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.
If any data is considered insufficient, assume suitable value and indicate the same clearly.
Newton may be converted to kg using the equality 1 kilonewton (1 kN) = 100 kg, if found necessary.

Section A

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

20 x 3 = 60

(a) In a vibrating system a coil spring of stiffness 50 N/mm supports a vibrating mass of 250 kg at the free end. In addition, the motion of mass is controlled by a dashpot whose resistance is proportional to velocity. From measurement it is found that the amplitude at the beginning of the fourth cycle is 0.8 times the amplitude of the third cycle. Determine:-
  (i) damping co-efficient of the dashpot.
  (ii) critical damping co-efficient.
  (iii) the damping factor.
  (iv) the ratio of the frequencies of damped and undamped vibrations.

(b) For the following states of stress, show the stresses on two given planes at right angles of an element. Find the magnitude and directions of the principal stresses and the maximum shear stresses in each case.
  (i) Simple uniaxial tension.
  (ii) Pure equal normal stresses on given planes.
  (iii) Pure shear stresses on given planes.

(c) Distinguish between thin and thick cylinders. A thin cylindrical shell having hemispherical ends is subjected to internal pressure 'p'. The internal diameter is 'd' and thicknesses of cylinder and hemisphere are t_1 and t_2 respectively. Assuming Poisson's ratio $\nu = 0.3$, prove the following:
  (i) For no distortion of juncture, $t_2/t_1 = 7/17$.
  (ii) For equal maximum stresses in cylindrical and hemispherical portions, $t_2/t_1 = 0.5$.

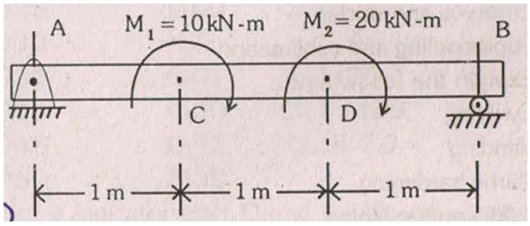
(d) What do you mean by 'plain carbon steels' and 'alloy steels'? Discuss the effect of addition of following elements in making alloy Steels:
  (i) Chromium (ii) Nickel (iii) Manganese
  (iv) Silicon (v) Molybdenum (vi) Vanadium (vii) Tungsten

2.(a) A gear with 42 teeth and a pinion with 19 teeth are cut with involute teeth of pressure angle 20° and module pitch 6 mm. The addendum of each wheel is 6 mm. Find:
  (i) the length of the arc of contact.

(ii) the number of pairs of teeth in contact.
(iii) the angle turned through by the pinion, while any one pair of teeth is in contact.
(iv) the ratios of sliding velocity to the rolling velocity at the instant (a) the engagement commences, (b) the engagement terminates and (c) at the pitch point. 30

(b) A rotating shaft carries four masses A, B, C and D at radii of 10 cm, 12.5 cm, 20 cm and *r* cm respectively. The planes in which the masses revolve are spaced 60 cm apart. The masses B, C and D are known to be 10 kg, 5 kg and 4 kg respectively.
It is desired that the rotating shaft should be in complete dynamic balance. For this to be achieved, determine:
(i) required mass A
(ii) the relative angular settings of the four masses, given that the angular spacing of the planes containing C and D are 118° and 260° respectively relative to B measured in the same sense.
(iii) find the radius at which mass D is to be placed. 30

3.(a) Draw Shear Force and Bending Moment diagrams for the beam ACDB shown in figure where two couples are acting.



Find the ratio of deflections in the beam at locations C and D where the couples are acting. 30

(b) (i) For a closed coil helical spring under compression illustrate the stress distribution across wire diameter.
(ii) Differentiate between compound and composite helical springs.
(iii) The spring load against which a valve is opened is provided by an inner helical spring arranged within and concentric with an outer helical spring. The free length of inner spring is 6mm longer than the outer. The outer spring has 12 coils of mean diameter 25 mm, wire diameter 3 mm, and initial compression5 mm when the valve is closed. Find the stiffness of the outer spring if the greatest force required to open the valve by 10 mm is 150 N. If the radial clearance between the springs is 1.6 mm, find the Wire diameter of the inner spring if it has 10 coils. For both springs, G = 82,000 N/mm^2. 30

4.(a) For engineering materials,' differentiate between the following: 10
(i) A system and state
(ii) Extrinsic and intrinsic properties
(iii) Degree of freedom and constraint
(iv) Phase and component

(b) Differentiate between the following: 20
(i) Homogeneous nucleation and heterogeneous nucleation
(ii) Nucleation and growth
(iii) Embryos and nuclei
(iv) Supercooling and sublimation

(c) Explain the following: 10

(i) Cyniding
(ii) Nitriding
(iii) Flame hardening
(iv) Induction hardening

(d) Differentiate between: 20

(i) Directional and non-directional bond
(ii) Bond length and bond energy
(iii) Ionic bond and covalent bond
(iv) Metallic bond and hydrogen bond

SECTION B

5. Answer any three of the following:

(a) Consider the following time series data:

Week	1	2	3	4	5	6
Value	8	13	15	17	16	9

(i) Using a 3-week moving average, what is the forecast for week 7?
(ii) Using $\alpha = 0.2$ for exponential smoothening, what is the forecast for week 7?
(iii) Using the mean squared forecast error as a basis, which forecast for week 7 would you recommend? 6 + 7 + 7

(b) This program drills two holes using a CNC machining center. Indicate the meaning of the following commands: 20

PROGRAM	φ0001	
N005	G54	G90 S499M03
N010	G00	X1. Y1.
N015	G43	H01 Z.O M08
N020	G01	Z-1.25 F3.5
N025	G00	Z.l
N030	X2	
N035	G01	Z-1.25
N040	G00	Z.l M09
N045	G91	G28 Z0
N050	M30	

Note: φ indicates letter O and 0 indicates numeral zero.

(c) (i) What is Taylor's equation?
(ii) Explain the various criteria of tool failure.
(iii) What is HSS?
(iv) How is surface finish measured? 20

(d) (i) Bevery Company, a weighing machine manufacturer essentially manufactures a mechanical weighing machine and another deluxe version which is a digital weighing machine. The company gives 7% commission on sales of the ordinary mechanical type and 8%commission on sales of the deluxe digital version. However, all such commissions are available, provided there is a base level sales of at least Rs. 10,000 of ordinary variety and Rs 15,000 of deluxe variety. To motivate the sales engineers, for a sales exceeding Rs. 20,000 and Rs. 25,000 for the ordinary and deluxe variety respectively, there is a 1% increase in the commission levels for both varieties. Draw a flow chart to enable writing a computer programme for the above.

(ii) Write a computer programme for the above situation. 10+ 10

6.(a) What is a three high rolling mill? Show the direction of motion of rolls and the work piece on a neat sketch of three high rolling mill. What lubricants are used during hot rolling? What is camber? Explain in relation to rolling process the function of providing camber. 30

(b) How will you measure taper on a machined component? Describe the procedure with the help of one example and neat sketches. 30

7.(a) Distinguish between allowance and tolerance. What are unilateral and bilateral systems of specifying tolerances? What is the condition for a force fit or an interference fit between mating parts? Why is hole basis system preferred over a shaft basis system? 30

(b) A person operates a machine that makes capacitors. He has been advised to keep track of the percent defectives at his work centre. He knows that with this type of process, they expect about 4% defectives plus or minus some chance variation. He wishes to initially construct a control chart for defectives. He has prepared ten daily samples of hundred capacitors each.

Sample Number	1	2	3	4	5	6	7	8	9	10
% defectives	4	3	3	6	1	9	5	12	4	3

(i) Construct the relevant control chart. What are the upper and lower control limits?

(ii) Plot the data points on the proposed control chart. Is the process under control? What follow up steps should be under take, if any? 15+15

8.(a) A materials manager had recently attended a short training programme on materials management. He thought of applying some of the optimization concepts that he had learnt. He picked on one item having code BV 1960 which was essentially a brass valve. From the current records, he found that the average annual demand was for 10,000 valves. The accounting information system revealed that the carrying cost was Rs. 0.40 per valve per year, whereas the ordering cost was Rs. 5.50 per order. The current policy adopted in the company was to order for 400 valves at a time.

Is this an optimal policy? What would be the annual savings if the EOQ concept was applied? 15 + 15

(b) A company produces two principal product lines - a powerful portable circular saw and precision table saws. Both product lines share the same production capacity and are sold through the same sales channels. The average profit is Rs. 900 for each circular saw and Rs. 600 for each table saw. The production capacity is constrained in fabrication and assembly capacity. A maximum of 4000 hours of fabrication capacity is available per month, and each circular saw requires two hours and each table saw requires one hour. A maximum of 5000 hours of assembly capacity is available per month, and each circular saw requires one hour and each table saw requires two hours. The marketing department estimates that there is a maximum market demand next year of 3500 saws per month for both product lines combined.

(i) Is there a single managerial objective? What is it?

(ii) What are the alternative feasible product mix possibilities?

(iii) What is the optimal product mix? [You can use either graphical or simplex method]

(iv) How much could the company product optimally if it was seen that the estimates of the next year's market demand have been raised to 4000? What would be the maximum total profit? 5+5+15+5

MECHANICAL ENGINEERING PAPER II

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Use of Psychometric chart is permitted.

Section A

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

(a) A reversible heat engine absorbs heat energy from a stream of hot gases whose temperature is falling linearly from T_1 to T_2. The engine rejects heat to a constant temperature sink atT0. Assuming that any reversible cycle can be considered to be equivalent to an infinite number of Carnot cycles, prove that the maximum efficiency attainable for this heat engine is:

$$1 - \frac{T_0}{T_1 - T_2}\, ln\left(\frac{T_1}{T_2}\right)$$

(b) A rigid insulated tank of 3 m^3 volume is divided into 2 compartments. One compartment of volume l m^3 contains an ideal gas at 0.1 MPa and 300 K while the second compartment of volume 2 m^3 contains the same gas at 1 MPa and 1000 K. If the partition between the two compartments is ruptured, calculate the final temperature and pressure of the gas.

(c) The actual amount of air supplied per kg of a fuel can be ascertained from the measured composition by volume of combustion products. Describe an apparatus to do the needful.

(d) Discuss why a carburetor is being replaced by an injection system in S.I. engine these days.

2.(a) A mass of air initially at 760 KPa and 250 °C occupies 0.026 m^3. The air is expanded at constant pressure to 0.07 m^3. A polytropic process with n = 1.52 is then carried out followed by an isothermal process and the cycle is thus completed. Assuming all the processes to be reversible,

(i) show all the processes on P-v and T-s planes
(ii) compute the heat received and rejected in the cycle
(iii) calculate the efficiency of the cycle. 30

(b) Define availability. Explain the difference between useful work and the maximum useful work done in the context of availability of a closed system. Heat flows through a wall at the rate of 3 x $l0^5$ kJ/h. The temperature of the two faces of the wall are 327°C and 207°C. If the surroundings are at 270°C, what is the loss in available energy? 30

3.(a) The exhaust gas analysis of an engine using Octane(C_8H_{18}) as fuel gives equal volumes of CO_2 and unused O_2. Compute the actual and stoichiometric air-fuel ratios. For equivalence ratio of 1, calculate:

(i) the volume of mixture per kg of fuel at pressure of 100 kPa and temperature 70 °C

(ii) the volume of the products of combustion per kg of fuel when the temperature of products of combustion is 127 °C at pressure 1 bar. 40

(b) Explain Cetane rating of a fuel. Discuss its importance for the selection of fuels. Justify the range of Cetane numbers of commercial diesel fuels. 20

4.(a) Define scavenging efficiency, trapping efficiency and scavenge factor in two-stroke I.C. engines. Develop a relationship between them. 20

(b) A 4-stroke petrol engine of 2 liters capacity is to develop maximum power at 4000 rpm. The volumetric efficiency at this speed is 0.75 and the air-fuel ratio is 14 : 1. The venturi throat diameter is 28 mm. The coefficient of discharge of venturi is 0.85 and that for fuel jet is 0.65. Calculate:

(i) the air velocity at the throat and

(ii) the diameter of the fuel jet.

The specific gravity of petrol is 0.76. Atmospheric pressure and temperature are 1 bar and 17°C respectively. 40

SECTION B

5. Answer any THREE of the following parts (Answer to each part should not exceed 200 words): **20 X 3 = 60**

(a) Show the following processes on the psychometric chart:

(i) Heating and humidification

(ii) Cooling and dehumidification

(iii) Cooling and humidification

(iv) Heating and dehumidification

(v) Adiabatic saturation

(b) Heat is transferred along the axis of a truncated conical cylinder of length l, radius r_1 at the shorter end and radius r_2 at the bigger end. The circumference of the cylinder is completely insulated. Develop an expression to calculate heat transfer along the axis of the cylinder. Assume no variation of conductivity with temperature.

(c) A thermal power plant of 200 MW capacity has the maximum load of 160 MW and its annual load factor is 0.65. The coal consumption is kg per kWh of energy generated and the cost of coal is Rs. 800 per ton. Other annual running expenses are Rs. 200 x 10^6. Calculate: (i) the annual revenue earned if the energy is sold at Rs. 1.5 per kWh and (ii) the capacity factor of the plant.

(d) A forced draught fan discharges 1200 m^3 of air per minute through the outlet of 2 m^2 area and maintains a steady pressure of 110 mm of water. The temperature of air is 27 °C. Calculate the power of the motor to drive the fan if the efficiency of the fan is 85%. Take the density of air at 27°C as 1.25 kg/m^3.

6.(a) A spherical thermocouple of 2.5 mm diameter is used to measure the temperature of air flowing in a pipe. Initially both the thermocouple and the air are at a temperature of 30 °C. The air is heated to a temperature of 235 °C and maintained at this temperature. Find the time required for the thermocouple to reach 200 °C. Also find out the time

constant of the thermocouple and comment on the suitability of this thermocouple to measure unsteady state temperature.

For thermocouple material take: density = 9000 kg/m^3, specific heat = 0.4kJ/kg K and thermal conductivity = 30 W/mK.

Convective heat transfer coefficient between thermocouple surface and the air is 120 W/m^2K. 30

(b) Air at 30 °C flows over a horizontal plate heated to 70°C at a speed of 3 m/s. Calculate the convective heat transfer coefficient and the rate of heat transfer between the plate and the air. The length of the plate is 2 m and width 1 m. Nusselt number is given by:

$$Nu = 0.664\ Re^{1/2}\ Pr^{1/3}.$$

The properties of air at 50 °C are: $\nu = 17.95 \times 10^{-6}$ m^2/s, K = 0.0283 W/mK, ρ = 1.093 kg/m^3, C_p = 1.005 kJ/kgK. 30

7.(a) A vapour compression refrigerator works between pressure limits of 10 bar and 3 bar. The working fluid is dry at the end of compression and there is no undercooling before the expansion valve. If refrigerant flow rate is 10 kg/min, determine (i) COP and (ii) the capacity of the refrigerant. Table for properties of the refrigerant is as under: 30

Pressure	Saturation temperature	Liquid heat	Latent heat	Liquid entropy
bar	°C	kJ/kg	kJ/kg	kJ/kgK
10	25	298.90	1165.94	1.1242
3	- 10	135.37	1297.68	0.5443

(b) Discuss the difference between natural circulation, forced circulation and one-through boilers. Explain, with the help of a sketch, the working of a La Mont boiler. 30

8.(a) Steam expands in a steam turbine isentropically from inlet to exhaust having an enthalpy drop = 1200 kJ/kg. Assuming ideal conditions, determine the mean diameter of the wheel if the turbine were of:

(i) single impulse stage,
(ii) single 50% reaction stage,
(iii) one two-row Curtis stage and
(iv) ten 50% reaction stages.

Take the nozzle angle as 18° and blade speed as 4000 rpm. 30

(b) 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 15° and 45° 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. 30