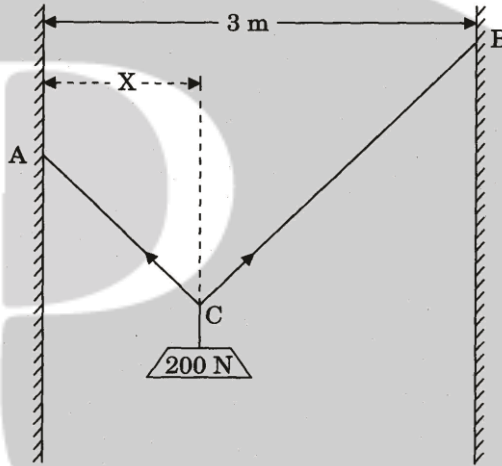


ESE (Mains), 2020

Mechanical Engineering (PAPER - II)

SECTION - A

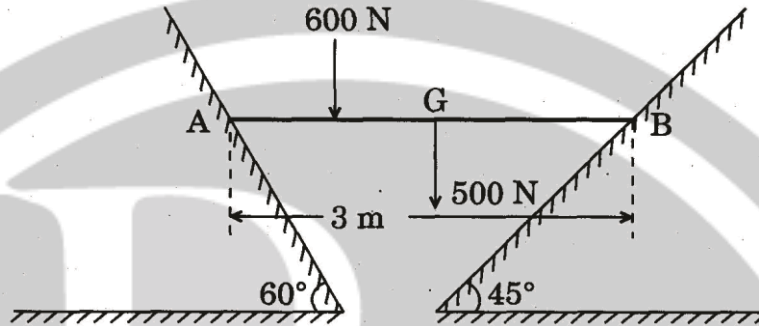
- Q1. (a) A cord ACB 5 m long is attached at points A and B to two vertical walls 3 m apart as shown in the figure. A pulley C of negligible radius carries a suspended load of 200 N and is free to roll without friction along the cord. Determine the position of equilibrium as defined by the distance X, that the pulley will assume and also the tensile force in the cord.



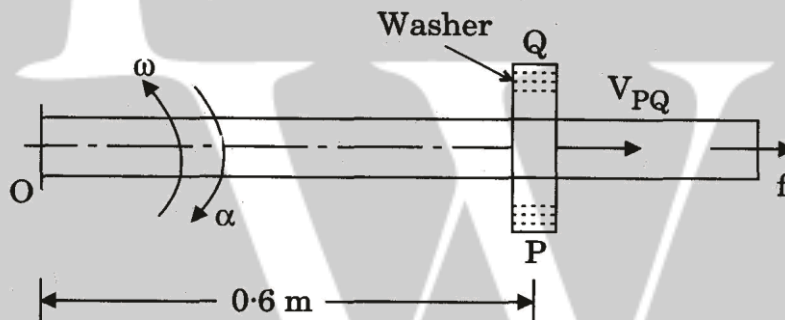
- (b) For a beam of hollow rectangular section of outer geometry of $b \times d$ and the inner geometry of $b_1 \times d_1$, compute the area moment of inertia about its axis passing through its C.G. Also compute the area moment of inertia about a line passing through the base and also compute the same about a line passing through the vertical side. Compare the results and offer your remarks if the ratio of $b : d = 1 : 2$ units and in the same scaling the ratio of $b_1 : d_1 = 0.8 : 1.6$ units.
- (c) (i) Explain about a double slider crank chain and its inversions.
(ii) The distance between two parallel shafts is 18 mm and they are connected by an Oldham's coupling. The driving shaft revolves at 160 rpm. What will be the maximum speed of sliding of the tongue of the intermediate piece along the groove?
- (d) A rotor has a mass of 10 kg and is mounted midway on a 20 mm diameter horizontal shaft supported at the ends by two bearings. The bearings are 1 m apart. The shaft rotates at 2000 rpm. If the centre of the mass of the rotor is 0.11 mm away from the geometric centre of the rotor due to a certain manufacturing defect, find the amplitude of the steady-state vibration. Take $E = 200 \text{ GN/m}^2$. Assume the shaft to be simply supported.
- (e) The non-zero stress components at the critical point in the hub of a flywheel where yield is initiated are $\sigma_{xx} = 100 \text{ MPa}$, $\sigma_{yy} = -20 \text{ MPa}$ and $\tau_{xy} = 50 \text{ MPa}$. The flywheel material has a yield strength $S_y = 300 \text{ MPa}$.
- (i) Determine the principal stresses and maximum shear stress. Also show them in the Mohr's circle of stress.

- (ii) Compare the factor of safety with Tresca's maximum shear stress theory and von Mises failure theory.

- Q2. (a) A horizontal bar AB of length 3 m and weighing 500 N is laying in a trough as shown in the figure below. Find how close to the end A and B can a load of 600 N be placed safely, if coefficient of friction between the bar and support is 0.2.



- (b) In the figure shown below, the washer is sliding outward on the rod with a velocity of 1.2 m/s when its distance from point 'O' is 0.6 m. Its velocity along the rod is increasing at the rate of 0.9 m/s². The angular velocity of the rod is 5 rad/s counter-clockwise and its angular acceleration is 10 rad/s² clockwise. Determine the absolute acceleration of a point in the washer.



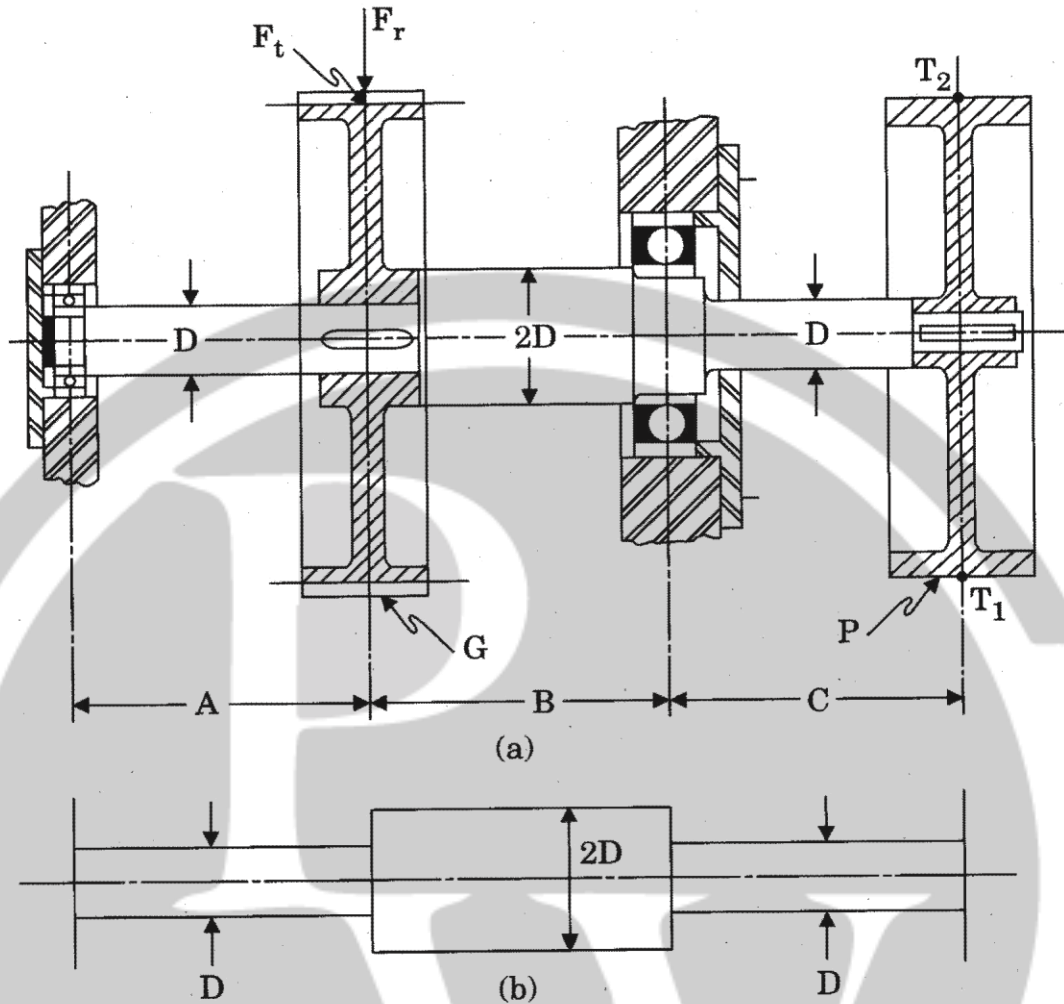
- (c) The shaft shown in the figure is to be designed from the standpoint of strength. Power is supplied to the pulley P by means of a flat belt and power is taken from the shaft through spur gear G. The shaft is supported by two deep groove ball bearings.

The following information has been established:

Power 7.5 kW (steady load conditions), speed of shaft = 1000 rev/min, diameter of pulley = 250 mm, pitch diameter of the gear = 250 mm, weight of the pulley 100 N, weight of the gear = 100 N. Ratio of belt tensions $T_1/T_2 = 2.5$, Gear pressure angle = 20°. Dimensions $A = B = C = 150$ mm in the figure. The belt forces are perpendicular to the plane of the paper, with $T_1 > T_2$ and the tangential force F_t on the gear is also perpendicular to the plane of the gear.

Shaft is to be machined from a hot rolled steel with $S_{ut} = 590$ MN/m² and $S_{yt} = 380$ MN/m². According to the ASME code, use allowable shear stress as minimum of either 0.18 S_{ut} or 0.30 S_{yt} . For steady load use $k_b = 1.5$ and $k_t = 1.0$.

Q3.

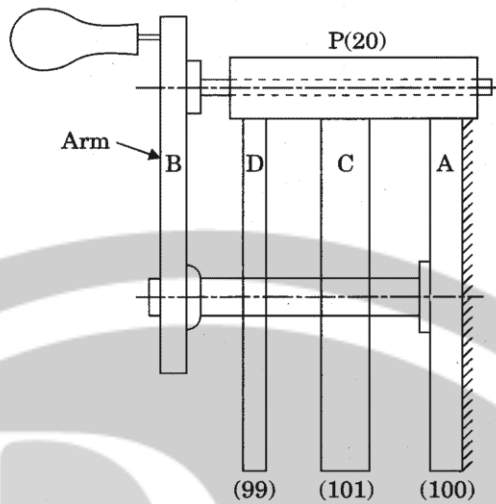


- (a) A cantilever beam of length 'L' carries the loading as below:
- Carrying a uniformly distributed load of 'w' per unit run over the whole length.
 - Carrying a distributed load when intensity varies from zero at the free end to 'w' per unit run at the fixed end.
 - Carrying a distributed load whose intensity varies from zero at the fixed end to 'w' per unit run at the free end.

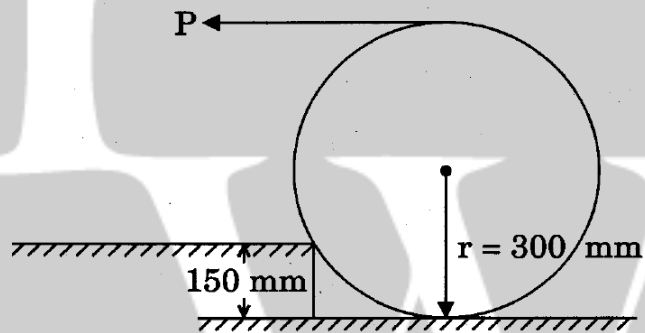
Calculate the maximum displacement and the maximum stress for each loading case and offer your remarks on the result.

- (b) (i) Define the terms Interference and Undercutting in the mating of a pair of teeth while transmitting the power and mention how we can avoid the same.
- Two 20° involute spur gears have a module of 10 mm. The addendum is one module. The larger gear has 50 teeth and the pinion 13 teeth. Does the interference occur and if it occurs, how can we eliminate the same?
- (ii) The figure below shows an epicyclic gear train known as Ferguson's paradox. Gear A is fixed to the frame and is therefore stationary. The arm B and gear C and D are free to rotate on the shaft. Gears A, C and D have 100, 101 and 99 teeth respectively. Planet gear P has 20 teeth. Pitch circle diameters of all are the same so that the planet gear P meshes with all of them. Determine the

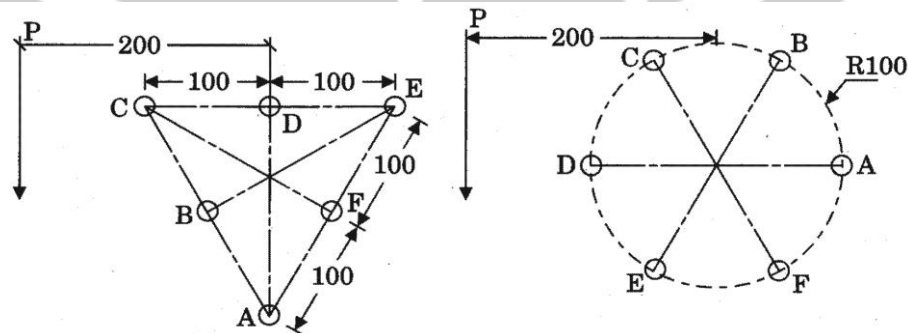
revolutions of gears C and D for one revolution of the arm B.



- (c) A roller of radius $r = 300$ mm and weight 2000 N is to be pulled over a curb of height 150 mm by a horizontal force P applied at the end of a string wound tightly around the circumference of the roller. Find the magnitude of P required to start the roller moving over the curb. What is the least pull P through the centre of the wheel to just turn the roller over the curb ?



- Q4. (a) A bracket is to be attached to a wall with the help of six rivets. The different arrangements in which the bracket can be attached to the wall are shown in the figure. The maximum allowable stress in shear is 60 N/mm^2 . Determine the way in which the rivets should be arranged so that the design is economical. The bracket is required to support a load of 60 kN with an eccentricity of 200 mm . Determine the diameter of rivets for the two arrangements.

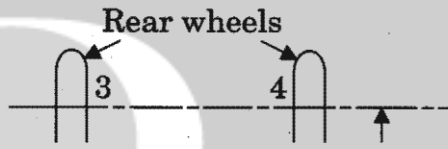


(a) Triangular Arrangement

(b) Circular Arrangement

All dimensions are in mm.

- (b) Draw the SFD and BMD of a simply supported beam with equal overhangs of length "a" carrying a uniformly distributed load of 'w' per unit run over the whole length 'l'. Show the BMD when $a = \frac{l}{2}$, $a < \frac{l}{2}$ and $a > \frac{l}{2}$. Offer your comments on the results.
- (c) A car is of total mass 200 kg. It has a wheel base equal to 2.5 m and track width equal to 1.5 m. The C.G. lies at 500 mm above ground level and 1.5 m from the rear axle. The effective diameter of each wheel is 800 mm and moment of inertia of each wheel is 1.0 kg m^2 . The rear axle ratio (gear ratio) is 4. The equivalent mass of engine rotating parts is 140 kg with radius of gyration of 150 mm. The spin axis of the rotating engine parts is perpendicular to the spin axis of wheels. The engine parts are rotating in clockwise direction when viewed from the front. Determine the reaction at each wheel if the car takes a right turn of 100 m radius at 90 km/hour speed.



**SECTION B**

- Q5. (a) Prove that the atomic packing factors for BCC and FCC crystal structures are 0.68 and 0.74 respectively.
- (b) Enlist various wear mechanisms and explain the term Wear and Debris Analysis.
- (c) A work sampling study was conducted to establish the standard time for an operation. The observations of the study conducted are given below:

Total number of observations	= 160
Manual (hand controlled work)	= 14
Machine controlled work	= 106
Machine idle time	= 40
Average performance rating	= 80%
No. of parts produced	= 36
Allowance for personal needs and fatigue	= 10%
Study conducted for 3 days	
Available working hours/day	
Calculate the standard time per piece.	= 8 hours

- (d) A cylindrical riser must be designed for a sand-casting mould. The casting itself is a steel rectangular plate with dimensions $3.75 \text{ cm} \times 6.25 \text{ cm} \times 1.0 \text{ cm}$. Previous observations have indicated that the total solidification time (T_{TS}) for this casting = 1.6 min. The cylinder for the riser will have a diameter-to-height ratio = 1.0. Determine the dimensions of the riser so that its TTs = 20 min. Assume the value of $n = 2$, for mould constant.
- (e) For a 4-DOF, RPPR manipulator, the joint-link transformation matrices with joint variables θ_1 , d_2 , d_3 and θ_4 are given as 0T_1 , 1T_2 , 2T_3 and 3T_4 . Generate the Denavit-Hartenberg parameters table and the frames for the manipulator as per D-H rules.

${}^0T_1 =$	C_1	$-S_1$	0	0
	S_1	C_1	0	0
	0	0	1	0
	0	0	0	1
${}^1T_2 =$	1	0	0	0
	0	0	1	0
	0	-1	0	d_2
	0	0	0	1
${}^2T_3 =$	1	0	0	10
	0	1	0	0
	0	0	1	d_3
	0	0	0	1
${}^3T_4 =$	C_4	$-S_4$	0	0
	S_4	C_4	0	0
	0	0	1	1
	0	0	0	1

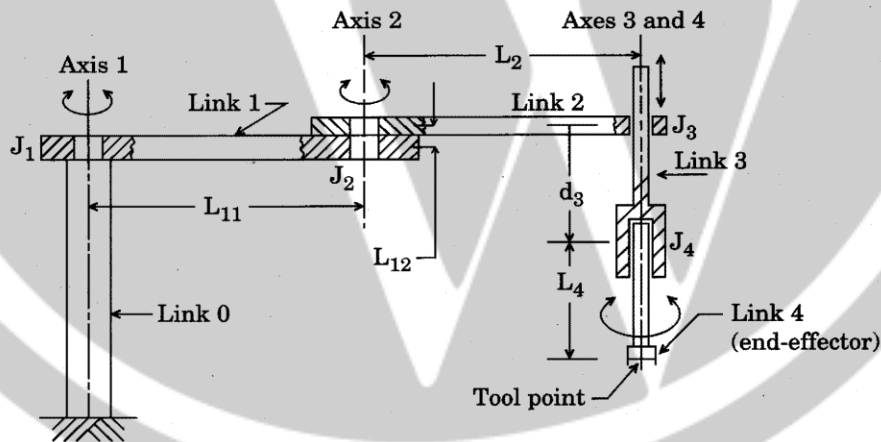
$$C_i = \cos \theta_i, S_i = \sin \theta_i$$

- Q6. (a) Explain electrochemical considerations of corrosion for metallic materials. Discuss the principle of cathodic protection of corrosion prevention.
- (b) The following table gives data on normal cost and time, crash cost and time for a project. The indirect cost is ₹ 50/week.

Activity	Time (week)	Normal Cost (₹)	Crash Time	Cost (₹)
1 – 2	3	300	2	400
2 – 3	3	30	3	30
2 – 4	7	420	5	580
2 – 5	9	720	7	810
3 – 5	5	250	4	300
4 – 5	0	0	0	0
5 – 6	6	320	4	410
6 – 7	4	400	3	470
6 – 8	13	780	10	900
7 – 8	10	1000	9	1200

Draw the network diagram and label it. Identify critical path and find out normal project duration and corresponding cost. Crash the relevant activities systematically and determine the optimum project duration and cost. Determine the minimum project duration and corresponding cost.

- (c) Obtain the direct kinematics model of the given 4 DOF SCARA robot by developing D-H frames, D-H parameters table and individual transformation matrices.



$${}^{i-1}T_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- Q7. (a) In an orthogonal turning operation of a mild steel bar of 60 mm diameter, cutting speed was 30 m/minute, rake angle of tool 30°, feed rate 0.10 mm/revolution, tangential force 3000 N, feed force

1300 N, length of continuous chip in one revolution 100 mm. Calculate coefficient of friction, shear plane angle, velocity of chip along tool face and chip thickness.

- (b) Determine the most economical order quantity when annual usage is 8000 parts. Unit commodity cost is 60 and the cost of placing an order is 150 and the annual inventory carrying cost is 30% of the average inventory. Also find out the most economical order quantity for the variable price schedule given below:

Lot Size	Unit Price
1- 200	₹ 62
201-500	₹ 60
501 and above	₹ 56

- (c) What are nanomaterials ? Cite examples of the special properties of Discuss the salient features of nanomaterials characterization tools.

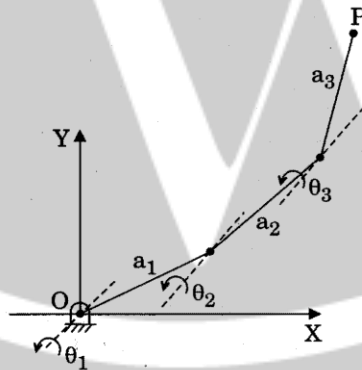
- Q8. (a) Prepare the forward kinematic model for a 3-link planar arm with link lengths l_1 , l_2 and l_3 respectively by developing

- Respective coordinate frames as per D-H rules,
- D-H parameters table,
- Individual transformation matrices, ${}^{i-1}T_i$, and
- The transformation matrix of the last frame with reference to the base frame.
- Also draw the orientation and position of the last frame with reference to the base frame, if link lengths are

$a_1 = a_2 = a_3 = 10$ units, $\theta_1 = 0^\circ$, $\theta_2 = 45^\circ$ and $\theta_3 = 45^\circ$.

Given that ${}^{i-1}T_i$ matrix form is as following.

Note: angles are measured in counter-clockwise direction.



${}^{i-1}T_i =$

$C\theta_i$	$-S\theta_i C\alpha_i$	$S\theta_i S\alpha_i$	$a_i C\theta_i$
$S\theta_i$	$C\theta_i C\alpha_i$	$-C\theta_i S\alpha_i$	$a_i S\theta_i$
0	$S\alpha_i$	$C\alpha_i$	d_i
0	0	0	1



- (b) The following data is available for a machine in a manufacturing unit.

Number of hours worked per day	8
Working days per month	25
Number of operators	1

Standard time per unit of production

Machine time	22 min
Operator time	<u>08 min</u>
Total time/unit	30 min

- (i) If plant is operated at 75% efficiency, and the operator is working at 100% efficiency, what is the output per month?
- (ii) If the machine productivity is increased by 10% over the existing level, what will be the output per month?
- (iii) If the operator efficiency is reduced by 20% over the existing level, what will be the output per month?
- (c) Explain the methods of numerical evaluation of surface texture. Compare their merits and demerits. Describe the construction and working of a Talysurf surface roughness tester.

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