MECHANICAL ENGINEERING

PAPER—II

| 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, 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.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

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

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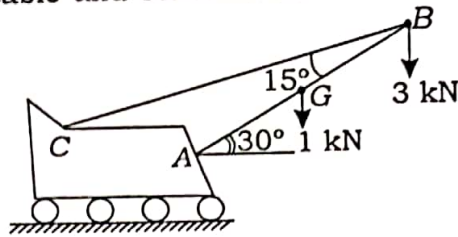
Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.

Answers must be written in ENGLISH only.

1. (a) (i) A 10 m boom AB weighs 1 kN. The distance of centre of gravity is 5 m from A. For the position shown in the figure given below, determine the tension T in the cable and reaction at A :   6

(ii) A rope making $1\frac{1}{4}$ turns around a stationary horizontal drum is used to support a weight as shown in the figure given below. If the coefficient of friction is 0·3, what range of weight can be supported by exerting an 800 N force at the end of the rope?   6
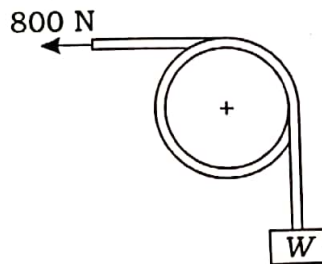
(b) A steel tube of 100 mm internal diameter and 10 mm wall thickness in a plant is lined internally with well-fitted copper sleeve of 2 mm wall thickness. If the composite tube is initially unstressed, calculate the hoop stress set up assumed to be uniform throughout the wall thickness, in a unit length of each part of the tube due to an increase in temperature of 100 °C.

For steel, $E = 208$ GPa, $\alpha = 11 \times 10^{-6}/°C$

For copper, $E = 104$ GPa, $\alpha = 18 \times 10^{-6}/°C$ 12

(c) (i) What is kinematic pair? How are kinematic pairs classified? Explain.   6

(ii) A four-bar mechanism has the following dimensions :

$DA = 200$ mm, $CB = AB = 300$ mm, $DC = 500$ mm

The link DC is fixed and the angle ADC is 60°. The driving link DA rotates uniformly at a speed of 100 r.p.m. clockwise and constant driving torque has the magnitude of 50 N-m. Determine the velocity of point B and angular velocity of the driven link CB. If the efficiency is 70%, calculate also the resisting torque :   6
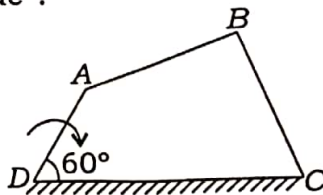
(d) (i) The tension T in the spring as shown in the figure given below can be assumed to be constant for small displacements. Determine the natural frequency of the vertical vibrations of the spring and also show that the period of vibration is greatest when $a = b$:

6
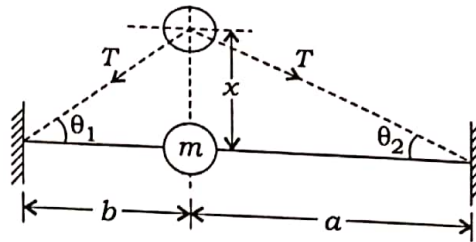
(ii) A vibrating system has the following constants :

$W = 19 \cdot 62$ kg, $K = 8$ kg/cm, $C = 0 \cdot 08$ kg-s/cm

Determine—

(1) damping factor;

(2) natural frequency of damped oscillations;

(3) logarithmic decrement.

Here, W = Weight of mass

K = Spring stiffness

C = Damping coefficient

$2 \times 3 = 6$

(e) Differentiate between 'shaft' and 'axle'. A solid shaft of diameter d is used in power transmission. Due to the modification of existing transmission system, the solid shaft is required to be replaced by a hollow shaft of the same material and equally strong in torsion. The weight of the hollow shaft per unit length is to be half of the solid shaft. Determine the outer diameter of the hollow shaft in terms of d.

12

2. (a) The turbine rotor of a ship has a mass of 3000 kg. It has a radius of gyration of 0·45 m and a speed of 2000 r.p.m. clockwise when looking from stern. Determine the gyroscopic couple and its effect on the ship—

(i) when the ship is steering to the left on a curve of 100 m radius at a speed of 30 km/hr;

(ii) when the ship is pitching in a simple harmonic motion, the bow falling with its maximum velocity. The period of pitching is 40 seconds and the total angular displacement between the two extreme positions of pitching is 12 degrees.

20

(b) A steel cantilever of length 2 m of circular cross-section, 50 mm in diameter, carries uniformly distributed load of intensity w. What is the maximum value of w so that deflection at free end is not to exceed 1 mm? Find out the slope at free end. Take $E = 200$ GPa.

20

(c) A thick cylinder is subjected to both internal and external pressure. The internal diameter of the cylinder is 200 mm and the external diameter is 250 mm. If the maximum permissible stress is 30 N/mm^2 and the external pressure is 8 N/mm^2, determine the intensity of internal radial pressure.   20

3. (a) A horizontal gas engine running at 200 r.p.m. has a bore of 200 mm and a stroke of 400 mm. The connecting rod is 900 mm long and the reciprocating parts weigh 20 kg. When the crank has turned through an angle of 30° from the inner dead centre, the gas pressures on the cover and the crank sides are 500 kN/m^2 and 60 kN/m^2 respectively. The diameter of the piston rod is 40 mm. Determine—

    (i) turning moment on the crankshaft;

    (ii) thrust on the bearings;

    (iii) acceleration of the flywheel which has a mass of 8 kg and radius of gyration of 600 mm while the power of the engine is 22 kW.   20

(b) An epicyclic gear consists of three gears A, B and C as shown in the figure given below. The gear A has 72 internal teeth and gear C has 32 external teeth. The gear B meshes with both A and C and is carried on an arm EF which rotates about the centre of A at 20 r.p.m. If the gear A is fixed, determine the speed of gears B and C :   20
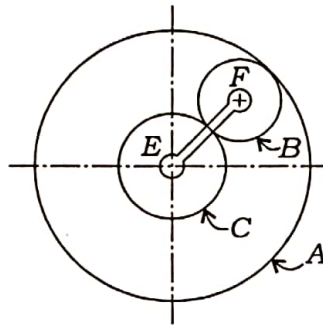

(c) A single-cylinder reciprocating engine has a speed of 300 r.p.m., stroke 300 mm, mass of reciprocating parts 50 kg, mass of revolving parts at 150 mm radius 37 kg. If two-thirds of the reciprocating parts and all the revolving parts are to be balanced, find—

    (i) the balance mass required at a radius of 300 mm;

    (ii) the residual unbalanced force when the crank has rotated 60° from top dead centre.   10

(d) Draw the shear force and bending moment diagram for the cantilever beam as shown in the figure given below :   10
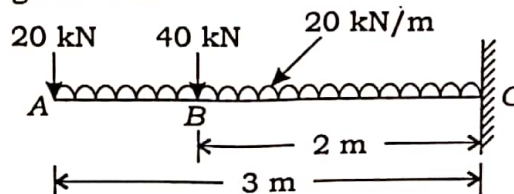
4. **(a)** **(i)** Describe angular contact bearings and taper roller bearings with the help of neat sketches. Also, cite at least two advantages and two disadvantages of each. 8

(ii) A pair of spur gears with $20°$ full-depth involute teeth consists of a 20 teeth pinion meshing with a 41 teeth gear. The module is 3 mm while the face width is 40 mm. The material for both the pinion and the gear is steel having an ultimate tensile strength of 660 N/mm^2. The gears are heat-treated to a surface hardness of 400 BHN. The pinion rotates at 1500 r.p.m. and the service factor is 2·0. Assume that the velocity factor accounts for the dynamic load and the factor of safety is 1·5. Determine the rated power that the gears can transmit. Assume a Lewis form factor of 0·32. 12

(b) What advantages do the welded joints offer in comparison to riveted joints? Neatly sketch the basic symbols used to specify the following types of weld :

(i) Fillet

(ii) Square butt

(iii) Single V-butt

(iv) Spot

(v) Seam

(vi) Projection

A beam of rectangular cross-section is welded to a support by means of fillet welds as shown in the figure given below. Determine the size of the welds if the permissible shear stress is 80 N/mm^2 : 20
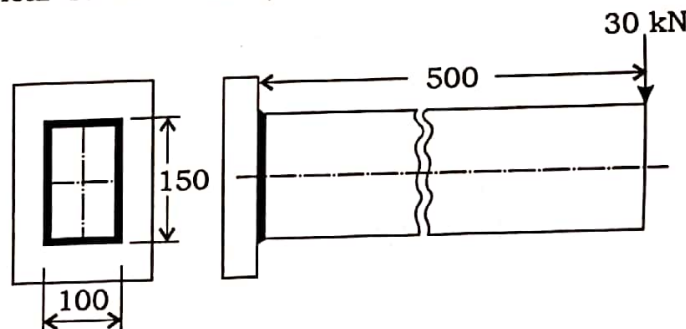
(c) A shaft is subjected to a maximum torque of 10 kN-m and a maximum bending moment of 7·5 kN-m at a particular section. If the allowable equivalent stress in simple tension is 160 MN/m^2, find the diameter of the shaft according to *(i)* maximum shear stress theory, *(ii)* strain energy theory and *(iii)* shear strain energy theory. Take Poisson's ratio as 0·24. 20

SECTION—B

5. *(a)* Describe the following microconstituents of iron-carbon alloys in relation to the phases present, arrangement of phases and their relative mechanical properties :   **12**

    (i) Spheroidite

    (ii) Pearlite

    (iii) Bainite

    (iv) Martensite

(b) In an orthogonal cutting operation, the cutting speed is 2·5 m/s, rake angle is 6° and the width of cut is 10 mm. The undeformed chip thickness is 0·2 mm. 13·36 grams of steel chips with total length of 50 cm are obtained. The tool post dynamometer gives cutting and thrust forces as 1134 N and 453·6 N respectively. Find—

    (i) shear plane angle;

    (ii) friction energy at tool-chip interface as percentage of total energy;

    (iii) specific cutting energy.

Assume density of steel = 7·8 grams/cm^3.   **12**

(c) Describe four tests of flexibility that an automated manufacturing system should satisfy to qualify as being flexible. Also list the application areas where FMS technology is successfully employed.   **12**

(d) Describe at least five main functions carried out by coating on electrode in electric arc welding process. Also, list the constituents of coating and their purpose.   **12**

(e) Explain the distinction between the following using block diagrams and examples :   **6+6**

    (i) Measurement systems and Control systems

    (ii) Open-loop systems and Closed-loop systems

6. *(a)* *(i)* In an open die forging, a strip 150 mm wide, 400 mm long and 10 mm thick is compressed in plane strain such that the dimension 400 remains same. The yield strength of material in uniaxial compression is equal to 200 N/mm^2. Find the minimum, average and maximum die pressures at the beginning of plastic deformation if the coefficient of friction on the interface between the die and the material is equal to 0·1.   **10**

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

Sl. No.	Order Quantity (Q_i)	Unit Prices (₹)
1	$Q_1 < 500$	10·00
2	$500 \leq Q_2 < 750$	9·25
3	$Q_3 \geq 750$	8·75

Determine the optimum purchase quantity if the annual demand of the product is 2400 units. The cost of ordering is ₹ 100 and the inventory carrying charge is 24% of the purchase price per year.   **10**

(b) What is a eutectoid reaction? Explain the development of microstructure in iron-carbon alloys of hypoeutectoid, eutectoid and hypereutectoid compositions when they are cooled from high temperature with the help of neatly labelled diagrams indicating the phases present. 20

(c) (i) Describe, with neat sketches, the working principle of—
(1) linear variable differential transformer (LVDT);
(2) Hall effect sensor. 5+5

(ii) A measurement system consists of a cylindrical load cell of diameter 2·5 mm. The material of the cell is steel with modulus of elasticity, $E = 210$ GPa and Poisson's ratio, $\gamma = 0.3$. This carries four strain gauges each with gauge factor 2·1. Two of them are mounted longitudinal and other two are transverse. The resistances of the gauges are 120 Ω. This load cell is required to yield a voltage through the bridge of strain gauges with bias 10 V. If the maximum load sustained by the cell is –2500 N, what is the corresponding voltage across the bridge? 10

7. (a) (i) On the basis of microstructure, briefly explain why gray iron is brittle and weak in tension. Compare gray and malleable cast irons with respect to (1) composition and heat treatment, (2) microstructure and (3) mechanical properties. 10

(ii) Cite three sources of internal residual stresses in metal components. What are two possible adverse consequences of these stresses? Describe the following heat treatment procedures for steels and for each, the intended final microstructure : 10

Full annealing, Normalizing, Tempering and Quenching

(b) (i) Why is unilateral tolerance preferred over bilateral tolerance? Find the limits of tolerance and allowance for a 25 mm H_8d_9 shaft and hole pair. The 25 mm shaft lies in the 18–30 diameter step. The fundamental tolerance can be computed using $i = 0.45 \sqrt[3]{D} + 0.001D$ μm. For H_8 hole, the fundamental tolerance is $25i$ and for d_9 shaft, the fundamental tolerance is $40i$. The fundamental deviation for the shaft can be computed using $-16D^{0.44}$ μm. What type of fit is given by H_8d_9? List the causes of getting primary texture and secondary texture in machined components. Further, list the three main methods of assessment of surface texture. 10

(ii) Five jobs are to be processed on three machines. The processing time (in hours) is given in the following table. Find the optimal schedule so that the total elapsed time is minimized. Also, find the idle time on each machine : 10

		Jobs				
		J_1	J_2	J_3	J_4	J_5
	M_1	8	10	6	7	11
Machines	M_2	5	6	2	3	4
	M_3	4	9	8	6	5

(c) (i) What are natural and forced responses of a dynamic system? Derive the expression for dynamic natural response of a spring-mass system. **10**

(ii) A vector $25i + 10j + 20k$ is translated by 8 units in X and 5 units in Y directions. Subsequent to this the vector is rotated by 60° about Z-axis and 30° about X-axis. Determine the final form of the vector. **10**

8. (a) (i) Explain briefly the following : **10**
   (1) Four configurations of Robot
   (2) Work volume
   (3) Spatial resolution
   (4) Accuracy
   (5) Repeatability

   (ii) A 4 d-o-f manipulator of Maker Robot type is shown in the figure given below. Prepare a D-H parameter table for this configuration. Define the position of end wrist P in terms of joint lengths and angles : **10**
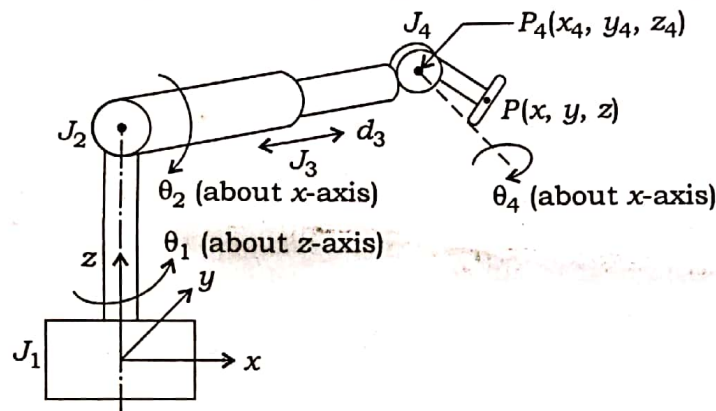
(b) (i) Draw the 'bathtub curve' and indicate various failure regions. List the major causes of failure in mechanical components/system. Draw the flowchart for failure modes and effects analysis (FMEA). **10**

(ii) Explain the mechanism of metal removal in die-sinking EDM. State the three main advantages of electron-beam machining (EBM). **10**

(c) A manufacturer of patient medicines is proposed to prepare a production plan for medicines A and B. There are sufficient ingredients available to make 20000 bottles of medicine A and 40000 bottles of medicine B. However, there are only 45000 bottles into which either of the medicines can be filled. Further, it takes three hours to prepare enough material to fill 1000 bottles of medicine A and one hour to prepare enough material to fill 1000 bottles of medicine B, and there are 66 hours available for this operation. The profit is ₹ 8 per bottle for medicine A and ₹ 7 per bottle for medicine B.

(i) Formulate this problem as linear programming problem.

(ii) How does the manufacturer schedule his production in order to maximize profit? Use graphical method. **20**

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