

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.

Answers must be written in ENGLISH only.

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

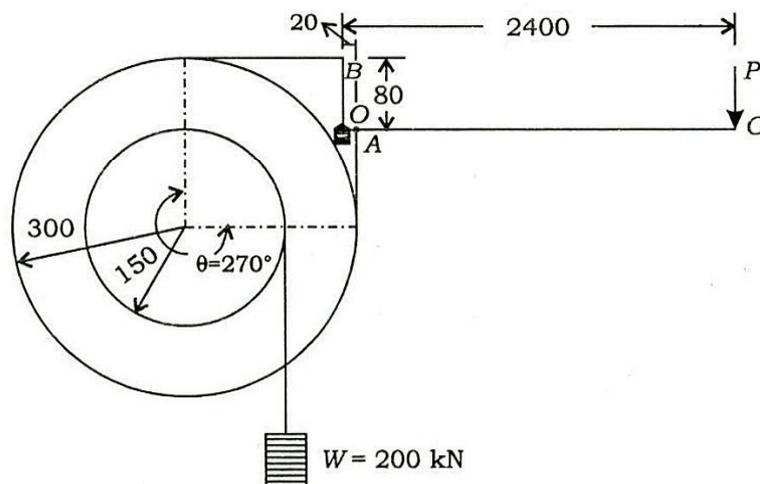
Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

SECTION—A

1. (a) Design a set of stepped pulleys to drive a machine from a countershaft that runs at 220 r.p.m. The centre distance between the two sets of pulleys is 2 m. The diameter of the smallest step on the countershaft is 160 mm. The machine is to run at 80 r.p.m., 100 r.p.m. and 130 r.p.m., and should be able to rotate in either direction. Find the length of the belt required for both the cases. 8
- (b) What is the chief difference between heat-treatable and non-heat-treatable alloys? 8
- (c) A bar of length L , material density S and modulus of elasticity E is rotating about one end with an angular speed of ω radians per second. Find the maximum stress set up in the bar and its extension due to rotation. 8
- (d) The end of a rod made of mild steel is sliding over the unlubricated surface of hardened tool steel with a load of 100 kg. The hardness of mild steel is 15 HB. What is the distance travelled to produce a wear volume of 1 mm^3 by adhesive wear of the mild steel rod? 8
- (e) Give a neat sketch of a unit cell of copper. Indicate Miller indices for its slip plane and slip direction. Why is copper so ductile? 8
2. (a) A simple beam supports a concentrated downward force P at a distance a from the left support. The flexural rigidity EI is constant. Find the equation of the elastic curve by successive integration. 20
- (b) A vertical shaft is held in long bearings and a disc is attached to the shaft at its midpoint. The centre of gravity of the disc does not coincide with the axis of the shaft. Determine (i) the critical speed of the shaft and (ii) the range of the speed over which it is unsafe to run the shaft.
The diameter of the shaft is 15 mm and the span of the shaft between the bearings is 1 m. The mass of the disc is 10 kg and the centre of gravity of the disc is 0.3 mm from the axis of the shaft. Take $E = 200 \text{ GN/mm}^2$ and permissible stress in the shaft material is $70 \times 10^6 \text{ N/mm}^2$. 10
- (c) Explain the phenomenon of interference in involute gears. What are the conditions to be satisfied in order to avoid interference? List the important physical characteristics of a good bearing material. 10

3. (a) A two-span continuous beam is clamped at one end and simply supported at two other points. Determine the reactions caused by the application of a uniformly distributed load W_a ; EI for the beam is constant. 20
- (b) Determine the composition in atoms percent of an alloy that consists of 97 wt% aluminium and 3 wt% copper. 10
- (c) A solid cylindrical ceramic part is to be made whose final length must be $L = 25$ mm. It has been established that for this material, linear shrinkages during drying and firing are 9% and 5% respectively. Based on the dried dimension L_d , calculate (i) the initial length L_0 of the part and (ii) the dried porosity P_d , if the porosity of the fired part P_f is 4%. 10
4. (a) The bearings A and B of a shaft are 5 m apart. The shaft carries three eccentric masses C, D and E which are 160 kg, 170 kg and 85 kg respectively. The respective eccentricity of each mass measured from axis of rotation is 0.5 cm, 0.3 cm and 0.6 cm, and distance from A is 1.3 m, 3 m and 4 m respectively. Determine the angular position of each mass with respect to C so that no dynamic force is exerted at B and also find dynamic force at A for this arrangement when the shaft runs at 100 r.p.m. 20
- (b) Draw a neat sketch of the Time-Temperature-Transformation diagram and enlist its salient points. 10
- (c) The following figure shows a barrel and a differential band brake which are keyed to the same shaft. A rope is wound round the barrel and supports a load of 200 kN. The brake drum diameter is 600 mm and diameter of the barrel is 300 mm. The two ends of the band are attached to pins on opposite sides of the fulcrum of the brake lever at a distance of 20 mm and 80 mm respectively. The angle of contact of band brake is 270° and the coefficient of friction is 0.25. Determine the minimum force required at the end of the lever to support the load, if the length of the lever from the fulcrum is 2400 mm. 10



SECTION—B

5. (a) Under what circumstances would you use PERT as opposed to CPM in project management? Name a few projects where each would be more suitable than other. 8
- (b) In a slab milling operation with straight teeth cutter, the cutter has 15 teeth with 10° rake angle and rotates at 200 r.p.m. The diameter of the cutter is 80 mm and table feed is 75 mm/min, the depth of cut is 5 mm, the width of slab is 50 mm and ultimate shear stress of work material is 420 N/mm^2 . Assuming the coefficient of friction between chip and cutter to be 0.7 and using Lee and Shaffer relation, plot variation of resultant torque and cutter rotation, and estimate average power consumption. 8
- (c) An extruder screw with a thread angle of 20° has a melt pumping zone that is 1 m long, with a channel depth of 7 mm for a 50 mm diameter barrel. The screw is used to extrude 5 mm diameter circular nylon bars through a die with a 20 mm land length at 573 K. If the extruder is operated at 50 r.p.m. = 0.833 rev/s, determine the extruder and the characteristics, and obtain the operating flow rate. What is the speed of material leaving the extruder? Ignore die swell. 8
- (d) Estimate the limiting drawing ratio (LDR) that you would expect from a sheet metal when stretched by 23% in length, decreases thickness by 10%. 8
- (e) Why do we need inventory? Explain why we need to optimize the order quantity. The demand for a component is 10000 pieces per year. The cost per item is ₹ 50 and the interest cost is 1% per month. The cost associated with placing an order is ₹ 240. What is the EOQ? 8
6. (a) Consider the simple one-dimensional open-loop and closed-loop control systems illustrated in the figure shown below. Assume that the worktable mass m is known and that control is achieved by changing the force applied to the worktable through a torque to the gear. If the system is frictionless, develop equations for the force needed to obtain a new position for (i) open-loop control and (ii) closed-loop control, where both position and velocity are measured. 10

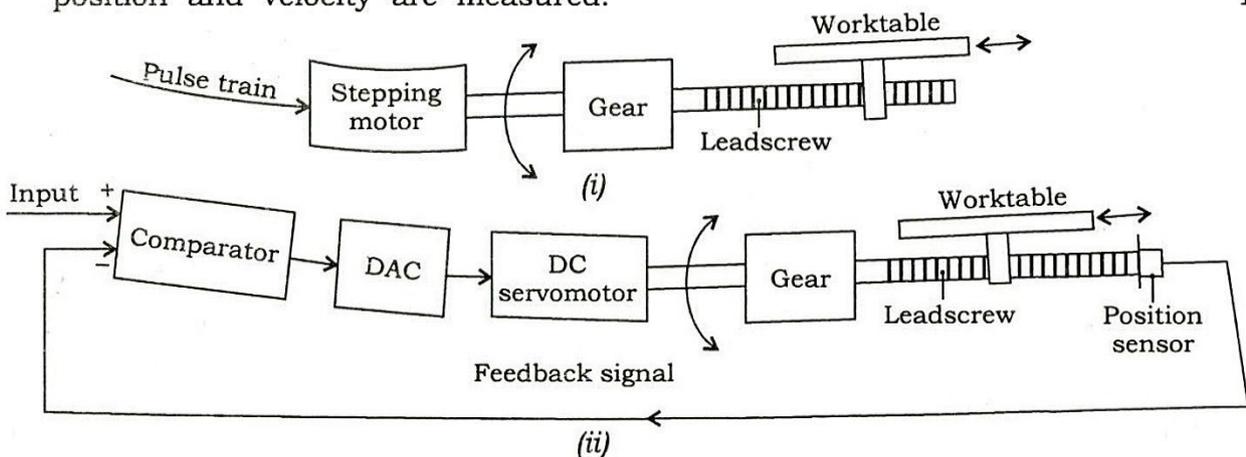


Fig. : Schematic illustration of the components of
 (i) an open-loop and (ii) a closed-loop control system

- (b) A round rod of annealed brass 70-30 is being drawn from a diameter of 6 mm to 3 mm at a speed of 0.6 m/s. Assume that the frictional and redundant work together constitutes 35% of the ideal work of deformation. Calculate (i) power required in this operation and (ii) die pressure at the exit of the die. 10
- (c) A lathe machine is targeted to produce shafts of 25 mm diameter. This conventional lathe is having process dispersion of 0.15 mm. Determine the following : 10
- (i) How many shafts the machine is producing below 24.9 mm?
- (ii) How many shafts the machine is producing above 25.2 mm?
- (iii) Normally the machine does produce shafts in what range?
- (iv) If the acceptable limit of shafts by consumer is $25 + 0.35$ mm, how many defective shafts the machine will produce?
- (d) The bore of an alloy steel component is to be finish broached to $31.75^{+0.01}$ mm diameter. The bore prior to broaching being $31.24^{+0.05}$ mm diameter, calculate (i) pitch of teeth, (ii) length of cutting portion and (iii) force to pull broach through work, if the length of hole = 25 mm, $t = 0.025$ mm, $k = 5000$ N and $S = 5$. Sketch the broach. 10

7. (a) Use dual simplex method to

$$\text{Maximize } Z = -3x_1 - 2x_2$$

subject to

$$x_1 + x_2 \geq 1$$

$$x_1 + x_2 \leq 7$$

$$x_1 + 2x_2 \geq 10$$

$$x_2 \leq 3, x_1, x_2 \geq 0$$

10

- (b) What are the various charts used for process control of SQC? Discuss the relative advantages and disadvantages of use of control charts. 10
- (c) A company is specialized in the manufacture of small-capacity motors. The structure cost of a motor is given below :
- Material = ₹ 50; Labour = ₹ 80; Variable overhead = 75% of labour cost; Fixed overhead of the company is ₹ 2,40,000; Sale price of each motor = ₹ 230.
- (i) Determine the breakeven point.
- (ii) Calculate the number of motors to be sold to make a profit of ₹ 1,00,000.
- (iii) In case the sale price of each motor is reduced by ₹ 15, then determine the number of motors to be sold to obtain breakeven point. 20

8. (a) Given an old forecast of ₹ 250 lakh initially, compare the difference between smoothing constants $\alpha = 0.5$ and $\alpha = 0.10$ for the following series of 10 observations of sales of M/s. Smith & Co. : 10

(₹ in Lakh)

Series : 290, 290, 220, 270, 240, 230, 280, 240, 290 and 210

- (b) Compare the working principles of Laser Beam Machining and Electron Beam Machining with the help of neat diagrams. 10
- (c) Explain 'FAST' with the help of diagram and discuss it with respect to Value Engineering. 10
- (d) What are MRP objectives? What are various lot sizes used for MRP? 10
