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) Explain the salient features of maximum distortion energy theory of elastic failure and discuss how it compares with maximum strain energy and maximum shear stress theories.

(b) Show that a flexible cable of constant section loaded due to its own weight and suspended from two supports at different heights, would have two main shapes of sagging.

(c) Two wheels W_1 and W_2 of radii r_1 and r_2 respectively are lying in a plane. Their centers are connected by a rod R of length $(r_1 + r_2)$ and the wheels engage without slipping. If the centre of W_1 is fixed then W_2 and R can rotate independently about this centre, and W_2 will roll on W_1. Derive a relationship between the angular velocities of W_1, W_2 and R.

(d) Why does a spinning top not fall down? Explain.

2.(a) Compare the elastic deflections at the points of loading produced in a simply supported beam of length *l*, carrying a concentrated load P at its midpoint to that of a cantilever of length *l*, carrying a load P at its free end. The moment of inertia of the section for the simply supported beam is J in the left half and 0.5 J in right half. For the cantilever, the moment of inertia of the section is 2J upto a distance of *l*/2 from the fixed end and J for the remaining portion. Assume that both the beams are made of same material. 25

(b) A brass tube fits closely over a steel shaft of 100 mm diameter. Find the thickness of the brass tube which would ensure that the torque applied to the assembly is shared equally by the two materials. Find maximum shear stress in each material and the angle of twist in a length of 3 m. The torque applied is equal to 20 x 10^4 kgf-cm. Assume modulus of rigidity (steel) = 8 x 105 kgf/cm^2 modulus of rigidity (brass) = 4 x 105 kgf/cm^2. 25

(c) A 1000 mm long bar is subjected to an axial pull P which induces a maximum stress of 1500 kg/cm^2. The area of cross-section of the bar is 2 cm^2 over a length of 950 mm and for the central 50 mm length the sectional area is equal to 1.0 cm^2. Assuming that E for the bar material is 20 x 10^5 kg/cm^2, calculate the strain energy stored in the bar. 10

3.(a) A parallel helical cast gear with 30° helix angle is required to transmit 50 HP at 2000 rpm. Find the module, pitch, diameter and width for 20° involute full depth tooth. The

gear has 25 teeth. The static stress for cast steel can be taken as 1000 kg/cm^2. Use Lewis formula, assume that face width is 3 x circular pitch and from factor is 0.123. Any other data not supplied can be assumed suitably. 25

(b) An automobile engine has a bore of 150 mm and stroke of 150 mm. It is expected that the engine would develop a maximum pressure of 32.0 kg/cm^2 and the engine would run at a speed of 1100 r.p.m. The connecting rod length to crank radius ratio is 5.0. Find the dimensions of the I-section connecting rod to be used for a safety factor of 8 and made of medium carbon steel. The I-section cross-section be taken as 6*t* x 4*t*, where *t* = flange and wed thickness. Assume that the yield strength of steel is 3500 kg/cm^2 and E = 2.0 x 10^6 kg/cm^2.

Weight of the reciprocating parts of the engine = 0.03 kg/cm^2 of piston area. Any data not given-can be assumed suitably. 20

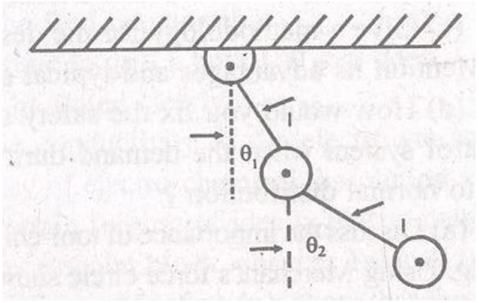
(c) A cast iron fly wheel is fitted to a punch press to run at 90 r.p.m. and must supply 1200 kg-m of energy during l/5th revolution and allow 15% charge of speed. The rim speed is limited to 350 m/min. Find the mean diameter and weight of the flywheel and the motor HP. Assume overall efficiency as 80%. 15

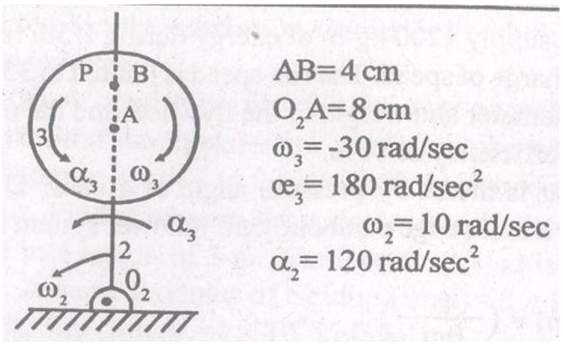
4.(a) What is meant by pressure angle of a cam? Discuss its significance. For a knife edge parabolic cam follower system show that

$$\tan \varphi_m = 1/\theta_m$$

when the follower is under constant acceleration from rest and where θ_m = maximum pressure angle φ_m = angle through which the cam turns while the follower rises from rest to where the pressure angle is maximum. State the assumptions made. 15

(b) Using Raleigh's principle approximate the natural frequency and mode shape for the lowest natural frequency of the double pendulum (Fig. l). 20





(c) A wheel 3 (Fig. 2) is planned to link 2 at A and rotates clock wise with angular velocity ω_3 and anti-clockwise angular acceleration α_3, while link 2 is rotating counter clockwise with positive values of angular velocity and acceleration. In Fig. 2, B is a point on link 2 while P is a point on link 3 (coincident at the particular instant of time). Find the acceleration of P. 25

Section B

5. Answer any three of the following (each answer should not exceed 200 words): **20 x 3 = 60**

(a) In the context of value engineering, explain what is meant by 'Use value' 'Esteem value' and 'Exchange value'. How can these be utilized in purchasing?

(b) Giving suitable reasons, explain how you would specify a particular sampling plan that would meet the requirements of AQL, LTPD, producer's risk and consumer's risk.

(c) Give a methodology for the design of diamond pin locators. Mention its advantages and typical applications.

(d) How would you fix the safety stock level in an inventory control system when the demand during lead time varies according to normal distribution?

6.(a) Discuss the importance of tool-chip contact length in metal machining. Using Merchant's force circle show that the tool-chip contact length (l_c) during orthogonal machining would be given by

$$l_c = \frac{t \cdot \tan(\varphi + \beta - \gamma)}{\sin\varphi \cdot \cos\beta}$$

where t = undeformed chip thickness

φ = shear angle

β = friction angle

γ = orthogonal rake

State the assumptions made, if any. 20

(b) Define the term machinability. Compare the machinabilities of two materials A and B, based on 60 min tool life using the following data. What is the drawback of this method of machinability evaluation? Also compute the cutting speed be used for the two materials so as to minimize the unit time of production. 20

Material	Tool life Equation
A	$VT^{0.11} = 67$
B	$VT^{0.13} = 77$

Tool changing time= 1.5 min (constant)

V= cutting speed (m\min), T= tool life (min)]

(c) We wish to sink a hole, using ECM process into a hardened steel block. The tool to be employed has 75 mm diameter and is electrically insulated from the sides. The operating voltage is 12 V, current density is 1.6 amp/mm^2. The electrolyte to be used is 20% Nacl solution in water with its temperature maintained at 40°C. Estimate-

(i) the average tool-work gap.

(ii) the feed rate possible.

(iii) time to drill a hole 100 mm deep.

Assumptions, if any, be stated clearly.

Given that: specific conductivity of the electrolyte solution is 0.2/ohm-cm and valency of electro-chemical dissolution as 2.0.

7.(a) For plain strain forging of ideally plastic material, initially in the form of a rectangular block, obeying Tresca's flow criterion and constant coefficient of friction (μ), show that the length of die-work contact xl at which sticking would start is given by

$$\frac{xl}{y} = \frac{1}{\mu}\ln\frac{1}{2\mu}$$

x_l is measured from the ends of the block, y is the final thickness of the block. Assumptions made, if any, be adapted clearly.

(b) A piece of lead, size, 25 x 25 x 150 mm, having a yield strength of 0.7 kg/mm^2 is pressed between two at dies to a final size of 6.25 x 100 x 150 mm. Assuming that μ = 0.25, determine the forging load required. 10

(c) List the factors that influence surface quality in machining operations. Explain why the ideal surface finish values are better than the actual values obtained experimentally. Show that the peak to valley height (h_{max}) of the surface produced by a straight tooth peripheral milling cutter would be equal to

$$h_{max} = f_t^2/4D$$

f_t = feed per tooth D= cutter diameter

8.(a) The following elemental data pertains to the assembly of a new model toy:

Element No.	Elemental time (min)	Immediate Predecessors
1	0.5	--
2	0.3	1
3	0.8	1
4	0.2	2
5	0.1	2
6	0.6	3
7	0.4	4, 5
8	0.5	3, 5
9	0.3	7, 8
10	0.6	6, 9

The desired value of the cycle times 1.0 min, compute (i) the balance delay and (ii) the theoretically minimum number of stations required so as to minimize the balance delay. Also mention some of the steps you would recommend to improve the line balance. 20

(b) Two producers P_1 and P_2 apply their produce to three warehouses (W_1, W_2, W_3,) as per unit supply cost, demand and capacity given below. The capacities of the suppliers P_1 and P_2 can be increased by 50% each by working overtime. This however, adds 10 and 15 to the unit cost of supplies from P_1 and P_2 respectively. Determine the regular and overtime production and supply schedule so as to minimize the total supply cost. 25

To	Unit Supply Cost			Capacity
From	W_1	W_2	W_3	
P_1	25	17	25	300
P_2	15	10	18	600
Demand	300	400	500	

(c) List some of the practical situations where waiting lines are likely to occur. What is meant by: queue discipline and utilization factor? Explain. Show that when cars arrive to a service station according to Poisson distribution, probability of more than one arrival in a small interval of time Δt is zero. 15

MECHANICAL ENGINEERING PAPER II

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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) Prove the validity or otherwise of the following statements:
  (i) Every process that fulfils the requirements of the first law of thermodynamics can occur in nature.
  (ii) For a perfect gas the work done by a constant pressure expansion from any point on a given isothermal to another given isothermal is constant.

(b) Why are dimensionless number used in Fluid Flow and Heat Transfer studies? Write down expressions for the following numbers indicating briefly their application and physical concept.
Mach number, Reynolds Number, Prandtl Number and Nusselt Number.

(c) Explain briefly the Boundary Layer Theory as propounded by prandtl. Obtain an expression for the thickness of the boundary layer for laminar flow assuming the velocity distribution law as

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) + \left(\frac{y}{\delta}\right)^2$$

where U = approach velocity of the stream, u = velocity of the stream in the boundary layer at a distance y from the boundary and δ = thickness of the boundary layer.

(d) What is meant by a lumped capacity? What are the physical assumptions necessary for a lumped capacity unsteady-state heat transfer analysis to apply?

2.(a) A gas expands in a convergent-divergent nozzle from 5 kgf/cm^2 to 1.4 kgf/cm^2, the initial temperature being 550° C and the nozzle efficiency is 90 percent. All the losses take place after the throat. Find the throat and exit areas per kg of gas per second. Prove any formula used. 30
Assume $\gamma = 1.4$ and R = 29.27 kgf-m/kg/ ° K.

(b) Using the dimensional analysis express the drag force on a body moving through a fluid in terms of the mass density of the fluid, viscosity of the fluid, body reference length and body velocity. 25

(c) State the Buckingham's Pi theorem. 5

3.(a) 1 kg of water in a closed container is 1/3 liquid and 2/3 vapour by volume. The temperature is 151.11 °C. Find the pressure, quality, volume and enthalpy of the mixture. 20

(b) A stoichiometric mixture of fuel and air has an enthalpy of combustion of approximately-670 kcal/kg of mixture. In order to approximate an actual spark ignition engine using such a mixture, consider an air-standard Otto cycle that has a heat addition of 670 kcal/kg of air: a compression ratio of 8, and a pressure and temperature at the beginning of compression process of 1.0 kgf/cm^2 and 27°C. Determine the maximum pressure and temperature in this cycle, the thermal efficiency and the mean effective pressure. Assume $_{CP}$ = 0.24 and $_{CV}$ = 0.17. 40

4.(a) Derive an expression for the overall heat transfer coefficient across a plane wall (thickness *b*, thermal conductivity *K*) having rectangular fins on both sides. Given that over an area A of the wall, the bare areas on the two sides not covered by fins are A_{b1} and A_{b2} the surface areas of the fins are A_{f1} and A_{f2} the fin efficiencies are η_1 and η_2 and the heat transfer coefficients are h_1 and h_2. 20

(b) Lubricating oil is expected to be cooled in a double pipe heat exchanger from about 70°C to 30°C by passing cold water in the outer pipe. The inner pipe diameter is 2 cm and the outer pipe diameter is 4 cm. The thickness of both tubes is 2 mm. The heat transfer coefficient on the water side is 140 W/m^2 K and on the oil side is 150 w/m^2 K. The pipes are made of galvanised iron (GI) whose thermal conductivity is 30 W/mK. Unfortunately the rate of heat transfer is grossly inadequate and the oil is not cooled sufficiently. The maintenance engineer decides to replace the GI pipes with copper pipes of the same dimensions (whose thermal conductivity is 385 W/m K) to increase the heat transfer rate. Do you agree with the decision of the maintenance engineer? Give justification for your answer. 20
[Note that l W/m^{2}K = 0.86 kcal/m^2 hr K]

(c) Write down the momentum and energy equations for boundary layers on a flat plate, hence deduce the dimensionless numbers which govern the heat transfer from a hot flat plate to a flowing fluid. 20

Section B

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

(a) With reference to the thermodynamic properties of refrigerants, explain why-
  (i) carbon dioxide is not commonly employed as refrigerant in India;
  (ii) ammonia is not used in domestic refrigerators.

(b) Explain why-
  (i) compression-ignition engines are more rough running as compared to spark ignition engines;
  (ii) delay period during combustion process in compression-ignition engines is more than delay period during combustion in SI engine.

(c) With reference to Air Conditioning practice explain:
  (i) The difference between Human Comfort Conditioning and Industrial Air Conditioning, pointing out the various parameters controlled in each of these applications, giving suitable examples.
  (ii) What are 'comfort zones' and how do they differ for summer and winter air conditioning?

(d) What are the two main types of boiler used in practice?
Which of these would be preferable under the following conditions?

(i) Mountainous district, water plentiful but time content high, large output of steam required.

(ii) Easy transport, high steam pressure required, good water supply available.

Give reasons for your choice in each case.

6.(a) With a line sketch, explain the working of an MHD system for power generation. 20

(b) The steam issues from the nozzle of a single wheel impulse turbine with a velocity of 1000 m/s. The nozzle angle is 20°, the mean diameter of the blades is 25 cm and the speed of the rotor is 15000 r.p.m. The mass flow through the turbine blading is 720 kg per hour. If the velocity coefficient for the blades is 0.85 and the blades are equiangular, determine-

(i) tangential force on the blades ;

(ii) axial force on the blades;

(iii) work done on the blades per second;

(iv) efficiency of the blading. 40

7.(a) Distinguish between Open Cycle and Closed Cycle gas-turbine plants and enumerate their relative merits and demerits. Describe various methods used to improve the thermal efficiency of a simple gas turbine plant. 20

(b) In a gas-turbine plant ambient air at 1.03 kgf/cm^2 and 288°K is drawn in the compressor having a pressure ratio 4 : 1 and an isentropic efficiency 0.86. After compression air enters a heat exchanger where it is heated by exhaust gases from the LP turbine. In the heat exchanger 75% of the available heat is utilised by the air. This heated air from the heat exchanger enters the HP combustion, chamber and then HP Turbine (which has an isentropic efficiency of 0.84) at a temperature of 898°K. The HP turbine drives the compressor alone and the mechanical efficiency of the drives is 0.92. Assuming that the specific heat C_p for both air and products of combustion is 0.24, determine (i) the pressure of the gases entering the low pressure turbine and (ii) the overall efficiency of the plant. 40

8.(a) Mention the various types of refrigeration systems used in practice and the field of application of each type. 20

(b) Atmospheric air at 12°C and relative humidity of 25 percent is to be conditioned to 5 kg/kga as it enters an insulated room with a flow rate of 60 cm3/min. Assuming that the humidifying water is at 12°C determine the

(i) relative humidity;

(ii) temperature of the conditioned air;

(iii) heat transfer per kg of dry air

for the cases of-

(1) constant dry bulb temperature;

(2) constant relative humidity;

(3) adiabatic evaporative process.

Show the three processes on the psychrometric plot. 40