

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.

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.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

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

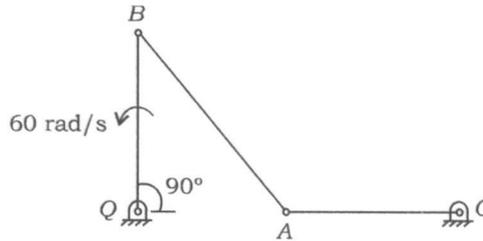
Assume suitable data, if necessary, and indicate the same clearly.

Neat sketches may be drawn, wherever required.

Answers must be written in ENGLISH only.

SECTION—A

1. (a) For the mechanism shown in the figure below, determine the angular velocities of the links AB and OA. Given, $QB = 20$ mm, $AB = 30$ mm, $OA = 20$ mm; O, A and Q are in the same horizontal level :



- (b) Two 20° involute gears are in mesh with gear ratio 2.5. The number of teeth on pinion is 24. The gears have a module of 6 mm and the addendum is equal to one module. Determine the (i) angle of action of the pinion and (ii) maximum velocity of sliding, if the pitch line velocity is 2 m/s.
- (c) The state of stress at some point in a body is defined as follows :

$$\sigma_x = 138 \text{ MPa}, \sigma_y = -28 \text{ MPa}, \tau_{xy} = 35 \text{ MPa}$$

- (i) Draw a view of the element for the given state of stress and mark the above stresses.
- (ii) Draw the Mohr circle for the combined stresses, showing the above state of stress and obtain the principal stresses from the same.
- (d) (i) Determine the number of lattice points per cell in the simple cubic (SC), body-centered cubic (BCC) and face-centered cubic (FCC) crystal systems. If there is only one atom located at each lattice point, calculate the number of atoms per unit cell.
- (ii) Determine the relationship between the atomic radius (r) and the lattice parameter (a_0) in simple cubic (SC), body-centered cubic (BCC) and face-centered cubic (FCC) structures when one atom is located at each lattice point.
- (e) A cemented carbide cutting tool used for machining contains 75 percent by weight of tungsten carbide (WC), 15 percent by weight of titanium carbide (TiC), 5 percent by weight of tantalum carbide (TaC) and 5 percent by weight of cobalt (Co). Estimate the density of the composite material. Given :

$$\text{Density of tungsten carbide, } \rho_{WC} = 15.77 \text{ gm/cm}^3$$

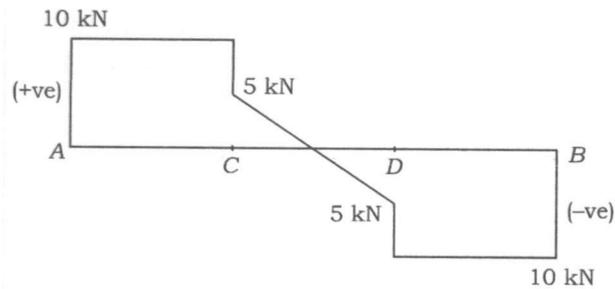
$$\text{Density of titanium carbide, } \rho_{TiC} = 4.94 \text{ gm/cm}^3$$

$$\text{Density of tantalum carbide, } \rho_{TaC} = 14.5 \text{ gm/cm}^3$$

$$\text{Density of cobalt, } \rho_{Co} = 8.90 \text{ gm/cm}^3$$

2. (a) A single-cylinder, 4-stroke engine develops 20 kW at 250 r.p.m. The work done by gases during the expansion stroke is 3 times the work done on the gases during the compression stroke and may be assumed for the sake of simplicity to be represented by two triangles. The work done during suction and exhaust may be neglected. If the flywheel has a mass of 1000 kg and radius of gyration 0.6 m, find the coefficient of fluctuation of speed. 15

- (b) The shearing force diagram for a beam simply supported at the ends is given below :



The three portions of the beam AC, CD and DB are of equal length each equal to 2 m.

Draw the loading on the beam and find the maximum deflection of the beam. Take the flexural rigidity (EI) of the beam as $2.5 \times 10^6 \text{ N-m}^2$. 15

- (c) (i) Compare the engineering stress and strain with true stress and strain for an aluminium alloy bar of diameter 1.263 cm and initial length 5 cm, undergoing a tensile test. The maximum load applied on the bar is 35580 N and the diameter of the bar at the maximum load is 1.243 cm. The change in length of the test specimen at the maximum load is 0.3 cm. 5
- (ii) If fracture of the specimen occurs at a load of 33800 N with the diameter at fracture 0.995 cm, determine the engineering stress and strain, and compare with true stress and strain at fracture. The change in length of the specimen at fracture is 0.5125 cm. 5

3. (a) Four masses A, B, C and D are completely balanced. Masses C and D make angles of 90° and 210° respectively with B in the same sense. The planes containing B and C are 300 mm apart. Masses A, B, C and D can be assumed to be concentrated at radii of 360 mm, 480 mm, 240 mm and 300 mm respectively. Masses B, C and D are 15 kg, 25 kg and 20 kg respectively. Determine (i) mass A and its angular position, and (ii) the position of planes A and D. 15

- (b) A bolt is subjected to a direct load of 30 kN and a shear load of 20 kN. Determine the size of the bolt, using (i) maximum normal stress theory, (ii) maximum shear stress theory and (iii) von Mises theory.

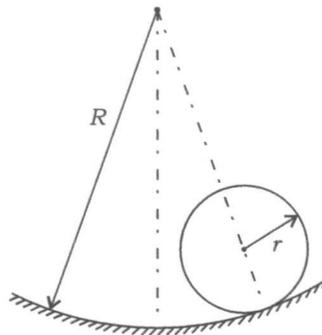
Given that the material of the bolt is C15 having a yield strength of 200 N/mm^2 . Use a factor of safety of $N = 2$.

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- (c) A solid steel shaft of 2.5 m length is to transmit 60 kW at 200 r.p.m. If the shear stress is not to exceed 50 MPa and the maximum allowable twist in the shaft is 1.5° , calculate the shaft diameter. Take modulus of rigidity as 80 GPa.

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4. (a) A uniform solid cylinder of radius r and mass m rolls without slipping on a cylindrical cavity of radius R . Determine the natural frequency of oscillation of the cylinder about its lowest position :



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- (b) (i) Bring out the differences in analyzing thin and thick cylinders based on some of the basic assumptions.

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- (ii) A thick cylinder of 100 mm internal radius and 150 mm external radius is subjected to an internal pressure of 60 MN/m^2 and an external pressure of 30 MN/m^2 . Determine the hoop and radial stresses at the inside and outside of the cylinder together with the longitudinal stress, if the cylinder is assumed to have closed ends.

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- (c) (i) With a neat sketch, explain a binary phase diagram.

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- (ii) Define and compare (1) thermoplastics, (2) thermosetting plastics, (3) elastomers and (4) thermoplastic elastomers.

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SECTION—B

5. (a) In an EDM operation with R-C pulse generator, the supply voltage, resistance (R) and capacitance (C) are 250 V, 10Ω and $3 \mu\text{F}$ respectively. Find the inter-electrode gap under maximum material removal condition as well as charging time. The dielectric strength of dielectric fluid is $175 \text{ V}/25 \mu\text{m}$.

8

- (b) Describe box jig and list four turning fixtures commonly used in lathe. 8
- (c) What is the concept of Total Quality Management? How is it different from inspection and quality control? 8
- (d) The arrival rate of the customers at a banking counter follows Poisson distribution with a mean of 40 per hour. The service rate of the counter clerk also follows Poisson distribution with a mean of 50 per hour.
- (i) What is the probability of having 0 (zero) customer in the system (P_0)?
- (ii) What is the probability of having 6 customers in the system (P_6)?
- (iii) Find the average number of customers waiting in the system (in the queue and in the service station) (L_s).
- (iv) Find the average waiting time of customers in the queue (W_s).
- (v) Find the average number of customers waiting in the queue (L_q). 8
- (e) What are the different types of 'instructions' in C programming language? 8

6. (a) Free cutting steel workpieces, 200 mm long and 100 mm in diameter, are to be turned on a lathe using a feed of 0.15 mm/rev and depth of cut of 2 mm. It is possible to use brazed and throwaway cemented carbide tools for the operation. The following data is available :

Labour cost per hour = ₹ 10

Machine overhead per hour = ₹ 50

Grinding cost per hour = ₹ 20

Grinding machining overhead per hour = ₹ 60

Idle time = 5 min

Taylor's tool life equation is $VT^{0.22} = 475$

For brazed tool	For throwaway cemented carbide tools
Tool cost = ₹ 90	Initial cost = ₹ 30
Number of regrinds before salvage = 10	Total number of edges = 4
Grinding time = 5 min/edge	Tool changing time = 1 min
Tool changing time = 2 min	

Suggest which tool should be used considering maximum production rate criterion.

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- (b) A company is setting an assembly line to produce 193 units per eight-hour shift. The information regarding work elements in terms of time and immediate predecessors is given in the table below :

Work element	Time (sec)	Immediate predecessors
1	60	None
2	70	1
3	40	4, 5, 6
4	50	2
5	20	2
6	40	1
7	100	1
8	110	7
9	140	8
10	110	3, 9

- (i) What is the desired cycle time?
- (ii) What is the theoretical number of stations?
- (iii) Use largest work element time rule to find a solution on a precedence diagram.
- (iv) What are the efficiency and balance delay of the solution obtained? 15
- (c) The annual demand for an item is 5400 units, ordering cost is ₹ 600 per order. The inventory carrying cost is 30% of the purchase price/unit/year. The price breaks are as shown below :

Quantity	Price (₹)
$0 \leq Q_1 < 2400$	12
$2400 \leq Q_2 < 3000$	10
$3000 \leq Q_3$	8

Find the optimal order size. 10

7. (a) (i) State three purposes of employing cutting fluid to improve machinability of any work-tool combination. Also list at least five properties of workpiece material that affect machinability. 8
- (ii) The worktable in an NC positioning system is driven by a leadscrew with a 4 mm pitch. The leadscrew is connected to the output shaft of a stepping motor through a gearbox with a gear ratio of 5 : 1. The stepping motor has 250 step angles. The worktable is programmed to move a distance of

100 mm from its present position at a travel speed of 300 mm/min. Find the—

- (1) number of pulses required to move the table the specified distance;
- (2) required motor speed;
- (3) pulse rate to achieve the desired table speed.

7

(b) Solve the following LP problem using simplex method :

$$\text{Maximize } Z = 3x_1 + 2x_2 + 5x_3$$

subject to

$$\begin{aligned} x_1 + x_2 + x_3 &\leq 9 \\ 2x_1 + 3x_2 + 5x_3 &\leq 30 \\ 2x_1 - x_2 - x_3 &\leq 8 \\ x_1, x_2 \text{ and } x_3 &\geq 0 \end{aligned}$$

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(c) Write the C program to calculate the real roots of the quadratic equation

$$ax^2 + bx + c = 0$$

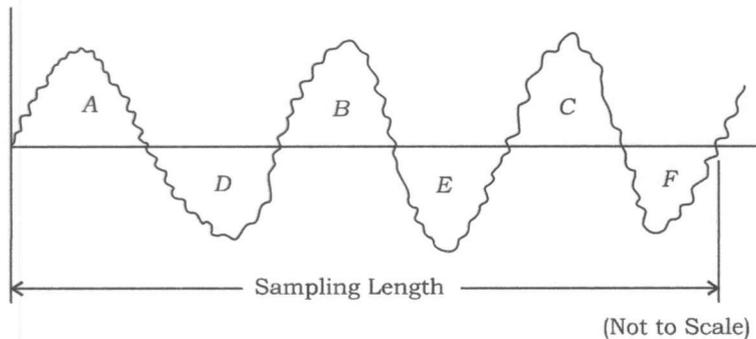
using the quadratic formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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8. (a) (i) Describe the principle of electro-hydraulic forming process with a neat sketch. Also state its advantages and applications.
- (ii) List at least three thread gauges that are used in a production shop for inspection of screw threads. Also find the centreline average value (R_a) of a diamond turned surface whose rectilinear pen recording is shown below :

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The sampling length is 1.2 mm and vertical/horizontal magnification ratio is 4000/100. The areas (in mm^2) above and below the mean line are as follows :

A	B	C	D	E	F
70	125	106	103	119	80

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- (b) Find the initial basic feasible solution of the following transportation problem by Vogel's approximation method. The cell entries represent the cost of transportation per unit in rupees :

<i>Factory</i> ↓	<i>Warehouse</i> →	W_1	W_2	W_3	W_4	<i>Factory capacity</i>
F_1		10	30	50	10	7
F_2		70	30	40	60	9
F_3		40	8	70	20	18
	<i>Warehouse requirement</i>	5	8	7	14	

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- (c) (i) The tool signature of a single point cutting tool is "7-8-6-6-12-20-2" in ASA (American Standards Association) system. State the meaning of each numeral. Also state the advantages of using helical milling cutters over straight milling cutters. 5
- (ii) Describe five major effects of friction in metal forming. 5
