

MECHANICAL ENGINEERING
(Paper I)

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, 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. Answer any three of the following

- (a) An I-beam has flanges 10 cm wide and 1 cm thick, and the web 12 cm high and 1 cm thick. At a section of this beam acts a bending moment of 1000 kg m and a shear force of 10,000 kg. Find the normal and shear stresses at the following points on the vertical centre line: (i) Top of flange (ii) In web at the junction with flange (iii) At the neutral axis **20**
- (b) For a two-dimensional stress state – (i) give the expressions specifying the acceptable stress domain according to the generally accepted theories of failure; (ii) plot the domains of different theories in σ_1, σ_2 space. **20**
- (c) Draw the flow chart and write a computer programme in Fortran for computing standard deviation σ of a given set of 100 numbers $x_1, x_2, \dots, x_{100}$, where

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2}$$

where x is an individual number of a group $\bar{x}$ is the arithmetic mean of the group of numbers and N is the size of the group of numbers. **20**

- (d) For effective vibration isolation of a machine with mass M subjected to harmonic steady force $F_0 \sin \omega t$, mounted on flexible isolators with total stiffness K and viscous damping constant C , what are the desirable conditions? Explain with the relevant analysis. **20**

2. (a) In a Hartnell governor where a central spring under initial compression is used for control, under what conditions does the governor become unstable? Also explain the effect of friction between the sleeve and spindle on the performance of the governor. **30**
- (b) For a 90° V-twin engine system, having two identical cylinders with centre line of each cylinder being inclined at 45° to the vertical, the speed is 2400 r.p.m. The reciprocating mass per cylinder = 1.5 kg, stroke = 14 cm, length of connecting rod = 28 cm. Find the values of maximum primary and secondary forces, and indicate whether the same can be balanced by suitable means. **30**
3. (a) A compound cylinder is made by shrinking an outer tube of outside diameter 200 mm and inside diameter 150 mm onto an inner tube, internal diameter 100 mm with a radial interference of 0.2 mm. Both the tubes are made of steel with elastic modulus $E = 2 \times 10^6 \text{ kg/cm}^2$ and Poisson's ratio

$\mu=0.3$. Calculate the value of pressure at the interface and values of hoop stress in the two tubes at the interface. Work from the first principles assuming the basic Lamé's equations

$$\sigma_r = A - \frac{B}{r^2}, \sigma_\theta = A + \frac{B}{r^2}$$

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- (b) In a slider crank mechanism the crank length is 10 cm and the connecting rod is 40 cm long. The crank rotates in anticlockwise direction at a constant speed of 600 r.p.m. Find the acceleration of the slider and the angular acceleration of the connecting rod at an instant when the crank is past the inner dead centre by 45° . **30**

4. (a) A copper tube, 22 mm internal diameter, 30 mm outer diameter and 150 mm long is compressed by a nut tightening over a steel bolt, 20 mm diameter with 1 mm pitch. (i) If the nut is tightened by a quarter of a turn beyond the just touching position, determine the stress in the bolt. (ii) What would be the final stress in the bolt if the temperature of the assembly in (i) is to increase by 10°C ? Assume $E_{steel} = 2 \times 10^6 \text{ kg/cm}^2$; $E_{Cu} = 6 \times 10^5 \text{ kg/cm}^2$; $\alpha_{steel} = 12 \times 10^{-6}/^\circ\text{C}$; $\alpha_{Cu} = 18 \times 10^{-5}/^\circ\text{C}$ **30**

- (b) A beam of flexural rigidity 20 MN/m^2 is simply supported over a span of 6 m as shown in the figure. It carries a concentrated load of 24 kN, 2 m from the left-hand support, and a UDL of 6 kN/m on the central 2 m part. The beam has vertical members welded onto it 2 m from the right-hand support which carry two horizontal loads of 24 kN as shown in the figure. The distance between these loads is 1 m. (i) Draw the Bending Moment Diagram for this beam. (ii) Calculate the vertical deflection of the central point of the beam. **30**

[Figure: Horizontal beam, 6 m span, simply supported at both ends (upward reaction arrows at the left and right ends). Marked distances: 2 m from the left support to the first load point and 2 m from the vertical member to the right support. A downward concentrated load of 24 kN acts at 2 m from the left support; a uniformly distributed load of 6 kN/m acts on the central 2 m (from 2 m to 4 m from the left support). At the end of the UDL (4 m from the left support, 2 m from the right support) a rigid vertical member is welded to the beam, extending above and below it: at its upper end a horizontal load of 24 kN acts towards the right; at its lower end a horizontal load of 24 kN acts towards the left; the vertical distance between the lines of action of the two horizontal loads is 1 m.]

SECTION 'B'

5. Answer any three of the following (Each answer should not exceed 200 words)
- (a) (i) What all costs result from poor quality of component production? (ii) How the concept of internal customer and external customer has improved quality manifold? (iii) How quality productivity, cost, market share, profit and scale of production are related qualitatively? (iv) What is Deming's Award for quality? Has any Indian firm been awarded this recently? **20**
- (b) What significant information's are provided by T T T diagrams? Sketch the T T T diagram for high carbon steel with low alloy content. Indicate a cooling line for full hardening. **20**
- (c) Define tolerance, Limit and fit. If the fit for a shaft-bearing assembly is indicated by $50 H_7 g_6$, what all informations you can infer from this? What types of gauges are needed to inspect these elements? **20**
- (d) How many degrees of freedom are there for a solid body? For proper location, how many locators are needed for restraining these freedoms? What general design considerations you advocate for proper location without redundancy? What are diamond locators and where they are used? **20**
6. (a) (i) What criteria are generally used to establish tool life while turning with a single-point tool? (ii) Are tool-life criteria different for material removal consideration and surface quality consideration – if so, why? (iii) Following data refer to the output of a tool-life experiment **30**

Cutting speed (meters/minute)	Tool life (minutes)
60	16
90	3

Establish the Taylor's tool-life equation. (iv) What is machinability of a material? What additives improve machinability?

- (b) (i) Distinguish between Waviness and Roughness of a machined surface. (ii) How do you define the surface finish under and systems [?]? (iii) In a turning operation following cutting conditions and tool geometry are used: Cutting speed = 20 meters/minute; Job dia = 50 mm; Feed = 0.3 mm/revolution; Depth of cut = 2 mm; Side cutting edge angle = 30°; (Approach angle = 60°); End cutting edge angle = 10°. Calculate the height of irregularities left by this operation. (iv) What do you suggest to improve the finish? (v) What is the R value in the above? **30**

7. (a) Machine shop of a small-scale entrepreneur consists of several general purpose machines, one each. A batch of 5 jobs from a customer arrives on one evening. Setting and processing times in two machines are given below **30**

Jobs in the Batch	Setting and Processing time (in hours): Machine 1 Milling Machine	Setting and Processing time (in hours): Machine 2 Grinding Machine
A	4	2
B	6	10
C	8	4
D	12	8
E	8	12

(i) In what sequence you will suggest to process them to minimize the make span of batch? (ii) Represent this in the form of a Gantt chart. (iii) Are there alternative sequences (min make span)? (iv) What algorithm you have used for this 2-machine system of batch processing and what is the logic of sequencing?

- (b) Annapurna Freight Company ships freights from 3 warehouses A, B and D to 4 markets P, Q, R and S. The transportation costs / truck load in Rs. and the quantity to be shipped are shown below: **30**

Warehouses	Market or Destinations: P	Market or Destinations: Q	Market or Destinations: R	Market or Destinations: S	Available in Truck loads
A	6000	2000	1000	3000	30
B	2000	4000	1000	2000	50
D	3000	6000	5000	1000	45
Required, in Truck Loads	20	25	40	40	

(i) How much should be shipped from each warehouse to each market destination to minimize the transportation cost? (ii) What is the minimum transportation cost? (iii) What is the effect of changing C_{AQ} from 2000 to 3000? (iv) When do you use dummies?

8. (a) A plant start up of activities are based on the following sequences: **30**

Activity	Immediate predecessor	Normal time (weeks)	Normal cost (Rs)	Possible crash time (weeks)	Crashed cost (Rs)
A	—	4	1,000	2	1,500
B	—	8	800	2	1,400
C	—	2	400	1	600
D	A	3	800	2	1,200
E	A	5	800	3	1,400
F	C	5	600 [?]	1	1,000
G	H, D [?]	6	1,200	2	1,600

(i) Draw the network for this project and label the activities and dummies. (ii) Identify the critical path. (iii) What is the normal project completion time and cost? (iv) How much it will cost to crash the project completion by 2 weeks; by 3 weeks? (Assume crashing cost is proportional to time). (v) What is cost over-run and time over-run, and which is worse?

- (b) A company has 4 salespersons and 4 clients to be visited. Each salesperson can visit only one client because of time constraint. The profit records from previous visits are shown in the table and it is required to maximize the profit by the best assignment: **30**

Clients	Salespersons, Profit (in Rs.): A	Salespersons, Profit (in Rs.): B	Salespersons, Profit (in Rs.): C	Salespersons, Profit (in Rs.): D
1	60	120	200	120
2	220	180	150	200
3	120	160	180	150
4	160	80	120	200

(i) Assign the salespersons to appropriate clients to maximise (ii) What are the maximum profits? (iii) Instead of profits, if the matrix indicates the distances to be traveled by each salesperson to the respective client and if the distance traveled by each salesperson is to be minimized, what will be the change in your solution procedure?

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