

MECHANICAL ENGINEERING (Paper I)

Time Allowed : Three Hours	Maximum Marks : 300
-----------------------------------	----------------------------

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. Attempt any three of the following:

(a)(i) Define a general case of forces acting on a rigid body. State clearly and precisely the equations of equilibrium for this body. How do these equations change when applied to a particle? **8**

(a)(ii) A smooth hollow cylinder of radius r open at both ends rests on a smooth horizontal plane. Two smooth spheres of weights W_1 and W_2 , and radii r_1 and r_2 respectively are placed inside the cylinder, with the larger sphere (radius r_2) resting on the horizontal plane as shown in Fig. 1. Determine the minimum weight W of the cylinder that will prevent the cylinder from tipping over. **12**

[Figure: Fig. 1 – Vertical hollow cylinder (walls hatched, wall thickness t marked at the bottom right) standing on a hatched horizontal plane; inside width between the walls marked $2r$. The larger sphere (radius r_2 , weight W_2 acting downward at its centre) rests on the horizontal plane touching the right wall; the smaller sphere (radius r_1 , weight W_1 acting downward at its centre) rests on top of the larger sphere, to its left, touching the left wall. Label “Hollow Cylinder” with arrow to the right wall.]

(b)(i) A beam is of square section with diagonals 60 mm long, vertical and horizontal, as shown in Fig. 2. Shear force at a particular section is 5 kN. What is the shear stress at layer AB as shown? **15**

[Figure: Fig. 2 – Square cross-section placed with its diagonals vertical and horizontal; overall height 60 mm (vertical diagonal) and overall width 60 mm (horizontal diagonal). Layer AB is a horizontal line across the upper half of the section (A on the upper-left side, B on the upper-right side), located 15 mm above the horizontal diagonal (neutral axis).]

(b)(ii) A beam ABCD, 6 m long, hinged at both ends A and D, is subjected to moments 6 kN-m (cw) at B and 3 kN-m (ccw) at C as shown in Fig. 3. Sketch the bending moment diagram of the beam. How many points of contraflexure are there in the beam? **5**

[Figure: Fig. 3 – Horizontal beam ABCD with hinged supports at A and D; AB = 2 m, BC = 2 m, CD = 2 m. A clockwise couple of 6 kN-m is applied at B and a counter-clockwise couple of 3 kN-m at C.]

(c)(i) In an orthogonal crystal structure with lattice parameters $a \neq b \neq c$, draw the direction $[2\bar{1}2]$. **10**

(c)(ii) Show that in a hexagonal close-packed structure, atomic packing factor is 0.74. Take dimension $c = 1.633a$. **10**

(d)(i) What is meant by ‘whirling or critical speed of shaft’? **4**

(d)(ii) Calculate the whirling speed in case of a rotating steel tube simply supported in short bearings 2 m centre-to-centre. The external and internal diameters of the tube are 35 mm and 25 mm,

respectively. The weight of steel may be taken as 78 kN/m^3 and Young's modulus of elasticity for steel is 200 GPa. **16**

2. (a)(i) State why gear teeth have to be undercut. **4**

(a)(ii) The following data refers to two 20° involute spur gears in mesh externally: Velocity ratio = 3; Module = 3 mm; Addendum = 1.1 module. If the pinion rotates at 120 r.p.m., find– (1) the minimum number of teeth on each gear wheel to avoid interference; (2) the number of pairs of teeth in contact. **16**

(b) A plate is riveted to a channel section in a structure as shown in Fig. 4. An eccentric load of 12.5 kN acts as shown on the plate. Determine the rivet diameter so that the maximum shear stress in any rivet is not to exceed 40 MPa. Diameter of the rivet should be chosen from preferred series. Preferred rivet diameters (in mm): 12, 14, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 42, 48. **40**

[Figure: Fig. 4 – A vertical channel (shown with dashed hidden edges) carries a horizontal rectangular plate riveted to it by four rivets at the corners of a rectangle: horizontal pitch 200 mm between the two rivet columns and vertical pitch 200 mm between the two rivet rows. The centroid of the rivet group (marked $\otimes$) is shown 100 mm above the lower rivet row and 100 mm from the right rivet column. The right rivet column is 50 mm from the right edge of the channel; the plate projects to the right, and a vertical downward load of 12.5 kN acts on the plate at 400 mm to the right of the channel edge.]

3. (a)(i) A homogeneous ball of weight Q and radius a as well as a weight P are suspended by cords from a point O as shown in Fig. 5. The distance OM is b . Find the inclination ϕ of OM with the vertical when the system is in equilibrium. **8**

[Figure: Fig. 5 – Ball of radius a with centre M hangs from point O by a cord OM of length b inclined at angle ϕ to the vertical through O . A second cord from O passes down over the right side of the ball (in contact with its surface) and hangs vertically, carrying the weight P below the ball.]

(a)(ii) A body A of weight 10 kN is connected to another body B of weight 50 kN, resting on a smooth table of weight 200 kN through an inextensible thread, passing over a freely rotating pulley mounted on a corner of the table. Find the vertical component of the reaction of the ground on the table when the bodies A and B are in motion. Does the reaction change with time? The system is shown in Fig. 6. **12**

[Figure: Fig. 6 – Table standing on the hatched ground; body B rests on the smooth horizontal table top; a horizontal thread from B runs over pulley C mounted at the right-hand top corner of the table and hangs vertically down beside the table, carrying body A .]

(b) Stresses on two perpendicular planes, at a point, are given in Fig. 7. What are the directions of principal planes with respect to plane BC ? What are the principal strains on principal planes, if $E = 67 \text{ kN/mm}^2$, $\nu = 0.33$? **20**

[Figure: Fig. 7 – Right-angled triangular element ABC with the right angle at C : BC horizontal (bottom face), AC vertical (right face), AB the inclined face making angle θ with BC at B . On face AC : normal stress 100 MPa (arrow pointing to the right, away from the face) and shear stress 20 MPa (arrow pointing downward). On face BC : normal stress 100 MPa (arrow pointing downward, away from the face) and shear stress 20 MPa (arrow pointing to the right).]

(c) A beam $ABCD$, 5 m long, is supported at A and C as shown in Fig. 8. It carries a point load of 2 kN at end D , and a moment of 2 kN-m (cw) at B . What is the flexural rigidity (EI) of the beam, if deflection at D is not to exceed 1 mm? **20**

[Figure: Fig. 8 – Beam $ABCD$ with hinged support at A and roller support at C ; $AB = 2 \text{ m}$, $BC = 2 \text{ m}$, overhang $CD = 1 \text{ m}$. A clockwise couple of 2 kN-m acts at B and a downward point load of 2 kN at the free end D .]

4. (a)(i) State the function of a flywheel. **4**

(a)(ii) A punching machine carries out 5 holes per minute. Each hole of 40 mm diameter in 40 mm thick plate requires 10 N-m/mm^2 of the sheared area. The punch has a stroke of 100 mm. Find the power of the motor required, if the mean speed of the flywheel is 25 m/s. If the total fluctuation of speed is not to exceed 4% of the mean speed, determine the mass of the flywheel. **16**

- (b) A shaft carries four rotating masses A, B, C and D in sequence along its axis. The masses A, B, C and D are assumed to be concentrated at radii of 12 cm, 16 cm, 8 cm and 10 cm, respectively. The masses of B, C and D are 30 kg, 50 kg and 40 kg, respectively. The planes containing B and C are 30 cm apart. The angular spacing of the planes containing C and D are 90° and 210° , respectively relative to B measured in the same sense. If the system is to be in complete dynamic balance, find—
(i) the mass and angular position of mass A; (ii) the spacing positions of the planes containing A and B. **20**
- (c) Give chemical reactions and temperature ranges in the cases of cyaniding, carbonitriding and nitriding processes. What is the serious problem encountered in nitriding process? In which process is case hardened thickness maximum? **20**

SECTION 'B'

5. Attempt any three of the following:

- (a)(i) Describe the properties of tungsten carbide as a cutting tool material and its applications. **5**
- (a)(ii) In orthogonal machining, prove that

$$\tan \phi = \frac{r_c \cos \alpha}{1 - r_c \sin \alpha}$$

where, r_c = chip thickness ratio, α = back rake angle, ϕ = shear angle **8**

- (a)(iii) Explain 'sudden-death mechanism' of tool failure. **4**
- (a)(iv) What are extreme-pressure lubricants? **3**
- (b)(i) Define the terms 'rose reamer' and 'feed in milling'. **2+2**
- (b)(ii) Name four independent variables and three dependent variables in metal cutting. **5**
- (b)(iii) What is the function of stepper motor? **2**
- (b)(iv) With a sketch, explain the principle of working and variations of bed-type milling machine. **9**
- (c)(i) Name the factors to be considered while choosing a good forecasting system. **5**
- (c)(ii) The quarterly demand of a company product for past six years is given in the table below. The four-quarter moving average is also given. Find the seasonality index for 3rd quarter. **15**

Year	Quarter	Demand $\times 10^5$ units	Four Quarter Moving Average
1	Q_1	0.5	
1	Q_2	0.8	0.875
1	Q_3	2.1	0.925
1	Q_4	0.1	1.025
2	Q_1	0.8	1.1
2	Q_2	1.1	1.1
2	Q_3	2.4	1.125
2	Q_4	0.1	1.15
3	Q_1	0.9	1.25
3	Q_2	1.2	1.25
3	Q_3	2.8	1.20
3	Q_4	0.1	1.15
4	Q_1	0.7	1.10
4	Q_2	1.0	1.10

4	Q_3	2.6	1.125
4	Q_4	0.1	1.125
5	Q_1	0.8	1.10
5	Q_2	1.0	1.10
5	Q_3	2.5	1.15
5	Q_4	0.1	1.20
6	Q_1	1.0	1.25
6	Q_2	1.2	1.275
6	Q_3	2.7	
6	Q_4	0.2	

[Table layout: in the printed table each four-quarter moving average is printed on the dividing line between the quarter in whose row it is placed here and the next quarter (e.g. 0.875 between Q_2 and Q_3 of Year 1).]

(d)(i) Explain briefly the MTM. Which basic motions does it recognize? Suggest its applications and also describe the sequence of steps of procedure to implement the same. **12**

(d)(ii) The following costs were incurred in a year in a company. Classify them into various quality costs. **8**

Sl. No.	Head	Cost (Rs)
1	Incoming material inspection	20,000
2	Training of personnel	40,000
3	Warranty	45,000
4	Process planning	15,000
5	Scrap	13,000
6	Quality laboratory	30,000
7	Rework	25,000
8	Allowances	10,000
9	Complaints	14,000

6. (a)(i) What do you mean by 'interchangeable manufacture' and 'combination set'? **8**

(a)(ii) What is the difference between a plug gauge and a ring gauge? **4**

(a)(iii) Discuss, with figure(s), pneumatic gauges and their applications. **8**

(b)(i) How does inventory level depend on service level? **5**

(b)(ii) 4000 spare parts are required annually. A set-up cost of Rs 100 and a carrying cost of 25% per year is charged on the item cost of Rs 320. The production facility is open for 5 days per week and 50 weeks per year. The lead time of this product is 9 days and the standard deviation of the demand is 2 units per day. The company wants to have a 95% service level for this spare part. (1) If the company were using continuous review system (Q-system) of inventory control, compute the order quantity and reorder level. Interpret the results. (2) If the company were using periodic review system (P-system) of inventory control, give the specific decision rule. **15**

(c)(i) Briefly state the intermittent process layout problem. **5**

(c)(ii) Five departments are currently arranged in the following manner: **15**

[Figure: Layout of departments in two rows – top row: 1, 2, 3 (left to right); bottom row: 4 (below 1 and the left half of 2) and 5 (below the right half of 2 and 3).]

New products have been added and the movements between the departments have changed substantially since the existing arrangement was made. The movement between the departments is on rectangular path. The monthly number of trips, cost/trip and distance of each trip are given below:

Item	1-2	1-3	1-4	1-5	2-3	2-4	2-5	3-4	3-5	4-5
Trips/month	100	200	100	400	200	500	300	100	100	200

Cost/trip	12	34	56	34	57	25	17	43	63	52
Distance units	1	2	2	3	1	1	2	2	1	1

(1) Calculate the monthly cost of travel between the departments. (2) How much is the saving in monthly cost of travel between the departments, if departments 1 and 3 are interchanged? (3) A one-time cost of Rs 22,500 is associated with interchanging the positions of departments 1 and 3, and if this cost is to be recovered within two months, should the change be made?

7. (a)(i) Name the various alloying elements used with tungsten for GTAW. Give the approximate content of any two used in GTAW process. Enumerate applications of GTAW process. **4**
- (a)(ii) Define the term 'keyholing' used in laser welding. **3**
- (a)(iii) What is 'dip transfer' in GMAW? **3**
- (a)(iv) Write the differences between coining and embossing. **4**
- (a)(v) What are the advantages of isothermal forging? **3**
- (a)(vi) What is the difference between extrusion and drawing? **3**
- (b)(i) Define 'slack'. **5**
- (b)(ii) A project consists of six activities. The precedence relationship of activities and the three time estimates of completion of activities in days are tabulated below: **15**

Sl. No.	Activity	Immediate Precedent Activity	Optimistic (days)	Pessimistic (days)	Most likely (days)
1	A	–	0.5	1.5	1.00
2	B	A	1.0	3.0	2.00
3	C	B	2.0	2.0	2.00
4	D	A	2.9	4.1	2.75
5	E	A	1.5	4.0	1.63
6	F	C, D, E	3.0	6.0	3.75

(1) Draw the arrow diagram. (2) Which of the six activities is most uncertain? (3) What is the probability that the project will be completed within 10 days? Refer the SND-chart (Cumulative Distribution Function for the Standard Normal Distribution) attached at the end.

- (c)(i) A company uses a decision rule to determine production level in t-th period, as under:

$$P_t = P_{t-1} + [A(F_t - P_{t-1})]$$

where P_t , F_t denote production and forecast for t-th period and A is smoothing constant. (1) Given the information in the table below, find the appropriate production level for period 2 using a smoothing constant of 0.5: **10**

Period t	Production Level	Forecast
1	36000	
2		42000
3		48000

(2) Assuming that actual production for period 2 will be equal to the value as determined in case (1) above, determine the production levels for period 3 using (A) chase, (B) level and (C) intermediate strategies.

- (c)(ii) A company manufactures two products A and B. The manufacturing and marketing data for the two products is given below: **10**

Department	Product A	Product B	Capacity
Welding	2.0 man-hr	2.5 man-hr	1000 man-hr
Machines	3.0 man-hr	1.5 man-hr	1200 man-hr
Assembly	1.5 man-hr	4.0 man-hr	1200 man-hr
Profit	Rs 120	Rs 100	

(1) Formulate the problem. (2) Find the product mix that will maximize the profit.

8. (a)(i) Describe the applications of abrasive-jet machining. **5**
- (a)(ii) What are the differences between electrolyte and dielectric? **5**

- (a)(iii)** What is wire EDM process? Explain the reasons for its popularity. **10**
- (b)(i)** With a figure, explain '3-2-1' method of location. **10**
- (b)(ii)** Draw leaf jig and mention its advantages. **10**
- (c)(i)** Give the steps for sequencing n jobs through 2 machines for minimum elapsed time. **5**
- (c)(ii)** A foreman wants to process four different jobs on three machines A, B and C in his shop. The order of machining for all the jobs is fixed, i.e., A, B and C. The processing time for all the jobs are given in the table below: **15**

Job	Machine A	Machine B	Machine C
1	40	10	10
2	50	15	5
3	30	8	15
4	25	20	10

Decide the optimal sequence for the jobs to minimize the elapsed time between start of the first job to completion of the last job.

* * *