331003

COMBINED COMPETITIVE EXAMINATION (MAIN)

MECHANICAL ENGINEERING

Paper–I

Time : 3 Hours *Full Marks* : 200

Note : *(1) The figures in the right-hand margin indicate full marks for the questions.*

*(2) Attempt **five** questions in all.*

*(3) Question No. **1** is compulsory.*

1. Answer any ***ten*** questions from the following : 4×10=40

(a) What is a beam? How do you classify beams?

(b) Draw the shear force and bending moment diagrams for a cantilever beam subjected to a concentrated load at its free end.

(c) What are necessary elements of a cam mechanism? Classify the cams according to the follower movement.

(d) Define transfer function. Determine the transfer function of a first-order torsional system.

(e) What is computer numerical control (CNC)? What are the different components of a CNC machine tool?

(f) Show the tool-work motions and the generatrix and directrix in external thread cutting in centre lathe schematically.

(g) Why are ceramics hard and brittle? Why are they not conductive?

(h) How many types of lattice defect exist? What is the fundamental difference between edge and screw dislocation?

(i) Briefly describe the break-even chart.

(j) What is a production system? Name various types of production system based on the type of production.

(d) In a belt drive, the mass of the belt is 1 kg/m length and its speed is 6 m/s. The drive transmits 9.6 kW of power. Determine the initial tension in the belt and the strength of the belt. The coefficient of friction is 0.25 and the angle of lap is 220°.

(e) The damped natural frequency of a system as obtained from a free vibration test is 9.8 Hz. During the forced vibration test with constant exciting force on the same system, the maximum amplitude of vibration is found to be at 9.6 Hz. Find the damping factor for the system and its natural frequency.

(f) A rotor having a mass of 5 kg is mounted midway on a shaft of diameter 0.01 m supported at the ends by two bearings. The bearing span is 0.4 m. Because of certain manufacturing inaccuracies, the centre of gravity of the disc is 0.02 mm away from the geometric centre of the rotor. If the system rotates at 3000 rpm, find the amplitude of steady state vibrations and the dynamic force transmitted to the bearings. Neglect damping and take Young's modulus of elasticity, $E = 1.96 \times 10^{11}$ N/m^2.

4. Answer any ***four*** questions from the following : 10×4=40

(a) A 25 mm diameter bar is subjected to an axial tensile load of 100 kN. Under the action of this load, a 200 mm gauge length is found to extend 0.19×10^{-3} mm. Determine the modulus of elasticity for the bar material. If, in order to reduce weight whilst keeping the external diameter constant, the bar is bored axially to produce a cylinder of uniform thickness, what is the maximum diameter of bore possible given that the maximum allowable stress is 240 MPa? The load can be assumed to remain constant at 100 kN.

(b) A beam AB, 3 m long, is simply-supported at A and B. It carries a 16 kN concentrated load at C, 1.2 m from A, and a uniformly distributed load of 5 kN/m over the remainder of the beam. Draw the shear force (S.F.) and bending moment (B.M.) diagrams and determine the value of the maximum B.M.

(c) A circular bar ABC, 3 m long, is rigidly fixed at its ends A and C. The portion AB is 1.8 m long and of 50 mm diameter and BC is 1.2 m long and of 25 mm diameter. If a twisting moment of 680 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. What will be the angle of twist of each portion? For the material of the shaft take modulus of rigidity, $G = 80$ GPa.

(d) Show that the tensile hoop stress set up in a thin rotating ring or cylinder is given by

$$\sigma = \rho\omega^2 r^2$$

where ρ is the density and ω is the angular velocity of rotation. Hence determine the angular velocity at which the disc can be rotated if the hoop stress is limited to 20 MPa. The ring has a mean diameter of 260 mm.

(e) Two shafts are made of same material and are also of equal length and weight. One is solid and 100 mm diameter, the other is hollow. If the hollow shaft is to store 25% more energy than the solid shaft when transmitting torque, what must be its internal and external diameters? Assume the same maximum shear stress is applied to both the shafts.

(f) State the assumptions made in deriving the Euler's formula for a column with pin-jointed ends. Derive Euler's crippling load for such a column.

5. Answer any ***four*** questions from the following : 10×4=40

(a) For body-centred cubic (BCC) iron, compute the interplanar spacing and the diffraction angle for the (220) set of planes. The lattice parameter for Fe is 0.2866 nm (nanometer). Also, assume that monochromatic radiation having a wavelength of 0.1790 nm is used and the order of reflection is 1.

(b) What is dislocation? Describe different types of dislocations in crystal.

(c) What is isomorphous system? Give example of an isomorphous system. Two metals *A* (melting point 800°C) and *B* (melting point 600°C) form a binary isomorphous system. An alloy having 35% *B* has 75% solid and rest liquid whereas an alloy having 55% *B* has 25% solid at 700 °C. Estimate the composition of solidus and luquidus at the above temperature.

(d) Describe age hardening and tempering heat treatment processes.

(e) Describe the advantages and disadvantages of composite materials.

(f) A piece of steel which was quenched after prolonged holding at 700°C was found to have ferrite martensite structure. Explain when would you expect this to happen? List the factors that determine the strength of properly hardened steel.

6. Answer any ***four*** questions from the following : 10×4=40

(a) A strip with a cross-section 150 mm × 60 mm is being rolled with 20% reduction of area using 400 mm diameter steel rolls. Before and after rolling, the shear yield stresses of the material are 0.35 kN/mm^2 and 0.4 kN/mm^2 respectively. Calculate *(i)* the final strip thickness, *(ii)* the average shear yield stress during the process, and *(iii)* the angle subtended by the deformation zone at the roll centre.

(b) During an orthogonal machining operation on mild steel, the result obtained are as follows : uncut thickness t_1 = 0.25 mm, chip thickness t_2 = 0.75 mm, width of the workpiece w = 2.5 mm, tool rake angle $\alpha = 0°$, cutting component of the machining force F_C = 950 N and thrust component of the machining force F_T = 475 N. Determine the coefficient of friction between the tool and the chip and the ultimate shear stress of the work material.

(c) Take $n = 0.5$ and $C = 90$ in the Taylor equation for tool life equation. What is the percentage increase in tool life if the cutting speed is reduced by 50%? What will be the tool life if the cutting speed is increased by 20%?

(d) Describe the mechanics of material removal in electrochemical machining (ECM) process with schematic.

(e) What are the types of automated manufacturing system? Describe briefly.

(f) Describe the effect of tool rake angle, tool nose radius and cutting fluids on machinability.

7. Answer any ***four*** questions from the following : 10×4=40

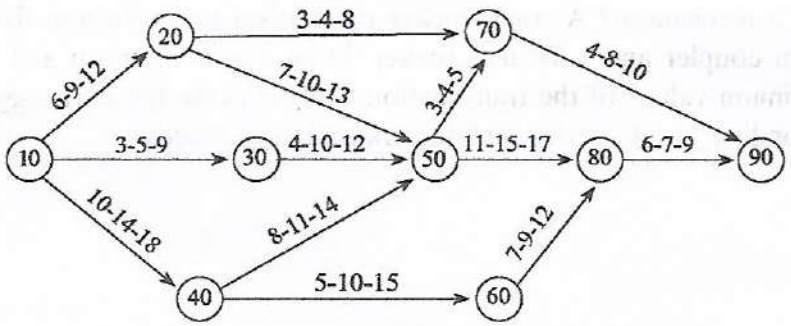
(a) What is forecasting? Discuss different types of forecasting method.

(b) From a manufacturing unit, following data was recorded : total revenue = $100Q - 0.001Q$ and total cost = $0.005Q^2 + 4Q + 20000$, where Q is the quantity of the product. Determine the number of quantities corresponding to *(i)* break-even point (BEP), *(ii)* maximum profit, and *(iii)* minimum average unit cost.

(c) ABC manufacturer produces 125000 oil seals each year to satisfy the requirement of their client. They order the metal for the bushing in lot of 30000 units. It costs them \$40 to place the order. The unit cost of bushing is \$0.12 and the estimated carrying cost is 25% of unit cost. Find out the economic order quantity. What percentage of increase or decrease in order quantity is required so that the ordered quantity is economic order quantity (EOQ)?

(d) In the network of the figure given below, the PERT time estimates of the activities are written along the activity arrows in the order $t_o - t_m - t_p$ (optimistic time–most likely time–pessimistic time). Compute the expected time and variance for each activity. Also compute the expected duration and standard deviation for the following paths of the network :

(i) 10-20-50-80-90 (ii) 10-30-50-70-90 (iii) 10-40-60-80-90



(e) Solve the following linear programming problem using Simplex method :

Maximize $12x + 16y$

subject to $10x + 20y \leq 120$

$8x + 8y \leq 80$

$x, y \geq 0$

(f) An office worker wants to set standard time to complete a task K comprised of three job elements. He clocked work elements and choose to take 6 cycles as shown in Table 1 :

Table 1 : Observed cycles and performance rating to complete the task K

Job element	Cycles observed in minutes						Performance rating
	1	2	3	4	5	6	
1	15	10	13	17	45	14	100%
2	30	20	26	72	25	23	110%
3	4	3	2	3	5	4	100%

The allowance for the task is 12% and performance rating for each element is also given in Table 1. Find the normal time and standard time to complete the task.

8. 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 together with an axial tensile load of 20 kN. If the elastic limit in tension of the material of the members is 270 MPa and there has a to be a factor of safety of 4, estimate the magnitude of d required according to *(i)* the maximum principal stress theory, and *(ii)* the maximum shear strain energy per unit volume theory. Take Poisson's ratio $\nu = 0.3$ 40

9. What is a mechanism? A crank-rocker mechanism has a 70 mm fixed link, a 20 mm crank, a 50 mm coupler and a 70 mm rocker. Draw the mechanism and determine the maximum and minimum values of the transmission angle. Locate the two toggle positions and find the corresponding crank angles and the transmission angles. 40

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