

MECHANICAL ENGINEERING
(Paper I)

Time Allowed : Three Hours	Maximum Marks : 300
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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. (a) An elevator starts from rest and raises vertically 40 m to attain its maximum velocity in T seconds, with acceleration record shown in the figure. Determine the time T and the maximum velocity reached by the elevator. **10**
[Figure: Acceleration–time record: vertical axis a, horizontal axis time; the acceleration rises linearly from zero at t = 0 to a peak of 0.6 m/s^2 at t = T/3 (dashed lines mark the peak value on the a-axis and the time T/3), then decreases linearly to zero at t = T]
- (b) For a conventional type 2-stroke cycle four cylinder inline reciprocating engine, sketch the primary and secondary crank diagrams for firing order of I-II-IV-III and find out balancing condition of the engine for primary and secondary effects. **10**
- (c) Sketch the displacement, velocity and acceleration curves for rise motion alone if the cam-follower is executing uniform and equal acceleration and retardation. State the main disadvantage of this type follower motion. **10**
- (d) How ductility of structural steel is evaluated from static tension test? What is the effect of gauge length on the value of ductility? **10**
- (e) A cast iron sample when tested in compression fails along approximately 45° plane from its axis while when tested in torsion also fails along a 45° (approx.) helical plane from its axis. Explain the reason for such failure and mention about the dominating stresses causing failure. **10**
- (f) Classify stainless steels based on the metallurgical considerations. Write main characteristics of each class of stainless steels. **10**
2. (a) A model rocket of mass 0.1 kg is launched vertically from rest at time t = 0, with a constant thrust of 10 N for one second and no thrust for t > 1 second. Neglecting the air resistance and decrease in the mass of the rocket determine (i) maximum height reached by the rocket, (ii) time required to reach maximum height. **15**
- (b) An automobile of mass 1225 kg starts from rest and travels a distance of 400 m. The co-efficient of static friction between tyre and road is 0.70, and air resistance is equivalent to $D = 0.575 v^2$, where D is in Newton and v is velocity in m/s. The automobile has front wheel drive and front wheel supports 62% of the total weight of vehicle. Determine the maximum speed reached by the automobile after travelling 400 m distance. **15**

- (c) Stress concentration factor is not considered harmful for ductile materials in static loading but for brittle materials it has damaging effect in both static and dynamic loading. Justify the above statement giving illustrations. **15**
- (d) A hollow shaft of outside diameter 50 mm and inside diameter 20 mm is subjected to a torque of T N.m and a bending moment of $0.5 T$ N.m. If the tensile yield stress of the shaft material is 250 N/mm^2 , what is the maximum permissible value of T to avoid failure according to Tresca's failure theory? Take a factor of safety of 2.0 for a given application. **15**
3. (a) A cantilever beam of length 'L' is subjected to two concentrated loads of $2P$ and P at its mid-length and free end respectively. If deflection at its free end is limited to $L/500$, what should be the value of P ? Take flexural rigidity of the beam as EI . **15**
- (b) The shaft of a small turbine with a single disc is found to have a static deflection of 0.355 mm. Find the critical speed of the shaft-disc system and calculate percentage change in the diameter of the shaft that will be required to raise the critical speed to 2100 rpm. If the initial displacement of the centre of the mass of the disc from the axis of shaft is 0.5 mm, compare the deflection of the shaft at 1500 rpm in the two cases. **20**
- (c) A beam ABCD is loaded as shown in Fig. given below. The beam is of rectangular section $50 \text{ mm} \times 100 \text{ mm}$. (i) Sketch the S.F. and B.M. diagram for the beam. (ii) Determine the maximum bending stress at section B of the beam. **25**
- [Figure: Horizontal beam ABCD, total length 11 m: A at the left end on a pin (hinged) support; B at 3 m from A; C at 6 m from A (3 m from B) on a roller support; D the free right end, 5 m beyond C (overhang). A triangularly distributed load acts over AC, increasing linearly from zero at A to 60 N/m at C; a couple of 5000 N.m is applied at B (curved arrow, anticlockwise as drawn); a downward arrow (concentrated load) is drawn at the free end D, with no magnitude marked]
4. (a) A $1 \text{ m} \times 1 \text{ m}$ mild steel sheet of 1 mm thickness is stretched in its own plane by stresses $\sigma_x = 20 \text{ MPa}$ and $\sigma_y = 30 \text{ MPa}$ as shown in figure below. Point O is centre of the plate. OC and OD are two mutually perpendicular lines inclined at 45° each to x and y directions respectively before application of stress. Determine the change in angle (in degrees) between OC and OD after application of stresses. Take modulus of rigidity of plate material $G = 80 \text{ GPa}$. **20**
- [Figure: Square plate with centre O, under tensile σ_x (arrows outward on the left and right edges, labelled σ_x on the left and $\sigma_x = 20 \text{ MPa}$ on the right) and tensile σ_y (arrows outward on the top and bottom edges, labelled σ_y at the top and $\sigma_y = 30 \text{ MPa}$ at the bottom); from O, line OC runs up to the right at 45° to the horizontal (dashed horizontal reference through O) and line OD runs up to the left at 45° to the vertical (dashed vertical reference through O); small x - y axes (x to the right, y upward) are drawn near the top right corner]
- (b) A simple gear train consists of three spur gears 1, 2 and 3, where gear 1 is the driver, gear 2 idler gear and gear 3 driven gear. The axes of all the 3 gears are in the horizontal plane. The bearing centres of gears 1, 2 and 3 are designated as A, B and C respectively. Gear 1 has 10 mm module, pressure angle 20° and 35 teeth. Gears 2 and 3 are having 45 teeth and 60 teeth respectively. The driver is rotating at 1000 rpm clockwise and delivers 30 kW of power. Find: (i) distance between A and C (ii) speed ratio of the gear train. Draw the free body diagram of the driven gear and show all the forces acting on it. **10**
- (c) (i) Differentiate between point defects and line defects in a crystalline solid. (ii) With a neat diagram show two types of line defects. How are they formed? **15**
- (d) What are ceramic materials? How do they differ from other materials? How are the ceramics toughened? Give one example. **15**

SECTION 'B'

5. (a) For punching a 10 mm circular hole, and cutting a rectangular blank of 50×200 mm from a sheet of 1 mm thickness (mild steel, shear stress = 240 N/mm^2), calculate, in each case: (i) Size of punch (ii) Size of die (iii) Force required. **10**
- (b) Sketch the international prototype metre. Explain briefly, with reasons, its: (i) material (ii) cross section (iii) support points (iv) plane of marking (v) environment. **10**
- (c) Sketch a mould for two hollow components to be cast. On the diagram, indicate runner, gate, riser, core, cope, sprue, pouring basin, sprue well, drag, parting line. **10**
- (d) An interference assembly, of nominal diameter 20 mm, is of a unilateral holes and a shafts. The manufacturing tolerances for the holes are twice that for the shaft. Permitted interference values are 0.03 to 0.09 mm. Determine the sizes, with limits, for the two mating parts. **10**
- (e) State the mechanism of cutting by abrasive jet. What are the advantages and disadvantages of AJM? Mention two applications. **10**
- (f) (i) Identify four major costs associated with poor quality. (ii) Name the tools for improving quality. (iii) The operations and their reliabilities for a beauty-product are given below: **10**

Operation	Reliability
Mix	0.99
Fill	0.98
Cap	0.99
Label	0.97

What is the reliability of the system? (iv) The feedback from customers shows the following:

Defect	Frequency
Lumps of un-mixed product	7
Over or underfilled jars	18
Jar lids did not seal	6
Labels rumpled or missing	29

Draw the Pareto chart to identify vital defects.

6. (a) Draw a self explanatory sketch of Sigma mechanical comparator. Explain how (i) shock load is avoided, (ii) oscillations of the pointer are damped. **10**
- (b) Explain, at least two, characteristics each of NC, CNC and DNC. **10**
- (c) Compare Smith forging, drop forging, press forging and upset forging. Mention three points for each. **10**
- (d) Determine the optimum speed for achieving maximum production rate in a machining operation. The data is as follows: Machining time/job = 6 min. Tool life = 90 min. Taylor's equation constants $C = 100$, $n = 0.5$ Job handling time = 4 min./job Tool changing time = 9 min. **10**
- (e) Three processes viz. automatic, semi-automatic and manual can be used to produce an item. The initial annual fixed cost and variable cost/unit for each of them is given below: **20**

Process	Annual fixed cost ₹	Variable cost/unit ₹
Automatic A	2,50,000	10
Semi-automatic S	1,50,000	20
Manual M	50,000	60

(i) Draw the total annual cost curves for the processes. (ii) Find the range of production volume for each process when it is most economical. (iii) Which process will you recommend if the forecasted production is 8000 units/annum? (iv) What is the most economic unit cost if the production is 8000 units/annum?

7. (a) An activity has four elements. The activity is work-measured and the times (r) are recorded on continuous basis over five cycles. The observations are given in table: **30**

Work Element	Observations: Cycle → 1	2	3	4	5	Rating Factor
1	0.50	3.30	5.70	8.20	10.85	1.1
2	0.70	3.45	5.95	8.55	11.10	1.2
3	1.45	4.05	6.50	9.25	11.75	1.2
4	2.75	5.25	7.60	10.35	13.05	0.9

The time r is recorded at the end of work-element. (i) Calculate: (a) Normal time of the activity (b) Standard time for the activity, if the allowance is 20%. (ii) What is the appropriate sample size for estimating the time for element 2 within $\pm 10\%$ of the true mean with 95% confidence; the standard deviation for the time for element 2 is 0.0742.

- (b) Draw a self explanatory sketch of oxy-acetylene gas cutting torch. Briefly explain how cutting is effected. **20**

- (c) In an NC drilling operation, the tool tip is at a location $(-100, 0, 100)$. The datum $(0, 0, 0)$ is left hand lower corner on top surface of the workpiece, which is rectangular $(300 \text{ mm} \times 300 \text{ mm} \times 15 \text{ mm}$ thick). A thru' hole of 10 mm diameter is to be drilled in the centre of the workpiece. Using only rapid positioning and linear interpolation functions, write the program blocks, in absolute mode. Assume permitted cutting speed = 32 m/min and feed rate = 150 mm/min. **10**

8. (a) Six operators are to be assigned to six machines. Their efficiency on the machines is given in the matrix below: **30**

Operator \ Machine	1	2	3	4	5	6
A	0.92	0.95	0.90	0.85	0.75	0.91
B	0.94	0.90	0.88	0.85	0.95	0.93
C	0.75	0.00	0.77	0.70	0.00	0.76
D	0.88	0.85	0.90	0.80	0.85	0.90
E	0.55	0.95	0.90	0.94	0.95	0.90
F	0.50	0.75	0.74	0.80	0.80	0.00

(i) Assign the operators to the machines to maximize overall efficiency. (ii) State the steps clearly. (iii) Is there any alternative optimal solution? Justify your answer.

- (b) What is the principle of electro-chemical machining (ECM)? What are the advantages and disadvantages of ECM over conventional drilling? Comment on the surface finish and the accuracy of the ECM. **20**

- (c) A seasonal fashion item is to be ordered. The acquisition cost is ₹ 300 and the selling price is ₹ 450. If the salvage value after the season is ₹ 150, what should be the order quantity? The probability of demand occurring is known as under: **10**

Demand items	100	110	120	130	140	150
Probability	0.1	0.2	0.2	0.3	0.1	0.1
