cm thick, has thermal conductivity 25 W/mK and its outside surface is exposed to a fluid at 30°C where the convective heat transfer coefficient is 32 W/m²K. The temperature at the interface between the two layers is estimated to be 70°C. Determine:

1. rate of heat flux from the slab to the fluid.
2. maximum temperature in the system, and
3. location of the point (from insulated surface) where the temperature is 80°C.

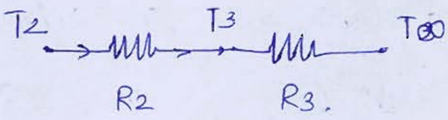
[20 marks]

→

$T_2 = 70°C$;



from ~~B~~ wall (B),



$R_2 = \dfrac{L_2}{k_2 A_2}$ &

→ Taking ($A_2 = 1m^2$) per m^2 analysis,

→ $R_2 = \dfrac{0.025}{25 \times 1} = 10^{-3}$ K/W → $R_3 = \dfrac{1}{hA} = \dfrac{1}{32 \times 1} = 0.03125$ (K/W)

→ Heat ~~to~~ conducted from wall (B),

$$q = \frac{T_2 - T_\infty}{R_2 + R_3} = \frac{70 - 30}{10^{-3} + 0.03125} = 1240.31 \text{ W/m}^2$$

(1) ∴ Rate of heat flux from slab to fluid, $q = 1240.31 \dfrac{W}{m^2}$

→ for wall (A), Heat conduction 1D equ^n at steady state,

$$\frac{\partial}{\partial x}\left(k_1 \frac{\partial T}{\partial x}\right) + \dot{q}_g = 0 \qquad \dot{q}_g = 0$$

∴ ~~0.4(1+0.07t) = C_1~~

Integrating, $0.4(1+0.07t)\dfrac{dT}{dx} = C_1$ ... (1)

→ Integrating again, $0.4\left[T + \dfrac{0.07\,T^2}{2}\right] = C_1 x + C_2$ ... (2)

→ from (1) at $x = 0.05$ m; ~~$\frac{dT}{dx}$ $-\frac{dT}{dx}$~~ $= -k_1 \dfrac{dT}{dx} = -C_1 = 1240.31$ W/m^2.

∴ $C_1 =$ ~~124~~ -1240.31 W/m^2

→ from (2) $0.4\left[T_2 + \dfrac{0.07\,T_2^2}{2}\right] = -1240.31(0.05) + C_2$

∴ $T_2 = 70°C$ → $C_2 = 158.6155$

∴ → at $x = 0$; from (2) $0.4\left[T_{max} + \dfrac{0.07\,T_{max}^2}{2}\right] = C_1(0) + C_2$

(2) ∴ $T_{max} = 93.1°C$

Maximum temp in system

→ locatⁿ where $T = 80°C$

∴ from eqⁿ (3), $0.4\left[80 + \frac{0.07(80)^2}{2}\right] = -1240.31(x) + 158.6155$

∴ $x = 0.0298437$ m

i.e. $x = 29.8437$ mm from LHS of wall A

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Q.3 (a) A water heater tank contains 150 kg of water at 6 bar and 15°C. The water is to be heated to 6 bar and 75°C. Assume that the pressure is maintained constant by an internal diaphragm. The environment is at 1 bar and 10°C. Calculate

(i) The change in the availability of the water.

(ii) The total change in availability when heated electrically.

(iii) The total availability change when heated by condensing steam at $p = 1$ bar.

(iv) The irreversibility when heated electrically.

(v) The irreversibility when heated by condensing steam at $p = 1$ bar.

[Use Steam Tables attached at the end]

[20 marks]

→ Initially (1) → Tank → $m_w = 150$ kg. $T_1 = 15°C$

↳ $P = 6$ bar → $T_2 = 75°C$ → $T_{sat} = 158.826°C$

from steam table.

$v_2 = 0.001025557$ m³/kg ; $u_2 = 313.86$, $h_2 = 314.48$ } kJ/kg

$s_2 = 1.0154$ kJ/kgK

$T_1 = 15°C$ → $v_1 = 0.00100067$ m³/kg

$u_1 = 62.95$, $h_1 = 63.55$ } kJ/kg $s_1 = 0.224372$ kJ/kg K

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→ change in availability of water.

→ $\phi_2 - \phi_1 = (h_2 - h_1) - T_0(s_2 - s_1)$

$= (314.48 - 63.55) - 283(1.0154 - 0.22437)$

$= -12.15529$ kJ/kg.

2

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Q.3 (b) The impeller of a centrifugal pump has an outer diameter of 27 cm and rotates at a speed of 1440 rpm. The impeller has 10 blades, each of 6 mm thickness. The blades are backward facing at 35° to the tangent. The breadth of the flow passages at the outlet is 12 mm. Pressure gauges are fitted close to the pump at the suction and discharge pipes and both are 2.4 m above the water level of the supply sump. When the discharge is 25 L/S, the pressure readings are 4 m water (vacuum) in the suction end and 16 m of water (gauge) at the delivery end of the pump. If 50% of the velocity is recovered as static head in the volute. If mechanical efficiency of the pump is 0.85. Determine:

(i) Theoretical head

(ii) Manometric efficiency

(iii) Losses in the impeller

(iv) Capacity of the motor to drive the pump

[Assume that there is no whirl at inlet and no whirl slip]

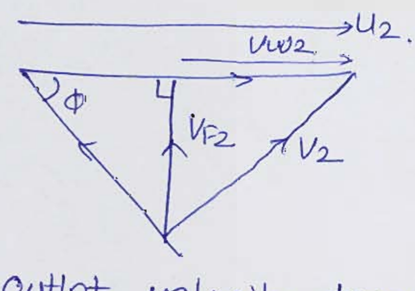
[20 marks]

→ $D_2 = 0.27m$; $N = 1440 rpm$.

∴ vane speed, $u_2 = \frac{\pi D_2 N}{60} = 20.3575 \, m/s$

→ backward vane, $\phi = 35°$.

→ $B_2 = 0.012m$

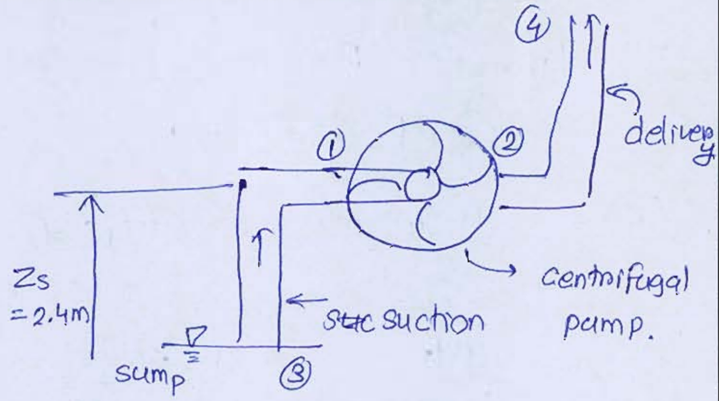


outlet velocity triangle.

→ $Q = 0.025\,m^3/s$

$\boxed{\frac{P_1}{\rho g} = -4m}$ (gauge)

$\boxed{\frac{P_2}{\rho g} = 16m}$ (gauge).



→ 50% of velocity
↳ recoved as static head in volute.

→ $\boxed{\eta_m = 0.85}$

$0.025 = (\pi D_2 - 10t) B_2 V_{F2}$.
$\therefore 0.025 = (\pi(0.27) - 10 \times 6 \times 10^{-3}) \times 0.012\, V_{F2}$
$\therefore \boxed{V_{F2} = 2.643\,m/s}$

→ At outlet, discharge, ~~$Q = 0.025\,m^3/s = \pi D_2 B_2 V_{F2}$~~

~~$\therefore 0.025 = \pi \times 0.27 \times 0.012\, V_{F2}$~~

$\therefore$ ~~$V_{F2} = 2.456\,m/s$~~ $\boxed{V_{F2} = 2.643\,m/s}$

→ from vel: triangle, $\tan\phi = \frac{V_{F2}}{U_2 - V_{w2}}$

$\therefore U_2 - V_{w2} = \frac{2.643}{\tan 35^0} = $ ~~3.507 m/s~~. 3.77467

$\therefore \boxed{V_{w2} = U_2 - 3.77467}$ = ~~16.85 m/s~~ $\boxed{V_{w2} = 16.5628\,m/s}$

→ velocity at outlet, $V_2^2 = V_{w2}^2 + V_{F2}^2 \Rightarrow \boxed{V_2 = 16.792\,m/s}$

~~$\therefore V_2 = \sqrt{16.85^2 + 2.456^2} = 17.027$~~

→ Applying Bernoullis Equn on Centrifugal Pump betn ① & ②,

$$\boxed{\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 + H_p = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 - 0.5\frac{V_2^2}{2g}}$$

& $\boxed{Z_1 = Z_2}$ $\boxed{V_1 = V_F = 2.643\,m/s}$ as $\boxed{V_{w1} = 0}$

$\therefore -4 + \frac{(2.643)^2}{2g} + H_p = 16 + (0.5)\frac{(16.792)^2}{2g}$

$\therefore$ (i) Theoretical Head, ~~$H_p = 41.2\,m$~~ $\boxed{H_p = 26.83\,m}$

→ Impeller Power, $IP = \rho Q V_{w2} u_2$

→ Water Power, $WP = \rho Q g H_p$.

(ii) ∴ manometric efficiency, $\eta_m = \frac{WP}{IP}$

$$\therefore \eta_{mano} = \frac{gH_p}{V_{w2}u_2} = \frac{9.81 \times 26.83}{20.3575 \times 16.5828} = 0.7796$$

$$\therefore \eta_{manometric} = 77.96\,\%$$

(iii) $IP = \rho Q V_{w2} u_2 = 10^3 \times 0.025 \times (20.3575 \times 16.5828)$
$= 8439.6$ watt

$WP = \rho Q g H_p = 6580.0575$ watt

→ losses in impeller $= IP - WP$
$= 1859.5425$ watt
$= \frac{1859.5425}{\rho Q g} = 7.582\,m$

(iv) $\eta_{mech} = \frac{IP}{SP}$ → shaft Power

∴ Shaft Power $= \frac{IP}{0.85} = \frac{8439.6}{0.85}$

$\therefore SP = 9928.94$ watt

↳ capacity of motor to drive pump.

Q.3 (c) A very long, 10 mm diameter copper rod (k = 370 W/mK) is exposed to an environment at 20°C. The base temperature of the rod is maintained at 120°C. The heat transfer coefficient between the rod and the surrounding air is 10 W/m^{2}K.

(i) Determine the heat transfer rate for finite lengths, 0.02, 0.04, 0.08, 0.2, 0.4, 0.8, 1 and 10 meters assuming heat loss at the end, and

(ii) Compare the results with that of an infinitely long fin whose tip temperature equals the environment temperature of 20°C.

[20 marks]

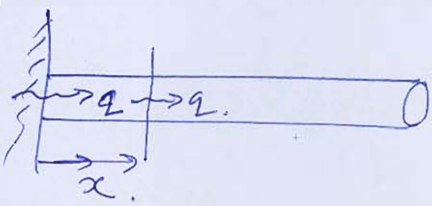
→ $D = 10\,mm$; $T_\infty = 20°C$; $T_b = 120°C$.

∴ $\theta_b = T_b - T_\infty = 100°C$ $h_o = 10\,W/m^2K$.

→ Perimeter,

$P = \pi D =$

$A_c = \frac{\pi}{4} D^2$



3

$m = \sqrt{\frac{hP}{kA_c}} = \sqrt{\frac{10 \times \pi D \times 4}{370 \times \pi D^2}}$ ∴ $m = 3.2879$

→ we have, heat lost from fin,

$q = \sqrt{hPkA_c}\,(\theta_x)\tan h(mx)$

$\sqrt{hPkA_c} = \sqrt{10 \times \pi D \times 370 \times \frac{\pi}{4} D^2}$

$= 0.095548$

$= k_1$ (let)

Also, we have,

$\frac{\theta_x}{\theta_b} = e^{-mx}$ ∴ $\theta_x = 100 e^{-mx}$

$q = ~~0.00~~\, K_1 \times 100 \times e^{-mx} \tan h(mx)$

where, $K_1 = 0.095548$ & $m = 3.2879$.

at $x = 0.02\,m$; $q = 0.58747\,W$

at $x = 0.04\,m$ → $q = 1.09544$

at $x = 0.08\,m$ → $q =$ ~~1.888~~

at $x = 0.2\,m$ → $q =$

at $x = 0.4\,m$ → $q =$

at $x = 0.8\,m$ → $q =$

at $x = 1\,m$ → $q =$

at $x = 10\,m$ → $q =$

→ for infinitely long fin,

$$q = \sqrt{hPkA_c} \times \theta_b.$$

$$q = 0.095548 \times 100$$

$$\boxed{q = 9.5548\ W}$$

Q.4 (a) An air-conditioned auditorium is to be maintained at 28°C DBT and 50% R.H. as shown in figure. The ambient condition is 40°C DBT and 40% R.H. The total sensible heat load is 34 kW and the total latent heat load is 45000 kJ/h. 65% of the return air is recirculated and mixed with 35% of make up air after the cooling coil. The condition of air leaving the coil is 17°C. Determine:

(i) Room sensible heat factor.

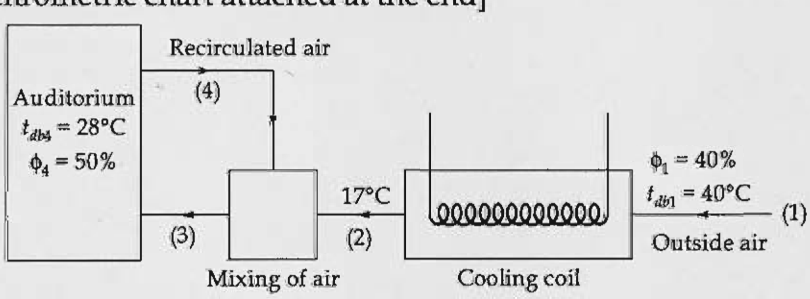
(ii) Condition of air entering the auditorium

(iii) Amount of make up air

(iv) Apparatus dew point

(v) By pass factor of the cooling coil

[Use Psychrometric chart attached at the end]



[20 Marks]

Q.4 (b) Explain the working principles of a Cyclone separator and a bag filter used in particulate matter removal from industrial flue gases with the help of neat sketches.

[20 Marks]

Q.4 (c) A vertical gate of width B and height H retains water on one side upto its top edge. Find the depths of two horizontal lines which divide the gate into three portions such that the total pressure on each portion is equal. Also locate the position of the centre of pressure for each of the three portions. Hence show that if a gate is divided into N such portions each of which is subjected to equal total pressure then the height of the each portion is given by

$$h_n = H\sqrt{\frac{n}{N}}$$

and the depth of centre of pressure for each portion below the top of the gate is given by

$$\bar{h}_n = \frac{2}{3}H\frac{\left[n^{3/2} - (n-1)^{3/2}\right]}{\sqrt{N}}$$

where $n = 1, 2, 3 \ldots.., N$

[20 marks]

Section : B

Q.5 (a) A single basin type tidal power plant has a basin area of 4 km^2. The tidal range of 12 m on average. Power generation is carried out only during the flood cycle and the turbine stops operating when the head on it falls below 3.6 m. Assuming the density of seawater to be 1027 kg/m^3 and the turbine-generator efficiency as 72%. Determine:

(i) The average power output (in MW) generated during a single filling of the basin.

(ii) The average annual energy output (in kWh) of the plant, assuming two tidal cycles per day and 365 days in a year.

[12 marks]

→ $A = 4\times10^6 \; m^2$; $R = 12m$; $r = 3.6m$;

$\rho = 1027 \; kg/m^3$; $\eta_{tg} = 72\%$.

→ during single filling of basin,

time req. for filling = 6 hrs 12.5 min

$t = 22350$ sec

→ $\text{Energy} = \dfrac{\rho A g (R^2 - r^2)}{2}$

$= \dfrac{1027\times4\times10^6\times9.81(12^2-3.6)^2}{2}$

$= 2.64\times10^{12}$ Joules.

(i) → Avg. Power ↳ one filling $= \dfrac{E}{t} = $ 118.139 MW

6

→ Two tidal cycles per day.

∴ Total Annual Tidal cycles = 365 × 2

= 730 cycles.

→ Energy given in one cycle = 2.64×10^{12} J

∴ Energy give by plant annually = $2.64\times10^{12}\times730$

$= 1927.2\times10^{12}$ J

$= 1927.2\times10^9$ kJ

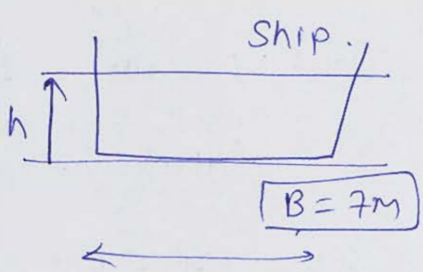
$= 535.33\times10^6$ kWh

Q.5 (b) A merchant ship coming into port has a draught of 1.25 m. After unloading its cargo it has a draught of 1 m. Find the ratio of the periodic times before and after leaving the cargo if the breadth of the ship is 7 m and it is assumed that the centre of gravity remains at the water line.

[12 marks]

→ initially, $h_1 = 1.25m$;

after unloading, $h_2 = 1m$.



→ initial periodic time

$$T_1 = 2\pi \sqrt{\frac{k^2}{g(GM)}}$$

→ Vol^m of fluid displaced, $V_{fd_1} = L(B)h_1$

→ $I_{N/A}$ → free surface, $= I = \frac{LB^3}{12} = k$

→ $BM_1 = \frac{I}{V} = \frac{LB^3}{12 \times LBh_1} = \frac{B^2}{12 \times h_1} = 3.266\ m.$

→ Metacentric height initially, $GM_1 = BM_1 - BG_1$

$= 3.266 - h_1 = \cdot$

$$GM_1 = 3.266 - 1.25 = 2.01667\,m$$

→ finally → Vol^m of fluid displaced, $V_{fd_2} = LBh_2$

$$\therefore I_{NA} = \frac{LB^3}{12}$$

$$\therefore BM_2 = \frac{I_2}{V_{fd_2}} = \frac{LB^3}{12 \times LB(1)} = \frac{B^2}{12} = ~~4.08\,m~~ \; 4.0833\,m.$$

→ Metacentric Height, $GM_2 = BM_2 - h_2$

$$\therefore GM_2 = 4.0833 - 1 = 3.0833\,m$$

→ we have,
periodic time $= t = 2\pi\sqrt{\frac{k^2}{g(GM)}}$

$$\therefore t \propto \frac{1}{\sqrt{GM}}$$

4

∴ Ratio → before & after, $\frac{t_1}{t_2} = \sqrt{\frac{GM_2}{GM_1}}$

$$\therefore \frac{t_1}{t_2} = \sqrt{\frac{3.08333}{2.01667}} = 1.2365$$

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Q.5 (c) What is the function of a thermostatic expansion valve used in vapour compression refrigeration systems? Discuss with the help of a neat sketch the working of an internally equalized thermostatic expansion valve. How does it differ from an externally equalized thermostatic expansion valve?

[12 marks]

Q.5 (d) An axial flow compressor of 50% reaction blading has isentropic efficiency of 82%. It draws air at 17°C and compresses in the pressure ratio of 4 : 1. The mean blade speed and flow velocity are constant throughout the compressor. The inlet and outlet angles of blades are 45° and 15° respectively (angles measured from axial direction). Blade speed = 180 m/s and work input factor = 0.84 . Calculate (i) flow velocity and (ii) number of stages.

[12 marks]

→ $\eta_{is} = 82\%$;

$T_1 = 17°C ; = 290 K ; \quad r_p = 4 ; \quad u_1 = u_2 = u = 180 m/s.$

$V_F = V_{F_1} = V_{F_2} = ?$

→ ~~$\alpha = 45°$~~ , $\theta = 45° ; \ \phi = 15°.$

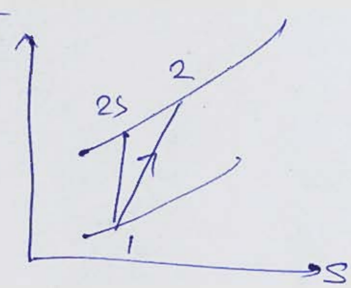
→ $\psi = 0.84$;

→ $\frac{(V_{w_2} - V_{w_1})u}{2g} = \frac{V_2^2 - V_1^2}{2g} + \frac{V_{r_1}^2 - V_{r_2}^2}{2g}$,

→ 50% Reaction → $\frac{V_2^2 - V_1^2}{2g} = \frac{0.5 \times (V_{w_2} - V_{w_1})u}{2g}$

→ $\boxed{(V_2^2 - V_1^2) = 0.5 (V_{w_2} - V_{w_1}) u}$.

→ Air → Ideal gas,



$\frac{T_{2s}}{T_1} = (r_p)^{\frac{\gamma-1}{\gamma}}$

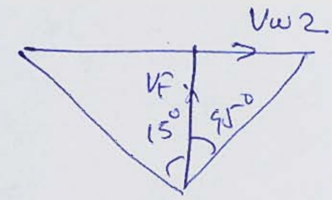
$\therefore T_{2s} = 290(4)^{\frac{\gamma-1}{\gamma}}$

$\therefore$ $\boxed{\gamma = 1.4}$ $\boxed{T_{2s} = 430.938 K}$

→ $\eta_{is} = .82 = \frac{T_{2s} - T_1}{T_2 - T_1} = \frac{430.938 - 290}{T_2 - 290} \Rightarrow \boxed{T_2 = 461.876 K}$

→ 50% Reaction,

$\boxed{\theta = B}$ $\boxed{\alpha = \phi}$



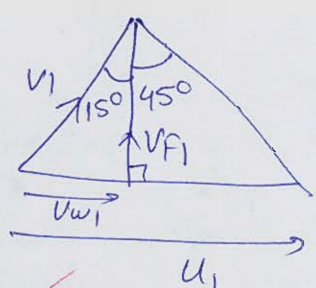
→ from vel. Δ,

$\tan 45^\circ = \frac{u_1 - V_{w1}}{V_{F1}}$.

$\therefore \boxed{180 - V_{w1} = V_{F1}}$

Also, $\tan 15^\circ = \frac{V_{w1}}{V_{F1}}$.

$\therefore \boxed{V_{w1} = 0.26795 V_{F1}}$



Vel. Δ inlet.

(i) $\boxed{\therefore V_{F1} = 141.96 m/s}$

↳ flow velocity.

12

$\therefore$ from outlet vel. Δ, $\tan 45^\circ = \frac{V_{w2}}{V_F}$.

$\therefore \boxed{V_{w2} = 141.96 m/s}$

→ $180 - V_{w1} = V_{F1}$ $\therefore$ $V_{w1} = 180 - V_F$

$\boxed{V_{w1} = 38.0384 m/s}$

→ 1 stage, work input, $w_{i/p} = \psi(V_{w2} - V_{w1})u$

$w_{i/p} = 0.84(141.96 - 38.0384)180 = \underline{15.712} kJ/kg$.

→ Total work input $= C_p(T_2 - T_1) = 1.005(461.876 - 290)$
$= 172.735 kJ/kg$

$\therefore$ no. of stages $= \boxed{n = \frac{172.735}{15.712} = 10.99 \approx 11 \text{ stages}}$

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Q.5 (e) What are the components of a photovoltaic (PV) system? How long do PV systems last? What's the difference between PV and other solar energy technologies? Briefly explain.

[12 marks]

Q.6 (a) What is a fuel cell and what are its main advantages? Classify fuel cells based on

(i) Type of electrolyte

(ii) Types of the fuel and oxidant

(iii) Operating temperature

(iv) Application

(v) Chemical nature of electrolyte

[20 marks]

Q.6 (b) A six cylinder four stroke CI engine develops 150 kW output at 1600 rpm. The calorific value of the fuel is 42000 kJ/kg and its percentage composition by mass is 85% carbon, 14% hydrogen and 1% non-combustibles. The absolute volumetric efficiency is 83%, the indicated thermal efficiency is 37% and the mechanical efficiency is 78%. The air consumption is 115% in excess of that required for stoichiometric combustion. Estimate the volumetric composition of dry exhaust gas and determine the bore and stroke of the engine taking a stroke/bore ratio as 1.25. Assume the density of the air at the given conditions as 1.26 kg/m^3 and air having only 23% of oxygen by mass and 21% by volume.

[20 marks]

Q.6 (c) In a jet propulsion unit air is drawn into the rotary compressor at 20°C and 1.01 bar and delivered at 4.04 bar. The isentropic efficiency of compression is 80% and the compression is uncooled. After delivery the air is heated at constant pressure until the temperature reaches 720°C. The air then passes through a turbine unit which drives the compressor only and has an isentropic efficiency of 75% before passing through the nozzle and expanding to atmospheric pressure of 1.01 bar with an efficiency of 85%. Neglecting any mass increase due to the weight of the fuel and assuming that R and y are unchanged by combustion, determine:

(i) The power required to drive the compressor.

(ii) The air-fuel ratio if the fuel has a calorific value of 42000 kJ/kg.

(iii) The pressure of the gases leaving the turbine.

(iv) The thrust per kg of air per second.

Neglect any effect of the velocity of approach.

Assume for air: $R = 0.287$ kJ/kgK; $\gamma = 1.4$

[20 marks]

Q.7 (a) A tank of volume 0.9 m^3 initially contains liquid vapour mixture at 240°C and dryness fraction is 0.6. From the top of the tank, saturated water vapour is withdrawn at 240°C through the valve and simultaneously heat is transferred to maintain the constant pressure. This continues till the dryness fraction becomes 0.9 at the same temperature. Neglect the changes in kinetic and potential energy.

(i) Calculate the initial mass in the tank.

(ii) Calculate the final mass in the tank.

(iii) What is the amount of heat transfer?

Properties at T = 240°C

$v_f = 0.001229\ m^3/kg$, $v_g = 0.05965\ m^3/kg$, $h_f = 1037.6$ kJ/kg, $h_g = 2802.2$ kJ/kg, $u_f = 1033.48$ kJ/kg, $u_g = 2602.4$ kJ/kg

[20 marks]

→ $V = 0.9 m^3$; initially → ①; $T_1 = 240°C$; $x_1 = 0.6$.

∴ its specific vol^m → $v_1 = v_f + x_1 v_{fg}$

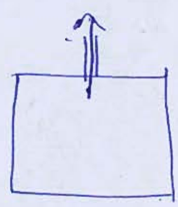
∴ $v_1 = 0.001229 + 0.6 v_{fg}$

∴ $v_1 = 0.0362816\ m^3/kg$

(i) ∴ initial mass in tank → $m_1 = \frac{V}{v_1} = \frac{0.9}{0.0362816} = 24.806$ kg

(ii) final condi^n → ②

$x_2 = 0.9$



∴ its specific vol^m

$v_2 = v_f + 0.9 (v_{fg})$

∴ $v_2 = 0.0538\ m^3/kg$

→ ∴ final mass in the tank, $m_2 = \frac{V}{v_2} = \frac{0.9}{0.0538}$

∴ $m_2 = 16.726$ kg

consv. of mass

→ ∴ mass exit from tank, $m_e = m_1 - m_2$

$m_e = 8.08$ kg

→ mass inlet $m_i = 0$

Initially, $x_1 = 0.6$; $\therefore$ $u_1 = u_f + 0.6 \times u_{fg}$

$u_1 = 1033.48 + 0.6\,(u_{fg})$

$\boxed{u_1 = 1974.832 \text{ kJ/kg}}$

finally, $x_2 = 0.9$;

$u_2 = u_f + 0.9\,(u_{fg})$

$\therefore \boxed{u_2 = 2445.508 \text{ kJ/kg}}$

$h_2 = h_f + 0.9\,(h_{fg})$

$\boxed{h_2 = 2625.74 \text{ kJ/kg}}$

→ Applying cons. of ~~mass~~ energy,

$\boxed{U_2 - U_1 = m_i h_i + Q - m_e h_e - W.}$

$m_i = 0$; $W = 0$.

$\boxed{m_2 u_2 - m_1 u_1 = 0 + Q - (8.08) h_e}$

exit → saturated vap. → $\boxed{h_e = h_g = 2802.2 \text{ kJ/kg}}$

$\therefore$ $16.726 \times (2445.508) - 24.806\,(1974.832) = Q - 8.08 \times 2802.2$

$\Rightarrow$ $-8084.115 = Q - 22641.776.$

(iii) $\therefore$ $\boxed{Q = +14557.661 \text{ kJ}}$

+ve → Heat added to system.

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Q.7 (b) Explain the construction and working of vortex tube with a suitable schematic diagram. Also draw T-s diagram and mention points clearly.

[20 marks]

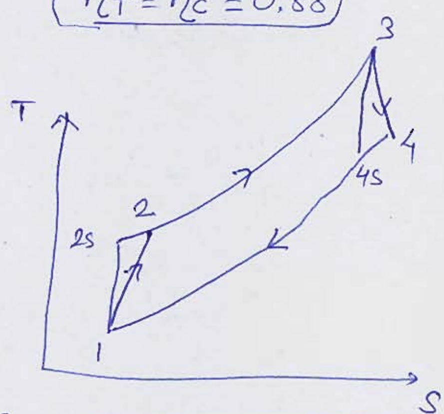
Q.7 (c) Air at temperature of 20°C enters a gas turbine plant working at pressure ratio of 5. Turbine inlet temperature is 780°C. Polytropic efficiency of compressor and turbine is 0.88. Assume, c_p = 1.005 kJ/kg-K for air and gases, calorific value of fuel = 42 MJ/kg of fuel. Calculate the following:

(i) Specific output of the plant (in kJ/kg of air)
(ii) Overall efficiency of the plant
(iii) Air fuel ratio
(iv) Specific fuel consumption

[20 marks]

→ Air → $T_1 = 293\ K$; $r_p = 5$;
Turbine → $T_3 = 780°C = 1053\ K$;

$\eta_T = \eta_c = 0.88$



→ Assuming Air → ideal gas,

$\frac{T_{2s}}{T_1} = (r_p)^{\frac{\gamma-1}{\gamma}}$

$\therefore T_{2s} = 464\ K$

$\eta_c = 0.88 = \frac{T_{2s} - T_1}{T_2 - T_1} = \frac{464 - 293}{T_2 - 293}$ $\therefore T_2 = 487.385\ K$

→ lly, $\frac{T_3}{T_{4s}} = (r_p)^{\frac{\gamma-1}{\gamma}}$ $\therefore T_{4s} = 664.85\ K$

$\eta_T = 0.88 = \frac{T_3 - T_4}{T_3 - T_{4s}} = \frac{1053 - T_4}{1053 - 664.85}$ $\Rightarrow T_4 = 711.43\ K$

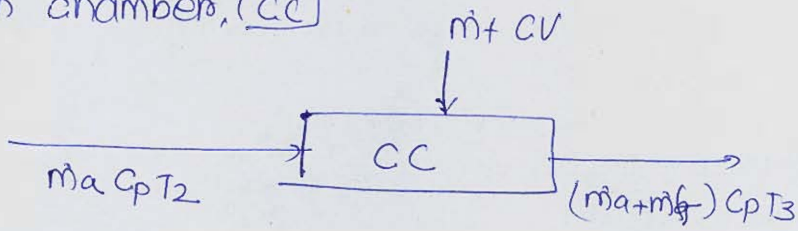
→ Work done by turbine, $W_T = C_p(T_3 - T_4)$
$= 1.005(1053 - 711.43)$
$= 343.2812\ kJ/kg.$

→ Work done by compressor, $W_c = C_p(T_2 - T_1)$
$= 1.005(487.385 - 293)$
$= 195.3567\ kJ/kg.$

→ (i) Specific output of Plant, $W_{net} = W_T - W_c$
$= 343.28 - 195.36$
=
$W_{net} = 147.92\ kJ/kg$

→ ~~Heat added; $Q_s = C_p(T_3 - T_2)$.~~

→ combustion chamber, (CC)



∴ Heat Balance equ^n;

$$\dot{m}_a C_p T_2 + \dot{m}_f \times CV = (\dot{m}_a + \dot{m}_f) C_p T_3.$$

$$\therefore \frac{\dot{m}_a}{\dot{m}_f} \times 1.005 \times (487.385) + 42000 = \left(\frac{\dot{m}_a}{\dot{m}_f} + 1\right) 1.005 \times 1053$$

(iii) $\therefore \boxed{\frac{\dot{m}_a}{\dot{m}_f} = 72.024}$ ← Air fuel ratio.

→ ∴ Heat added in comb. chamber $= \dot{m}_f \times CV$

$= 42000$ kJ/kg of fuel

$$Q_s = \frac{42000}{72.024} \times \cancel{72.024} \text{ kJ/kg of air}$$

$$Q_s = 583.136 \text{ kJ/kg of air},$$

(ii) ∴ efficiency of Plant, $\eta = \frac{W_{net}}{Q_s} = \frac{147.92}{583.136}$

$\therefore \boxed{\eta = 0.25366}$ or $\boxed{25.366\%}$

(iv) ~~$sfc = \frac{3600}{W_{net}} = \frac{3600}{147.92} =$~~

$$sfc = \frac{3600}{W_{net} \times AFR} = \frac{3600}{147.92 \times 72.024}$$

$\therefore \boxed{sfc = 0.3379 \text{ kg/kWhr}}$

↳ specific fuel consumption.

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Q.8 (a) (i) Explain the following terms of solar radiation geometry:

1. Latitude
2. Declination
3. Hour angle

Illustrate these terms with neat sketch.

(ii) Calculate the volume of the fixed dome type biogas digester for the output of the two cows. Also calculate the thermal power available from biogas. Use the following data:

Retention time = 50 days; Dry matter produced = 2 kg/day/cow

Biogas yield = 0.22 m^3/kg of dry matter; Percentage of dry matter in cow dung = 18%

Density of slurry = 1090 kg/m^3; Burner efficiency = 60%

Heating value of biogas = 22 MJ/m^3;

Digester volume occupied by the gas = 10%

[Add equal amount of water to make the slurry]

[10 + 10 marks]

Q.8 (b) A 4-stroke diesel engine of 3000 c.c. capacity develops 14 kW per m^3 of free air inducted per minute. When running at 3500 rpm it has a volumetric efficiency of 85 percent referred to free air conditions of 1.013 bar and 27°C. It is proposed to boost the power of the engine by supercharging by a blower (driven mechanically from the engine) of the pressure ratio 1.6 and isentropic efficiency of 80 percent. Assuming that at the end of induction the cylinder contains a volume of charge equal to the swept volume at the pressure and temperature of the delivery from the blower? Estimate the increase in brake power to be expected from the engine. Take overall mechanical efficiency as 90 percent.

[20 marks]

Q.8 (c) (i) Explain the different types of condensation based on the condition of the cooling surface, with the help of neat sketches.

(ii) A reversible cycle using an ideal gas as the working substance consists of an isentropic compression from initial temperature to 555 K, a constant volume process 555 K to 835 K, a reversible adiabatic expansion to 555 K, a constant pressure expansion from 555 K to 835 K followed by a constant volume process to initial temperature. Draw the cycle on p-V and T-s diagrams and determine the initial temperature. Also compute the work done in kJ/kg. Assume $R = 0.287$ kJ/kgK, $\gamma = 1.4$.

[10 + 10 marks]

OOOO

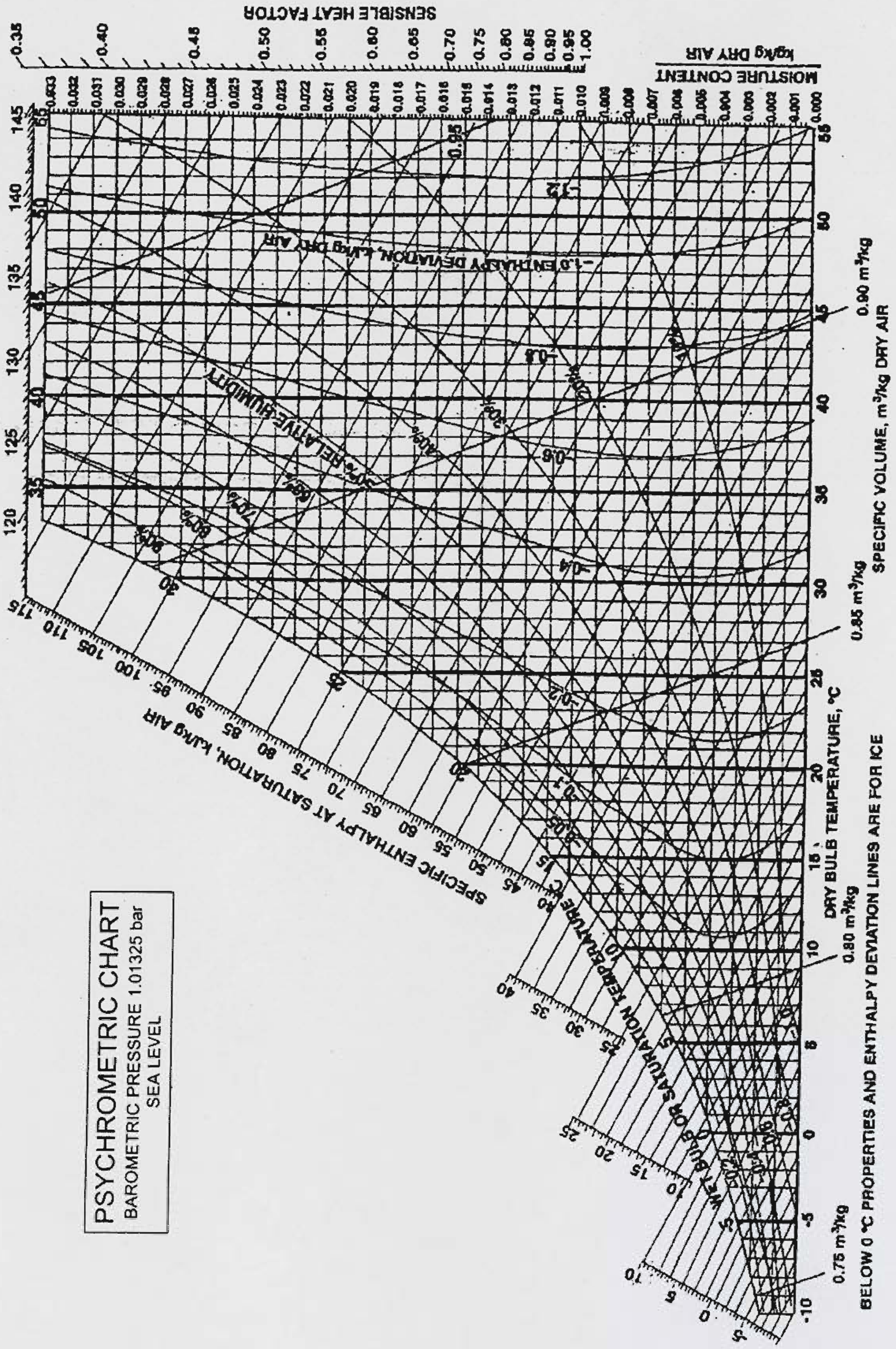
Water/Steam at $p = 0.60$ MPa ($T_{sat} = 158.826$°C)

T	v	u	h	s
°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg K
0	0.00099990	-0.03	0.57	-0.00011
5	0.00099979	21.02	21.62	0.07624
10	0.00100006	42.01	42.61	0.15103
15	0.00100067	62.95	63.55	0.22437
20	0.00100157	83.88	84.48	0.29636
25	0.00100273	104.78	105.38	0.36707
30	0.00100415	125.68	126.28	0.43657
35	0.00100578	146.57	147.17	0.50492
40	0.00100762	167.46	168.06	0.57217
45	0.00100966	188.34	188.95	0.63836
50	0.00101189	209.24	209.85	0.70354
55	0.00101429	230.14	230.75	0.76773
60	0.00101687	251.06	251.67	0.83098
65	0.00101961	271.98	272.59	0.89333
70	0.00102251	292.92	293.53	0.95479
75	0.00102557	313.86	314.48	1.0154
80	0.00102879	334.83	335.45	1.0752
85	0.00103217	355.82	356.44	1.1342
90	0.00103569	376.83	377.45	1.1925
95	0.00103937	397.86	398.48	1.2500
100	0.00104321	418.91	419.54	1.3068
105	0.00104719	440.00	440.63	1.3630
110	0.00105134	461.12	461.75	1.4184
115	0.00105564	482.27	482.90	1.4733
120	0.00106010	503.45	504.09	1.5275
125	0.00106472	524.69	525.33	1.5812
130	0.00106951	545.97	546.61	1.6343
135	0.00107447	567.29	567.93	1.6869
140	0.00107961	588.67	589.32	1.7390
145	0.00108492	610.11	610.76	1.7905
150	0.00109042	631.61	632.26	1.8417
155	0.00109611	653.16	653.82	1.8923
158.826	0.00110060	669.72	670.38	1.9308
158.826	0.31558	2566.8	2756.1	6.7592
160	0.31668	2569.0	2759.0	6.7659
165	0.32129	2578.3	2771.1	6.7937
170	0.32583	2587.5	2783.0	6.8206
175	0.33032	2596.4	2794.6	6.8466
180	0.33475	2605.1	2806.0	6.8720
185	0.33915	2613.8	2817.3	6.8968
190	0.34350	2622.4	2828.5	6.9211
195	0.34783	2630.9	2839.6	6.9449
200	0.35212	2639.3	2850.6	6.9683
210	0.36063	2656.0	2872.4	7.0139
220	0.36905	2672.5	2893.9	7.0580
230	0.37740	2688.9	2915.3	7.1008
240	0.38568	2705.1	2936.5	7.1426
250	0.39390	2721.3	2957.6	7.1832
260	0.40208	2737.3	2978.5	7.2230
270	0.41021	2753.4	2999.5	7.2619

T	v	u	h	s
°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg K
270	0.41021	2753.4	2999.5	7.2619
280	0.41831	2769.3	3020.3	7.3000
290	0.42638	2785.4	3041.2	7.3373
300	0.43442	2801.3	3062.0	7.3740
310	0.44243	2817.3	3082.8	7.4100
320	0.45042	2833.3	3103.6	7.4453
330	0.45839	2849.4	3124.4	7.4801
340	0.46634	2865.5	3145.3	7.5144
350	0.47427	2881.5	3166.1	7.5481
360	0.48219	2897.7	3187.0	7.5813
370	0.49010	2913.8	3207.9	7.6141
380	0.49799	2930.0	3228.8	7.6464
390	0.50587	2946.3	3249.8	7.6782
400	0.51374	2962.6	3270.8	7.7097
410	0.52160	2978.8	3291.8	7.7407
420	0.52945	2995.2	3312.9	7.7713
430	0.53729	3011.6	3334.0	7.8016
440	0.54513	3028.1	3355.2	7.8315
450	0.55296	3044.7	3376.5	7.8611
460	0.56078	3061.2	3397.7	7.8903
470	0.56859	3077.9	3419.1	7.9192
480	0.57640	3094.7	3440.5	7.9478
490	0.58420	3111.4	3461.9	7.9761
500	0.59200	3128.2	3483.4	8.0041
520	0.60758	3162.1	3526.6	8.0592
540	0.62315	3196.1	3570.0	8.1132
560	0.63870	3230.4	3613.6	8.1663
580	0.65424	3265.0	3657.5	8.2183
600	0.66976	3299.8	3701.7	8.2695
620	0.68528	3334.9	3746.1	8.3198
640	0.70078	3370.3	3790.8	8.3693
660	0.71628	3405.9	3835.7	8.4180
680	0.73176	3441.8	3880.9	8.4659
700	0.74725	3478.0	3926.4	8.5131
720	0.76272	3514.6	3972.2	8.5597
740	0.77819	3551.3	4018.2	8.6056
760	0.79365	3588.3	4064.5	8.6508
780	0.80911	3625.6	4111.1	8.6954
800	0.82457	3663.2	4157.9	8.7395
820	0.84002	3701.0	4205.0	8.7830
840	0.85547	3739.1	4252.4	8.8260
860	0.87091	3777.6	4300.1	8.8684
880	0.88635	3816.2	4348.0	8.9103
900	0.90178	3855.1	4396.2	8.9518
920	0.91722	3894.4	4444.7	8.9927
940	0.93265	3933.8	4493.4	9.0332
960	0.94808	3973.6	4542.4	9.0733
980	0.96351	4013.5	4591.6	9.1129
1000	0.97893	4053.7	4641.1	9.1521

Ref. Point for S.H.F. is 25°C, 50% R.H.

Do not write your Roll No. on this Sheet



Space for Rough Work

Space for Rough Work

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