

MECHANICAL ENGINEERING
(Paper I)

Time Allowed : Three Hours	Maximum Marks : 300
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QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

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

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. (a) The critical buckling load of a cast iron hollow cylindrical column 3 m in length when hinged at both the ends is equal to P kN. When the column is fixed at both the ends, its critical load increases to $(P + 300)$ kN. If the ratio of external diameter to internal diameter is 1.25 and $E = 100 \text{ GPa}$, determine the external diameter of the column. **12**
 - (b) A stuntman drives a motorcycle around a circular vertical wall 30 m in diameter. The coefficient of friction between the tyre and wall is 0.6. Determine the minimum speed that will prevent sliding down the wall. Determine the angle also by which the motorcycle is inclined to the horizontal. **12**
 - (c) A hypoeutectoid plain c-steel is heated to 1540°C and then cooled slowly to 725°C . What is the percentage of ferrite and austenite in steel after the process? Mark the process on Iron-carbon diagram. **12**
 - (d) An I-beam with the following dimensions is subjected to a shearing force of 20 kN. Flange: breadth = 50 mm, thickness = 5.5 mm Web: depth = 109 mm, thickness = 3.5 mm Area of cross-section = $9.4 \times 10^4 \text{ mm}^2$ M.I. = $I_{xx} = 220 \times 10^4 \text{ mm}^4$. Calculate the value of the transverse shear stress at the neutral axis $x-x$ and at the top of the web. **12**
 - (e) A band brake is used to stop a machine. The brake band is in contact with the brake drum through an angle of 250° . The coefficient of the friction is 0.3. Determine the force P required to develop the braking torque of magnitude 400 Nm. The arrangement is shown in the above figure. **12**
[Figure: Band brake (printed above the text of 1(e)) – brake drum of radius 20 cm rotating clockwise; the band wraps the upper part of the drum and its two straight ends run down to a horizontal lever below the drum: one end is attached at A, the left end of the lever, which is the fulcrum (pin), the other end at B, 5 cm to the right of A; the lever extends to the right to C, where an upward force P is applied; horizontal distance from B to the line of action of P at C = 40 cm]
2. (a)(i) 1. Define interference in involute gears. 2. How do you prevent interference? 3. Determine the minimum number of teeth required on a pinion, in order to avoid interference which is to gear with an equal wheel. The pressure angle is 20° and a standard addendum of 1 module for the wheel may be assumed. **2+3+10=15**
 - (a)(ii) 1. Sketch the arrangement of a reverted gear train comprising of gears A and D mounted on co-axial driving and driven shafts, respectively. Gears B and C are mounted on a parallel counter shaft to mesh with gears A and D, respectively. 2. The speed ratio (driving speed ÷ driven speed) in the reverted gear train of above arrangement is to be 14. The module pitch of gears A and B are 3.125 mm and of gears C and D are 2.5 mm. Calculate the suitable numbers of teeth for the

gears. No gear is to have less than 24 teeth. The centre distance between the counter-shaft and driving shaft is 200 mm. **5+10=15**

- (b) A cylinder having mass 40 kg is hung by means of cables AB and AC which are attached to the top of the vertical wall. The distance of points B and C on the wall from a line along the wall parallel to the axis of cylinder are 8 m and 10 m respectively. A horizontal force along the line perpendicular to the wall has been applied at the cylinder which pulls it by a distance 1.2 m away from the wall. The point A is on the cylinder and it is 10 m below BC . Determine tension in each cable and the force applied at the cylinder. **20**

- (c) (i) How are the thermosetting plastic products processed? (ii) Name two polymerization processes. **10**

3. (a) Compute second moment of area of the plane lamina shown in the above figure about an axis parallel to the base and passing through the centroid. **20**

[Figure: Plane lamina (printed above the text of 3(a)) – a rectangle 22 cm high standing on the base, topped by a semicircle of radius 8 cm whose diameter is the top edge of the rectangle (so the rectangle is 16 cm wide); attached to the right side of the rectangle is a right-angled triangle whose vertical side is the 22 cm right edge of the rectangle (shown dashed) and whose base lies along the common base line; overall base length = 25 cm (so the triangle base is 9 cm), the hypotenuse running from the top-right corner of the rectangle down to the right end of the base]

- (b)(i) A hollow shaft having an inside diameter 50% of its outer diameter is to replace a solid shaft transmitting the same power at the same speed. Calculate the percentage saving in material if the material to be used is also the same. **10**

- (b)(ii) A close coiled spring has coil diameter to wire diameter ratio of 6. The spring deflects 30 mm under a load of 500 N and the maximum shear stress is not to exceed 350 MPa. Find the diameter and length of wire required. Modulus of rigidity of wire material = 80 GPa. **10**

- (c) Compare the main characteristics with regard to their hardening and magnetic properties of various stainless steels. **10**

- (d) Four masses m_1 , m_2 , m_3 and m_4 are 160 kg, 225 kg, 200 kg and 312 kg, respectively. The corresponding radii of rotation are 0.25 m, 0.2 m, 0.3 m and 0.25 m, respectively. The angles between the successive masses are 45° , 75° and 135° . Find the position and magnitude of the balance mass required, if its radius of rotation is 0.25 m. Presume that all masses including the balance mass rotate in the same plane. **10**

4. (a)(i) Compare the flexural strengths of the following three beams of equal weight. 1. I-section 300 mm $\times$ 150 mm with flanges 20 mm thick and web 12 mm thick. 2. Rectangular section having depth twice the width. 3. Solid circular section. **15**

- (a)(ii) A cantilever, 3 m long, and of symmetrical section 250 mm deep carries a uniformly distributed load of 30 kN per m run throughout, together with a point load of 80 kN at a section 1.2 m from the fixed end. Find the deflection at the free end. Take, $E = 200 \text{ GPa}$ and $I = 54,000 \text{ cm}^4$. **15**

- (b)(i) Discuss criteria of stability for spring controlled governors. **5**

- (b)(ii) The sleeve arm and the ball arm of a Hartnell governor are 9 cm and 10 cm long respectively. At mean position of the sleeve, the equilibrium speed is 300 rpm and balls rotate at the radius of 12 cm. The mass of each ball is 2 kg and the sleeve movement is ± 2 cm from the mean position. The minimum speed is 96% of the mean speed. Determine the stiffness of the spring and the maximum speed of the governor. **15**

- (c) A particle has initial velocity of 30 m/s towards the right at 30° with the horizontal. The retardation along horizontal axis is 1 m/s^2 and along upward vertical axis is 6 m/s^2 . Determine the horizontal distance covered until the particle reached a point 30 m below its original elevation. **10**

SECTION 'B'

5. (a) Define “tool life” and list down four methods for quantitative measurement of tool life. **12**
- (b) (i) With the help of an example, clarify the function of a clamp in a fixture. (ii) Sketch a cam type clamp and suggest its two applications. **12**
- (c) Explain how flatness of a surface is measured with an optical flat. **12**
- (d) Following table shows the predecessor relationship of the activities in an assembly line. The output is 200 units per day and operating time is 450 minutes per day. Using the most successors rule to assign tasks to work centre and longest work time rule as a tie breaker, (a) group the tasks into work centres and (b) compute balance efficiency, idle time and balance delay. **12**

Task	Predecessor	Time (sec)
A	None	40
B	A	20
C	None	60
D	C	40
E	D	30
F	None	35
G	None	45
H	G	60
I	H	40

- (e) What are the principles of motion economy related to work place? If these principles are adopted in design of work place, what will be the advantages? **12**
6. (a)(i) A hole is to be drilled in a high-strength copper alloy workpiece with a 10 mm bit at a feed of 0.2 mm/rev. The spindle speed is 500 rpm. Estimate the material removal rate and the torque required for this operation. Take specific energy value of the work material as 1.9 W.s./mm^3 . **11**
- (a)(ii) Discuss in brief the mechanism involved in grinding wheel wear. Why aluminium oxide and cubic boron nitride abrasives are suitable for grinding of steel, but silicon carbide or diamond are not? **20**
- (b)(i) Explain in brief, with sketches, the pressure and vacuum gap flushing techniques used in EDM. **10**
- (b)(ii) Which one of the above will result in a more accurate cavity? Give reason. **5**
- (b)(iii) Also discuss how the gap flushing conditions may be improved while drilling small holes. **5**
- (c) Find the sequence that minimises the total elapsed time required to complete the following jobs. Each job is processed in the order ACB. **10**

Processing times in hours

Job No.	1	2	3	4	5
Machine A	5	7	6	9	5
Machine B	3	7	5	6	7
Machine C	2	1	4	5	3

Determine the sequence of the jobs, makespan and idle time of machines. Illustrate the method of solution and assumptions taken.

7. (a) (i) What is understood by the statement “Process under statistical control”? (ii) State the conditions when the process is considered statistically out of control on the basis of theory of runs? (iii) What is JIT? What are its objectives and key elements? Illustrate in brief the single card Kanban and two card Kanban systems. **5+10+15=30**
- (b)(i) Compare the process capabilities of Shielded Metal-Arc Welding (SMAW) and Submerged Arc Welding (SAW) processes. **15**
- (b)(ii) How thick jobs (> 20 mm) may be welded by SMAW process? **5**

(c) What are the objectives of an efficient facility layout? What are the principles to be adopted to achieve these objectives? Compare product, process and cellular layout. **10**

8. (a)(i) What is the significance of (1) angle of nip, and (2) angle of bite during rolling operation? How are they related to roll friction? **10**

(a)(ii) Classify the process of extrusion with the help of sketches. Enumerate the conditions under which central burst may occur. Where does a 'pipe' occur? **15**

(a)(iii) What is "friction hill"? **5**

(b) (i) A firm manufactures a product whose selling price is ₹ 10. It has a capacity of 10,000 units. The variable costs are ₹ 2.50 per unit. The fixed costs are estimated at ₹ 30,000 up to 50% capacity utilization, ₹ 36,000 above 50% level, and ₹ 42,000 if the utilization is 80% or above. a. What will be the operating profit of the firm at 70%, 80% and 90% utilization? b. What is the lowest level of activity at which the firm can make a profit of ₹ 18,000? (ii) What is detailed work factor system of PMT? List the common areas of its application. **10+10=20**

(c) In the above figure define the lines L_1 , L_2 , L_3 and L_4 in the APT language. **10**

[Figure: (printed above the text of 8(c)) – x–y axes; two equal circles C_1 (left) and C_2 (right) side by side at the same height; L_1 is a horizontal line tangent to the tops of both circles and L_4 a horizontal line tangent to the bottoms of both circles; L_2 and L_3 are the two inclined cross (internal) tangents of the circles, crossing each other midway between the circles: L_2 comes down from the upper left, touches C_1 near its top, passes between the circles and touches C_2 near its bottom, continuing to the lower right; L_3 rises from the lower left, touches C_1 near its bottom and C_2 near its top, continuing to the upper right; no dimensions are given]

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