

# MECHANICAL ENGINEERING

## Paper – II

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.

Questions No. **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.

Diagrams / Figures, wherever required, shall be drawn in the space provided for answering the question itself.

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

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 (QCA) Booklet must be clearly struck off.

Answers must be written in **ENGLISH** only.

## SECTION A

- Q1. (a)** Find the centroidal coordinates of an area bounded by the following curves :

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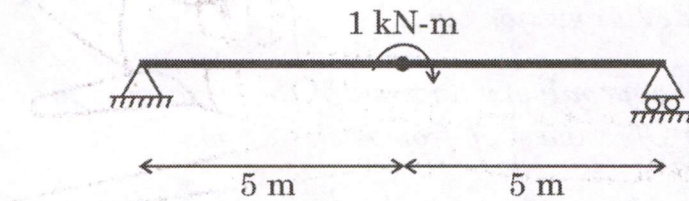
$$y = 4$$

$$x = 20$$

$$y^2 = 4x$$

- (b)** Draw the shear force and bending moment diagrams for the following beam :

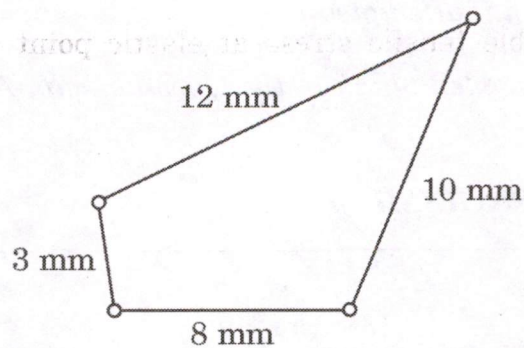
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- (c)** Define kinematic chain.

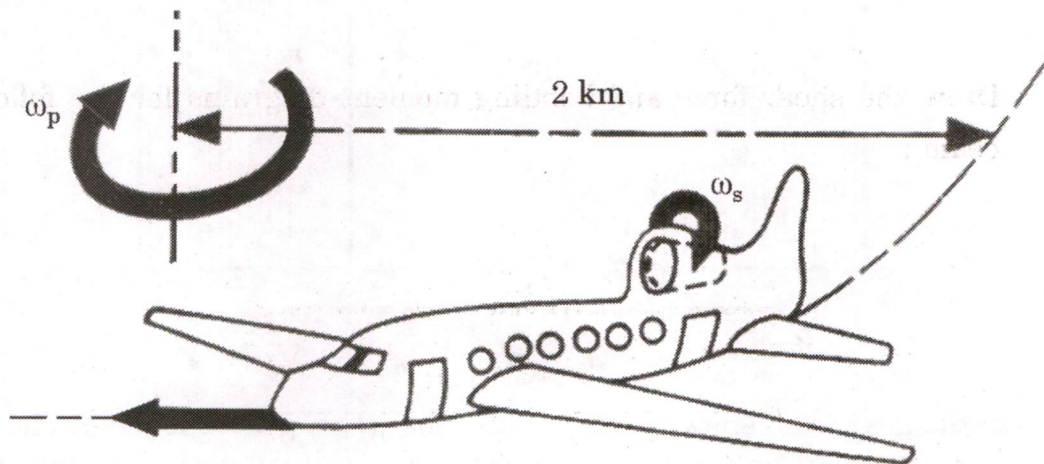
Find all the inversions of the chain shown in the figure.

12



- (d) The rotor of a turbojet engine has a mass of 250 kg and a radius of gyration of 25 cm. The engine rotates at a speed of 12000 rpm in the clockwise direction if viewed from the front of the aeroplane. The plane while flying at 1500 km/hr turns with a radius of 2 km to the right. Compute the gyroscopic moment the rotor exerts on the plane structure. Also, determine whether the nose of the plane tends to rise or fall when the plane turns.

12



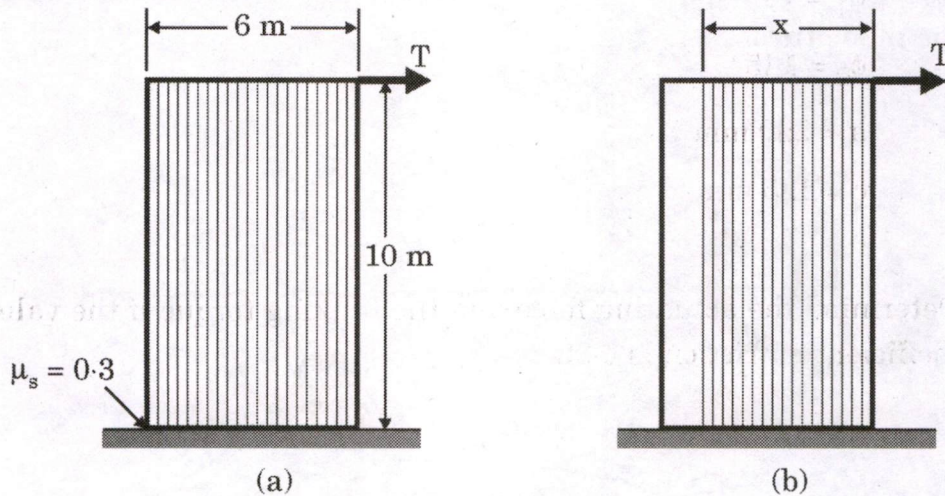
- (e) A bolt is loaded with an axial pull of 12 kN along with a transverse shear force of 6 kN. Find the diameter of the bolt required, according to
- the maximum principal stress theory.
  - the maximum shear stress theory.

12

Take permissible tensile stress at elastic point = 100 MPa, Poisson's ratio = 0.3.

- Q2.** (a) A rectangular case is loaded with uniform vertical thin rods such that when it is full, as shown in the figure (a), the case has a total weight of 1000 N. The case weighs 100 N when empty and has a coefficient of static friction 0.3 with the floor as shown in the diagram. A force  $T$  of 200 N is maintained on the case. If the rods are unloaded from the left end as shown in the figure (b), what is the limiting value of  $x$  for equilibrium to be maintained?

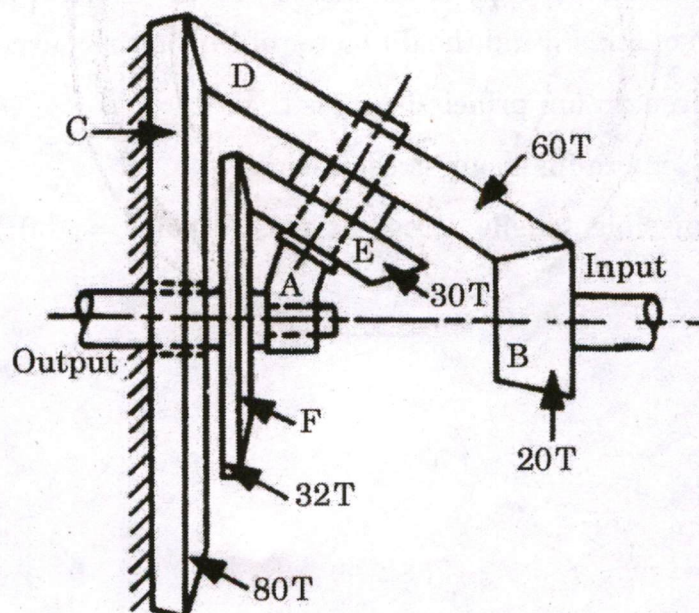
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- (b) What is planetary or epicyclic gear train?

In the gear train shown in the figure, the wheel gear C is fixed. The gear B is connected to the input shaft, and gear F is connected to the output shaft. The arm A, carrying the compound gears D and E, turns freely on the output shaft. If the input shaft speed is 1000 rpm in the counter clockwise (ccw) direction when seen from the right, determine the speed of the output shaft. The number of teeth on each gear is indicated in the figure.

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- (c) An internal expanding shoe brake has a diameter of 320 mm and a width of 30 mm. The actuating forces are equal. The maximum pressure is not to exceed  $80 \text{ kN/m}^2$ . In reference to the figure given below, the values of various parameters are as follows :

$$\phi_1 = 15^\circ$$

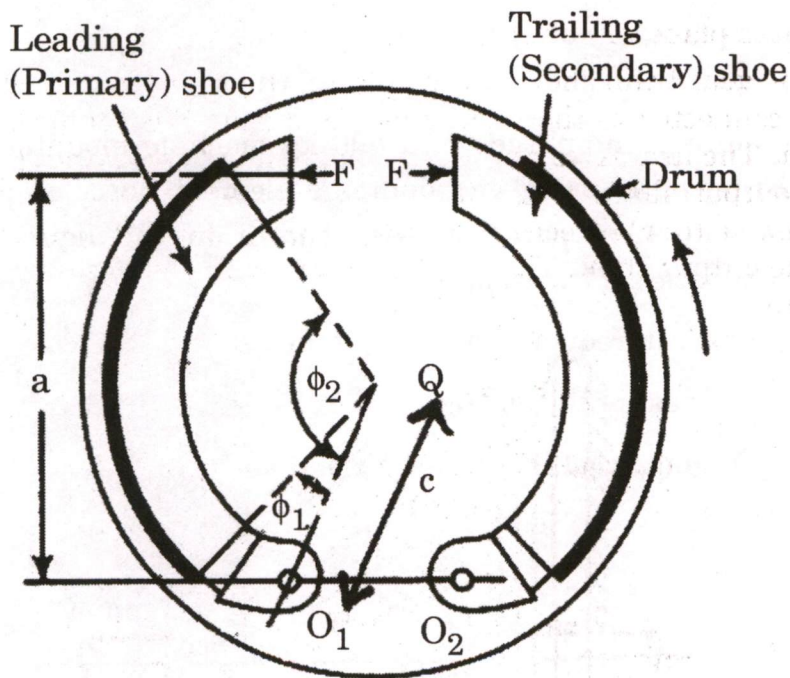
$$\phi_2 = 145^\circ$$

$$a = 220 \text{ mm}$$

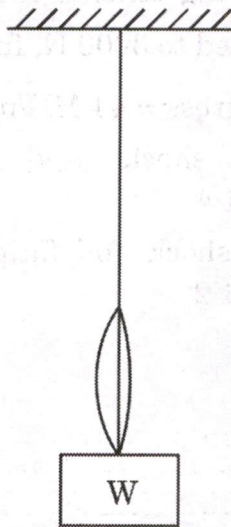
$$c = 125 \text{ mm}$$

Determine the actuating force and the braking torque if the value of the coefficient of friction is 0.32.

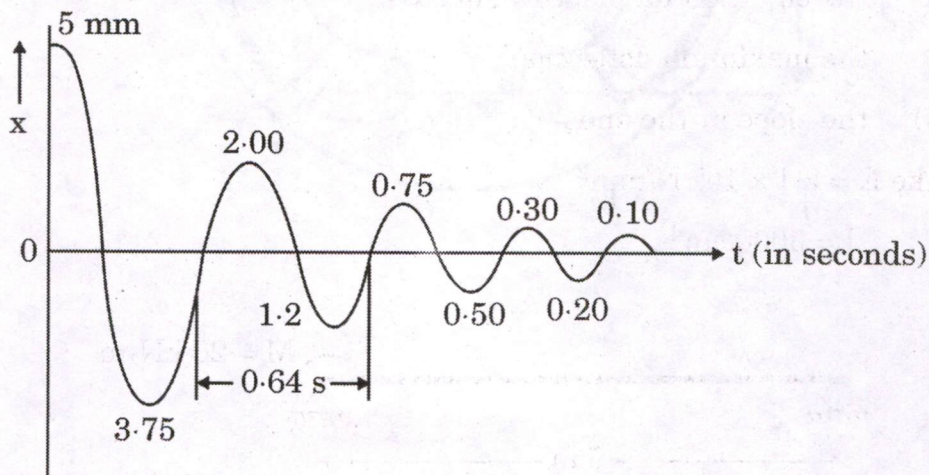
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- Q3.** (a) Three wires each of 5 mm diameter are used to lift a load of  $W = 7500$  N. An indicative diagram is shown below. The unstressed lengths of the three wires are 18 m, 17.997 m and 17.994 m.
- Find
- the stress in the longest wire.
  - the stress in the shortest wire if the load is reduced to 2000 N.
- Take  $E = 2.1 \times 10^5$  N/mm<sup>2</sup>



- (b) Free vibration amplitude of a 500 kg machine mounted on an isolator consisting of a spring and damping element (viscous) is shown in the figure. The time period is also shown in the figure. Find out the characteristics of the isolator i.e.,
- natural frequency of the system.
  - stiffness of the spring.
  - damping coefficient of the isolator.



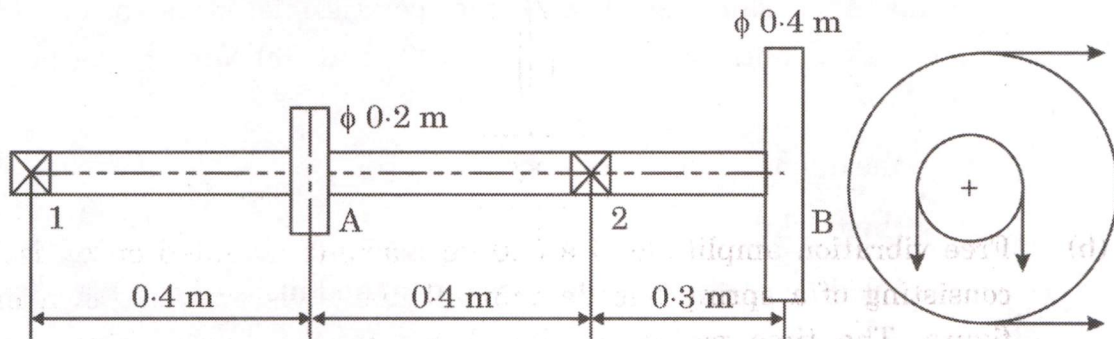
- (c) A shaft is supported on two bearings 0.8 m apart as shown in the figure. A pulley of diameter 0.2 m is mounted on the shaft which takes the power from vertical belt drive. The shaft also carries another pulley, which transmits power to a machine. The diameter of the pulley is 0.4 m and it is placed to the right hand side of the right bearing at a distance of 0.3 m from the bearing. Both the pulleys contain flat belt at right angles to each other having tension ratio of 2.5 : 1. If the maximum tension in the belt is limited to 3000 N, find the shaft diameter.

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Given : Allowable shear stress =  $44 \text{ MN/m}^2$

$k_b$  = Combined shock and fatigue factor applied to bending = 1.4

$k_f$  = Combined shock and fatigue factor applied to torsional moment = 1.2



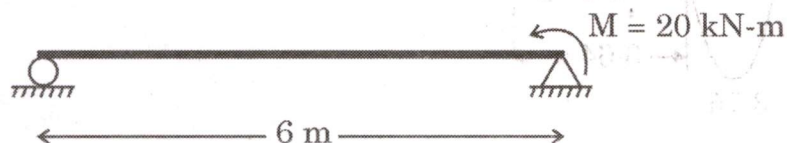
- Q4. (a) A simply supported beam of length 6 m is loaded with a couple-moment of 20 kN-m at the right end as shown in the figure. Determine

- the equation for elastic deflection.
- the maximum deflection.
- the slope at the ends.

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Take  $E = 2.1 \times 10^5 \text{ N/mm}^2$

$I = 3000 \text{ cm}^4$



- (b) The turning moment diagram for a multicylinder engine is to be drawn to a vertical scale of  $1 \text{ mm} = 650 \text{ Nm}$  and a horizontal scale of  $1 \text{ mm} = 4.5^\circ$ . The areas above and below the mean torque line are  $-28, +380, -260, +310, -300, +242, -380, +265$  and  $-229 \text{ mm}^2$ .

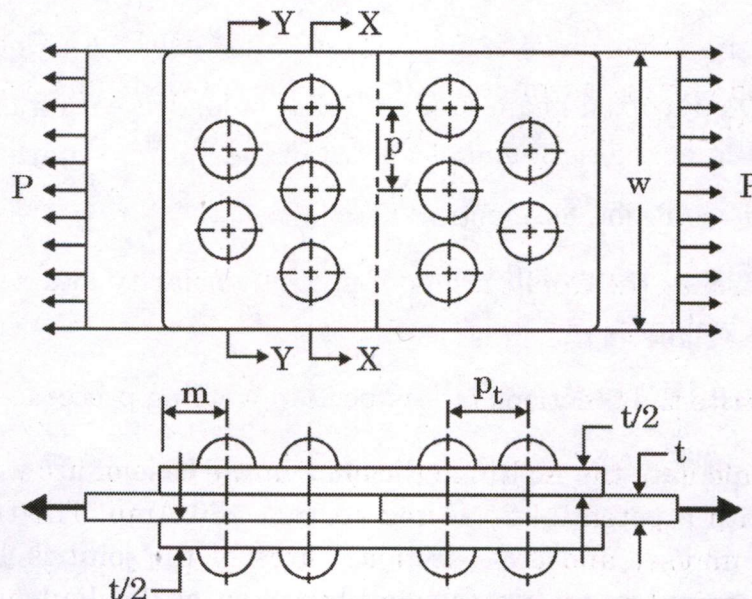
The fluctuation of speed is limited to  $\pm 1.8\%$  of the mean speed which is  $400 \text{ rpm}$ . The density of the rim material is  $7000 \text{ kg/m}^3$  and the width of the rim is  $4.5$  times its thickness. The centrifugal stress in the rim material is limited to  $6 \text{ N/mm}^2$ . Neglecting the effect of boss and arm, determine the diameter and cross-section of the flywheel rim. The turning moment diagram may be drawn free-hand.

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- (c) Two flat plates subjected to a tensile force  $P$  are connected together by means of double-strap butt joint as shown in the figure. The force  $P$  is  $250 \text{ kN}$  and the width of the plate  $w$  is  $200 \text{ mm}$ . The rivets and plates are made of same steel and the permissible stresses in tension, compression and shear are  $70, 100$  and  $60 \text{ N/mm}^2$ , respectively. Calculate

- the diameter of the rivets,
- the thickness of the plates,
- the dimension of the seam viz.  $p, p_t$  and  $m$ ,
- the efficiency of the joint.

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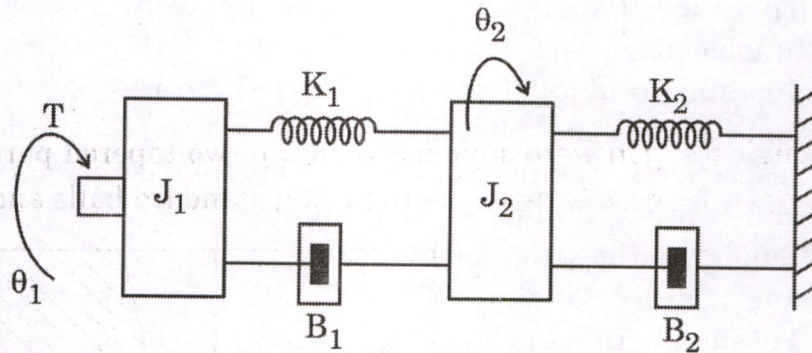




## SECTION B

- Q5.** (a) What do you mean by Atomic Packing Factor ? Find the volume of unit cell and atomic packing factor for face-centred cubic structure having atomic radius 'R'. 12
- (b) A pipe of annealed steel with internal diameter of 60 mm and wall thickness of 3.0 mm is to be reduced down to the internal diameter of 54 mm and wall thickness 2.0 mm. Die angle used for pipe drawing is  $30^\circ$ ,  $\mu = 0.1$  and draft = 3.1. Compare the drawing force on the plug and the movable mandrels. Given :  $\sigma_0 = 240 \text{ N/mm}^2$ . 12
- (c) (i) Write the basic assumptions of Linear Programming Problem.
- (ii) There are two suppliers X and Y producing a product used in automobiles. The suppliers X and Y can produce maximum 100 and 60 units of the product per day, respectively. Buyers A and B consume 50 and 110 units of the product per day, respectively. The transportation costs from supplier X to buyers A and B are ₹ 30 and ₹ 50 per unit of the product, respectively. Similarly, the transportation costs from supplier Y to buyers A and B are ₹ 20 and ₹ 80 per unit of the product, respectively. Formulate the Linear Programming Problem to minimize the transportation cost. 4+8
- (d) List down the requirements that govern the selection of actuator sizing for a motion axis in a mechatronic equipment. Will the requirements remain same for different types of actuators ? Justify the answer. 12
- (e) Discuss the importance of Fault Tree Analysis (FTA). Construct a FTA for a windowless room that contains one switch and two light-bulbs. Assume that the top fault event is dark room. 12
- Q6.** (a) (i) Discuss the applications of straight polarity and reverse polarity in welding.
- (ii) Write the functions of flux used in welding process.
- (iii) Calculate the melting efficiency in the case of arc welding of steel with a potential 25 V and current 180 Amp. The travel speed is 4 mm/sec and cross-sectional area of the joint is  $16 \text{ mm}^2$ . Heat required to melt steel may be taken as  $12 \text{ Joule/mm}^3$  and heat transfer efficiency as 0.80. 5+5+10

- (b) (i) Differentiate between True stress-strain and Engineering stress-strain, using a stress-strain diagram for mild steel.
- (ii) A cylindrical specimen of alloy steel having an original diameter of 12 mm is subjected to a tensile load of 60 kN. If the instantaneous cross-sectional diameter of 10 mm and elongation observed is 10%, determine the true stress and strain hardening exponent 'n' in true stress-strain diagram. The value of tensile strength (K) is given as 1035 MPa. 8+12
- (c) A rotational mechanical system representing motor trailer is shown below. Derive the system of differential equation and the transfer function. 20



where, T is a torque applied to the free end

$\theta_1$  is an angular displacement of rotor with moment of inertia  $J_1$

$B_1$  is the damping coefficient of torsional damper

$K_1$  is the torsional spring stiffness

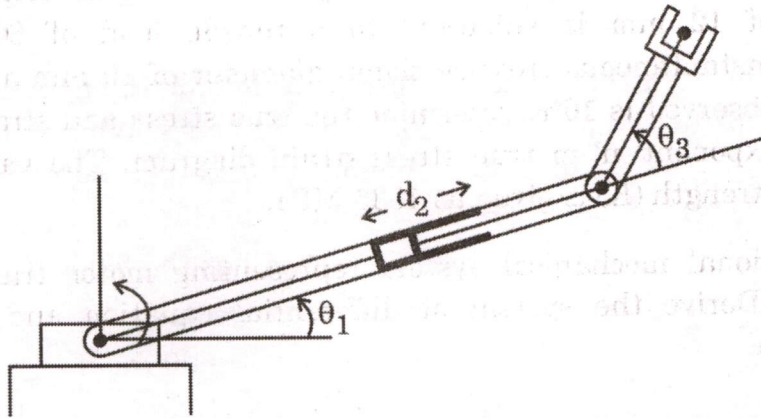
$K_2$  is the torsional spring stiffness

$B_2$  is the torsional damping coefficient

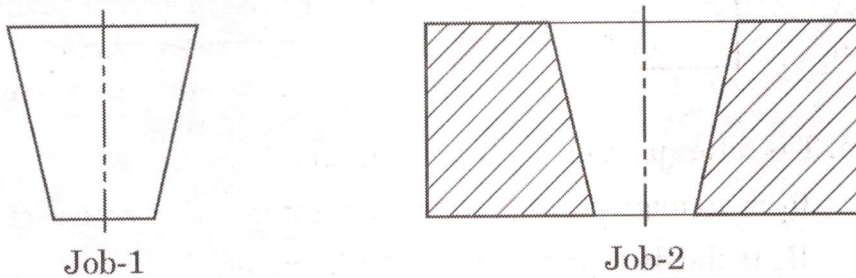
$\theta_2$  is the angular displacement of rotor with moment of inertia  $J_2$ .

- Q7.** (a) (i) The demand for an item in a company is observed as 15,000 units per year and the production capacity of the plant is 2,000 units per month. The set-up cost is ₹ 800 and the inventory holding cost is ₹ 25 per unit per year. The shortage cost of one unit is given as ₹ 250 per year. Determine the economic batch quantity and the number of shortages. Also, determine the cycle time, production time, and utilization percentage.
- (ii) Discuss the classification of inventory items such as ABC analysis, SDE, VED and FSN. 10+10

- (b) For the below given 3 DOF (Degree of Freedom) arm, determine the forward kinematic model, using D-H algorithm. Clearly indicate the assumptions, if any, to derive the kinematic model. 20



- (c) As an engineer, you were supplied with the two tapered parts as shown below whose taper is to be measured using standard balls and rollers. 20



Elaborate the steps necessary to measure the taper angles of these parts. Provide the list of instruments and materials required, with detailed mathematical derivation for the measurement. Specify the precautions you need to take while measuring the angles. 20

- Q8. (a) (i) The position of a point P of a rigid body B is located at  $B_P = [1, 2, 3]^T$ . Determine the global position after rotation  $30^\circ$  about X-axis and then  $45^\circ$  about Y-axis. 10
- (ii) If a homogeneous transformation matrix T is given by

$$T = \begin{bmatrix} c\theta & -c\alpha s\theta & s\alpha s\theta & a c\theta \\ s\theta & c\alpha c\theta & -s\alpha c\theta & a s\theta \\ 0 & s\alpha & c\alpha & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Determine its inverse, using concepts of rigid body motion. 10

- (b) (i) Discuss the failure rate model having Burn-in period, Useful life period and Wear-out period.
- (ii) Show the relationship between failure rate ( $\lambda$ ), reliability (R), pdf (f) and cdf (F).
- (iii) Twenty machines have been operated for 100 hours. One machine fails in 70 hours and another in 80 hours. What is the mean time between failure and reliability at 500 hours ? Assume the constant failure rate for the above machines. 5+5+10
- (c) (i) The armature controlled DC motor has the following ratings :  
 $K_T = 0.08 \text{ Nm/A}$ , Maximum current = 3 A  
 $K_e = 0.06 \text{ V rad/s}$ , Maximum speed = 600 rad/s  
Armature resistance =  $1.5 \Omega$   
Determine the maximum output torque, maximum output power, maximum armature voltage and no-load motor speed. Assume that the frictional torque is zero. 10
- (ii) What are the important components of Programmable Logic Controllers (PLCs) ? List down the differences between PLCs and computers in terms of program and memory used, power supply and its disruption, and flexibility in operation. 10