

# ESE (Mains), 2021

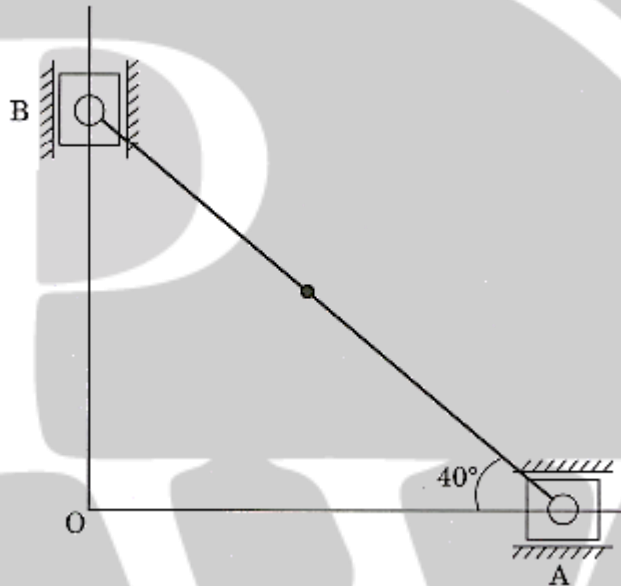
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## MECHANICAL ENGINEERING Paper-II

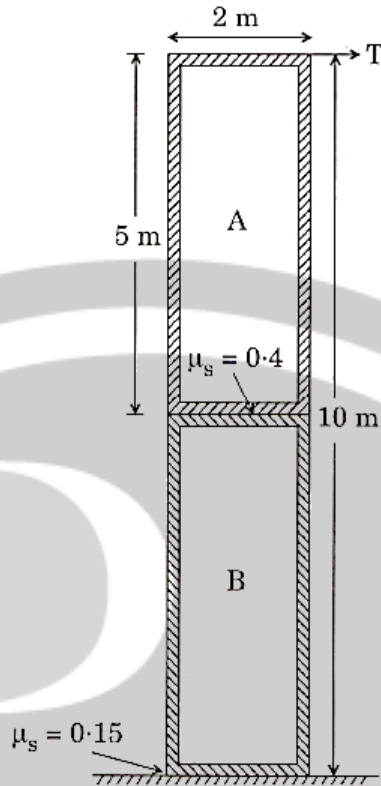
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### SECTION 'A'

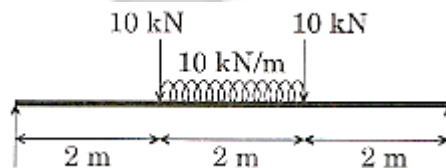
1. (a) A light wooden log of length  $L$  is floating on water with a concentrated load  $W$  acting at the mid-point. Write the equations and draw the diagram for shearing force and bending moment. 12
- (b) The slider A, of an elliptical trammel shown in the figure moves towards O with a velocity of 3 m/s at the instant when AB makes an angle of  $40^\circ$  with the horizontal. Determine the velocity of the mid-point of the link AB at this instant. 12



- (c) State and prove the law of gearing. 12
  - (d) Explain with suitable illustration the S-N curve of a ferrous material and briefly discuss its significance in the design of machine elements. 12
  - (e) A shaft made of mild steel is required to transmit 100 kW at 300 rpm. The supported length of the shaft is 3 metres. It carries two pulleys, each weighing 1500 N supported at a distance of 1 metre from the ends respectively. Assuming the safe value of stress to be 60 N/mm<sup>2</sup>, determine the diameter of the shaft. 12
2. (a) A 500 N crate A rests on a 1000 N crate B. The centres of gravity of the crates are at the geometric centres. The coefficients of static friction between contact surfaces are shown in the diagram. The force  $T$  is increased from zero. What is the first action to occur? 20



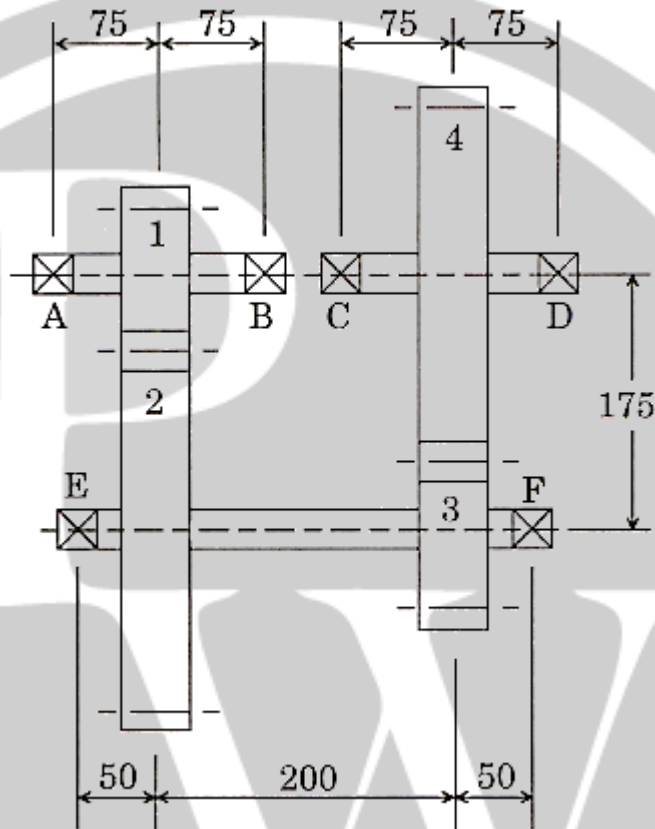
- (b) A single cylinder, single acting, 4-stroke engine develops 20 kW at 250 rpm. For the sake of simplicity, the turning moment curve is represented by two isosceles triangles during compression and expansion stroke. The turning moment can be assumed zero for suction and exhaust stroke. The work done by the gases is 3 times more than the work done on the gases. If the flywheel has a mass of 1500 kg and has a radius of gyration of 0.6 m, find the coefficient of fluctuation of speed. 20
- (c) A single-plate clutch is used to rotate a machine from a shaft rotating at a uniform speed of 300 rpm. Both sides of the clutch are effective, friction lining is of 140 mm inner diameter and 220 mm outer diameter, respectively. The coefficient of friction between friction lining and flywheel surface is 0.28. Assuming uniform wear theory for clutch and maximum intensity of pressure 0.1 MPa, determine the time required to attain full speed by the machine if moment of inertia of the rotating parts is 7.2 kg-m<sup>2</sup>. How much energy has been lost during slipping of the clutch? 20
3. (a) A beam is loaded as shown in the figure. If  $E = 200 \times 10^6 \text{ kN/m}^2$  and  $I = 10.4 \text{ m}^4$ , determine
- slope at the ends, and
  - maximum deflection of the beam.
- 20



- (b) A shaft rotates in two bearings A and B, 1.8 m apart and projects 0.45 m beyond A and B. At the extreme ends of the shaft, two pulleys of masses 20 kg and 48 kg are attached with eccentricity of 12.5 mm and 15.5 mm respectively. In the middle of the bearings, another pulley of mass 50 kg is attached with an eccentricity of 15.5 mm.

If the three pulleys have been arranged so as to obtain static balance, determine the dynamic forces produced on the bearings when shaft speed is 300 rpm. 20

- (c) The layout of a two-stage gear box is shown in the figure.

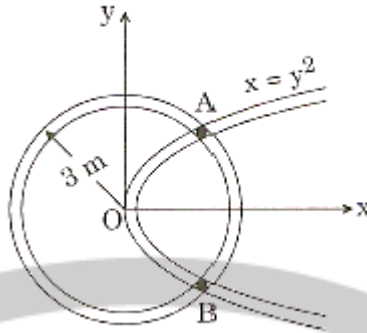


The number of teeth on the gears are as follows :

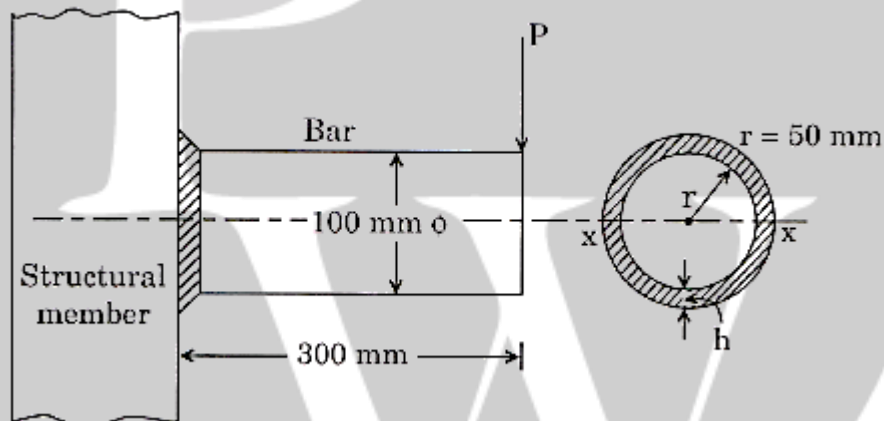
$$z_1 = 20 \quad z_2 = 50 \quad z_3 = 20 \quad z_4 = 50$$

Pinion 1 rotates at 1440 rpm in anti-clockwise direction when observed from the left side and transmits 10 kW power to the gear train. The pressure angle is  $20^\circ$ . Draw a free body diagram of the gear tooth forces and determine the reactions at bearings E and F. 20

4. (a) Particles A and B are confined to always be in a circular groove of radius 3 m. At the same time, these particles must also be in a slot that has the shape of a parabola. The slot is shown at time  $t = 0$  with equation  $x = y^2$ . If the slot moves to the right at a constant speed of 1.5 m/s, what are the speed and rate of change of speed of the particles towards each other at  $t = 1$  s? 20



- (b) A uniform disc of radius of gyration 60 mm and a mass of 4 kg is mounted centrally on a horizontal axle of 80 mm length between the bearings. It spins at 800 rpm CCW when viewed from the right side bearing. The axle precesses about the vertical axis at 50 rpm in the clockwise direction when viewed from the top. Determine the reaction at each bearing due to the mass and gyroscopic effect. 20
- (c) A solid circular bar of 100 mm diameter is welded to a structural member, as shown in the figure, by a fillet weld all round the bar. Determine the leg dimension of the fillet weld if  $P = 16$  kN and permissible shear stress in weld is  $90 \text{ N/mm}^2$ . 20



### SECTION B

5. (a) A slab of aluminium of dimensions  $25 \text{ cm} \times 20 \text{ cm} \times 5 \text{ cm}$  is to be cast along with a side cylindrical riser. The riser is not insulated on any surface. If the volume shrinkage of aluminium during solidification is 5%, find
- the relationship between diameter and height of cylindrical riser for longest solidification time.
  - the minimum volume of riser required to compensate the shrinkage volume of casting. (Assume volume of riser = 3 x shrinkage volume of casting) 12
- (b) To minimize the total processing time, arrange the sequence of operations of the jobs on the following five machines using Johnson's rule. The processing times (in minutes) of different jobs on individual machines are given below. Also find the total idle time on each machine. 12

Jobs	M/C 1	M/C 2	M/C 3	M/C 4	M/C 5
A	10	8	5	6	12
B	9	9	7	8	13
C	8	7	8	9	11
D	11	6	6	5	9

(c) What are the basic types of corrosion? Briefly describe any one of them. 12

(d) For an electronic component, the failure density function is defined as

$$f(t) = \begin{cases} 0.002e^{-0.002t} & t \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

Determine the reliability of the component at 346.6 hours. Also determine the MTTF of the same component. 12

(e) What kind of motors are used in paper-feed and print-head-positioning motors in printers and plotters? Justify your answer(s) with reason. Show a schematic diagram of a two-phase permanent magnet stepper motor. 12

6. (a) During an orthogonal cutting of a metal, the following data were observed :

Chip thickness = 0.5 mm; width of cut = 3 mm; depth of cut = 0.3 mm; feed rate = 0.3 mm/rev; cutting force = 1200 N; feed thrust force = 300 N; cutting speed = 3 m/sec; rake angle = 10°

Calculate :

(i) Shear force on the shear plane,

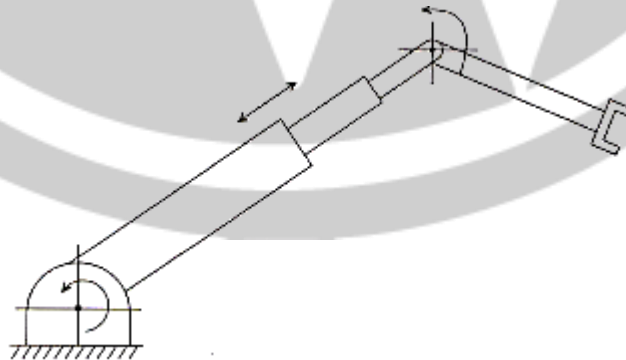
(ii) Coefficient of friction on chip-tool interface and friction angle, and

(iii) Percentage of total energy that goes into overcoming friction at chip-tool interface. 20

(b) (i) What are the different structures of ceramic compounds? Explain with neat sketches and examples. 12

(ii) The lattice constant of a metal with cubic lattice is 2.88 Å. The density of the metal is 7200 kg m<sup>-3</sup>. Calculate the number of unit cells present in 1 kg of the metal. 8

(c) Consider the three-link planar manipulator of the figure given below. Derive the forward kinematic equations using the D-H Algorithm. Assume suitable link and joint parameters. 20



where,

Link length -  $a_i$

Link twist -  $\alpha_i$

Joint angle -  $\theta_i$

Joint displacement -  $d_i$

7. (a) The production rates (units/day) of five workers on five different machines are given in the following table. To maximize the total production, assign the workers on specific machines using Hungarian method. Also find the total production per day. 20

		Production Units per day				
		M1	M2	M3	M4	M5
Workers	A	24	37	18	34	34
	B	18	37	20	31	42
	C	26	25	14	37	42
	D	22	25	26	40	50
	E	24	34	30	37	46

- (b) In a roll forming process, a 20 mm thick plate is rolled to 16 mm in a four high mill. Determine the coefficient of friction considering it as maximum possible reduction. The diameter of the roll is 480 mm. Also find neutral section, backward and forward slips and maximum pressure. It is given that the value of  $q = 120 \text{ N/mm}^2$  for hot rolls of mild steel at about  $1100^\circ\text{C}$ . 20
- (c) The kinematic parameters of a 3R planar articulated robot are given below :

link	$a_i$	$\alpha_i$	$d_i$	$\theta_i$
1	$a_1$	0	0	$\theta_1$
2	$a_2$	0	0	$\theta_2$
3	0	0	$d_3$	$\theta_3$

Determine the kinematic model of the robot using D-H Algorithm and relation between adjacent frames. 20

8. (a) (i) There are three coordinate frames  $O_1 x_1 y_1 z_1$ ,  $O_2 x_2 y_2 z_2$  and  $O_3 x_3 y_3 z_3$ , and relation between frames are given below :

$${}^1R_2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{2} & -\frac{\sqrt{3}}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{1}{2} \end{bmatrix} \quad {}^1R_3 = \begin{bmatrix} 0 & 0 & -1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

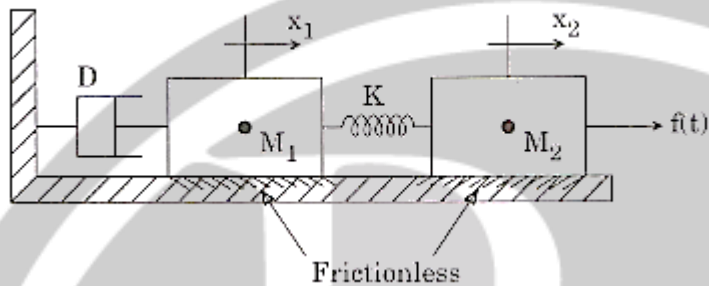
Find the matrix  ${}^2R_3$  that relates frame {2} and {3}. 10

- (ii) The homogeneous coordinates of a point are  $l_p = [0 \ 0 \ 10 \ 1]^T$ . The coordinate frame is translated relative to the fixed {F} coordinate frame, by 6 units along x-axis and -2 units along y-axis. What is the homogeneous transformation matrix that represents the operation? What is the description of point P relative to the reference frame {F} following the translation? 10

- (b) The demand for an item is observed as 24,000 units per year. The production capacity of the plant is 3,000 units per month. The item cost is  $\text{Rs } 40$  per unit and inventory carrying cost is 12% of the item cost per unit per year. The cost of one set-up is  $\text{Rs } 480$ . The shortage cost of one unit is  $\text{Rs } 240$  per year. Supply of the item is non-instantaneous (gradual).

Determine the economic order quantity, optimal number of shortages, production line required for each cycle and the number of set-ups in a year. 20

(c)



Find the state equations in matrix form for the translational mechanical system as shown above.

Assume zero initial conditions, where

20

$M_1$  = Mass of block 1

$M_2$  = Mass of block 2

$K$  = Spring stiffness constant

$D$  = Coefficient of viscous friction

$x_1$  = Displacement of block 1

$x_2$  = Displacement of block 2

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