

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 state of stress at a given point in a loaded component is given by σ_x , σ_y and τ_{xy} and the principal stresses at the point are σ_1 and σ_2 . If the new axes at the point are changed to x' and y' such that state of stress w.r.t. the new axes are $\sigma_{x'}$, $\sigma_{y'}$ and $\tau_{x'y'}$.

(a)(i) Show that:

$$\sigma_x + \sigma_y = \sigma_{x'} + \sigma_{y'} = \sigma_1 + \sigma_2.$$

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(a)(ii) Sketch the Mohr's stress circle for pure shear stress state and hydrostatic state of stress. 3

(a)(iii) A cast iron bar of 30 mm diameter and 1 m length is subjected to equal and opposite torque T applied at its ends. If tensile strength of cast iron is 80 MPa, what is the maximum value of torque T? Show the plane of failure for the applied sense of torque T. 3

(b)(i) A hollow shaft whose internal diameter is half of the external diameter is subjected to maximum bending moment of 2 kN-m at a section and constant torque of 4 kN-m all along its length. If yield stress of the shaft material is 280 MPa and factor of safety is 3.0, what should be the minimum safe diameters of the shaft? 9

(b)(ii) What is the difference between centrifugal and inertia type of governors? Which one is more sensitive? Why is the former preferred to the latter? 3

(c)(i) Distinguish between the pressure angle of a radial cam and that of a spur gear, with the help of a sketch. 8

(c)(ii) What type of motion is performed by a point on the surface of a football rolling on the ground and a point on the surface of a nut moving over a threaded bolt? 4

(d) Distinguish between Eutectoid and Eutectic, in the case of Fe – C system. Give the composition and the maximum temperature at which eutectoid and eutectic are formed. 12

(e)(i) A solid cylinder of mass m and radius r starts rolling down an inclined plane. What will be the velocity of its centre of mass after it has come down by 3 m vertically? (Assume $g = 9.81 \text{ m/s}^2$) 4

(e)(ii) The crane shown in Figure above is supported by cables BD and BE. The distances marked are in m. What are the tensions in the cables BC, BD and BE, when BC is parallel to the x-axis? 8

[Figure: Space crane with axes x (horizontal, to the right), y (vertical) and z (horizontal, towards the viewer) through A. Vertical mast AB of height 12 standing on a ball and socket joint at A (origin). A boom runs from A up to point C,

from which a load of 50 kN hangs; cable BC runs from the top of the mast B to C, parallel to the x-axis, and the horizontal distance of C from the mast along x is 12. Cables BD and BE run from B down to ground anchors D and E. D and E lie on a dashed ground line parallel to the z-axis, which meets the negative x-axis (through A) at right angles at a point 10 from A; D is 8 from that point on one side and E is 8 on the other side. All distances in m.]

2. (a) A hollow shaft is subjected to a steady bending moment of 40 N-m and twisting moment of 50 N-m. Outer diameter of the shaft is twice the inside diameter. Calculate the diameters of the shaft using ASME Code for transmission shafting on the basis of maximum shearing stress theory of failure. Take: Yield point stress in tension of shaft material = 280 MPa; Factor of safety = 2.0; Combined bending and fatigue shock factor = 1.5; Combined shock and fatigue factor for twisting = 1.0 **30**
- (b)(i) What is a quick-return mechanism? Give its types and applications. How is the ratio of time of cutting stroke to return stroke calculated for a slotted lever and crank type of quick-return mechanism? Explain with the help of a neat sketch. **15**
- (b)(ii) Which type of epicyclic gear train is used for rear wheel drive of automotive trucks? Show that rpm of the propeller shaft is arithmetical mean of rpm of two rear wheels, while negotiating a road curve. **15**
3. (a)(i) Figure shows a polyspast lifting a weight Q equalling 1000 N by another weight of P equalling 300 N. Neglecting friction and the masses of the pulleys and cables and the inclinations of cables, determine the distance moved by Q in 2 seconds from start. **18**
 [Figure: Polyspast (block and tackle): an upper block hung from the ceiling carries a large pulley and, below it on the same strap, a smaller pulley; a lower movable block carries a smaller pulley above a large pulley, with the weight Q hanging from the bottom of the lower block. A single cable, its end fixed to a hook under the upper block, passes alternately round the pulleys of the lower and upper blocks (four cable runs supporting the lower block); its free end comes down from the left side of the upper large pulley and carries the weight P. A hatched vertical wall is drawn at the left.]
- (a)(ii) Small steel balls fall from rest through the opening at A at a steady rate of two per second. Find the vertical separation h of two consecutive balls when the lower one has dropped 5 m from A. **12**
 [Figure: A row of steel balls on a horizontal (hatched) shelf rolls to an opening at A at the end of the shelf; balls fall vertically one below the other through A, and the vertical distance between two consecutive falling balls is marked h.]
- (b)(i) A body A weighing P_1 descends down an inclined plane D which makes an angle α with the horizontal and pulls a load B that weighs P_2 by means of a weightless and inextensible string passing over a pulley C as shown in Figure. Determine the horizontal component of the pressure with which the inclined plane D acts on the floor rib E. **20**
 [Figure: Wedge-shaped inclined plane D resting on the horizontal (hatched) floor, with a vertical face on the left and the inclined face rising from the right at angle α to the horizontal. Pulley C is mounted at the top corner of the wedge. Body A lies on the inclined face; the string from A runs parallel to the incline over pulley C and hangs vertically down beside the vertical face, carrying load B. E marks the floor rib at the foot of the vertical face of the wedge.]
- (b)(ii) A satellite is orbiting around the Earth at an altitude of 320 km. Assuming the Earth radius as 6500 km and both the orbit and the Earth as circular, determine the speed of the satellite. **10**
4. (a) What is Tin Babbitt? What is the composition and major application of this alloy? How is it different from other Babbitts? **20**
- (b) What is the application of glass fibre reinforced plastic (epoxy)? How do these composites compare with carbon reinforced plastics (epoxy)? **20**
- (c) Explain the transformation of iron from BCC to FCC. What properties change when iron changes from BCC structure to FCC structure? **20**

SECTION 'B'

5. (a) Compare 'Work Sampling' with 'Time Study'. When are they used for calculating standard time of performing short cycle jobs? Give respective areas of application. **12**

- (b) XYZ Corporation has a production (and sales) capacity of ₹ 10,00,000 per month. Its fixed costs are ₹ 3,50,000 per month and the variable costs over a considerable range of volume are ₹ 0.50 per Rupee of sales. (i) Determine annual break-even point and develop break-even graph. (ii) Determine the effect on break-even point if fixed costs were decreased by 10% and the variable costs per unit are increased by the same percentage. **8+4=12**

- (c) In a metal cutting operation, the following equation for tool-life was obtained for H.S.S. tool:

$$VT^{0.13}f^{0.6}t^{0.3}=C.$$

Given that: tool-life (T) = 60 min, cutting speed (V) = 40 m/min, feed (f) = 0.25 mm/rev, depth of cut (t) = 2.0 mm. Compute tool-life if speed, feed and depth of cut are together increased by 25% and also if they are increased individually by 25%. **12**

- (d) What is the difference between hole basis system and shaft basis system? Why is hole basis system the more extensive in use? What are the differences between interchangeability and selective assembly? **12**

- (e) Why is Total Quality Management (TQM) important? What are the benefits that can be obtained by applying TQM in the software industries? What are the principles of TQM in such applications? **12**

6. (a) What are the various five fuel gases used for gas welding? Give their chemical composition, formula and specific heat content. Indicate also the maximum temperature reached in the respective flames. What percentage of oxygen is supplied by the torch in any one of the fuel gases? Give the chemical reactions in the various zones of the neutral flame. **30**

- (b) How are metal tooth-paste tubes made commercially? Draw the tools configuration with the help of a neat sketch. **30**

7. (a)(i) Illustrate with the help of neat sketches the differences between open-loop and closed-loop control in NC system. Why is feedback not possible in open-loop control system? **22**

- (a)(ii) In open-loop NC system the shaft of a stepping motor is connected directly to the lead screw x-axis of the machine table. The pitch of the lead screw is 3.0 mm. The number of step angles on the stepping motor is 200. Determine how closely the position of the table can be controlled, assuming that there are no mechanical errors in the positioning system. Also, what is the required frequency of the pulse train and the corresponding rotational speed of the stepping motor in order to drive the table at a travel rate of 100 mm/min? **8**

- (b)(i) Determine the trial central line and control limits for a p chart using the following data, which are for the payment of dental insurance claims. Plot the values on graph paper and determine if the process is stable. If there are any out-of-control points, assume an assignable cause and determine the revised central line and control limits. **15**

Subgroup Number	Number Inspected	Number Nonconforming	Subgroup Number	Number Inspected	Number Nonconforming
1	300	3	14	300	6
2	300	6	15	300	7
3	300	4	16	300	4
4	300	6	17	300	5
5	300	20	18	300	7
6	300	2	19	300	5
7	300	6	20	300	0
8	300	7	21	300	2
9	300	3	22	300	3
10	300	0	23	300	6
11	300	6	24	300	1
12	300	9	25	300	8
13	300	5			

- (b)(ii)** Determine the trial limits and revised control limits for a $\bar{u}$ chart using the data in the table for the surface finish of rolls of white paper. Assume any out-of-control points have assignable causes.
- 15**

Lot Number	Sample Size	Total Nonconformities	Lot Number	Sample Size	Total Nonconformities
1	10	45	15	10	48
2	10	51	16	11	35
3	10	36	17	10	39
4	9	48	18	10	29
5	10	42	19	10	37
6	10	5	20	10	33
7	10	33	21	10	15
8	8	27	22	10	33
9	8	31	23	11	27
10	8	22	24	10	23
11	12	25	25	10	25
12	12	35	26	10	41
13	12	32	27	9	37
14	10	43	28	10	28

In both cases assume 3σ limit.

8. **(a)** JIT, Toyota Production System (TPS) and lean operations sustain competitive advantage. Distinguish among the three. Secondly, discuss how effective JIT contributes to competitive advantage. Thirdly, identify three core components of TPS. **5+20+5=30**
- (b)** A cost matrix is provided, here amount available exceeds the amount required. **20+10=30**

	D_1	D_2	D_3	D_4	Available
S_1	8	9	3	7	130
S_2	3	6	8	4	180
S_3	7	5	4	5	240
S_4	8	7	2	6	160
S_5	5	4	2	9	90
S_6	8	4	4	3	120
Required	300	100	150	200	

- (i) Using Vogel's Approximation determine initial feasible solution. Give all assumptions and provide clear steps. (ii) What is total transportation cost? How can this be checked for optimality? Show one step only.
