Civil Services (Main) Examination, 2002

# 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)** In a vibrating system a coil spring of stiffness 50 N/mm supports a vibrating mass of 250 kg at the free end. In addition; the motion of mass is controlled by a dashpot whose resistance is proportional to velocity. From measurement it is found that the amplitude at the beginning of the fourth cycle is 0.8 times the amplitude of the third cycle. Determine (i) damping co-efficient of the dashpot. (ii) critical damping co-efficient. (iii) the damping factor. (iv) the ratio of the frequencies of damped and undamped vibrations. **20**

**(b)** For the following states of stress, show the stresses on two given planes at right angles of an element. Find the magnitude and directions of the principal stresses and the maximum shear stresses in each case. (i) Simple uniaxial tension. (ii) Pure equal normal stresses on given planes. (iii) Pure shear stresses on given planes. **20**

**(c)** Distinguish between thin and thick cylinders. A thin cylindrical shell having hemispherical ends is subjected to internal pressure 'p'. The internal diameter is 'd' and thicknesses of cylinder and hemisphere are $t_1$ and $t_2$ respectively. Assuming Poisson's ratio $v = 0.3$, prove the following (i) For no distortion of juncture, $t_2/t_2 = 7/17$. (ii) For equal maximum stresses in cylindrical and hemispherical portions, $t_2/t_1 = 0.5$ **20**

**(d)** What do you mean by 'plain carbon steels' and 'alloy steels'? Discuss the effect of addition of following elements in making alloy steels (i) Chromium (ii) Nickel (iii) Manganese (iv) Silicon (v) Molybdenum (vi) Vanadium (vii) Tungsten **20**

**2.** **(a)** A gear with 42 teeth and a pinion with 19 teeth are cut with involutes teeth of pressure angle 20° and module pitch 6 mm. The addendum of each wheel is 6 mm. Find: (i) the length of the arc of contact. (ii) the number of pairs of teeth in contact. (iii) the angle turned through by the pinion, while any one pair of teeth is in contact. (iv) the ratios of sliding velocity to the rolling velocity at the instant (a) the engagement commences, (b) the engagement terminates and (c) at the pitch point. **30**

**(b)** A rotating shaft carries four masses A, B, C and D at radii of 10 cm, 12.5 cm, 20 cm and r cm respectively. The planes in which the masses revolve are spaced 60 cm apart. The masses B, C and D are known to be 10 kg, 5 kg and 4 kg respectively. It is desired that the rotating shaft should be in complete dynamic balance, For this to be achieved, determine: (i) required mass A (ii) the relative angular settings of the four masses, given that the angular spacing of the planes containing C and D

*English version compiled from published transcriptions and cross-checked across sources; not a facsimile of the official UPSC question paper.*



Optional Province · optionalprovince.com

are 118° and 260° respectively relative to B measured in the same sense. (iii) find the radius at which mass D is to be placed. **30**

**3.** **(a)** Draw Shear Force and Bending Moment diagrams for the beam ACDB shown in figure where two couples are acting. Find the ratio of deflections in the beam at locations C and D where the couples are acting. **30**

[Figure: Horizontal beam ACDB, 3 m long, with a hinged (pin) support at the left end A and a roller support at the right end B. Points C and D divide it into three equal spans: AC = 1 m, CD = 1 m, DB = 1 m. A clockwise couple $M_1 = 10\,kN \cdot m$ is applied at C and a clockwise couple $M_2 = 20\,kN \cdot m$ is applied at D (each drawn as a curved arrow over the beam with the arrowhead on the right-hand side pointing down). No other loads.]

**(b)** (i) For a closed coil helical spring under compression illustrate the stress distribution across wire diameter. (ii) Differentiate between compound and composite helical springs. (iii) The spring load against which a valve is opened is provided by an inner helical spring arranged within and concentric with an outer helical spring. The free length of inner spring is 6 mm longer than the outer. The outer spring has 12 coils of mean diameter 25 mm, wire diameter 3 mm, and initial compression 5 mm when the valve is closed. Find the stiffness of the outer spring if the greatest force required to open the valve by 10 mm is 150 N. If the radial clearance between the springs is 1.6 mm, find the wire diameter of the inner spring if it has 10 coils. For both springs, $G = 82,000\,N/mm^2$. **30**

**4.** **(a)** For engineering materials; differentiate between the following: (i) A system and state (ii) Extrinsic and intrinsic properties (iii) Degree of freedom and constraint (iv) Phase and component

**(b)** Differentiate between the following (i) Homogeneous nucleation and heterogeneous nucleation (ii) Nucleation and growth (iii) Embryos and nuclei (iv) Supercooling and sublimation **20**

**(c)** Explain the following: (i) Cyaniding (ii) Nitriding (iii) Flame hardening (iv) Induction hardening **10**

**(d)** Differentiate between: (i) Directional and non-directional bond (ii) Bond length and bond energy (iii) Ionic bond and covalent bond (iv) Metallic bond and hydrogen bond **20**

## SECTION 'B'

**5.** Answer any three of the following:

**(a)** Consider the following time series data: (i) Using a 3-week moving average, what is the forecast for week 7? (ii) Using $\alpha = 0.2$ for exponential smoothening, what is the forecast for week 7? (iii) Using the mean squared forecast error as a basis, which forecast for week 7 would you recommend? **6+7+7**

| Week | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Value | 8 | 13 | 15 | 17 | 16 | 9 |

**(b)** This program drills two holes using a CNC machining center. Indicate the meaning of the following commands **20**

| PROGRAM | ϕ0001 | |
|---|---|---|
| N005 | G54 | G90 S499M03 |
| N010 | G00 | X1. Y1. |
| N015 | G43 | H01 Z.0 M08 |
| N020 | G01 | Z-1.25 F3.5 |
| N025 | G00 | Z.1 |
| N030 | X2 | |
| N035 | G01 | Z-1.25 |
| N040 | G00 | Z.1 M09 |
| N045 | G91 | G28 Z0 |
| N050 | M30 | |

Note: ϕ indicates letter O and 0 indicates numeral zero.



Optional Province · optionalprovince.com

**(c)** (i) What is Taylor's equation? (ii) Explain the various criteria of tool failure. (iii) What is HSS? (iv) How is surface finish measured? **20**

**(d)** (i) Bevery Company, a weighing machine manufacturer essentially manufactures a mechanical weighing machine and another deluxe version which is a digital weighing machine. The company gives 7% commission on sales of the ordinary mechanical type and 8% commission on sales of the deluxe digital version. However, all such commissions are available, provided there is a base level sale of at least Rs. 10,000 of ordinary variety and Rs. 15,000 of deluxe variety. To motivate the sales engineers, for a sales exceeding Rs. 20,000 and Rs. 25,000 for the ordinary and deluxe variety respectively, there is a 1% increase in the commission levels for both varieties. Draw a flow chart to enable writing a computer programme for the above. (ii) Write a computer programme for the above situation. **10+10**

**6. (a)** What is a three high rolling mill? Show the direction of motion of rolls and the workpiece on a neat sketch of three high rolling mill. What lubricants are used during hot rolling? What is camber? Explain in relation to rolling process the function of providing camber. **30**

**(b)** How will you measure taper on a machined component? Describe the procedure with the help of one example and neat sketches. **30**

**7. (a)** Distinguish between allowance and tolerance. What are unilateral and bilateral systems of specifying tolerances? What is the condition for a force fit or interference fit between mating parts? Why is hole basis system preferred over a shaft basis system? **30**

**(b)** A person operates a machine that makes capacitors. He has been advised to keep track of the percent defectives at his work centre. He knows that with this type of process, they expect about 4% defectives plus or minus some chance variation. He wishes to initially construct a control chart for defectives. He has prepared ten daily samples of hundred capacitors each. **15+15**

| Sample Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| % defectives | 4 | 3 | 3 | 6 | 1 | 9 | 5 | 12 | 4 | 3 |

(i) Construct the relevant control chart. What are the upper and lower control limits? (ii) Plot the data points on the proposed control chart. Is the process under control? What follow up steps should be undertaken, if any?

**8. (a)** A materials manager had recently attended a short training programme on materials management. He thought of applying some of the optimization concepts that he had learnt. He picked on one item having code BV 1960 which was essentially a brass valve. From the current records, he found that the average annual demand was for 10,000 valves. The accounting information system revealed that the carrying cost was Rs. 0.40 per valve per year, whereas the ordering cost was Rs. 5.50 per order. The current policy adopted in the company was to order for 400 valves at a time. Is this an optimal policy? What would be the annual savings if the EOQ concept was applied? **15+15**

**(b)** A company produces two principal product lines - a powerful portable circular saw and precision table saws. Both product lines share the same production capacity and are sold through the same sales channels. The average profit is Rs. 900 for each circular saw and Rs. 600 for each table saw. The production capacity is constrained in fabrication and assembly capacity. A maximum of 4000 hours of fabrication capacity is available per month, and each circular saw requires two hours and each table saw requires one hour. A maximum of 5000 hours of assembly capacity is available per month, and each circular saw requires one hour and each table saw requires two hours. The marketing department estimates that there is a maximum market demand next year of 3500 saws per month for both product lines combined. (i) Is there a single managerial objective? What is it? (ii) What are the alternative feasible product mix possibilities? (iii) What is the optimal product mix? [You can use either graphical or simplex method] (iv) How much could the company product optimally if it was seen that the estimates of the next years market demand have been raised to 4000? What would be the maximum total profit? **5+5+15+5**



Optional Province · optionalprovince.com

✶✶✶