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.

Questions No. **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.

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.

SECTION A

Q1. (a) A circular bar ABC, 4 m long, is rigidly fixed at its ends A and C. The portion AB is 2·8 m long and of 50 mm diameter whereas BC is 1·2 m long and of 25 mm diameter. If the twisting moment of 700 Nm 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. For the material of the shaft G = 80 GN/m^2. **12**

(b) What are supporting forces for the frame ? Neglect all weights except the 10 kN weight. **12**
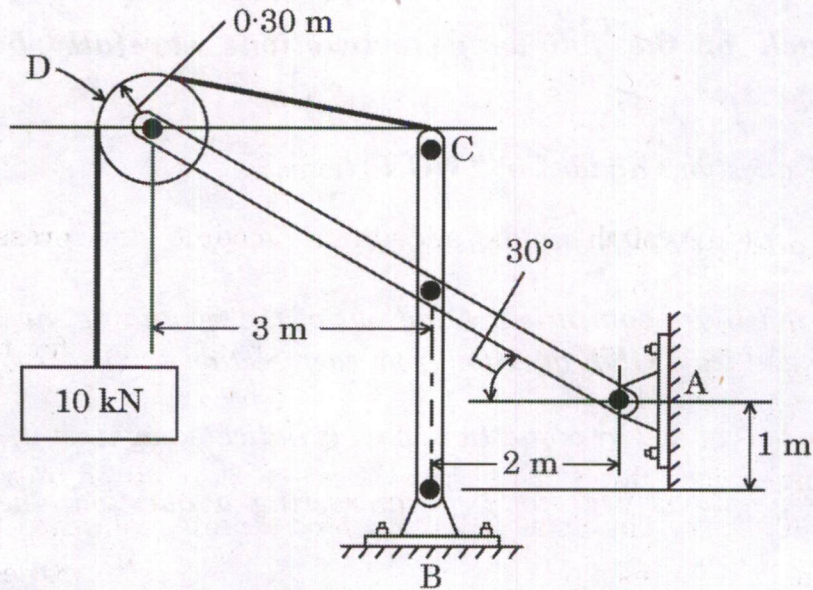
(c) An electronic instrument is to be isolated from a panel that vibrates at frequencies ranging from 25 Hz to 35 Hz. It is estimated that at least 80% vibration isolation must be achieved to prevent damage to the instrument. If the instrument weighs 85 N, find the necessary static deflection of the isolator. **12**

(d) Describe all the inversions of a slider-crank mechanism. **12**

(e) A structure is composed of circular members of diameter d. At a certain position along one member the loading is found to consist of a shear force of 10 kN along with an axial tensile load of 20 kN. If the elastic limit in tension of the material of the members is 300 MN/m^2 and there is to be a factor of safety of 3, estimate the magnitude of d required according to the maximum shear strain energy per unit volume theory. Poisson's ratio $v = 0.3$. **12**

Q2. **(a)** The rod AD is pulled at A and it moves to the left. If the coefficient of dynamic friction for the rod at A and B is 0·4, what must the minimum of W_2 be to prevent the block from tipping when $\alpha = 20°$? With this value of W_2, determine the minimum coefficient of static friction between the block and the supporting plane needed to just prevent the block from sliding. Take $W_1 = 100$ N.

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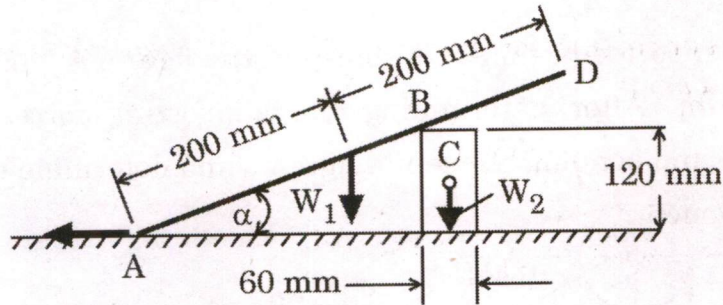
(b) **(i)** Define pitch point, addendum, module and pressure angle as applied to toothed gears.

8

(ii) Compare involute curve with cycloidal curve for the profiles of gear teeth.

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(c) A single plate clutch (both sides effective) is required to transmit 27 kW at 1600 rpm. The outer diameter of the plate is limited to 30 cm, and intensity of pressure between the plates is not to exceed 0·1 N/mm². Assuming uniform wear and a coefficient of friction 0·3, find the required inner diameter of the plates, and axial force necessary to engage the clutch.

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Q3. **(a)** Find the slope and deflection at the tip of the cantilever shown in the figure. What load P must be applied upwards at mid-span to reduce the deflection by half ? EI = 20 MN/m²

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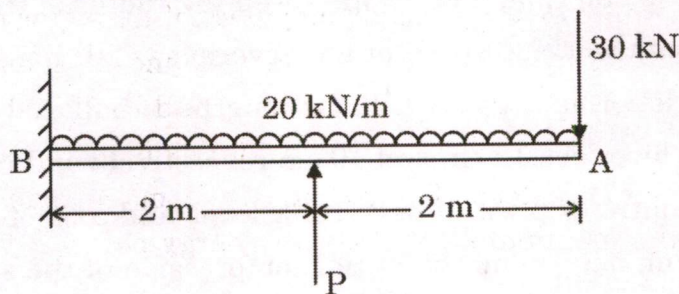
(b) The axes of a three-cylinder air compressor are 120° apart and their connecting rods are connected to a common crank. The length of each connecting rod is 200 mm and the stroke is 160 mm. The mass of the reciprocating parts per cylinder is 2 kg. Find the maximum primary and secondary forces acting on the frame of the compressor when running at 2500 rpm.

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(c) A simply supported beam AB is shown in the figure. A bar CD is welded to the beam. After determining the supporting forces, sketch the shear force and bending moment diagrams and determine the maximum bending moment.

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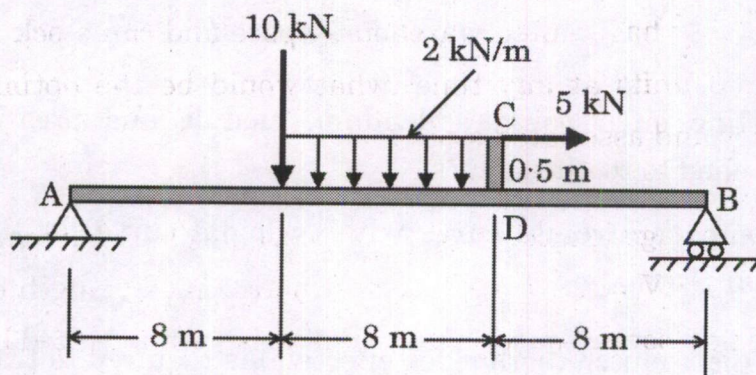
Q4. (a) A uniform T-section beam is 100 mm wide and 150 mm deep with flange thickness of 25 mm and a web thickness of 12 mm. If the limiting bending stresses for the material of the beam are 80 MN/m^2 in compression and 160 MN/m^2 in tension, find the maximum u.d.l. that the beam can carry over a simply supported span of 5 m.

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(b) In a spring loaded governor of Hartnell type, the weight of each ball is 5 kg and the lift of the sleeve is 5 cm. The speed at which the governor begins to float is 250 rpm, and at this speed the radius of the ball path is 10 cm. The mean working speed of the governor is 20 times the range of speed when friction is neglected. If the lengths of ball and roller arm of the bell crank lever are 12 cm and 10 cm respectively and if the distance between the centre of pivot of bell crank lever and axis of the governor spindle is 14 cm, determine the initial compression of the spring, taking into account obliquity of arms.

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(c) (i) What are the assumptions made in the Lewis equation for beam strength ?   8

(ii) A pair of spur gears with 20° full depth involute teeth consists of a 20 teeth pinion meshing with a 50 teeth gear. The pinion is mounted on a crank shaft of 5 kW engine running at 1200 rpm. The driven shaft is connected to a compressor. The pinion as well as the gear is made of steel having ultimate strength in tension equal to 500 N/mm². The module and face width of the gears are 4 mm and 44 mm. Assume service factor as 2. Using the velocity factor to account for the dynamic load, determine the factor of safety. Take Lewis form factor for 20 teeth equal to 0·320 and for 50 teeth equal to 0·408. Take velocity factor, $C_v = \dfrac{3}{3+v}$, where v is the pitch line velocity in m/s.   12
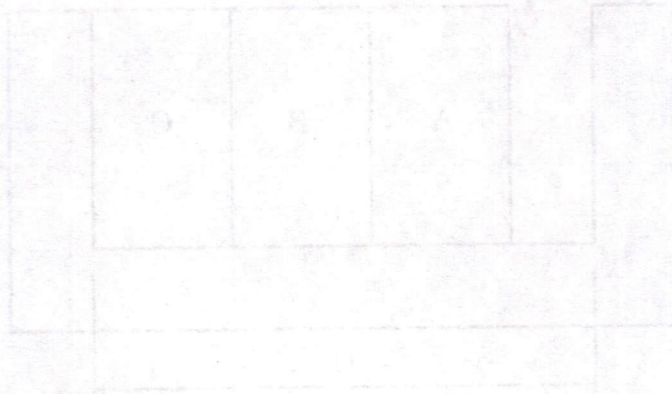
SECTION B

Q5. **(a)** What is the distinction between hypoeutectoid and hypereutectoid steels ? Explain the development of microstructure in a hypoeutectoid steel with the help of neatly labelled diagram. **12**

(b) With the help of schematic diagram, discuss the following : **12**

(i) Single manufacturing cell

(ii) Flexible manufacturing cell

(iii) Flexible manufacturing system

(c) (i) Express unilateral and bilateral tolerances with the help of diagram considering normal size 24·00 mm and tolerance 0·030 mm. **6**

(ii) Three blocks A, B and C are to be assembled in a channel of dimension D as shown in figure. Determine the tolerance that must be assigned to D, if it is essential that the minimum gap E is not less than 0·005 mm. The dimensions of blocks are : **6**

$$A = 0.75 \pm 0.003 \text{ mm}$$

$$B = 1.0 \pm 0.005 \text{ mm}$$

$$C = 1.125 \pm 0.004 \text{ mm}$$

Consider basic dimension of channel D = 2·894 mm.
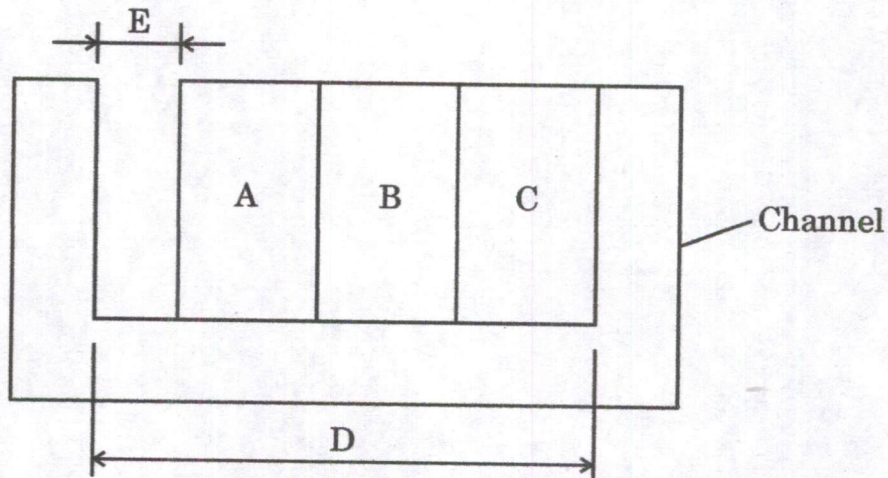
(d) (i) Why is it necessary to schedule debris sampling for wear debris ?

(ii) Wear particles of spherical shape were found in a wear debris sample. What is the possible mode of failure for such case ? Justify. **6+6=12**

(e) Each unit of an item costs a company ₹ 40. Annual holding costs are 18% of unit cost for interest charges, 1% for insurance, 2% allowances for obsolescence, ₹ 2 for building overheads, ₹ 1·50 for damage and loss, and ₹ 4 miscellaneous cost. Annual demand for the item is constant at 1,000 units and each order costs ₹ 100 to place.

    (i) Calculate EOQ and the total costs associated with stocking the item.

    (ii) If the supplier of the item will only deliver batches of 250 units, how are the stock holding costs affected ?

    (iii) If the supplier relaxes his order size requirement, but the company has limited warehouse space and can stock a maximum of 100 units at any time, what would be the optimal ordering policy and associated costs ?   *12*

Q6. (a) (i) The voltage-length characteristic of a direct current (dc) arc is given by $V = (20 + 40\,l)$ volts, where l is the length of the arc in cm. The power source characteristic is approximated by a straight line with an open circuit voltage = 80 V and a short circuit current = 1000 amp.

Determine the optimum arc length and the corresponding arc power.   *12*

    (ii) Enlist the most common defects encountered in sand mould casting. Describe the reasons for Scab and Misrun.   *8*

(b) (i) Compare gray, malleable, white and modular cast irons with respect to (I) composition and heat treatment, (II) microstructure, and (III) mechanical properties.   *12*

    (ii) Make a schematic plot showing the tensile engineering stress-strain behaviour for mild steel and label the salient points. State the reason of occurrence of two yield points in mild steel. Also, explain the following on the basis of the plot (I) Ductility, (II) Resilience, and (III) Toughness.   *8*

(c) (i) (I) Derive the characteristic equation for the piezoelectric accelerometer supporting a mass (M) on a spring of stiffness (K) and viscous damper with damping coefficient (C). Assume the input and output displacement to be (x_i) and (x_o) respectively.

(II) What is the amplitude ratio for a frequency response analysis assuming input displacement to be sinusoidal ?   *10*

(ii) An accelerometer is designed with a seismic mass of 0·05 kg, a spring constant of 5000 N/m, and a damping constant of 30 NS/m. If the accelerometer is mounted to an object experiencing displacement $x_i = 5 \sin (100t)$ mm, find an expression for the steady state relative displacement of seismic mass relative to housing as a function of time $x_r(t)$.   *10*

Q7. (a) (i) An engine is to be designed to have a minimum reliability of 0·8 and minimum availability of 0·98 over a period of 2×10^3 hours. Determine MTTR and frequency of failures of engine.   *8*

(ii) Explain the mechanism of chip formation. What are the conditions that result in the formation of   *12*

(I) Continuous chips without built up edge,

(II) Continuous chips with built up edge,

(III) Discontinuous chips ?

(b) Explain with the working principle a suitable Non-Destructive Testing (NDT) technique to be used for detecting surface as well as fully embedded defects for a wide range of materials including polymers. Also, list the other NDT techniques with reasoning that are not suitable for inspection of above described requirements.   *20*

(c) (i) A 12-bit Analog-to-Digital Converter operating at a sampling rate of 5 kHz is used with a sensor. What is the size of computer memory (in bytes) required to store 20 seconds of sensor data ? What will be the memory size in case a 8-bit Analog to Digital Converter is used ? Why is it not possible to connect sensors such as accelerometers, strain gauges and thermocouple directly to a microprocessor or computer ?   *12*

(ii) A CNC machine tool table is powered by a servo motor, lead screw and optical encoder. The lead screw has a pitch of 5 mm and is connected to the motor shaft with a gear ratio of 16 : 1. The optical encoder connected directly to the lead screw generates 200 pulses per revolution of the lead screw. The table moves a distance of 100 mm at a feed rate of 500 mm/min.

Determine the pulse count received by the control system to verify that the table has moved exactly 100 mm. 8

Q8. (a) An automatic door is designed to open the door when a person approaches and close automatically after five seconds. The door is operated by an electric motor-based actuator, responsible for sliding the door on rail.

(i) Explain the working mechanism assuming a microprocessor based control using a schematic diagram of the control system used. Also, specify the primary components of the control system.

(ii) If a microcontroller based system is used, what would be the merits and demerits of such system ? 20

(b) (i) It is desired to measure the angular position of a motor shaft with a set-up using two Hall Sensors A and B and a permanent magnet multi-pole wheel. Explain the logic that is used for measuring the position as well as direction of the motor shaft based on states of output signals from Hall Sensors A and B. 10

(ii) With the help of a schematic diagram, explain the working principle of a resolver. How does the output for resolver differ from that of an encoder ? 10

(c) What are the fundamental arm architecture of a basic robot arm on the basis of geometric work envelope ? How can these fundamental arm architecture be derived from one another ? What arm configurations do Gantry and SCARA robots correspond to ? Also, show the geometric work envelope and arm configuration of Gantry and SCARA robots with a suitable figure. 20