MECHANICAL ENGINEERING PAPER I

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.

Section A

1. Answer any three of the following: (Each answer should not exceed 200 words):

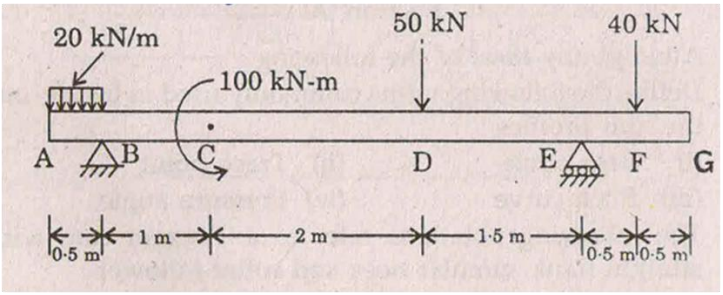
20 x 3 = 60

(a) Define the following terms commonly used in laying out the cam profiles:
(i) Base circle
(ii) Trace point
(iii) Pitch curve
(iv) Pressure angle

The following notations refer to a Tangent cam with straight flank, circular nose and roller follower:
R_c = Base circle radius
R_f = Roller radius
R_n = Nose radius
α = Semi-angle of action of the cam
β = Angle by which cam rotates for contact for roller with the flank
θ = Any angle by which the cam has rotated
h = Lift or stroke at an angle θ
Draw a neat sketch of this cam. Determine the expressions for evaluating the lift (h), velocity (v) and the acceleration of the follower when the cam has turned through an angle θ (which is less than β).

(b) A hollow shaft 30 mm inner diameter and 50 mm outer diameter is subjected to a twisting moment of 800 N-m and an axial compressive force of 40 kN. Determine the factor of safety according to theories of failure based on Normal stress theory, Maximum shear stress theory and Distortion energy theory. The tensile and compressive yield strength of material is 280 N/mm^2 and Poisson's ratio = 0.3.

(c) Construct the bending moment and shearing force diagram for the beam as shown in the figure given below:



(d) What are the various types of plain carbon steel? List important mechanical properties and their common industrial applications.

2.(a) A 350 N electronic instrument is attached to a ship deck which vibrates at an amplitude of 1.60 mm at 50 Hz. The instrument is to be isolated from the deck with four flexible mounts. Determine the required combined spring constant of the mounts such that the amplitude of vibration of the instrument is no more than 0.130 mm. If the springs are equal, what is the spring constant of each mount? What is the static deflection of each mount? 30

(b) A compressor requires 120 kW to run at 240 rpm from an electric motor of speed 750 rpm, by means of a V-belt drive. The diameter of the compressor shaft pulley should not be more than 1000 mm while the centre distance between the shafts is 2000 mm. The belt speed should not exceed 25 m/sec.

Determine the number of V - belts required to transmit the power, if each belt has a cross sectional area of 375 mm^2 density 1000 kg/m^3 and an allowable tensile stress of 2.5 MPa. The pulley groove angle is 40° and coefficient of friction between the belt and pulley sides is 0.25. 30

3.(a) A circular disc 50 cm outside diameter has a central hole and rotates at a uniform speed about an axis through its centre. The diameter of the hole is such that the maximum stress due to rotation is 85% of that in thin ring whose mean diameter is also 50 cm. If both are of the same material and rotate at the same speed, determine the diameter of the central hole and speed of the disc for the data given below: 30

Allowable stress = 900 kg/cm^3 Specific weight = 7.8 gm/ cm^3 Poisson's ratio = 0.3

(b) A cantilever of length L is loaded by a uniformly increasing load, starting from zero at the free end to a maximum of w_0 at the fixed end. The free end is propped to the level of fixed end. Determine the reaction at the prop and equation to the elastic curve along with the slope at the propped end. EI is assumed constant. 30

4.(a) (i) What are the important properties possessed by stainless steel? 15

(ii) Give composition and uses of following stainless steels: 15

(1) Ferritic stainless steel

(2) Martensitic stainless steel

(3) Austenitic stainless steel

(b) What are the composite materials? Explain major composite materials, depending upon state of reinforcing phase. 30

Section 'B'

5. Answer any three of the following:

(a) During orthogonal machining with an HSS Tool, the rake angle was 5°, the undeformed chip thickness was 0.25 mm and width of cut was 4 mm. Assuming shear strength of work material to be 350 N/mm^2 and coefficient of friction to be 0.5, estimate cutting force and thrust force. 20

(b) List various types of chips that are formed in cutting and the conditions in which they occur. 20

(c) Following is information regarding a manufacturing enterprise:

Total fixed costs = Rs. 4,500

Total variable costs = Rs. 7,500

Total sales = Rs. 15,000
Units sold = 5,000 Find out:

(i). Break-even point in units
(ii). Margin of safety
(iii). Profit
(iv). Volume of sales to earn a profit of Rs 6,000 20

(d) A work measurement study was conducted in a manufacturing company for 8 hours and following observations were made:
Idle time: 15%
Performance rating: 120%
Allowance time: 12% of standard time
Number of units produced: 320
Calculate the standard time for the task. 20

6.(a) In drilling of 20 mm diameter hole in a mild steel solid block of 25 mm thickness, the feed used is 0.25mm/rev. The drill must be changed after making 10 holes if it is rotated at 250 rpm. But drill can produce 50 holes if rotated at 200 rpm. How many holes can be produced if rpm is 150? 30

(b) Prove that in EDM, using resistance-capacitance relaxation circuit with a constant DC source, for maximum power delivery, the discharge voltage should be 72% of supply voltage. How is the MRR affected by variation in resistance, mean current, capacitance and spark gap? 30

7.(a) Five different machines can do any of the five required jobs, with different profits resulting from each assignment as shown in the table. Find out maximum profit possible through optimal assignments. 30

	Machine				
Job	Ml	M2	M3	M4	M5
Jl	30	37	40	28	40
J2	40	24	27	21	36
J3	40	32	33	30	35
J4	25	38	40	36	36
J5	29	62	41	34	39

(b) A project is composed of eleven activities. The time estimates are given below:

Activity	t_0	t_P	t_m
1-2	7	17	9
1-3	10	60	20
1-4	5	15	10
2-5	50	110	65
2-6	30	50	40
3-6	50	90	55
3-7	1	9	5
4-7	40	68	48
5-8	5	15	10
6-8	20	52	27
7-8	30	50	40

(i) Draw the network diagram of project.
(ii) Calculate slack time for each node.
(iii) Determine critical path. 30

8.(a) What is friction hill in rolling process? State the condition of skidding in rolling. How does the roll pressure change with (i) front tension and back tension, and (ii) the roll diameter? 20

(b) A company makes 16 gm toffees (net weight) for sale. As policy, a toffee is considered unacceptable if the net weight is more than 0.1 gm greater or less than this amount. The company took 20 samples of five toffees each (100 in total) from production line when the process was known to be in control. The average weight for 100 toffees was 16.003 gm and the average range for the 20 samples was 0.093 gm.

(i) Compute the upper and lower limits for three sigma $\bar{X}$ - chart.

(ii) Compute the upper and lower limits for three sigma R-chart.

(iii) Based on (i) and (ii), suppose the company now samples 5 toffees from the production line.

The net weight of these toffees are 16.018, 15.870, 16.115, 16.02 and 16.005 gm. Determine whether or not the process is in control. If not, specify what the problem is and how you determined this.

[Given that for sample size of 5 $d_2 = 2.33$ For R chart $UCL_R = d_4\bar{R}$ and $LCL_R = d_3\bar{R}$ where $d_4 = 211$ and $d_3 = 0$] 20

(c) Write a "C" program to calculate the factorial of a positive integer quantity by incorporating user defined function for calculating factorial in main program. 20

MECHANICAL ENGINEERING PAPER II

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.

Section A

1. Answer any three of the following (Answers to each of the parts should be in about 200 words only): **20 X 3 = 60**

(a) 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: 20

$$\mu_j = \left(\frac{\partial T}{\partial T}\right)_h = \frac{T^2}{C_P}\left[\frac{\partial}{\partial T}\left(\frac{v}{T}\right)_P\right]$$

(b) A 0.8 kg metal bar kept initially at 1500 °C is removed suddenly from an oven and quenched by immersing it in a closed tank containing 12 kg of water kept initially at400°C. The metal and water can be modelled as incompressible and the specific heat of water and metal are 4.18 kJ/kg-K and 0.5 kJ/kg-K respectively. The heat transfer from the tank may be neglected. Work out the following 20

(i) Draw the system and system boundary and list assumptions made
(ii) The final temperature of metal bar and water
(iii) The entropy produced

(c) Draw the characteristic curves between the following parameters for an SI engine:

(i) Air standard efficiency vs Compression ratio
(ii) Relative efficiency vs Air-fuel ratio
(iii) Brake thermal efficiency vs Load
(iv) Volumetric efficiency vs Engine speed
(v) Peak-cycle temperature vs Equivalence ratio

Discuss significant points in each case in the light of design parameters. 4 x 5

(d) A rectangular cooper plate 10 cm x 50 cm, having a mass of 1 kg and at a temperature of 100°C, is suspended vertically in still air at 20°C so that 50 cm side is vertical. Neglecting radiation effect, find heat transfer coefficient due to natural convection and initial rate of cooling of the plate in °C/ minute.

Take C_p for copper = 383 J/kg-K

The properties of air at mean temperature 60 °C are:

ρ = 1.06 kg/^{m3}, $\nu = 18.97 \times 10^{-6}$ m^2/s

Pr = 0.696, C_p = 1005 kJ/kg-K, $k = 28.96 \times 10^{-3}$ W/m-K; $\mu = 20.1 \times 10^{-6}$ N-s/m^2.

You may use the following correlation:

$$Nu = 0.1\ (Gr\ Pr)^{1/}3$$

Will the result change if 10 cm side is vertical? Why? 20

2.(a) A counterflow heat exchanger acting as a recuperator, of gas turbine receives compressed air operating at steady state at 650 K, 12 bars and exits at 850 K, 11.6 bars. Hot combustion from the exhaust of gas turbine enters as a separate stream at 1000 K, 1.1 bars and comes out at 1 bar. The mass flow rate of each stream is 200 kg/s. The heat transfer from the outer surface of the heat exchanger to surroundings may be neglected. The change in kinetic and potential energy are negligible.

Take T_0 = 228 K and P_0 = 1 bar.

Assume ideal gas model for combustion gas. Work out the following: 30

(i) Draw the system and show the temperature distribution for each stream
(ii) The exit temperature of combustion gas
(iii) The net change in the flow energy rate from inlet to outlet for each stream
(iv) The energy distribution rate
(v) Comment on the results.

(b) During summer to cool water for drinking purpose, 2 kg of ice at -3 °C in an insulated container which is subjected to atmospheric pressure of 1 bar. Assume specific heat of ice is 2.093 kJ/kg-K and latent heat of ice as 335 kj/kg. Work out the following: 30

(i) Draw the system and show the process on T-Q for both ice and water
(ii) The temperature of the mixture
(iii) The change of entropy for instantaneous process.

3.(a) Derive an expression for air-fuel ratio delivered by a simple carburetor, neglecting the effect of compressibility. Discuss the limitations of simple carburetor. What are the modifications incorporated for its use in automotive vehicles? 10+10+10

(b) A four-stroke petrol engine develops 30 kW at 2600 r.p.m. The compression ratio of the engine is 8 and its fuel consumption is 8.4 kg/h with calorific value of 44 MJ/kg. The air consumption of the engine as measured by means of a sharp edge orifice is 2 m^3 per min. If the piston displacement volume is 2 liters, calculate: 6 X 5

(i) Volumetric efficiency
(ii) Air-fuel ratio
(iii) Brake mean effective pressure
(iv) Brake thermal efficiency
(v) Relative efficiency

The ambient temperature of air can be taken as 27 °C, R for air as 287 J/kg-K and γ = 1.4. The barometer reads 755 mm of mercury.

4.(a) A counterflow, concentric tubes heat exchanger is designed to heat water from 20 °C to 80°C using hot oil flowing through the annulus. The oil temperature gets reduced from 160°C to 140 °C. The nominal diameter of the inner tube is 20 mm and the corresponding overall heat transfer coefficient is 500 W/m^2-K. The heat transfer rate from the oil is 3000 watts. Determine the length of the exchanger. Because of fouling after some days the outlet temperature of water reduced to 65 °C for the same flow rates and same inlet conditions. Determine the outlet temperature of oil, the fouling factor and the new heat transfer rate. Sketch the heat exchanger arrangement and the temperature profiles. 30

(b) The temperature of a gas flowing through a pipe was measured by a mercury-in-glass thermometer, dipped in an oil-filled steel tube welded radially to the pipeline. The thermometer indicates a temperature lower than the gas temperature. How large is the

error in the temperature measurement if the thermometer reads 85 °C and the temperature of the pipe wall is 40 °C? The steel tube is 125 mm long and has a 1.5 mm thick wall. The thermal conductivity of this tube material is 56 W/m-K and the local heat transfer coefficient between the gas and the tube is 23.5 W/m^2 -K.
In what way the thermometric error can be reduced? 30

Section 'B'

5. Write any three of the following: -

(a) For flow through a compressor cascade, show that lift and drag coefficients are given by the following expressions: 20

$$C_L = Z\left(\frac{s}{c}\right)\frac{\Delta C L_w}{C_m} - \xi\left(\frac{s}{c}\right)\frac{Cos^3\,\alpha_m}{Cos^2\,\alpha_1}\,tan\,\alpha_m$$

$$and \quad C_D = \xi\left(\frac{s}{c}\right)\frac{Cos^3\,\alpha_m}{Cos^2\,\alpha_1}$$

where
s/c = Pitch-chord ratio
$\Delta C_W = C_{W1} - C_{W2}$
α_m = Mean flow angle
ξ = Total pressure loss coefficient

(b) An ammonia ice plant operates on simple saturation cycle at the following temperatures:
Condensing temperature = 40 °C
Evaporation temperature = -15 °C
It produces 10 tonnes of ice per day at -5 °C from water at 30 °C. If the COP of the system is 5, determine: 20
(i) Capacity of the refrigeration plant in tonnes of refrigeration
(ii) Mass flow rate of the refrigerant, kg/min
(iii) Isentropic discharge enthalpy, kJ/kg.
Take: Cp= 4.187 kJ/kg-K for water = 2.000 kJ/kg-K for ice
Latent heat of fusion of ice = 335 kJ/kg
Sensible enthalpy at 40 °C = 600 kJ/kg
Enthalpy of sat. vapour at -15 °C = 1675 kJ/kg

(c) Explain the concept of effective temperature (ET) used in air-conditioning practice. Discuss the parameters on which it depends. 20

(d) A superheater is to be designed using metallic coils (heat flux 150 kW/m^2) of inside diameter 50 mm and wall thickness 5 mm. The steam leaving the superheater coils is at 60 bars, 500 °C and flows at a velocity of 10 m/s. If the steam mass flow rate is 90 kg/s, find the number and length of coils.
For steam at 60 bars, take the following values: dry saturated steam h = 2784.3 kJ/kg, at 500 °C superheated steam temperature h_{sup} = 3422.2 kJ/kg and specific volume v_{sup} = 0.05665 m^3/kg. The steam enters the superheater as dry and saturated. 20

6.(a) A VCC refrigerating machine using R-12 refrigerant produces 10 tonnes of refrigeration at 10 °C when the ambient is at 35 °C. A temperature difference of minimum 5 °C is required at the evaporator and condenser for spontaneous heat transfer. The refrigerant is dry saturated at the outlet and to the inlet of compressor. The adiabatic efficiency of the compressor is 90%. The enthalpy at the end of isentropic compression is estimated to be 370 kJ/kg. Determine: 20

(i) COP
(ii) Power of the compressor
(iii) Capacity of the condenser

Represent the cycle on hand drawn T-S plane and show the refrigerating effect, compressor work and condenser capacity on the same. 30

Properties of R-12 are:

Temperature	Pressure	Specific Enthalpy, kJ/kg	
(°C)	(bar)	Sensible	Evaporation
5	3.62	204.64	148.97
10	4.23	209.32	146.37
15	4.91	214.10	143.69
30	7.45	228.54	135.04
35	8.47	233.50	131.90
40	9.60	238.53	128.62

(b) Explain the procedure for cooling load estimation for comfort air-conditioning in the summer. Also explain the concept of different Sensible Heat Factors (SHFs) and importance in designing an air-conditioning system. 30

7.(a) Explain the concept of types of similarities between model and prototype. What do you mean by distorted model? What are its advantages?

It is proposed to design a ship. The proposed ship (prototype) is having a length of 150 m and a wetted surface area of 2000 m^2 with a speed of 40 km/h. A model of 1 : 20 is to be tested in the laboratory at a velocity corresponding to the wave resistance. The total drag of the model is 50 N. Determine the following: 15 + 25

(i) Wave resistance drag of the model
(ii) Wave resistance drag of the prototype
(iii) Friction drag of the prototype.

Give, Friction drag,

$$R_f = \frac{1}{2} C_D \rho A V^2$$

where

A = Wetted surface area

C_D = Average friction drag coefficient

$$= \frac{0.074}{(R_e)^{1/5}} \quad \text{for } R_e < 2\ X\ 10^7$$

$$= \frac{0.01}{(R_e)^{1/5}} \quad \text{for } R_e > 2\ X\ 10^7$$

ρ_{model} = 1000 kg/m^3; ν_{model} = 1.125 x 10^{-6} m^2/s, $\rho_{Prototype}$ = 1020 kg/m^3; $\nu_{Pototype}$ = 1.125 x 10^{-6} m^2/s.

(b) Define Rayleigh flow. Give one practical example of Rayleigh flow. Show that the Mach numbers at the maximum enthalpy and maximum entropy points on the Rayleigh line are $1/\sqrt{\nu}$ and 1.0 respectively. 6 + 14

8.(a) An axial flow compressor compresses the air up to overall stagnation pressure 10 bars with overall stagnation isentropic efficiency of 88%. The inlet stagnation pressure and temperature are 1 bar and 300 K. The mean blade speed is 200 m/s. The degree of reaction is 0.5 at the mean radius with air angles of 30° and 10° at rotor inlet and outlet

with axial direction respectively. The work done factor is 0.88.The hub-tip ratio is 0.4. The mass flow rate is 50kg/s. Work out the following: 30

(i) Draw the inlet and outlet velocity triangles and show the compression process on T-S diagram

(ii) The stagnation polytropic efficiency

(iii) The number of stages

(iv) The blade height in first stage of the compressor

(b) A nuclear power plant is set up with a generating capacity of 10 MW, the capital cost being Rs 80,000 per kW. It meets the following demands:

(i) Service sector: Total load 400 kW at 30 % load factor

(ii) Cottage industries: Total load 3.6 MW at 50% load factor

(iii) Household: Total load 6 MW at 20% load factor.

The operative cost of the plant is Rs 30,00,000 per annum and annual rate of interest and depreciation is 10%. If as per promotion policy of government, a flat rate is to be charged from all categories of consumers, calculate the overall production cost. If the power is sold at the rate of production cost, estimate the loss/gain each sector consumer will get per kWh for power consumed. 30