

MECHANICAL ENGINEERING
(Paper I)

Time Allowed : Three Hours	Maximum Marks : 250
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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.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION 'A'

1. (a) In the Figure shown below, block C has a mass of 50 kg and is confined between two walls by smooth rollers. If the block rests on the top of the 40 kg spool, determine the required coefficient of static friction at A and B so that the spool slips at A and B when the magnitude of applied force P is increased to 300 N. **10**
[Figure: Block C (50 kg) held between two vertical walls by smooth rollers on both sides; it rests on top of a spool (40 kg) at point A (top of the spool's outer rim). The spool, centre O, rests on the horizontal ground at B (bottom of the outer rim). Outer radius OE = 0.4 m, inner hub radius OD = 0.2 m. A cord wound on the inner hub leaves from the bottom of the hub horizontally to the right and carries the applied force P.]
- (b) In the Figure shown, a plate is supported at three positions, A, B and C. A is the ball and socket support, B is the roller support and CD is the cord. Determine the components of reactions at A and B and tension in cord CD. **10**
[Figure: Horizontal triangular plate ABC in the x-y plane with C at the origin; B on the x-axis 4 m from C (marked 2 m + 2 m) and A on the y-axis 3 m from C (marked 2 m + 1 m). A vertical load of 400 N acts downward on edge CB at 2 m from C (2 m from B); a vertical load of 300 N acts downward on edge CA at 2 m from C (1 m from A). Cord CD runs vertically upward along the z-axis from corner C to a fixed support D. Supports at A and B as stated in the text.]
- (c) The bending moment diagram for a simply supported beam AB is shown in Fig. below. Sketch the loading diagram and S.F. diagram of the beam. **10**
[Figure: Bending moment diagram for simply supported beam AB of span 5 m: the moment varies linearly from zero at A to 12 kN.m (negative, marked "–") at a section 2 m from B, where it jumps to 8 kN.m (positive, marked "+") and then varies linearly to zero at B.]
- (d) Distinguish clearly the function of a flywheel used in I.C. Engines and in mechanical punching presses. For the same power output, why flywheels of multi-cylinder inline engines are relatively smaller than that of single cylinder engine? **10**
- (e) Differentiate between (i) annealing, and (ii) tempering. Mark the processes on a TTT diagram and bring out the transformations that take place during the process. **10**
2. (a) A compound pendulum of mass 27 kg is suspended from a pivot, such that the distance of pivot from the mass centre of pendulum is 380 mm. When the pendulum swings about its pivot with small oscillation, the period of oscillation is 1.60 second. If the pendulum is now made to swing with amplitude of 45° on each side of the vertical, find the force exerted on the pivot at the extremity of the swing. **25**

- (b) A simply supported beam of 3 m span is subjected to loads as shown below. The beam is of I-section and all its dimensions are shown in mm. Determine the principal stresses at point D in the web. This section is located at a distance of 1 m from the right hand support of the beam. **25**

[Figure: Simply supported beam AB of span 3 m, hinged at A and on rollers at B, carrying a uniformly distributed load of 2 kN/m over the whole span and a concentrated load of 4 kN at C, 1 m from B. I-section (dimensions in mm): overall depth 200, flanges 75 wide and 10 thick, web 15 thick; point D in the web at 50 above the neutral axis N–A.]

3. (a) In a loaded component principal stresses at a point are 130 MPa and 30 MPa. Using Mohr's stress circle, determine the state of stress at the point with respect to axes x' and y' which are inclined to σ_1 and σ_2 (principal stress) axes at 30° each in anticlockwise direction. Also determine principal strains at the point. Take $E = 200$ GPa and $G = 80$ GPa. **20**
- (b) The mass of an electric motor is 100 kg. The mass of the armature alone is 30 kg and its centre of gravity lies 0.5 mm from the axis of rotation. The motor is mounted on five springs of negligible damping and the force transmitted to the floor is one-eleventh of the applied force. Assuming mass of the motor is equally distributed among the five springs, determine the (i) stiffness of each spring (ii) dynamic force transmitted to the floor. The motor is operating at a speed of 1400 rpm. **10**
- (c) In the epicyclic gear train shown in the Figure, S_1 is the driver, A_2 is connected to output. A_1 and A_2 are annulus gears, and S_1 and S_2 are external gears, in which S_2 is fixed gear. Given the tooth numbers of gears are $S_1 = 40$, $S_2 = 30$, $A_1 = 120$ and $A_2 = 100$, determine the velocity ratio of the co-axial shafts. Determine also the magnitude and direction of the torque required to fix S_2 , if a torque of 300 N-m is applied in a clockwise direction to S_1 . **20**

[Figure: Sectional sketch of a compound epicyclic gear train on a common axis: sun S_1 on the input shaft (left) meshes with planets that also mesh with annulus A_1 ; a second gear set has sun S_2 on a fixed (hatched) sleeve around the shaft, meshing with planets that also mesh with annulus A_2 ; the planets of the two sets are carried on pins (shown dashed) of a common carrier, and A_2 is connected to the output shaft (right).]

4. (a) In the figure shown, the end A of a bar AB, is constrained to move along vertical path AD and the bar passes through a swivel bearing pivoted at C. When A has a velocity of 3 m/s towards D and an acceleration of 25 m/s^2 in the opposite direction, determine: (i) velocity and acceleration of sliding of bar through the swivel, (ii) angular velocity and angular acceleration of AB. **25**
- [Figure: End A of bar AB moves on a vertical line through D, with A above D; the swivel bearing C is pivoted at the same level as D, 0.4 m horizontally from D. The bar runs from A down through the swivel at C and extends beyond it to B; at the instant shown the bar makes 30° with the horizontal line DC at C.]
- (b) What are the desirable properties while selecting a tool material for metal-cutting applications? Compare HSS and ceramic tools with regard to their application in high speed machining. **15**
- (c) What are composite materials? Enumerate the advantages and limitations of the use of composites as engineering materials. **10**

SECTION 'B'

5. (a) What is underlying philosophy behind JIT systems? Briefly describe the characteristics of JIT systems. **10**
- (b) List the basic principles of plant layout. **10**
- (c) Bars of length 20.05/19.95 mm are in stock. From each, piece of 5.03/4.98 mm are cut. Determine the lengths of the remaining parts. **10**
- (d) A cup, of 50 mm diameter and 100 mm height, is to be drawn from low carbon steel sheet. Neglecting the influence of thickness and corner radii: (i) calculate the blank diameter (ii) decide whether it can be drawn in a single draw, if maximum reduction permitted is 40%. **10**

- (e) For a machined surface, show macro- and micro-irregularities. What are their causes? What are the various measures of surface finish? Explain any three of them. **10**

6. (a) An open loop type NC machine has a stepper motor with a step of 0.9 degree. The lead screw of the machine is of 4 mm pitch. (i) If the tool has to be moved by 2.87 mm, how many pulses will have to be fed? (ii) If the motor is rotating at 15 r.p.m., what is the pulse frequency and the feed rate of the machining operation? **10**
- (b) The process capability of machines manufacturing holes and shafts is ± 0.24 min. The assembly requirements for the hole/shaft, of nominal dimension 20.00 mm, are of clearance between 0.04 and 0.08 mm. Devise the complete scheme (state what it is?) so that satisfactory assemblies are made. **10**

[Attached: Cumulative distribution function table for the standard normal distribution (SND), with a sketch of $N(0, 1)$ and

the note "For the SND, the table gives the cdf value at z , that is $\int_{-\infty}^z N(0, 1) dz$ " – not transcribed.]

- (c) Sketch the set-up for spot welding showing details of power input and electrodes: (i) Draw the force/time and current/time diagrams. (ii) Explain how heating takes place. (iii) Indicate order of magnitude of current, voltage and time. (iv) How projection welding is different from spot welding? **10**

- (d) The following table gives the monthwise actual demand of units of some product: **20**

Month	March	April	May	June	July	August
Demand (units)	350	440	450	460	495	510

The forecasted demand for the month of March was 400 units. The firm uses exponential smoothing method with smoothing factor 0.2 to forecast demand. (i) Calculate the tracking signal for the model. (ii) Comment on the smoothing factor.

7. (a) An assembly line is to produce 40 microwave ovens an hour. The relevant data for the work elements involved in assembly are given below: **25**

Work element	Time (sec)	Immediate Predecessor(s)
A	20	None
B	55	A
C	25	B
D	40	B
E	05	B
F	35	A
G	14	D, E
H	40	C, F, G

(i) Draw the precedence diagram. (ii) Design a balanced assembly line. (iii) Calculate (a) idle time, (b) efficiency, and (c) balance delay. (iv) What can be the maximum output from this assembly line?

- (b) How is the domestic kitchen gas cylinder manufactured? State the raw material, its shape and the processes involved. **10**

- (c) A manufacturer carries stock of an item with an annual demand of 30,000 units. The set-up cost (s) and holding cost (h) are not known precisely, though they vary between 100:1 and 150:1. (i) Calculate EOQ in both conditions. (ii) How sensitive is the optimal Q to s/h ratio? (iii) If s/h doubles or triples, what happens to economic order quantity Q^* ? **15**

8. (a) A special screw is being produced on a machine. The diameter of screw is critical and the process is to be controlled. Twelve samples of four screws each are drawn chronologically and inspected. The data is tabulated below: **20**

Sample No.	Screw Diameter (mm) 1	Screw Diameter (mm) 2	Screw Diameter (mm) 3	Screw Diameter (mm) 4
1	12.50	12.56	12.51	12.49
2	12.55	12.52	12.51	12.56

3	12.58	12.55	12.54	12.50
4	12.53	12.55	12.56	12.52
5	12.54	12.53	12.51	12.59
6	12.50	12.48	12.53	12.60
7	12.52	12.53	12.51	12.55
8	12.55	12.51	12.58	12.59
9	12.53	12.54	12.51	12.58
10	12.56	12.53	12.55	12.56
11	12.55	12.54	12.54	12.57
12	12.60	12.55	12.54	12.58

The statistical control chart constants for some samples are as under:

No. of observations in sample n	Chart for Average – Factors for Control Limits A_1	A_2	A_3	Factor for central line d_2	Chart for ranges of Factors for Control Limits D_1	D_2	D_3	D_4
2	2.121	3.759	1.880	1.128	0.0	3.686	0.0	3.268
3	1.732	2.394	1.023	1.693	0.0	4.358	0.0	2.574
4	1.500	1.880	0.729	2.059	0.0	4.698	0.0	2.282
5	1.342	1.596	0.577	2.326	0.0	4.918	0.0	2.114

Is the process under statistical control? Justify your answer.

- (b) What is the principle of LBM (Laser Beam Machining)? Draw a sketch and name the salient elements used in LBM. 15
- (c) Determine the optimum speed, for minimum cost, for a machining operation. The data is as follows: Machine hour rate = ₹ 3,000; Cost of tool = ₹ 4,000; Machining time/job = 6 min.; Tool life = 90 min.; Taylor's equation constants $c = 100$, $n = 0.5$; Handling time/job = 4 min.; Tool changing time = 9 min. 15
