MECHANICAL ENGINEERING

PAPER—I

Time Allowed : Three Hours

Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

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

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

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.

Answers must be written in ENGLISH only.

SECTION—A

1. *(a)* What are meant by killed steels and rimmed steels? Explain the characteristics of these steels. Enlist its applications. 8

(b) A flat belt transmits 10 kW power at a speed of 5 m/s. The mass of the belt is 1·5 kg/m and the angle of lap at smaller pulley is 200°. The coefficient of friction between the belt and the pulley is 0·30. Determine the initial tension in the belt. 8

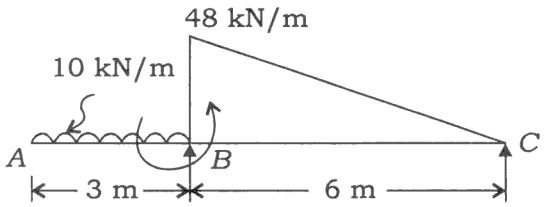
(c) Compare between involute and cycloidal gear tooth profiles. List the important properties of a good material for sliding contact bearing. 8

(d) A compound bar is constructed from three bars 50 mm wide by 12 mm thick fastened together to form a bar 50 mm wide by 36 mm thick. The middle bar is of aluminium alloy for which $E = 70 \times 10^9$ N/m^2 and the outside bars are of brass with $E = 100 \times 10^9$ N/m^2. If the bars are initially fastened at 18 °C and the temperature of the whole assembly is then raised to 50 °C, determine the stresses set up in the brass and the aluminium alloy. Take the coefficient of expansion of the brass (α_B) and the aluminium alloy (α_A) as follows :

$$\alpha_B = 18 \times 10^{-6} \text{ per °C} \quad \text{and} \quad \alpha_A = 22 \times 10^{-6} \text{ per °C}$$ 8

(e) State the difference between elastic and plastic deformation. Explain each in detail. 8

2. *(a)* A beam *ABC* is 9 m long and supported at *B* and *C*, 6 m apart as shown in the figure below. The beam carries a triangular distribution of load over the portion *BC* together with an applied counterclockwise couple of moment 80 kN-m at *B* and a uniformly distributed load of 10 kN/m over *AB*. Draw the shear force and bending moment diagrams for the beam :



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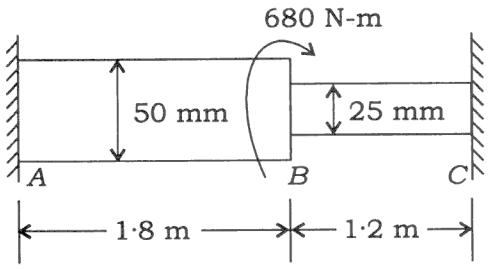
(b) Determine the load required to produce an extension of 8 mm on an open-coiled helical spring of 10 coils of mean diameter 76 mm, with helix angle of 20° and manufactured from wire of 6 mm diameter. What will then be the bending and shear stresses in the surface of the wire? For the material of the spring, $E = 210 \times 10^9$ N/m^2 and $G = 70 \times 10^9$ N/m^2. What would be the angular twist at the free end of the above spring when subjected to an axial torque of 1·5 N-m? 15

(c) The lines of strokes of a three-cylinder radial engine are 120° apart. The length of each connecting rod is 250 mm and the crank radius is 75 mm. The reciprocating parts have a mass of 2·5 kg per cylinder. Determine the primary and secondary forces if the engine runs at 2000 r.p.m. 15

3. (a) A circular bar *ABC*, 3 m long is rigidly fixed at its ends *A* and *C*. The portion *AB* is 1·8 m long and of 50 mm diameter and *BC* is 1·2 m long and of 25 mm diameter. If a twisting moment of 680 N-m is applied at *B*, determine the values of the resisting moments at *A* and *C*, and the maximum stress in each section of the shaft. What will be the angle of twist of each portion? Take the value of *G* for the shaft material as 80×10^9 N/m^2. The appearance of the shaft (bar) is shown in the figure below :



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(b) What is meant by atomic packing factor? Calculate atomic packing factor for the following cases :

(i) Simple cubic

(ii) Body-centred cubic

(iii) Face-centred cubic 15

(c) A Hartnell governor has equal balls of mass 3 kg, set initially at a radius of 200 mm. The arms of the bell crank lever are 100 mm vertically and 150 mm horizontally. Find—

(i) the initial compressive force on the spring if the speed for an initial ball radius of 200 mm is 300 r.p.m.;

(ii) the spring stiffness required to permit a sleeve movement of 5 mm on a fluctuation of 10% in the engine speed. 15

4. *(a)* Define the term hardenability of steel. What factors affect hardenability? Name any three methods for determining the hardenability of steel. 10

(b) At a point in a piece of elastic material, direct stresses of 90×10^6 N/m^2 tensile and 50×10^6 N/m^2 compressive are applied on mutually perpendicular planes. The planes are also subjected to shear stress. If the greater principal stress is limited to 100×10^6 N/m^2 tensile, determine—

(i) the value of the shear stress;

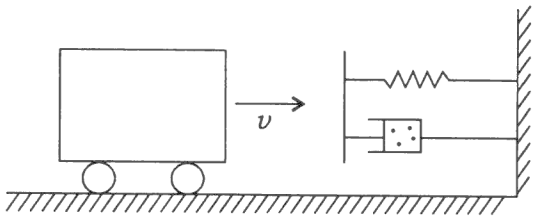
(ii) the other principal stress;

(iii) the normal stress on the plane of maximum shear;

(iv) the maximum shear stress.

Make a neat sketch showing clearly the positions of the principal planes and planes of maximum shear stress with respect to the planes of applied stresses. 15

(c) A railroad car of mass 2000 kg travelling at a velocity $v = 10$ m/s is stopped at the end by a spring-damper system as shown in the figure below. The stiffness of the spring is 40 kN/m and the damping coefficient is 20 N-s/mm. Determine the maximum displacement of the car after engaging the spring-damper system :



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SECTION—B

5. *(a)* What is the principle of Plasma Arc Machining? Explain with the help of a neat sketch. 8

(b) During orthogonal machining with an HSS tool, the rake angle was 5°, the undeformed chip thickness was 0·25 mm and the width of cut was 4 mm. Taking the shear strength of the work material to be 350 N/mm^2 and the coefficient of friction between the chip and the tool to be 0·5, estimate the cutting force and the thrust force. 8

(c) What are control charts and where are they used?

Draw the control charts for mean $\overline{X}$ and range R from the following data relating to the thickness of a job, by taking 5 samples from a lot of 100 and 6 lots are checked. Comment whether it is in statistical control or not.

(Given : For sample of size 5; $D_3 = 0$, $D_4 = 2 \cdot 115$ and $A_2 = 0 \cdot 577$)

Lot → *Sample* ↓	*1*	*2*	*3*	*4*	*5*	*6*
1	7	6	8	5	4	2
2	8	5	7	4	6	3
3	5	4	5	3	2	1
4	4	3	2	3	1	5
5	6	1	4	2	5	6

8

(d) In time series analysis of forecasting, explain the terms demand noise, pattern and stability.

Demand for a particular product was 500 in April, 350 in May and 600 in June. The forecast for April was 250 units. With a smoothing constant of 0·15 and using first-order exponential smoothing, find the July forecast. 8

(e) Differentiate between RAM and ROM, and also discuss different types of RAM and ROM. 8

6. (a) The number of identical components produced at different spindle speeds and feeds between consecutive tool changes in a single-pass turning operation is given in the table below :

Spindle speed (r.p.m.)	300	300	400
Feed (mm/rev)	0·100	0·125	0·125
Number of components produced	300	250	150

Estimate the number of components that can be produced at a spindle speed of 500 r.p.m. and a feed of 0·20 mm/rev. 15

(b) Define the term automation. Differentiate between the types of automation with examples. 10

(c) (i) Differentiate between the following :

(1) Job design and Job rotation

(2) Job enlargement and Job enrichment 10

(ii) An industrial engineer conducted a direct time study for an acid mixing operation. The analyst found cycle times as shown below, rated the observed worker at 80 percent, and used the firm's 0·10 allowance fraction :

Cycle time (in minutes)	2·7	2·7	2·9	3·1	3·2
Number of times observed	3	4	2	1	1

Determine the standard time. 5

7. *(a)* A company has three plants at locations P_1, P_2 and P_3 which supply warehouses W_1, W_2, W_3, W_4 and W_5. The monthly plant capacities are 800 units, 500 units and 900 units respectively. The monthly warehouse requirements are 400 units, 350 units, 300 units, 250 units and 900 units respectively. The unit transportation costs in rupees are given below :

Warehouse → *Plant* ↓	W_1	W_2	W_3	W_4	W_5
P_1	8	8	9	4	3
P_2	5	8	5	11	6
P_3	8	9	7	3	3

Determine an optimum distribution for the company in order to minimize the total transportation cost. How much is the cost? 15

(b) For a product, the purchase prices are given below :

Sl. No.	*Order quantity* (Q_i)	*Unit price* (₹)
1	1–49	200·00
2	50–99	190·00
3	100 or more	180·00

Determine the optimum purchase quantity if the annual demand of the product is 400, the cost of placing an order is ₹ 100·00 and the inventory carrying cost is 20%. 15

(c) Differentiate between rolling and forging forming processes.

A strip with a cross-section of 160 mm × 7 mm is being rolled with 15% reduction of area, using 300 mm diameter steel rolls. Before and after rolling, the shear yield stresses of the material are 0·45 kN/mm^2 and 0·50 kN/mm^2 respectively. Calculate—

(i) the final strip thickness;

(ii) the average shear yield stress during the process;

(iii) the angle subtended by the deformation zone at the roll centre. 10

8. *(a)* The composition (% by weight) of a Monel alloy workpiece undergoing electrochemical machining is as given below :

Ni	Cu	Fe	Mn	Si	C
63	31·7	2·5	2	0·5	0·3

Calculate the removal rate (in cm^3/min) when a current of 1000 amperes is passed. Use the lowest valency of dissolution for each element.

Use the table given below for atomic weight, valency of dissolution and density of the above elements :

Elements	Ni	Cu	Fe	Mn	Si	C
Atomic weight	58·71	63·57	55·85	54·94	28·09	12
Valency	2/3	1/2	2/3	2/4/6/7	4	4
Density (gm/cm^3)	8·90	8·96	7·86	7·43	2·33	3·5

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(b) The annual demand for a manufacturing company is expected to be as follows :

Units demanded	10000	12000	14000	16000
Probability	0·4	0·3	0·2	0·1

Revenues are at ₹ 300·00/unit. The existing manufacturing facility has annual fixed operating costs of ₹ 20,00,000·00. The variable manufacturing costs are ₹ 75·00/unit at the 10000 units output level; ₹ 60·00/unit at the 12000 units output level; ₹ 50·00/unit at the 14000 units output level and ₹ 45·00/unit at the 16000 units output level.

An expected facility under consideration would require ₹ 25,00,000·00 fixed operating costs. The variable costs would average ₹ 78·00/unit at the 10000 units output level; ₹ 63·00/unit at the 12000 units output level; ₹ 47·00/unit at the 14000 units output level and ₹ 42·00/unit at the 16000 units output level.

To maximize net earning, which size facility is to be selected? 15

(c) Write a C program to multiply two matrices whose elements are only integers, and print the result. 10

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