ENGINEERING SERVICES
EXAMINATION-2014

Sl. No. 42584

A-DMHH-N-NFA

MECHANICAL ENGINEERING

Paper I
(Conventional)

Time Allowed : Three Hours | *Maximum Marks : 200*

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions.

Candidates should attempt FIVE questions in all.

Question No. 1 is compulsory.

Out of the remaining SIX questions attempt any FOUR questions.

The number of marks carried by a part of a question are indicated against it.

Answers must be written in ENGLISH only.

Assume suitable data, if necessary, and indicate the same clearly.

For air $R = 0{\cdot}287$ kJ/kg-K, $C_p = 1{\cdot}005$ kJ/kg-K, $\gamma = 1{\cdot}4$, $M = 28{\cdot}97$ kg/kg-mole, Universal gas constant $R = 8{\cdot}314$ kJ/kg mole-K.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the answer book must be clearly struck off.

A psychrometric chart is attached to this question paper for necessary use by the candidate.

1. Answer *all* of the following :

(a) Give reasons why the Carnot cycle cannot be considered as the theoretical cycle for steam power plants even though its efficiency is the highest for the given heat source and sink temperatures. A Carnot cycle heat engine has an efficiency of 40%. If the high temperature is raised by 10%, what is the new efficiency keeping the same low temperature ? 10

(b) What do you understand by the lumped capacity ? What are the physical assumptions necessary for a lumped capacity unsteady state analysis to apply ?

Determine time required in minutes for a 50 mm diameter steel sphere ($\rho = 7800$ kg/m^3, $c = 0{\cdot}46$ kJ/kg-K, $k = 35$ W/m-K) to cool from 600°C temperature to 100°C temperature if exposed to a cooling air at 30°C. The convection heat transfer coefficient is 10 W/m-K. 10

(c) (i) From fundamental laws derive the Prandtl-Mayer relation for a normal shock in compressible fluid flow in a constant area duct for a perfect gas. 5

(ii) Show that the maximum efficiency for a jet striking at the centre of a single symmetrically curved vane moving with a velocity u is given by $\frac{16}{27}\cos^2\frac{\theta}{2}$ where θ is the curvature of the vane. 5

(d) Define specific speed of a hydraulic turbine. Where is it used ? Show that the specific speed (N_s) can be expressed as :

$$N_s = \sqrt{\frac{N^2 P}{H^{5/2}}} = \frac{N\sqrt{P}}{H^{5/4}}$$

N = Speed, P = Power developed or shaft power and H = Head under which the turbine is working.

What is the range of specific speed in r.p.m. for Pelton wheel ? 10

(e) Calculate the volume rate of flow of water through a pipe of 100 mm dia. When measured by (a) An orifice plate of orifice size 50 mm dia and (b) venturi tube of throat size 50 mm dia. The recorded D.P. 250 pa. The density of water is 1000 kg/m^3. Assume orifice c_d equal to 0·6 and venturi c_d equal to 0·9. 10

(f) A single acting reciprocating pump has a plunger 10 cm diameter and a stroke of 200 mm. The centre of the pump is 4 m above the water level in the sump and 14 m below the level of water in a tank to which water is delivered by the pump. The diameter and length of suction pipe are 40 mm and 6 m respectively while those of delivery pipe are 30 mm and 18 m respectively. Determine the maximum speed at which the pump may be run without separation, if separation occurs at 7·848 N/cm^2 below the atmospheric pressure. Take atmospheric pressure head = 10·3 m of water. 10

(g) Use the following mathematical relation for any three properties x, y, z

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1$$

to show the following relations for the Joule-Thomson coefficient

$$\mu_j = \left(\frac{\partial T}{\partial p}\right)_h = \frac{T\left(\frac{\partial v}{\partial T}\right)_P - v}{c_p} = \frac{RT^2}{pc_p}\left(\frac{\partial Z}{\partial T}\right)_P$$

Z is the compressibility factor. 10

(h) Write down the chemical formula of R-134a. What does 'a' signify in the nomenclature ? Explain the effect of critical temperature and critical pressure of refrigerant on the COP of the cycle.

A straight-charged Thermostatic Expansion Valve (TEV) is designed to operate at an evaporator temperature of 7°C with a degree of superheat of 5°C. R-134a is the refrigerant used in the refrigeration system as well as the bulb.

Find :

(i) The required spring pressure at the design condition,

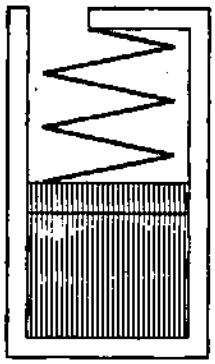
(ii) Assuming the spring pressure to remain constant, find the degree of superheat, if the same TEV operates at an evaporator temperature of –23°C.

The saturation temperature and corresponding pressure of R-134a are given in the Table below :

T_{sat}, °C	–23	–13	–12	–11	2	7	12	13
P_{sat}, kPa	116·39	177·92	185·24	192·8	314·62	374·63	443·01	457·76

10

2. (a)



A cylinder having a piston restrained by a linear spring (of spring constant 15 kN/m) contains 0·5 kg of saturated vapour water at 120°C, as shown in the above figure. Heat is transferred to the water, causing the piston to rise. If the piston cross-sectional area is 0·05 m^2, and the pressure varies linearly with volume until a final pressure of 500 kPa is reached. Find the final temperature in the cylinder and the heat transfer for the process. The properties of water are given in the Table below :

t, °C	p, kPa	v_g, m^3/kg	u_g, kJ/kg	h_g, kJ/kg
120	198·50 (p_{sat})	0·89186	2529·2	2705·9
151·83	500·00 (p_{sat})	0·37477	2559·5	2746·6
801	500·00	0·99055	3664·2	4159·2
802	500·00	0·99147	3666·1	4161·6
803	500·00	0·99240	3668·0	4163·9
804	500·00	0·99333	3669·9	4166·3
805	500·00	0·99425	3671·8	4168·6

10

(b) In an oil cooler the oil enters 10 mm diameter tubes at 160°C and is cooled to 40°C. The mean velocity of oil in the tubes is 1·5 m/s. Calculate the mean heat transfer coefficient. For turbulent flow of liquid being cooled take $Nu = 0{\cdot}0265\ Re^{0{\cdot}8}Pr^{0{\cdot}3}$ and for laminar flow $Nu = 3{\cdot}65$. Take all properties at bulk mean temperature and the properties are listed below :

t °C	P kg/m³	v centi stokes	K W/m K	c kJ/kg K
40	878	251·0	0·144	1·96
100	839	20·4	0·137	2·22
160	806	5·7	0·131	2·48

1 centi stoke = 10^{-6} m²/s. 10

(c) The cylinder bore diameter of a single acting reciprocating pump is 150 mm and stroke is 300 mm. The pump runs at 50 rpm and lifts water through a height of 25 m. The delivery pipe is 32 m long and 100 mm diameter. Find the theoretical discharge and power required to run the pump. If the actual discharge is 4·2 lit/s find the percentage slip. Also determine the acceleration head at the beginning and middle of delivery stroke. 10

3. (a) In an air standard Otto cycle the maximum and minimum temperatures are 1400 and 15°C. The heat supplied per kg of air is 800 kJ. Calculate the compression ratio and cycle efficiency. Also calculate the maximum to minimum pressure ratio in the cycle. 10

(b) An R717 based vapour compression refrigerating machine works between 38°C and –20°C temperature. The ammonia leaves the compressor dry and saturated. Liquid ammonia is undercooled to 30°C temperature inside the condenser, before throttling. Find the theoretical COP of the machine. The c_p of saturated ammonia liquid is 4·91 kJ/kg-K. If net refrigeration required is 25·0 TR, find the mass flow rate of ammonia in kg/h, assuming relative COP 0·75. The saturation properties of R717 are given in the following Table :

	Liquid		Vapour
t, °C	h, kJ/kg	s, kJ/kg-K	h, kJ/kg
38	380·78	1·6134	1489·36
–20	108·55	0·6538	1437·68

10

(c) A smaller power plant produces steam at 3 MPa, 600°C in the boiler. It keeps the condenser at 45°C by transfer of 10 MW out as heat transfer. The first turbine section expands to 500 kPa and then flow is reheated followed by the expansion in the low pressure turbine. Find the reheat temperature so the turbine output is saturated vapour. For this reheat find the total turbine power output and the boiler heat transfer. Properties of water are given in the Table below :

t, °C	p, kPa	v_l, kg/m³	v_g, m³/kg	h_l, kJ/kg	h_v, kJ/kg	s_l, kJ/kg-K	s_v, kJ/kg-K
45	9·59 (P_{sat})	0·00101	15·252	188·42	2583·19	0·63861	8·1647
233·85	3000 (P_{sat})	0·0012167	0·066664	1008·29	2803·99	2·6455	6·1870
600	3000	-	0·13245	-	3682·34	-	7·5084

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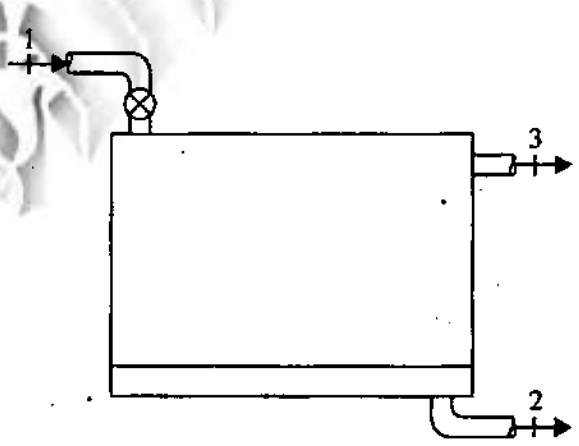
4. (a)



A geothermal supply of hot water at 500 kPa, 150°C is fed to an insulated flash evaporator at the rate of 1·5 kg/s. A stream of saturated

liquid at 200 kPa is drained from the bottom of the chamber and a stream of saturated vapour at 200 kPa is drawn from the top and fed to a turbine. Find the rate of entropy generation in the flash evaporator. Properties of water are given in the Table below :

p, kPa	t, °C	h_l, kJ/kg	h_v, kJ/kg	s_l, kJ/kg-K	s_v, kJ/kg-K
200	120·20 (t_{sat})	504·68	2706·63	1·5300	7·1271
500	151·83 (t_{sat})	640·08	2746·60	1·8603	6·8202
500	150·00	632·18	-	1·8417	-

10

(b) In a chemical plant a solution of density 1100 kg/m^3 and specific heat capacity 4·6 kJ/kg-K is to be heated from 65 to 100°C. The required flow rate of the solution is 11·8 kg/s. A tubular heat exchanger is used for this with the solution flowing at about 1·2 m/s in 25 mm bore iron tubes and being heated by wet steam at 115°C. The length of the tubes is not to exceed 3·5 m. Taking inside and outside heat transfer coefficient as 5 and 10 kW/m^2 K and neglecting the thermal resistance of the tube wall estimate the number of tubes and the number of tube passes required. 10

(c) A water storage tank 10 m × 10 m × 10 m has a drainage opening on one of the vertical sides at the bottom which is trapezoidal in shape with a width 2 m at the bottom 4 m at the top and 1 m height. A gate of same dimension hinged along the top edge is used to close it. What is the minimum horizontal force required to be applied at the bottom to keep the gate closed if the tank has full of water in it ? Will there be any change in the force required if the tank is only half full ? If yes how much ? 10

5. (a) A four cylinder 4 stroke diesel engine has a bore of 212 mm and stroke 292 mm. At full load at 720 rpm the break mean effective pressure is 5·93 bar and specific fuel consumption is 0·226 kg/kWH. The air fuel ratio as determined by exhaust gas analysis is 25 : 1. Calculate the break thermal efficiency and volumetric efficiency of the engine. Atmospheric conditions are 1·01 bar and 15°C. The calorific value of fuel may be taken as 44200 kJ/kg. 10

(b) One kg of air at 35°C DBT and 60% RH is mixed with 2 kg of air at 20°C DBT and 13°C dew point temperature. Calculate the specific humidity, temperature and enthalpy of the mixture. Assume specific heat of steam as 1·88 kJ/kg K and the following properties may be used :

Temperature °C	Saturation pressure p_s bar	Enthalpy of saturated steam h_g kJ/kg
13	0·0150	2525·4
20	0·0234	2538·2
26	0·0336	2549·1
27	0·0356	2550·9
35	0·0563	2565·4

10

(c) Air at 27°C temperature and 100 kPa pressure flows over a flat plate at a speed of 2·5 m/s. Calculate the boundary layer thickness at distance of 25 and 50 cm from the leading edge of the plate. Calculate the mass flow that enters the boundary layer between x = 25 cm and x = 50 cm from leading edge. The viscosity of air at 27°C is 30·8 μ Pa-m. Assume unit depth in z-direction. 10

6. (a) A 100 cc petrol Engine with a compression ratio of 6 compresses the air fuel mixture to 900 kPa and 375°C. At the end of compression the ignition is started and the pressure rises along a straight line and attains the highest value of 3·0 MPa after the piston has travelled 4% of the working stroke. The air fuel ratio is 15 : 1. Take R for mixture as 0·275 kJ/kg-K, calorific value of fuel = 44 MJ/kg and $c_v = 0{\cdot}965$ kJ/kg-K. Find the heat loss per kg of charge during explosion. Flue gases and air has same gas constant. 10

(b) The following data relates to an air-conditioned space :

Outdoor condition	38°C DBT/50% RH
Room condition	24°C DBT/50% RH
Sensible heat load	24 kW
Latent heat load	6 kW
Bypass factor of the cooling coil	0·16

If the ventilation requirement is such that on mass flow rate basis 20% fresh air is introduced and 80% supply air is recirculated, determine

(i) Supply air flow rate

(ii) Outside air sensible heat

(iii) Outside air latent heat

(iv) Grand total heat

(v) Effective room sensible heat factor. 10

(c) (i) 1 m^3 of air is heated at constant pressure from 15°C to 300°C and then cooled at constant volume back to its initial temperature. If the initial pressure is 1·03 bar calculate the net heat flow and overall change in entropy. Show the process on a T S diagram. 5

(ii) With simple schematic diagram explain the differences between fire tube and water tube boilers. Mention the merits and demerits of both. 5

7. (a) A sample bituminous coal gave the following ultimate analysis by mass :

Carbon 81·9%,

Hydrogen 4·9%,

Oxygen 6%,

Nitrogen 2·3% and

Ash 4·9%.

Calculate

(i) the stocheometric air fuel ratio for complete combustion and

(ii) the volumetric analysis of wet and dry products of combustion when the air supplied is 25% in excess of that required for complete combustion. 10

(b) Three thin-walled, long, circular cylinders 1, 2 and 3 of diameters 150 mm, 250 mm and 350 mm respectively are arranged concentrically. Temperature of cylinder 1 is 80 K and that of cylinder 3 is 300 K. Emissivity of cylinder 1, 2 and 3 is 0·05, 0·1 and 0·2 respectively. Assuming that there is vacuum inside the annular spaces, determine the steady state temperature attained by cylinder 2. 10

(c) Find an expression for the drag force on smooth sphere of diameter D, moving with a uniform velocity V in a fluid of density ρ and dynamic viscosity μ. 10

MECHANICAL ENGINEERING
Paper I

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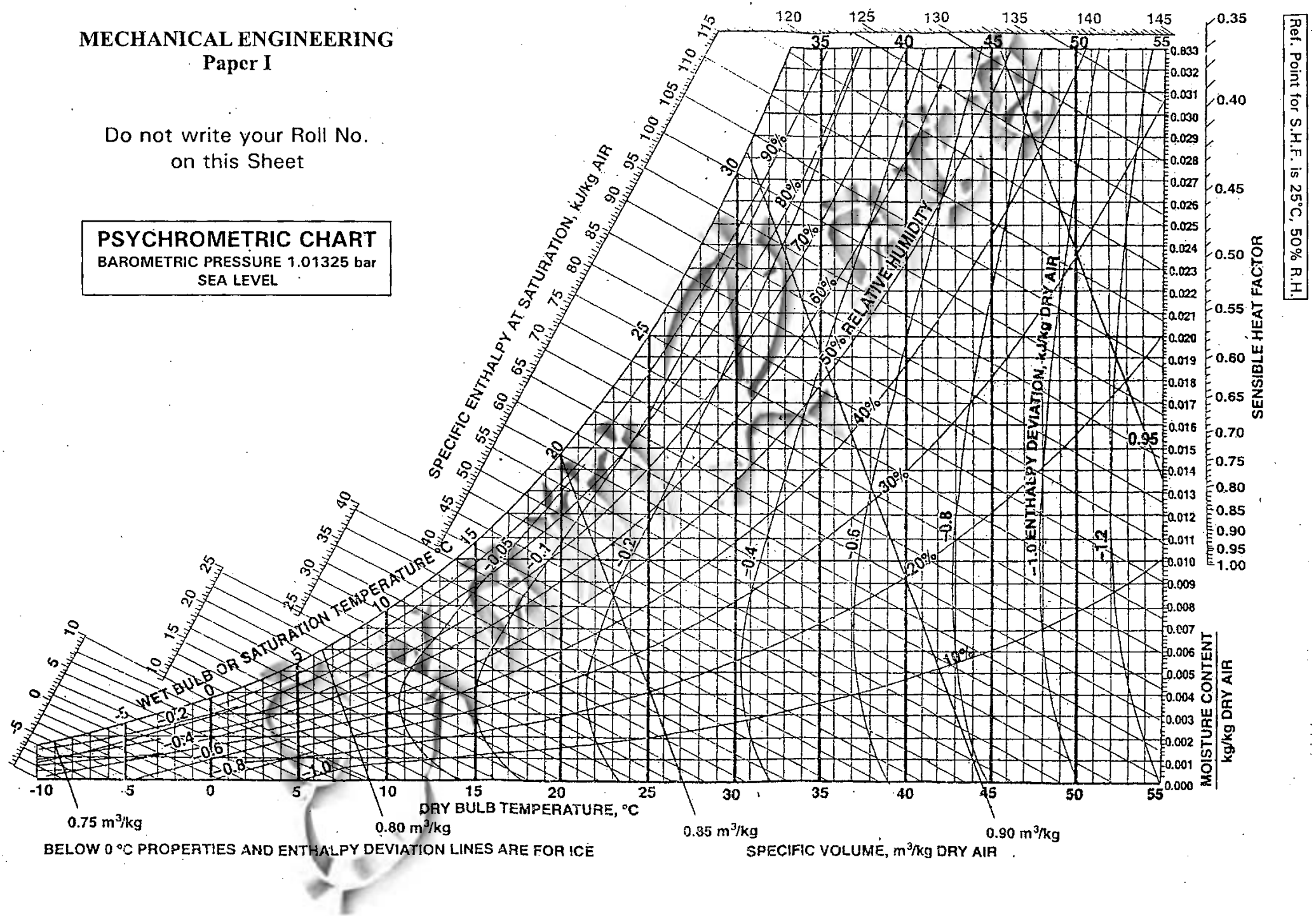

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MECHANICAL ENGINEERING

Paper—II

(Conventional)

Time Allowed : Three Hours *Maximum Marks : 200*

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions :

*Candidate should attempt **FIVE** questions in all.*

*Question No. **1** in Section A is compulsory.*

*Out of the remaining, attempt **TWO** from Section—B and **TWO** from Section—C.*

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

*Answer must be written in **ENGLISH** only.*

Unless other-wise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the answer book must be clearly struck off.

SECTION—A

1. Answer all of the following (Each part carries **4** marks) :

(a) Draw a crank rocker mechanism and identify all instantaneous centres. 4

(b) A steel tube 2.5 cm external diameter and 1.8 cm internal diameter encloses a copper rod 1.6 cm diameter to which it is rigidly joined at each end. If, at a temperature of 20°C there is no longitudinal stress, calculate the stresses in the rod and tube when the temperature is raised to 210°C.

Given : $E_s = 210$ Pa and $\alpha_s = 12\times10^{-6}/°C$

and $E_c = 100$ GPa and $\alpha_c = 20\times10^{-6}/°C$ 4

(c) A drive shaft of 40 mm diameter transmitting 25 kW at 300 rpm is connected to a gear by a flat key of width 22 mm and thickness 14 mm. It is made of steel having 300 MPa yield stress. Determine the length of the key to withstand shear. Use a factor of safety 2. 4

(d) A plate clutch has a single surface with an outside diameter of 250 mm and inside diameter of 100 mm with a coefficient of friction 0.2. Find the required axial force to develop a maximum pressure of 0.65 MPa. Under this pressure, find the torque capacity of the clutch. 4

(e) What are ceramics ? Classify ceramics into four groups and describe their utilities and applications. 4

(f) Describe the characteristics of tool materials. 4

(g) Name the defects that may develop in arc welding of steel parts. 4

(h) Differentiate between orthogonal and oblique cutting. 4

(i) What is ABC analysis ? 4

(j) Explain Queueing model and its applications. 4

4×10=40

SECTION—B

Answer any **TWO** questions.

2. (a) A power screw is made with Acme threads 34 mm-6 mm, single start to lift and lower a load of 10 kN. The screw and nut are well lubricated. Sliding friction is 0.15 and rolling friction is 0.02. Take semi thread angle as 14.5°. Determine :

(i) raising torque

(ii) lowering torque

(iii) efficiency of the power screw. 10

(b) Design a gib and cotter joint for two rods of square cross section transmitting an axial tensile load of 40 kN. The gib, cotter and rods are made of same material having allowable tensile strength of 120 MPa and shear strength of 60 MPa and crushing strength of 160 MPa. Assume the thickness of cotter as one-third of side of the square cross section. 20

(c) Determine the diameter of a circular shaft subjected to a bending moment M = 13 kN-m and a torque T = 30 kN-m according to maximum shear stress theory. Take σ_y = 700 MPa and use a Factor of safety of 2.6. 10

3. (a) Compare the flexural strengths of the following three beams of equal weight and same material :

(i) I-section 300×160 mm with flanges 20 mm thick and web 16 mm thick.

(ii) Rectangular section having depth twice the width.

(iii) Circular solid section. 10

(b) The internal diameter of the cylinder of a hydraulic ram is 10 cm. Find the thickness required to withstand an internal pressure of 500 atm (1 atm = 98.07 kPa), if the yield point for the material (in tension as well as compression) is σ_y = 500 MPa. Use a Factor of safety of 2. 10

(c) Draw the profile of a cam operating a knife-edged follower having a lift of 30 mm. The cam raises the follower with S.H.M. for 150° of its rotation followed by a period of dwell for 60°. The follower descends for the next 100° rotation of the cam with uniform velocity, again followed by a dwell period. The cam rotates at a uniform speed of 120 rpm and has a least radius of 20 mm.

What are the maximum velocity and acceleration of the follower during lift and return ? 10

(d) A 360° hydrodynamic bearing has a journal diameter of 60 mm and length 60 mm. It is running at a speed of 1200 rpm. The radial clearance is 0.04 mm and minimum oil thickness is 0.008 mm. Sommerfeld number is 0.0446. Find the viscosity of the oil suitable for the bearing. 10

4. (a) The state of stress at a point in a structural component of elastic material are given as follows : A normal tensile stress of 160 MPa and a shearing stress of 120 MPa on one plane, a normal compressive stress of 110 MPa and the complementary shearing stress of 120 MPa on a second plane orthogonal to the first plane, and no stress on the third plane which is orthogonal to the above two planes.

Determine :

(i) the principal stresses and the positions of the planes on which they act, and

(ii) the positions of planes on which there is no normal stress. 10

(b) Describe the methods of the following heat treatment procedures of steels :

(i) Nitriding

(ii) Cyaniding. 10

(c) Four rotating masses A, B, C and D rotating in four different parallel planes are completely balanced. Angular position of masses C and D are 90° and 195° respectively from B in anticlockwise direction looking from right hand side. The rotating masses and their radius of mass centres are given below :

$m_b = 25$ kg $m_c = 40$ kg $m_d = 35$ kg

$r_b = 150$ mm $r_c = 100$ mm $r_d = 180$ mm

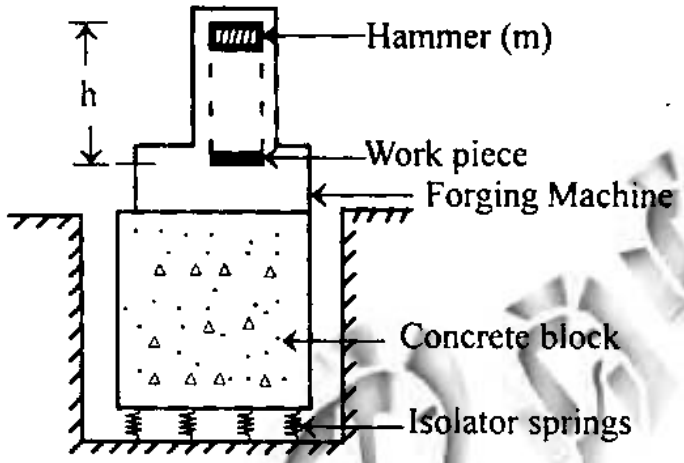
Planes B and C are 250 mm apart and mass centre radius for mass A is 150 mm. Determine using graphical method :

(i) the mass of A and its angular position with respect to B, and

(ii) position of planes A and D with respect to plane B. 10

(d) Figure below shows an impact type forging machine mounted rigidly on a large concrete block with total mass, M = 10,000 kg. The concrete block is placed on ground through isolators of total stiffness, K = 1.7 MN/m. A hammer with a mass, m = 500 kg falls from a height, h = 2 m on to the work piece as shown in the figure. Assuming that

the impact is inelastic and instantaneous, analyse and determine the motion (amplitude) of the machine. Also find its natural frequency. 10



SECTION—C

Answer any **TWO** questions.

5. (a) Determine the dimensions of an optimum cylindrical riser attached to the side of a steel plate casting having dimensions 25 cm × 12.5 cm × 5 cm. The volume shrinkage of steel during solidification is 3% and the volume of riser is 3 times that of dictated by the shrinkage consideration alone. 10

(b) (i) What kind of products are manufactured by wire drawing process ?

(ii) How much force will approximately be required to draw a wire from 1.5 mm diameter steel wire to 1.0 mm diameter wire if the average yield strength of the work material is 300 MPa ? 10

(c) A bar of 70 mm diameter is being cut orthogonally and is reduced to 68 mm by a cutting tool. In case mean length of the chip is 68.9 mm, find the cutting ratio. Determine shear angle also if the rake angle is 10°. 10

(d) Name the machine tools by which teeth of straight toothed spur gears are produced in mass scale. Also mention what motions are imparted to the cutter and the blank in each of those machine tools. 10

6. (a) Draw neat sketches of different Oxy-acetylene flames, label them and describe the two stages of combustion in gas welding. Show graphically the effects of current, pressure and time on the weld strength in resistance welding. What are the consequences of excessive or insufficient pressure during resistance welding ? 10

(b) Show schematically the Merchant's force circle in orthogonal cutting. Derive the equations for shear and friction forces in terms of the material properties and cutting process parameters. State also the assumptions made while arriving at the final equations. 15

(c) Discuss the effect of welding speed on grain structure and properties of weld metals. 5

(d) State the principles of Riser Design and discuss the factors affecting riser efficiency. 10

7. (a) Distinguish between CPM and PERT.

The table given below is for manufacture and installation of a generator for a small scale industry to generate power in case of supply failure. Show the critical path and calculate the project duration time.

Activity	Description of Activity	Duration of Activity	Immediate Predecessor
A	Design Plant Layout	12 days	—
B	Select Site	8 days	A

Activity	Description of Activity	Duration of Activity	Immediate Predecessor
C	Select Vendors	4 days	A
D	Select Personnel	3 days	A
E	Prepare Site	12 days	B
F	Manufacture/ Assemble Generator	18 days	C
G	Prepare Operation Manual	5 days	C
H	Install Generator	4 days	E, F
I	Train Operators	9 days	D, G
J	Obtain Licence	6 days	H, I

15

(b) There is a proposal to purchase a machine for ₹ 30,000/-. Manufacturing cost of a component from this machine is estimated at ₹ 6.0. The component can be sold in the market for ₹ 9.0. The life of the machine is estimated as 18 years. An attractive rate of return is reckoned as 12% and estimated average insurance and taxes as 3%. What quantity should be produced in year to make this proposal profitable ? 10

(c) (i) Describe seven phase job plan of value engineering. 5

(ii) Enlist the advantages of DNC over CNC. 5

(d) If cost price and selling price of an item is input through the keyboard, write a C-program to determine whether the seller has made profit or incurred loss. Also determine the percentage of profit made or loss incurred.

Test the C-program by an illustrative example. 5