MADE EASY
India's Best Institute for IES, GATE & PSUs

ESE 2023

Main Exam Detailed Solutions

Mechanical Engineering

PAPER-II

EXAM DATE : 25-06-2023 | 02:00 PM to 5:00 PM

MADE EASY has taken due care in making solutions. If you find any discrepency/error/typo or want to contest the solution given by us, kindly send your suggested answer(s) with detailed explanation(s) at:
info@madeeasy.in

Corporate Office : 44-A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi-110016
Delhi | Hyderabad | Bhopal | Jaipur | Bhubaneswar | Pune | Kolkata
9021300500 www.madeeasy.in

ANALYSIS

Mechanical Engineering Paper-II
ESE 2023 Main Examination

Sl.	Subjects	Marks
1.	Strength of Materials	72
2.	Engineering Mechanics	32
3.	Theory of Machines	84
4.	Machine Design	52
5.	Industrial Engineering	32
6.	Production Engineering	108
7.	Mechatronics	100
		Total 480

Scroll down for detailed solutions

SECTION : A

Q.1 (a) A circular bar ABC, 4 m long, is rigidly fixed at its ends A and C. The portion AB is 2.8 m long and of 50 mm diameter whereas BC is 1.2 m long and of 25 mm diameter. If the twisting moment of 700 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. For the material of the shaft G = 80 GN/m².

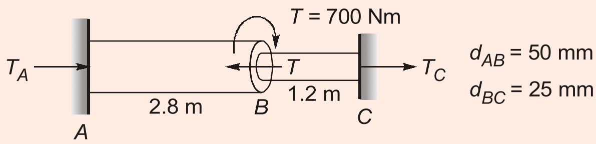
[12 marks : 2023]

Solution:

$$T_A + T_C = T = 700 \text{ Nm} \quad \text{... (i)}$$

$$\theta_{AB} + \theta_{BC} = 0$$

$$\frac{T_{AB}L_{AB}}{GJ_{AB}} + \frac{T_{BC}L_{BC}}{GJ_{BC}} = 0$$



$$\frac{T_A \times 2.8}{50^4} + \frac{(T_A - T)\times 1.2}{25^4} = 0$$

$$\frac{T_A \times 2.8}{16} + 1.2(T_A - T) = 0$$

$$0.175\, T_A + 1.2T_A = 1.2T$$

$$T_A = 610.91 \text{ Nm}$$

$$T_C = 89.09 \text{ Nm}$$

Twisting moment at A = 610.9 Nm

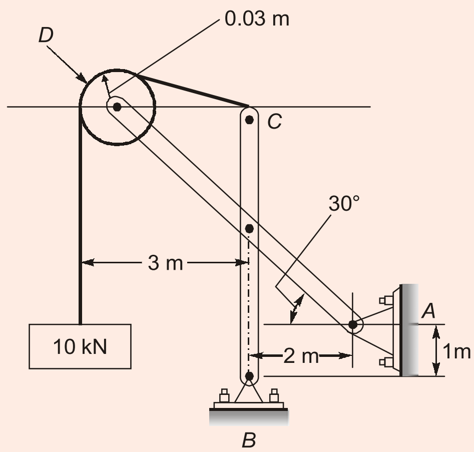
Twisting moment at C = 89.09 Nm

Maximum stress in AB section = $\dfrac{16T_A}{\pi d_{AB}^3} = 24.89 \text{ N/mm}^2$

Maximum stress in BC section = $\dfrac{16T_C}{\pi d_{BC}^3} = 29.03 \text{ N/mm}^2$

End of Solution

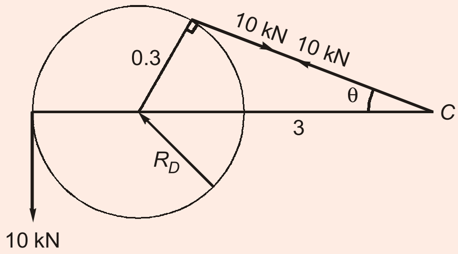
Q.1 (b) What are supporting forces for the frame? Neglect all weights except the 10 kN weight.



[12 marks : 2023]

Solution:

FBD of D



$\text{Sin } \theta = \frac{0.3}{3}$

or, θ = 5.7391°

$$R_{Dx} = 10\cos\theta = 10\cos(5.7391) = 9.9498 \text{ kN}$$

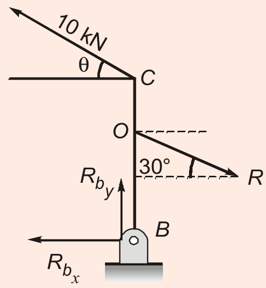
$$R_{Dy} = 10\sin\theta + 10 = 10\cos(5.7391) + 10 = 11 \text{ kN}$$

∴ $$R_D = \sqrt{(R_{Dx})^2 + (R_{Dy})^2} = \sqrt{(9.9498)^2 + (11)^2} = 14.8323 \text{ kN}$$

and $$\tan\alpha = \frac{R_{Dy}}{R_{Dx}}, \text{ or } \alpha = 47.869°$$

FBD of BC

$\Sigma M_B = 0$



$$10\cos\theta \times CB = R\cos(30) \times OB \quad \text{... (i)}$$

$$CB = 1 + 2\tan(30°) + 3\tan(30°)$$

$$= 3.8867 \text{ m}$$

$$OB = 1 + 2\tan(30°) = 2.1547 \text{ m}$$

From equation (i),

$$10\cos(5.7391) \times 3.8867 = R\cos(30) \times 2.1547$$

or, $$R = 20.7243 \text{ kN}$$

Now, Balancing forces in horizontal direction,

$$R_{Bx} = R\cos(30°) - 10\cos(5.7391)$$

$$= 20.7243 \times \cos(30°) - 10\cos(5.7391) = 7.9978 \text{ kN}$$

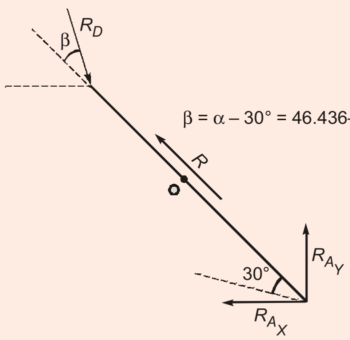
Balancing forces in vertical direction,

$$R_{By} = R\sin(30°) - 10\sin(5.7391) = 9.36216 \text{ kN}$$

$$R_B = \sqrt{R_{Bx}^2 + R_{By}^2} = \sqrt{7.9978^2 + 9.36216^2} = 12.3131 \text{ kN} \qquad \textbf{Ans.}$$

Now,

FBD of AD



Now, Balancing forces in horizontal direction,

$$R_{Ax} + R\cos(30°) = R_D\cos(47.869°)$$

or, $$R_{Ax} = 14.8323\cos(47.869°) - 20.7243\cos(30°)$$

$$= 7.9978 \text{ kN}$$

Balancing forces in vertical direction,

$$R_{Ay} + R\sin(30°) = R_D \sin(47.869°)$$

or,

$$R_{Ay} = 14.8323\sin(47.869°) - 20.7243\sin(30°) = 0.63767 \text{ kN}$$

$$R_A = \sqrt{R_{Ax}^2 + R_{Ay}^2} = \sqrt{(-7.9978)^2 + (0.63767)^2}$$

$$= 8.0231 \text{ kN} \quad \textbf{Ans.}$$

End of Solution

Q.1 (c) An electronic instrument is to be isolated from a panel that vibrates at frequencies ranging from 25 Hz to 35 Hz. It is estimated that at least 80% vibration isolation must be achieved to prevent damage to the instrument. If the instrument weighs 85 N, find the necessary static deflection of the isolator.

[12 marks : 2023]

Solution:

80% vibration isolation at least

$$F_{T\max} = (0.20)F_o$$

$$\Rightarrow \quad \frac{F_{T\max}}{F_o} = \epsilon_{\max} = 0.20$$

$$\epsilon_{\max} = \frac{\sqrt{1+\left(\frac{2\xi\omega}{\omega_n}\right)^2}}{\sqrt{\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(\frac{2\xi\omega}{\omega_n}\right)^2}}$$

$\xi = 0$

$$\epsilon_{\max} = 0.20 = \frac{1}{\left[\pm\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}\right]}$$

Taking +ve sign:

$$\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right] = \frac{1}{20} = 5$$

$$\left(\frac{\omega}{\omega_n}\right)^2 = 1 - 5 = -4 \text{ (Not possible)}$$

Taking –ve sign:

$$-\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right] = \frac{1}{0.20} = 5$$

$$\left(\frac{\omega}{\omega_n}\right)^2 - 1 = 5$$

$$\left(\frac{\omega}{\omega_n}\right)^2 = 6 \Rightarrow \text{it will be minimum when } \omega \to \text{min}$$

Frequency:

$$f \to \text{Ranges} \to 25 \text{ Hz to } 35 \text{ Hz}$$

$$\omega \to \underbrace{(2\pi \times 25)}_{\omega_{min}} \text{ rad/s to } \underbrace{(2\pi \times 35)}_{\omega_{max}} \text{ rad/s}$$

$$\Rightarrow \quad \frac{\omega_{min}}{\omega_n} = 6$$

$$\Rightarrow \quad \omega_n = \frac{\omega_{min}}{6} = \frac{2\pi \times 25}{6} = \frac{100\pi}{6}$$

$$\Rightarrow \quad \omega_n = 52.3598 \text{ rad/s}$$

$$\omega_n = \sqrt{\frac{g}{\Delta}} \Rightarrow 52.3598 = \sqrt{\frac{9.81}{\Delta}}$$

$$\Rightarrow \quad \Delta = 0.003578 \text{ m} = 3.578 \times 10^{-3} \text{ m}$$ Ans.

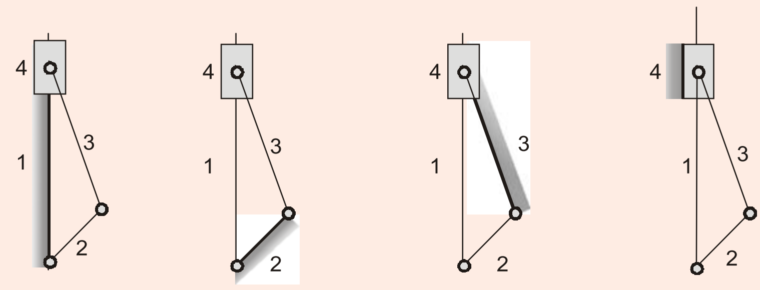
End of Solution

Q.1 (d) Describe all the inversions of a slider-crank mechanism.

[12 marks : 2023]

Solution:

Taking a different link as the fixed link, the slider-crank mechanism shown in figure (a) can be inverted into the mechanisms shown in figure (b), (c) and (d).



(a) First (Cylinder is fixed) (b) Second (Crank is fixed) (c) Third (Connecting rod is fixed) (d) Fourth (Slider is fixed)

First inversion [fig. (a)]

This inversion is obtained when link 1 (i.e.; cylinder) is fixed.

Applications:

- Reciprocating engine
- Reciprocating compressor

Second inversion [fig. (b)]

Fixing of the link 2 (i.e. crank) of a slider-crank chain results in the second inversion.

Applications:

- Whitworth quick return mechanism
- Rotary engine (GNOME engine)

Third inversion [fig. (c)]

By fixing of the link 3 (i.e. connecting rod) of the slider-crank mechanism, the third inversion is obtained.

MADE EASY

Live-Online

Rank Improvement Course for GATE 2024

Teaching Hours :	Course Validity :	Fee :
300 to 350 hours	Till GATE 2024 Exam	₹18,000 + GST

Streams : CE, ME, EE, EC, CS

Key Features

- Comprehensive problem-solving sessions by India's top faculties.
- Focus on improving accuracy & speed.
- Practice all types of questions to brush up on your concepts.
- Newly develop workbooks (e-copy) in line with recent trends in GATE.
- Highly useful for repeaters candidates.

Batches Commencement Dates :

CE, ME, CS : 19th June 2023
Time : 8:00 AM to 10:00 AM

EE, EC : 21st June 2023
Time : 8:00 AM to 10:00 AM

Scan to enroll

www.madeeasy.in 9021300500

Applications:
- Oscillating cylinder engine
- Crank and slotted-lever mechanism

Fourth inversion [fig. (d)]

If the link 4 (i.e. slider) of the slider-crank mechanism is fixed, the fourth inversion is obtained.

Applications:
- Hand pump

Summary of slider Crank Chain and its Inversions				
Mechanism	Links			
	Fixed	Rotates	Oscillates	Reciprocates
Single slider crank chain	1	2	3	4
INVERSIONS:				
Pendulum pump	4	2	3	1
Oscillating cylinder engine	3	2	4	1
Crank-slotted lever	3	2	4	1
Whitworth mechanism	2	3	1	4
Gnome engine	2	3	1	4

End of Solution

Q.1 (e) 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 along with an axial tensile load of 20 kN. If the elastic limit in tension of the material of the members is 300 MN/m^2 and there is to be a factor of safety of 3, estimate the magnitude of *d* required according to the maximum shear strain energy per unit volume theory. Poisson's ratio, $\nu = 0.3$.

[12 marks : 2023]

Solution:

Given: FOS = 3, $\sigma_y = 300$ MPa, $\mu = 0.3$

$$\text{Normal stress, } \sigma = \frac{20}{A} \text{ kN/mm}^2$$

$$\text{Shear stress, } \tau = \frac{10}{A} \text{ kN/mm}^2$$

$$\text{Principal stress, } \sigma_1, \sigma_2 = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2} = \frac{10}{A} \pm \sqrt{\left(\frac{10}{A}\right)^2 + \left(\frac{10}{A}\right)^2} = \frac{10}{A} \pm \frac{14.142}{A}$$

$$\sigma_1 = \frac{24.142}{A} \text{ kN/mm}^2 = \frac{24142.13}{A} \text{ N/mm}^2$$

$$\sigma_2 = -\frac{4142.13}{A} \text{ N/mm}^2$$

Maximum shear strain energy theory,

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = \left(\frac{\sigma_y}{FOS}\right)^2$$

$$\left(\frac{24142.13}{A}\right)^2 + \left(\frac{4142.13}{A}\right)^2 + \frac{24142.13 \times 4142.13}{A^2} = 100^2$$

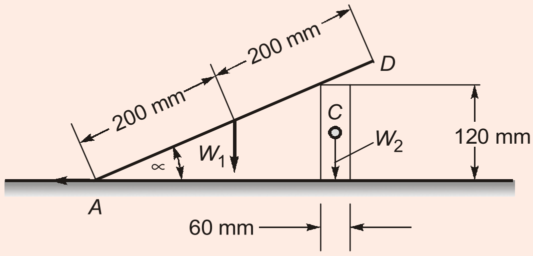
$$A = 264.57 \text{ mm}^2$$

$$\frac{\pi}{4}d^2 = 264.57 \text{ mm}^2$$

$$d = 18.35 \text{ mm}$$

End of Solution

Q.2 (a) The rod AD is pulled at A and it moves to the left. If the coefficient of dynamic friction for the rod at A and B is 0.4, what must the minimum of W_2 be to prevent the block from tipping when $\alpha = 20°$? With this value of W_2, determine the minimum coefficient of static friction between the block and the supporting plane needed to just prevent the block from sliding. Take $W_1 = 100$ N.



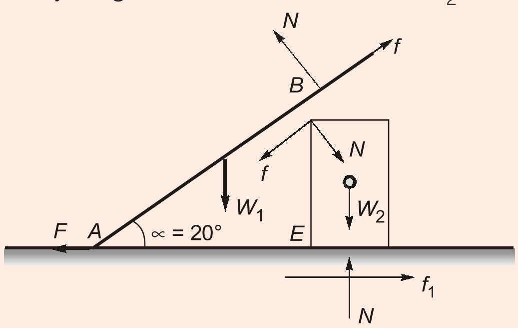
[20 marks : 2023]

Solution:

Given: Weight of rod AD, $W_1 = 100$ N

Coefficient of kinetic friction at A and B, $\mu = 0.4$.

To find the minimum value of W_2, we need to calculate the friction forces at the limiting values. Making free body diagram of rod AD and block W_2.



Taking moment about A for the rod AB,

$$W_1\, 200 \cos 20° = N \times 350.856$$

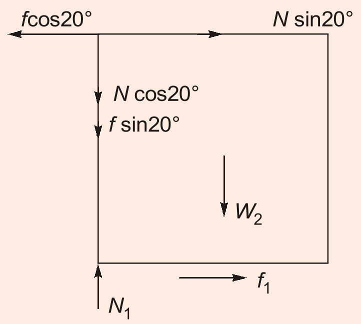
$$\therefore \quad N = \frac{100 \times 200 \cos 20°}{350.856} = 53.56 \text{ N}$$

When the block W_2 will be at the verge of tipping, the normal force on the block due to ground will shift to point E. Taking moment of forces about the point E, we get

$$W_2 \times 30 + N\sin 20° \times 120 = f\cos 20° \times 120$$

$$W_2 = \frac{f\cos 20° \times 120 + N\sin 20° \times 120}{30}$$
$$= \frac{\mu N\cos 20° \times 120 + N\sin 20° \times 120}{30}$$
$$= \frac{21.424 \times 120 \times \cos 20° + 53.56 \times \sin 20° \times 120}{30}$$
$$= \frac{2415.837 + 2198.23}{30} = 153.80 \text{ N} \quad \textbf{Ans.}$$

For the calculation of minimum coefficient of static equilibrium, we need to take equilibrium equations.



$\Sigma F_y = 0$

$$N_1 = W_2 + N\cos 20° + f\sin 20°$$
$$= 153.80 + 53.56\cos 20° + 21.424\sin 20° = 211.46 \text{ N}$$

$\Sigma F_x = 0$

$$f\cos 20° = N\sin 20° + f_1$$

$\therefore$
$$f_1 = f\cos 20° + N\sin 20° = 21.424\cos 20° + 53.56\sin 20°$$
$$= 38.45 \text{ N}$$

$\therefore$ Minimum coefficient of static friction,

$$\mu_{min} = \frac{f_1}{N_1} = \frac{38.45}{211.46} = 0.1818 \quad \textbf{Ans.}$$

End of Solution

Q.2 (b) (i) Define pitch point, addendum, module and pressure angle as applied to toothed gears.

(ii) Compare involute curve with cycloidal curve for the profiles of gear teeth.

[8+12=20 marks : 2023]

Solution:

(i)
- **Pitch point:** The point of contact of two pitch circles is known as pitch point.
- **Addendum:** It is the radial height of a tooth above the pitch circle. Its standard value is one module.
- **Module (m):** It is the ratio of the pitch diameter in mm to the number of teeth. This term is used in SI units in place of diametral pitch.

$$m = \frac{d}{T}$$

Also, $p_c = \dfrac{\pi d}{T} = \pi m$

Module of two mating gears must be same

- **Pressure angle (ϕ):** The angle between the pressure line and the common tangent to the pitch circle is known as the pressure angle or the angle of obliquity. Most gears are manufactured with $\phi = 14.5°$ or 20°. In order for two gears to mesh, they must have the same pressure angle on the pitch circles. The pressure angle must be kept small for more power transmission and lesser pressure/thrust on the bearings. Standard pressure angles are 20° and 25°.

(ii)

Sl.	Cycloidal Teeth	Involute Teeth
1.	Pressure angle varies from maximum at the beginning of engagement, reduce to zero at the pitch point and again increase to maximum at the end of engagement resulting in less smooth running of the gears	Pressure angle is constant throughout the engagement of teeth. This results in smooth running of the gears.
2.	It involves double curve for the teeth, epicycloid and hypocycloid. This complicates the manufacturing.	It involves single curve for the teeth resulting in simplicity of manufacturing of tools.
3.	Costlier as they are difficult to manufacture	Cheaper as they are easier to manufacture.
4.	Exact center-distance is required to transmit a constant velocity ratio.	A little variation in the center distance does not affect the velocity ratio.
5.	Phenomenon of interference does not occur at all.	Interference can occur if the condition of minimum number of teeth on a gear is not followed.
6.	The teeth have spreading flanks and thus are stronger.	The teeth have radial flanks and thus are weaker as compared to the cycloidal form for the same pitch.
7.	In this, a convex flank always has contact with a Concave face resulting in less wear.	Two convex surfaces are in contact and thus there is more wear.

End of Solution

Q.2 (c) A single plate clutch (both sides effective) is required to transmit 27 kW at 1600 rpm. The outer diameter of the plate is limited to 30 cm, and intensity of pressure between the plates is not to exceed 0.1 N/mm^2. Assuming uniform wear and a coefficient of friction 0.3, find the required inner diameter of the plates, and axial force necessary to engage the clutch.

[20 marks : 2023]

Solution:

Given data: Type of clutch : Single plate clutch, Number of frictional contact surfaces (n) = 2, Power, P = 27 kW, Speed, N = 1600 rpm, Maximum outside diameter of plate, D_o = 300 mm, Maximum pressure P_{max} = 0.1 MPa, Coefficient of friction, μ = 0.3.

Determine by using uniform weary theory,

(i) Inner diameter of plate (D_i)

(ii) Axial force required (W)

$$T_t = \text{Torque to be transmitted by clutch}$$

$$= \frac{P \times 60}{2\pi N} \times 10^6 = 161144.38 \text{ N-mm}$$

$$T_f = \text{Frictional torque by using uniform wear theory}$$

$$= (n \mu \pi p_{max}) R_i (R_o^2 - R_i^2)$$

$$= (2 \times 0.3 \times \pi \times 0.1)(R_i)(150^2 - R_i^2) = 0.1885(R_i)(150^2 - R_i^2)$$

For safe design, $T_f \geq T_t$

$$0.1885(R_i)(150^2 - R_i^2) \geq 161144.38$$

$$R_i^3 - (150^3) R_i + 854897.488 = 0$$

$$R_i = 125.1832, 41.0756 \text{ mm} \qquad \textbf{Ans.}$$

Inner radius (R_i) should be larger of above values.

Hence, $R_i = 125.1832$ mm

$$W = \text{Axial force required to engage the clutch}$$

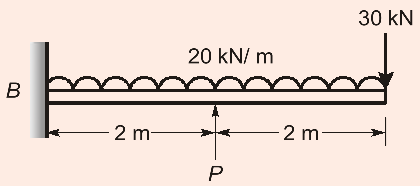
$$= \pi \times 2\pi R_i (R_o - R_i)$$

$$= 0.1 \times 2\pi \times 125.1832 \times (150 - 125.1832)$$

$$= 1951.964 \text{ N} \qquad \textbf{Ans.}$$

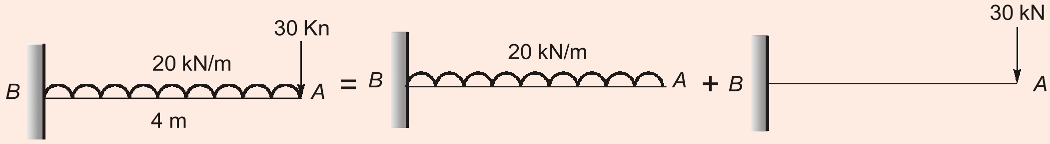
End of Solution

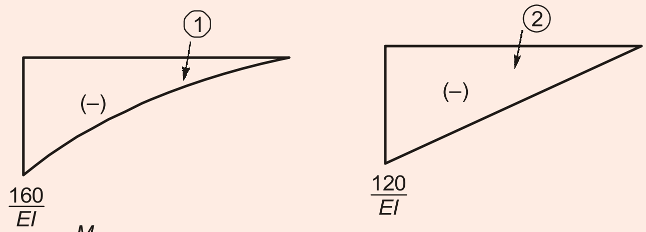
Q.3 (a) Find the slope and deflection at the tip of the cantilever shown in the figure. What load P must be applied upwards at mid-span to reduce the deflection by half? EI = 20 MN/m².



[20 marks : 2023]

Solution:





$\frac{M}{EI}$ diagram for respective loadings

According to moment area method, slope at A is given by,

$$\theta_A = A_1 + A_2 = -\frac{1}{3} \times 4 \times \frac{160}{EI} - \frac{1}{2} \times 4 \times \frac{120}{EI}$$

MADE EASY

Live-Online

General Studies & Engineering Aptitude for ESE 2024 Prelims (Paper-I)

- Course duration approx. 3 Months.
- 200 Hrs of comprehensive classes.
- Teaching pedagogy similar to the classroom course.
- Study material will be provided.
- **Streams :** CE, ME, EE, E&T

Fee : ₹ ~~14,000 + GST~~

₹ 11,000 + GST

Early bird discount of ₹ 3000

Valid till **30th June 2023**

Total 8 Subjects are covered

(Engineering Maths and Reasoning Aptitude will not be covered)

- Current Affairs
- General Principles of Design, Drawing & Safety
- Standards and Quality Practices in Production, Construction, Maintenance and Services
- Basics of Energy and Environment
- Basics of Project Management
- Basics of Material Science and Engineering
- Information and Communication Technologies
- Ethics and values in Engineering Profession

Batches commenced from

15th June 2023

Timing : **6:30 PM - 9:30 PM**

Scan to enroll

www.madeeasy.in **9021300500**

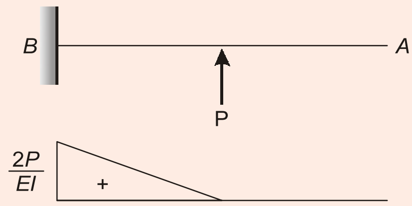
$$= -\frac{453.33}{EI} = -\frac{453.33}{20 \times 10^3} = -0.0226 \text{ rad (CW)}$$

Deflection at A is given by,

$$\Delta_A = A_1\bar{x}_1 + A_2\bar{x}_2$$

$$= -\frac{1}{3} \times 4 \times \frac{160}{EI} \times \frac{3}{4} \times 4 - \frac{1}{2} \times 4 \times \frac{120}{EI} \times \frac{2}{3} \times 4$$

$$= -\frac{1280}{EI} = -\frac{1280}{20 \times 10^3} = -64 \text{ mm} (\downarrow)$$



$\frac{M}{EI}$ diagram

For $\Delta_A = 32$ mm

$$\Delta_A = \frac{1}{2} \times 2 \times \frac{2P}{EI} \times \left(2 + \frac{4}{3}\right) \Rightarrow P = 96 \text{ kN}$$

Force P required to make deflection half at A = 96 kN

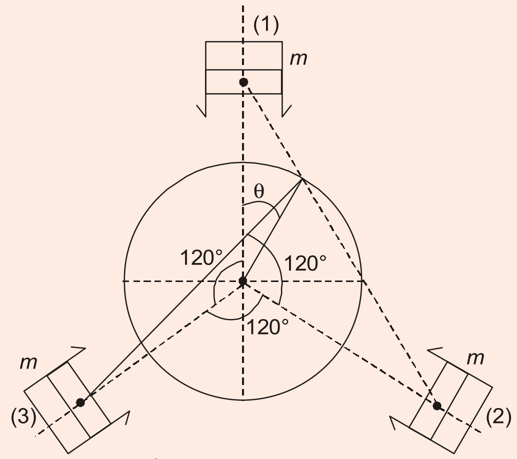
End of Solution

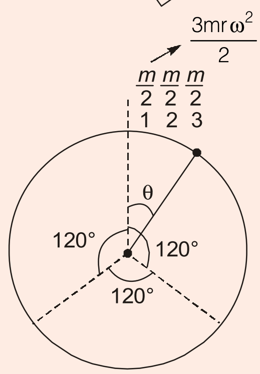
Q.3 (b) The axes of a three-cylinder air compressor are 120° apart and their connecting rods are connected to a common crank. The length of each connecting rod is 200 mm and the stroke is 160 mm. The mass of the reciprocating parts per cylinder is 2 kg. Find the maximum primary and secondary forces acting on the frame of the compressor when running at 2500 rpm.

[20 marks : 2023]

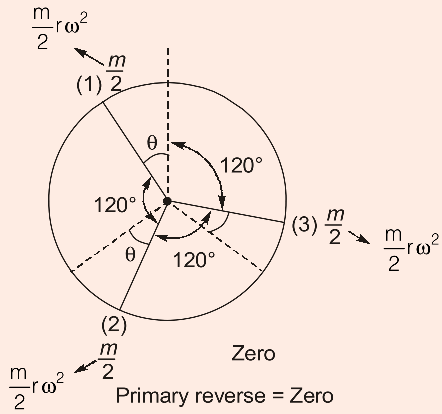
Solution:

Given: Stroke length, $s = 160$ mm, Crank radius, $r = \frac{s}{2} = \frac{160}{2} = 80 \text{ mm} = 0.08 \text{ m}$, Connecting rod, $l = 200$ mm $= 0.2$ m, $n = \frac{l}{r} = \frac{0.20}{0.08} = 2.5$, $m = 2$ kg, $N = 2500$ rpm.





Primary direct = $\frac{3mr\omega^2}{2}$



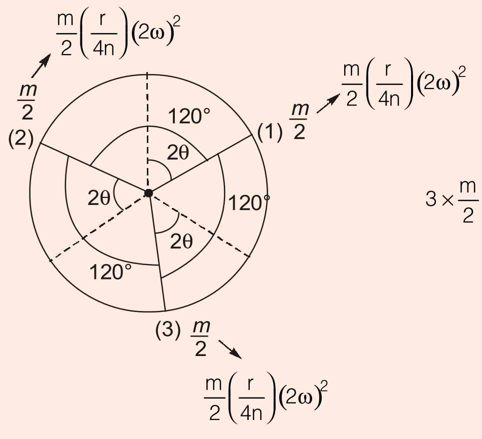
Primary reverse = Zero

Here, Primary reverse crank force = 0

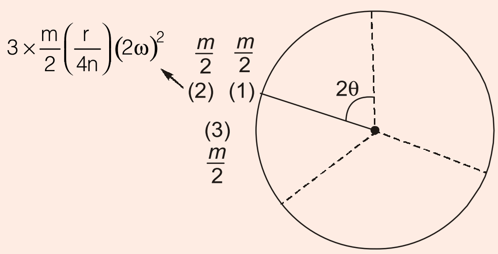
Total primary force is only primary direct force = $\frac{3}{2}m r\omega^2$ (Independent of crank orientation)

$$(F_{primary})_{max} = \frac{3}{2}mr\omega^2$$

$$(F_{primary})_{min} = \frac{3}{2}mr\omega^2$$



Secondary direct = Zero



Secondary reverse = $\frac{3}{2}\frac{mr\omega^2}{n}$

Here, Secondary direct force = 0

$$\text{Secondary reverse force} = 3\times\frac{m}{2}\left(\frac{r}{4n}\right)(2\omega)^2 = \frac{3}{2}\frac{mr\omega^2}{n}$$

Total secondary force is $= \frac{3}{2}\frac{mr\omega^2}{n}$ (Independent of Crank orientation)

$$(F_{secondary})_{max} = \frac{3}{2}\frac{mr\omega^2}{n}$$

$$(F_{secondary})_{min} = \frac{3}{2}\frac{mr\omega^2}{n}$$

$$\text{Maximum primary force} = 3\times\frac{m}{2}r\omega^2 = 3\times\frac{2}{2}\times 0.08\times\left(\frac{2\pi\times 2500}{60}\right)^2$$

$$= 3\times 1\times 0.08\times 68538.92 = 16449.34\text{ N} = 16.44934\text{ kN}$$

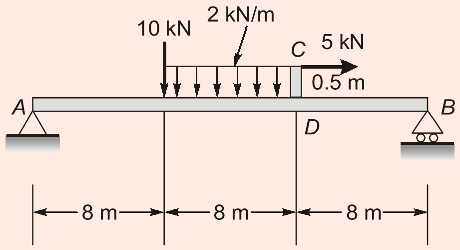
$$\text{Maximum secondary force} = 3\times\frac{m}{2}\left(\frac{r}{4n}\right)\times(2\omega)^2 = \frac{3}{2}\times\frac{mr\omega^2}{n}$$

$$= \frac{3}{2}\times\frac{2\times 0.08}{2.5}\times\left(\frac{2\pi\times 2500}{60}\right)^2 = 3\times 0.032\times 68538.92$$

$$= 6579.74\text{ N} = 6.57974\text{ kN}$$

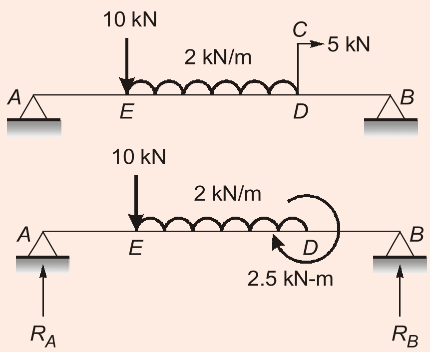
End of Solution

Q.3 (c) A simply supported beam AB is shown in the figure. A bar CD is welded to the beam. After determining the supporting forces, sketch the shear force and bending moment diagrams and determine the maximum bending moment.



[20 marks : 2023]

Solution:



$\Sigma F_V = 0$

$$R_A + R_B = 10 + 16$$

$\Sigma M_A = 0$

$24R_B - 2.5 - (10\times 8) - (2\times 8\times 12) = 0$

$$R_B = 11.4375\text{ kN}$$

$$R_A = 14.5625\text{ kN}$$

SF in AE [x from A]

$$S_x = R_A = 14.5625\text{ kN}$$

$$S_A = S_E = 14.5625\text{ kN}$$

SF in ED [x from E]

$$S_x = R_A - 10 - 2x$$

$$= 4.5625 - 2x$$

$$S_E = 4.5625 \text{ kN}$$
$$S_D = 11.4375 \text{ kN}$$

For $S_x = 0$, $x = 2.28125$ m

SF in DB [x from B]

$$S_x = -R_B = -11.4375$$
$$S_D = S_B = -11.4375 \text{ kN}$$

BM in AE [x from A]

$$M_x = R_A x = 14.5625x$$
$$M_A = 0$$
$$M_E = 116.5 \text{ kNm}$$

BM in ED [x from E]

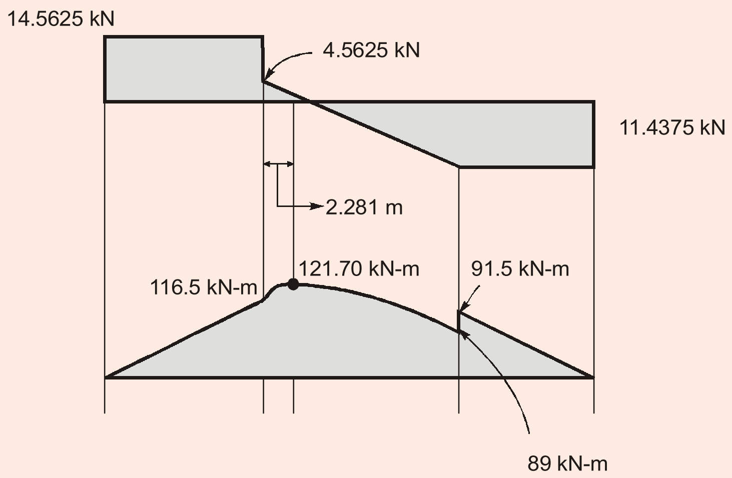
$$M_x = R_A(x+8) - 10x - \frac{2x^2}{2} = 116.5 + 4.5625x - x^2$$

$$M_E = 116.5 \text{ kNm}$$
$$M_D = 89 \text{ kNm}$$
$$M_{max} = 121.70 \text{ kNm}$$

BM in DB [x from B]

$$M_x = R_B x = 11.4375x$$
$$M_B = 0$$
$$M_D = 91.5 \text{ kNm}$$

Maximum bending moment = 121.7 kNm

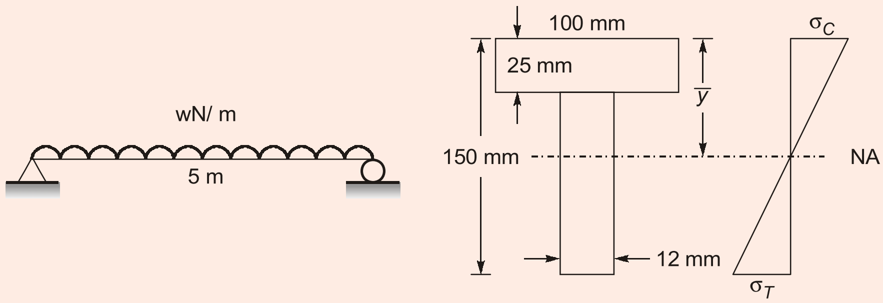


End of Solution

Q.4 (a) A uniform T-section beam is 100 mm wide and 150 mm deep with flange thickness of 25 mm and a web thickness of 12 mm. If the limiting bending stresses for the material of the beam are 80 MN/m^2 in compression and 160 MN/m^2 in tension, find the maximum u.d.l. that the beam can carry over a simply supported span of 5 m.

[20 marks : 2023]

Solution:



Calculating the distance of neutral axis from top fiber,

$$\bar{y} = \frac{(100 \times 25 \times 12.5) + (12 \times 125 \times 87.5)}{(100 \times 25) + (12 \times 125)} = 40.625 \text{ mm}$$

$$I_{NA} = \frac{100 \times 25^3}{12} + \left(100 \times 25 \times 28.125^2\right) + \frac{12 \times 125^3}{12} + \left(12 \times 125 \times 46.875^2\right)$$

$$= 7.357 \times 10^6 \text{ mm}^4$$

Maximum bending moment, $M = \frac{wL^2}{8} = 3.125w \text{ Nm}$

Maximum stress in compression, $\sigma_c = 80 \text{ N/mm}^2$

Now, $$\sigma_c = \frac{M}{I} \times 40.625$$

$$80 = \frac{3.125w \times 10^3}{7.357 \times 10^6} \times 40.625$$

$$w = 4.647 \text{ kN/m}$$

Maximum stress in tension, $\sigma_T = 160 \text{ N/mm}^2$

$$= \frac{M}{I} \times 109.375$$

$$160 = \frac{3.125w \times 10^3}{7.357 \times 10^6} \times 109.375$$

$$w = 3.443 \text{ kN/m}$$

Maximum intensity of UDL = 3.443 kN/m

End of Solution

Q.4 (b) In a spring loaded governor of Hartnell type, the weight of each ball is 5 kg and the lift of the sleeve is 5 cm. The speed at which the governor begins to float is 250 rpm, and at this speed the radius of the ball path is 10 cm. The mean working speed of the governor is 20 times the range of speed when friction is neglected. If the lengths of ball and roller arm of the bell crank lever are 12 cm and 10 cm respectively and if the distance between the centre of pivot of bell crank and axis of the governor spindle is 14 cm, determine the initial compression of the spring, taking into account obliquity of arms.

[20 marks : 2023]

MADE EASY

Live-Online Course for GENERAL STUDIES for State Engineering and SSC Exams

Full Fledged Course for General Studies

Subject Covered : History, General Science, Polity, Environment, Geography, General Knowledge, Economy & Current Affairs

Duration : 3 Months | **Validity :** 6 Months

Batch commencing from **15th July, 2023**

Scan to enroll

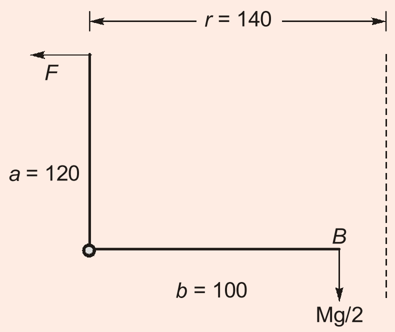
Key Features

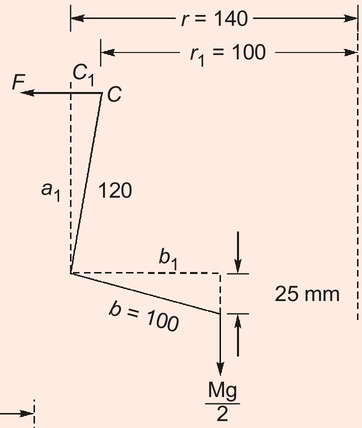
- 250 Hrs of quality teaching by renowned teachers of MADE EASY.
- Printed study material will be dispatched to your address.
- Comprehensive coverage as per latest syllabus and trends of various competitive exams.

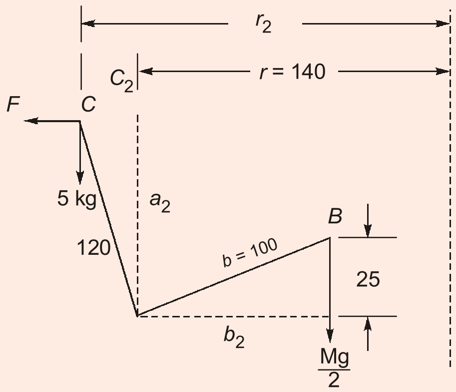
www.madeeasy.in 9021300500

Solution:

Given: $m = 5$ kg, $N_1 = 250$ rpm, $h_1 = 50$ mm, $r_1 = 100$ mm, $a = 120$ mm, $b = 100$ mm







$$\text{Mean speed, } N = \frac{N_1 + N_2}{2}$$

$$N = 20\,(N_2 - N_1) \qquad \text{[Given]}$$

or,
$$\frac{N_1 + N_2}{2} = 20\,(N_2 - N_1)$$

or,
$$N_1 + N_2 = 40N_2 - 40N_1$$

$$39N_2 = 41\,N_1,\; N_2 = \frac{41 \times 250}{39} = 262.82 \text{ rpm}$$

Angle turned by bell-crank lever between two extreme positions

$$= \frac{\text{Lift}(h_1)}{\text{b}} = \frac{c_1 + c_2}{a}$$

$$c_1 + c_2 = \frac{h_1 a}{b} = \frac{50 \times 120}{100} = 60 \text{ mm}$$

But,
$$c_1 = r - r_1 = 140 - 100 = 40 \text{ mm}$$

$$c_2 = 20 \text{ mm}$$

$$r_2 = r + c_2 = 140 + 20 = 160 \text{ mm}$$

$$b_1 = b_2 = \sqrt{b^2 - \left(\frac{h}{2}\right)^2} = \sqrt{100^2 - 25^2} = 96.824 \text{ mm}$$

$$a_1 = \sqrt{120^2 - 40^2} = 113.137 \text{ mm}$$

$$a_2 = \sqrt{120^2 - 20^2} = 118.321\text{mm}$$

$$\omega_1 = \frac{2\pi \times 250}{60} = 26.1799 \text{ rad/s}$$

$$\omega_2 = \frac{2\pi \times 262.82}{60} = 27.522 \text{ rad/s}$$

In the extreme positions,

$$mr_1\omega_1^2 a_1 = \frac{1}{2}F_{s1}b_1 + mgc_1 \qquad [m = 0,\ f = 0]$$

$$5 \times 0.1 \times (26.1799)^2 \times 0.113137 = \frac{1}{2}F_{s1} \times 0.09682 + 5 \times 9.81 \times 0.04$$

or, $F_{s1} = 760.366$ N

Similarly, $mr_2\omega_2^2 a_2 = \frac{1}{2}F_{s2}b_2 + mgc_2$

$$5 \times 0.16 \times (27.522)^2 \times 0.11832 = \frac{1}{2}F_{s2} \times 0.09682 + 5 \times 9.81 \times 0.02$$

or, $F_{s2} = 1460.7969$ N

Here, $k = \frac{F_{s2} - F_{s1}}{h_1} = \frac{1460.7969 - 760.366}{50}$

or, $k = 14$ N/mm

Initial compression $= \frac{F_{s1}}{k} = \frac{760.366}{14} = 54.278$ mm **Ans.**

End of Solution

Q.4 (c) (i) What are the assumptions made in the Lewis equation for beam strength?

(ii) A pair of spur gears with 20° full depth involute teeth consists of a 20 teeth pinion meshing with a 50 teeth gear. The pinion is mounted on a crank shaft of 5 kW engine running at 1200 rpm. The driven shaft is connected to a compressor. The pinion as well as the gear is made of steel having ultimate strength in tension equal to 500 N/mm^2. The module and face width of the gears are 4 mm and 44 mm. Assume service factor as 2. Using the velocity factor to account for the dynamic load, determine the factor of safety. Take Lewis form factor for 20 teeth equal to 0.320 and for 50 teeth equal to 0.408.

Take velocity factor, $C_V = \frac{3}{3+v}$, where v is the pitch line velocity in m/s

[8+12=20 marks : 2023]

Solution:

(i)

Assumptions made in Lewis equation:

1. Effect of radial load (i.e.axial compressive stresses) are neglected.
2. Tangential load is assumed to be uniformly distributed over the face width of gear tooth.

3. Contact ratio is assumed as 1.
4. Effect of stress concentration at the root of gear tooth is neglected.
5. Manufacturing errors (i.e. errors in tooth spacing & inaccuracies in tooth profiles) are neglected.
6. Each gear tooth is considered as cantilever beam.

(ii)

Input data: $\phi = 20$(FD) = Number of teeth on pinion $(z_1) = 20$.

Number of teeth on gear $(z_2) = 50$

Power, P = 5 kW at 1200 rpm

Speed of pinion, N_1 = 1200 rpm

S_{ut} = Ultimate strength for pinion and gear = 500 MPa

Face width (b) = 44 mm

Module = 4 mm

Service factor, $C_s = 2$

Velocity factor, $C_V = \dfrac{3}{3+V}$

Lewis form factor for pinion, $Y_1 = 0.32$

Lewis form factor for gear, $Y_2 = 0.408$

To determine FOS (N) = ?

T_1 = Torque to be transmitted by pinion (or) Rated torque for pinion

$$= \frac{P0 \times 60}{2\pi N_1} \times 10^6 = 39788.736 \text{ N-mm}$$

Design torque for pinion $(T_{max}) = T_1 \times C_s$

$$(T_{max})_1 = 79577.472 \text{ N-mm}$$

$$\text{Velocity of pinion, } V_1 = \frac{\pi(D_1 = mz_1)N_1}{60} = 5.027 \text{ m/s}$$

$$F_t = \text{Tangential force} = \frac{2(T_{max})_1}{D_1} = 1989.4368 \text{ N}$$

$$C_V = \frac{3}{3+V} = 0.374$$

$$F_d = \text{Dynamic load} = \frac{F_t}{C_V} = 5319.35 \text{ N}$$

F_s = Beam strength for weaker gear, pinion is the weaker gear because pinion and gear are made of same material.

Hence,
$$F_s = \left[\sigma_b = \frac{S_{ut}}{N}\right][Y_1]bm$$

$$= \left(\frac{500}{N}\right) \times 0.32 \times 44 \times 4 = \frac{28160}{N} \text{ N}$$

Safe condition with respect to bending failure, $F_d \le F_s$

$$5319.35 \le \frac{28160}{N} \Rightarrow N \le 5.29$$

Hence, FOS (N) = 5.29

End of Solution

SECTION : B

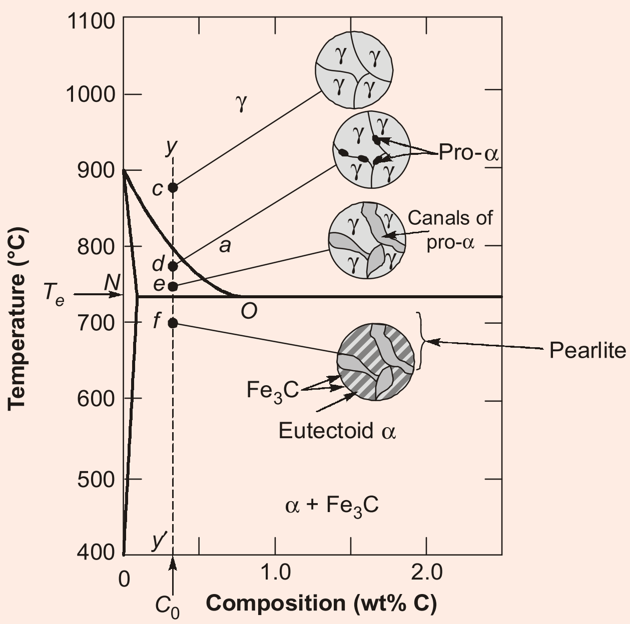
Q.5 (a) What is the distinction between hypoeutectoid and hypereutectoid steels? Explain the development of microstructure in a hypoeutectoid steel with the help of neatly labelled diagram.

[12 marks : 2023]

Solution:

Steels containing carbon upto 0.8% are said to be hypoeutectoid steels while steels with 0.8% to 2.14%C are said to be hypereutectoid steels.

Hypoeutectoid Alloys (<0.8%C): A steel sample in hypo eutectoid steel range is cooled along yy′. At *point c*, the alloy is entirely in the austenite phase. The moment temperature decreases to *point d*, ferrite start appearing in the microstructure. This ferrite that appears before eutectoid temperature is called pro- eutectoid ferrite (pro-α). As temperature decreases mass fraction of pro-α will increase and at *point e* there will be canals of pro α at the grain boundary. As the temperature is lowered just below the eutectoid, to point *f*, all the γ phase that was present at temperature T_e(and having the eutectoid composition) will transform to pearlite. There will be virtually no change in the α phase that existed at *point e* in crossing the eutectoid temperature. It will normally be present as a continuous matrix phase surrounding the isolated pearlite colonies. It should also be noted that two micro constituents are present, i.e., proeutectoid ferrite and pearlite which will appear in all hypoeutectoid iron–carbon alloys that are slowly cooled to a temperature below the eutectoid.



End of Solution

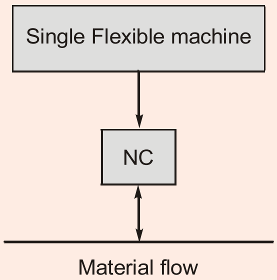
Q.5 (b) With the help of schematic diagram, discuss the following:
(i) Single manufacturing cell
(ii) Flexible manufacturing cell
(iii) Flexible manufacturing system

[12 marks : 2023]

Solution:

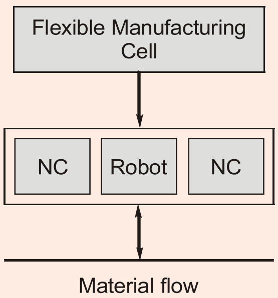
(i) Single manufacturing cell

Single Flexible Machine (SFM) is defined as the production unit formed by NC machine, completed by the manipulation facility to change the objects of the production.



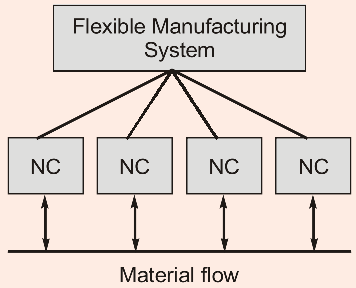
(ii) Flexible manufacturing cell

Flexible Manufacturing Cell (FMC) is the manufacturing system, created by grouping several NC machines, determined for the certain group of parts with the similar sequence of the operations or for the certain type of operations. Characteristic sign of the cell is the mutual material and information interconnection among machines. Usually they apply for the interoperation manipulations the common manipulation facility.



(iii) Flexible Manufacturing System

Flexible Manufacturing System (FMS) is understood as the grouping of several manufacturing machines without mutual dependence of their activity, for example AGV transport system. Machines are first of all the machining centres, machines determined for the special operations as to produce the gearing operations and so on. Characteristic sign of their activity are the longer operation times.



End of Solution

Q.5 (c) (i) Express unilateral and bilateral tolerances with the help of diagram considering normal size 24.00 mm and tolerance 0.030 mm.

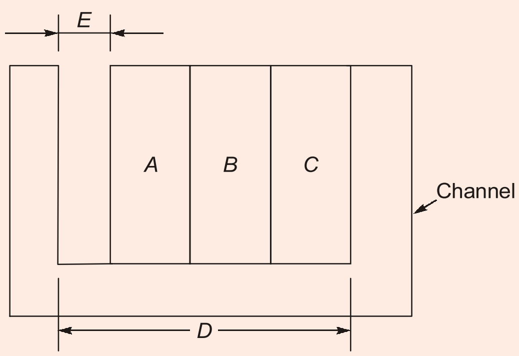
(ii) Three blocks A, B and C are to be assembled in a channel of dimension D as shown in figure. Determine the tolerance that must be assigned to D, if it is essential that the minimum gap E is not less than 0.005 mm. The dimensions of block are:

A = 0.75 ± 0.003 mm

B = 1.0 ± 0.005 mm

C = 1.125 ± 0.004 mm

Consider basic dimension of channel D = 2.894 mm.



[6+6=12 marks : 2023]

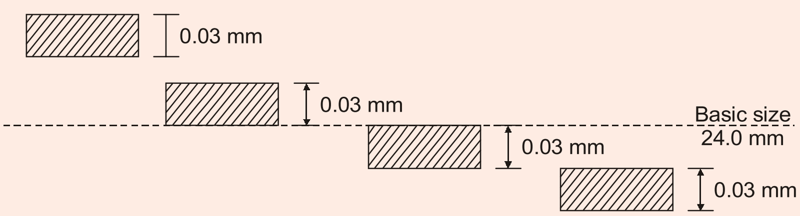
Solution:

(i)

Unilateral Tolerance

In this system, the dimension of a part is allowed to vary only on one side of basic or normal size i.e. tolerance lies wholly on one side of basic size either above or below it.

For a unilateral tolerance of 0.03 mm and normal size 24.00 mm, the dimension can be represented as shown below.



MADE EASY

FOUNDATION COURSES for

ESE 2024 | **ESE+GATE 2024**

The Foundation Batches are taught comprehensively which cover the requirements of all technical-syllabus based examinations.

KEY FEATURES

- Classes by experienced & renowned faculties.
- Systematic subject sequence & timely completion of syllabus.
- Comprehensive & updated study material.
- Regular performance assessment through class tests.
- Exam oriented learning ecosystem.
- Result oriented teaching with comprehensive coverage.
- Concept of problems solving through workbooks.
- Similar teaching pedagogy in online and offline classes.

Offline Batches Commencement Dates

Delhi : 30th June, 2023 & 3rd July, 2023

Hyderabad : 21st June, 2023	**Bhopal :** 3rd & 17th July, 2023	**Bhubaneswar :** 01st June, 2023
Jaipur : 18th June, 2023	**Kolkata :** 22nd June, 2023	**Pune :** 18th June, 2023

Scan to Enroll

Online Batches Commencement Dates

New batches commencing from 3rd July, 2023

English / Hinglish (2:00 PM - 10:00 PM) **Streams :** CE, ME, EE, EC, CS & IN	**Hinglish** (8:00 AM - 4:30 PM) **Streams :** CE, ME, EE, EC, CS & IN

Scan to Enroll

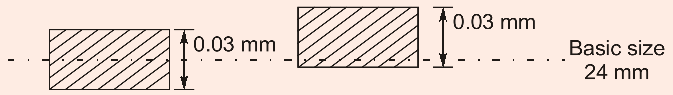
Corporate Office: 44 - A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi - 110016

Centres : Delhi | Hyderabad | Jaipur | Bhopal | Bhubaneswar | Pune | Kolkata

9021300500 www.madeeasy.in

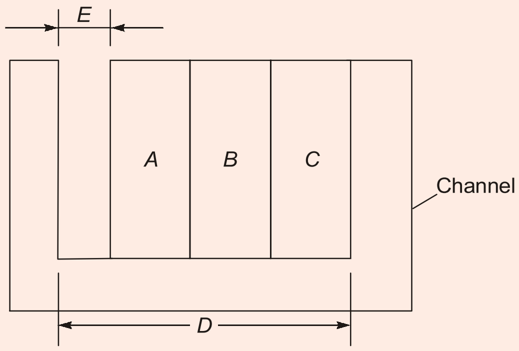
Bilateral Tolerance

In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size.



(ii)

$$\text{Upper limit of } A = 0.75 + 0.03 = 0.753 \text{ mm}$$
$$\text{Upper limit of } B = 1.0 + 0.005 = 1.005 \text{ mm}$$
$$\text{Upper limit of } C = 1.125 + 0.004 = 1.129 \text{ mm}$$
$$\text{Minimum gap of } E = 0.005 \text{ mm}$$



∴ According to the given situation

$$E_{min} = D_{min.} - A_{max.} - B_{max.} - C_{max.}$$
$$\Rightarrow \quad 0.005 = (2.894 - x) - 0.753 - 1.005 - 1.129$$
$$\Rightarrow \quad x = 2 \times 10^{-3} \text{ mm} = 0.002 \text{ mm}$$
$$\therefore \quad D = 2.894 \pm 0.002$$
$$\therefore \quad \text{Tolerance} = 0.004 \text{ mm}$$

Ans.

End of Solution

Q.5 (d) (i) Why is it necessary to schedule debris sampling for wear debris?

(ii) Wear particles of spherical shape were found in a wear debris sample. What is the possible mode of failure for such case? Justify.

[6+6=12 marks : 2023]

Solution:

(i)

Wear debris analysis is a useful tool that can be used as part of an oil condition monitoring program to gain valuable insight into how machinary is operating, helping to plan for maintenance, reduce downtime, and optimise the lifespan of assets.

It is necessary to schedule debris sampling for wear debris analysis to know the type of wear, severity of wear rate on the equipment within a given time. After wear debris analysis necessary action has to the taken to minimize the failure of the system.

(ii)
Wear debris analysis is carried out on used oil or greases by extracting magnetic particles from the sample using a magnet. Microscopic analysis of the identified numerous small and large spherical particles. Research has shown that spherical wear debris can reveal the severity of rolling-contact fatigue wear. Because large spherical (50 microns) are the product of high metal to metal contact and high frictional temperature, their presence is considered a supporting symptoms for assessing the wear severity levels.

End of Solution

Q.5 (e) Each unit of an item costs a company Rs.40. Annual holding costs are 18% of unit cost for interest charges, 1% for insurance, 2% allowances for obsolescence, Rs. 2 for building overheads, Rs. 1.50 for damage and loss, and Rs. 4 miscellaneous cost. Annual demand for the item is constant at 1,000 units and each order costs Rs. 100 to place.

(i) Calculate EOQ and the total costs associated with stocking the item.

(ii) If the supplier of the item will only deliver batches of 250 units, how are the stock holding costs affected?

(iii) If the supplier relaxes his order size requirement, but the company has limited warehouse space and can stock a maximum of 100 units at any time, what would be the optimal ordering policy and associated costs?

[12 marks : 2023]

Solution:

Given : D = 1000 units per year; C = Rs. 40 per unit;

$$C_h = (18 + 1 + 2)\% \text{ of } 40 + (2 + 1.5 + 4)$$

$$= \text{Rs. } 15.9 \text{ per unit per year}$$

$$C_o = \text{Rs. } 100 \text{ per order}$$

1.
$$Q^* = \sqrt{\frac{2DC_0}{C_h}} = 112.15 \text{ units per order}$$

$$TIC^* = \sqrt{2DC_0C_h} = \text{Rs. } 1783.25$$

$$\text{Total stocking cost} = \frac{Q^*}{2} \times C_h = \frac{112.15}{2} \times 15.9 = \text{Rs.}891.625$$

or
$$\text{H.C.} = \frac{TIC^*}{2} = \text{Rs.}891.625$$

2. If Q = 250

$$\text{H.C.} = \frac{Q}{2} \times C_h = \frac{250}{2} \times 15.9 = \text{Rs.}1987.5$$

$$\text{Stocking cost increases by} = 1987.5 - 891.625 = \text{Rs.}1095.875$$

3. If Q = 100

$$\text{TIC} = \frac{D}{Q}\cdot C_0 + \frac{Q}{2}\cdot C_h$$
$$= \frac{1000}{100}\times 100 + \frac{100}{2}\times 15.9$$
$$= \text{Rs. } 1795$$

End of Solution

Q.6 (a) (i) The voltage length characteristics of a direct current (dc) arc is given by $V = (20 + 40l)$ volts, where l is the length of the arc in cm. The power source characteristics is approximated by a straight line with an open circuit voltage = 80 V and a short circuit current = 1000 amp.
Determine the optimum arc length and the corresponding arc power.

(ii) Enlist the most common defects encountered in sand mould casting. Describe the reasons for Scab and Misrun.

[12+8=20 marks : 2023]

Solution:

(i)

Given for linear V-I characteristics,

$$V = (20 + 40\,l); \qquad l = \text{Arc length in cm}$$
$$V_0 = 80\text{V},\ I_S = 1000\text{A}$$
$$(l_a)_{opt} = ?; \qquad P = ?$$

$$V_t = V_0 - \left(\frac{I_t}{I_s}\right)V_0 = 80 - \left(\frac{I_t}{1000}\right)80$$

Stable Arc condition

$$V_t = V_a \qquad (\because \text{ Linear power source characteristics})$$
$$80 - \left(\frac{I_t}{1000}\right)80 = 20 + 40l_a$$
$$I_t = 750 - 500l_a$$
$$P = VI$$
$$P = (20 + 40l_a)(750 - 500l_a)$$
$$\frac{dP}{dl_a} = 0$$
$$\Rightarrow \qquad (l_a)_{opt} = 0.5 \text{ cm}$$
$$P_{max} = (20 + 40(0.5))(750 - 500(0.5))$$
$$P_{max} = 20000$$
$$P_{max} = 20 \text{ kW}$$

(ii)

Most common defects in sand mould casting:

1. Gas defects

(a) Blow hole
(b) Pinhole
(c) Porosity
(d) Scab

2. Moulding material or methods defects

(a) Drop and dirt
(b) Cuts and washes
(c) Scab
(d) Rat tail

3. Gating design

(a) Shrinkage cavities

4. Pouring metal defects

(a) Misrun
(b) Coldshuts

5. Metallurgical defects

(a) Hot tears or cracks

6. Other defects

(a) Mould shift
(b) Core shift

Scab : These are the projections on the casting which occurs when a portion of the mould face or core lifts and the metal flows beneath in a thin layer. These are rough, irregular projection on the surface containing embedded sand.

Misrun : A misrun casting is one that remains incomplete due to the failure of metal of fill the entire mould cavity, due to in-sufficient fluidity.

End of Solution

Q.6 (b) (i) Compare gray, malleable, white and nodular cast irons with respect to (I) composition and heat treatment, (II) microstructure, and (III) mechanical properties.

(ii) Make a schematic plot showing the tensile engineering stress-strain behaviour for mild steel and label the salient points. State the reason of occurrence of two yield points in mild steel. Also, explain the following on the basis of the plot (I) Ductility, (II) Resilience, and (III) Toughness.

[12+8=20 marks : 2023]

Solution:

(i) Gray cast iron:

The carbon and silicon contents of gray cost irons vary between 2.5 and 4.0 wt% and 1.0 and 3.0 wt%, respectively. For most of these cast irons, the graphite exists in the form of flakes (similar to corn flakes), which are normally surrounded by an α-ferrite or pearlite matrix; the microstructure of a typical gray iron. Because of these graphite flakes, a fractured surface takes on a gray appearance, hence its name.

Mechanically, gray iron is comparatively weak and brittle in tension as a consequence of its microstructure; the tips of the graphite flakes are sharp and pointed, and may serve as points of stress concentration when an external tensile stress is applied. Strength and ductility are much higher under compressive loads.

White and Malleable Cast Iron : For low-silicon cast irons (containing less than 1.0 wt% Si) and rapid cooling rates, most of the carbon exists as cementite instead of graphite

A fracture surface of this alloy has a white appearance, and thus it is termed white cast iron. Thick sections may have only a surface layer of white iron that was "chilled" during the casting process; gray iron forms at interior regions, which cool more slowly. As a consequence of large amounts of the cementite phase, white iron is extremely hard but also very brittle, to the point of being virtually unmachinable. Its use is limited to applications that necessitate a very hard and wear resistant surface, without a high degree of ductility - for example, as rollers in rolling mills. Generally, white iron is used as an intermediary in the production of yet another cast iron, malleable iron.

Heating white iron at temperatures between 800 and 900°C (1470 and 1650°F) for a prolonged time period and in a neutral atmosphere (to prevent oxidation) causes a decomposition of the cementite, forming graphite, which exists in the form of clusters or rosettes surrounded by a ferrite or pearlite matrix, depending on cooling rate. The microstructure is similar to that for nodular iron which accounts for relatively high strength and appreciable ductility or malleability.

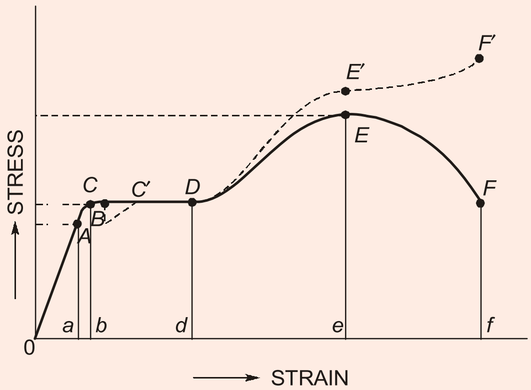
Representative applications include connecting rods, transmission gears, and differential cases for the automotive industry, and also flanges, pipe fittings, and valve parts for railroad, marine, and other heavy-duty services.

Nodular Cast Iron : Adding a small amount of magnesium and/or cerium to the gray iron before casting produces a distinctly different microstructure and set of mechanical properties. Graphite still forms, but as nodules or sphere-like particles instead of flakes. The resulting alloy is called nodular or ductile iron.

The matrix phase surrounding these particles is either pearlite or ferrite, depending on heat treatment; it is normally pearlite for an as-cast piece. However, a heat treatment for several hours at about 700°C (1300°F) will yield a ferrite matrix. Castings are stronger and much more ductile than gray iron. In fact, ductile iron has mechanical characteristics approaching those of steel. For example, ferritic ductile irons have tensile strengths ranging between 380 and 480 MPa (55000 and 70000 psi), and ductilities (as percent elongation) from 10% to 20%. Typical applications for this material include valves, pump bodies, crank-shafts, gears, and other automotive and machine components.

(ii)

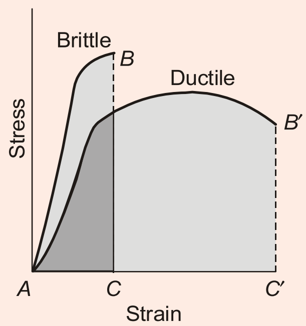
A = Proportional limit	Oa = Linear deformation
B = Elastic limit	Ob = Elastic deformation
C = Yield point	bd = Perfect Plastic Yielding
C' = Lower Yield Point	de = Strain Hardening
E = Ultimate strength	ef = Necking
F = Rupture strength	



Schematic plot showing tensile engineering stress-strain behaviour for mild steel

If the material is stressed beyond point *B*, the plastic stage will reach i.e., on the removal of the load, the material will not be able to recover its original size and shape. A little consideration will show that beyond point *B*, the strain increases at a faster rate with any increase in the stress until the point C is reached. At this point, the material yields before the load and there is an appreciable strain without any increase in stress. In case of mild steel, it will be seen that a small load drops to *D*, immediately after yielding commences. Hence for mild steel there are two yield points *C* and *D*. The point *C* and *D* are called the upper and lower yield points respectively. The stress corresponding to yield point is known as yield point stress.

Ductility: Ductility is an important mechanical property. It is a measure of the degree of plastic deformation that has been sustained at fracture. A material that experiences very little or no plastic deformation upon fracture is termed brittle. The tensile stress-strain behaviors for both ductile and brittle materials are schematically illustrated in Figure below.



Schematic representations of tensile stress-strain behaviour for brittle and ductile materials loaded to fracture

Resilience is the capacity of a material to absorb energy when it is deformed elastically and then, upon unloading, to have this energy recovered. The associated property is the modulus of resilience, U_r, which is the strain energy per unit volume required to stress a material from an unloaded state up to the point of yielding.

Computationally, the modulus of resilience for a specimen subjected to a uniaxial tension test is just the area under the engineering stress-strain curve taken to yielding.

MADE EASY

Recorded Video Course for ESE & GATE

GATE + ESE 2024 & 2025

Course without Books
- **1 Year Validity :** Rs. 48,000 + GST
- **2 Years Validity :** Rs. 62,000 + GST
- GATE Online Test Series and ESE Prelims Online Test series will be provided.

Course with Books
- **1 Year Validity :** Rs. 54,000 + GST
- **2 Years Validity :** Rs. 68,000 + GST
- GATE Online Test Series and ESE Prelims Online Test series will be provided.

Streams : CE, ME, EE, E&T
Duration : 1300-1400 Hrs
Enrollment Open

Scan to Enroll

GATE 2024 & 2025

Course without Books
- **1 Year Validity :** Rs. 42,000 + GST
- **2 Years Validity :** Rs. 56,000 + GST
- GATE Online Test Series will be provided.

Course with Books
- **1 Year Validity :** Rs. 48,000 + GST
- **2 Years Validity :** Rs. 62,000 + GST
- GATE Online Test Series will be provided.

Streams : CE, ME, EE, EC, CS, IN, CH
Duration : 1100-1200 Hrs
Enrollment Open

Scan to Enroll

Tablet Courses for ESE & GATE

GATE + ESE 2024 & 2025

Course Fee : Rs. 65,000 + GST
- **Course Validity :** 24 Months
- Printed Study material will be provided.
- GATE Online Test Series and ESE Online Test Series will be provided.
- **Streams :** CE, ME, EE, EC

Scan to Enroll

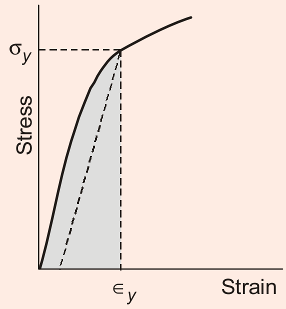
GATE 2024 & 2025

Course Fee : Rs. 60,000 + GST
- **Course Validity :** 24 Months
- Printed Study material will be provided.
- GATE Online Test Series will be provided.
- **Streams :** CE, ME, EE, EC, CS, IN

Scan to Enroll

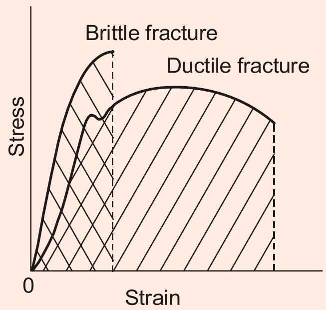
www.madeeasy.in 9021300500

$$U_r = \int_0^{\epsilon_y} \sigma d \epsilon$$



Schematic representations showing how modulus of resilience (corresponding to the shaded area) is determined from the tensile stress-strain behaviour of a material.

Toughness is a measure of the ability of a material to absorb energy up to fracture. Specimen geometry as well as the manner of load application are important in toughness determinations. For dynamic (high strain rate) loading conditions and when a notch (or point of stress concentration) is present, notch toughness is assessed by using an impact test. Furthermore, fracture toughness is a property indicative of a material's resistance to fracture when a crack is present.



End of Solution

Q.6 (c) (i) (a) Derive the characteristic equation for the piezoelectric accelerometer supporting a mass (M) on a spring of stiffness (K) and viscous damper with damping coefficient (C). Assume the input and output displacement to be (x_i) and (x_o) respectively.

(b) What is the amplitude ratio for a frequency response analysis assuming input displacement to be sinusoidal?

(ii) An accelerometer is designed with a seismic mass of 0.05 kg, a spring constant of 5000 N/m, and a damping constant of 30 NS/m. If the accelerometer is mounted to an object experiencing displacement $x_i = 5 \sin (100t)$ mm, find an expression for the steady state relative displacement of seismic mass relative to housing as a function of time $x_r(t)$.

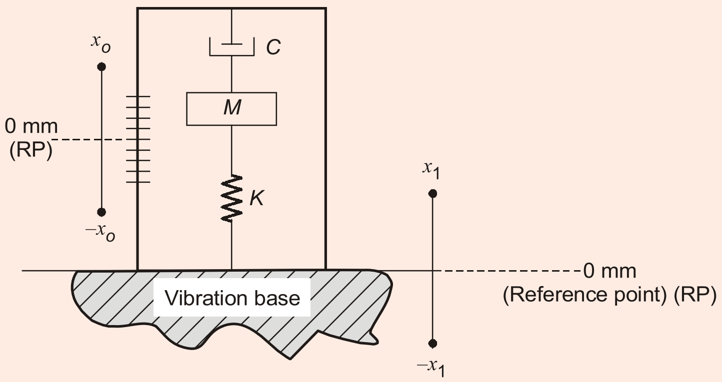
[20 marks : 2023]

Solution:

(i)

Input displacement, $x_i(t) = x_i \sin\omega t$

where x_i = Amplitude of vibration



$$\text{Input acceleration, } a_i(t) = \frac{d^2 x_i(t)}{dt^2}$$

or $$a_i(t) = -\omega^2 \sin\omega t$$

Here, $A_i = \omega^2 x_i$, amplitude of acceleration

Relative displacement of mass,

$$x_0(t) = x_0 \sin(\omega t - \phi)$$

Here, x_0 = Amplitude of relative displacement of mass

Refer figure, using FBD of mass and spring $\dfrac{Md^2x_0(t)}{dt^2} + \dfrac{Cdx_0(t)}{dt} + Kx_0(t) = Ma_i(t)$

or $$\frac{d^2x_0(t)}{dt^2} + \frac{C}{M}\frac{dx_0(t)}{dt} + \frac{K}{M}x_0(t) = a_i(t)$$

By solving above differential equation

$$x_0(t) = x_0 \sin(\omega t - \phi)$$ Proved.

where,

$$x_0 = \frac{r^2 \times x_i}{\sqrt{(1-r^2)^2 + (2\xi r)^2}}; \quad \tan\phi = \frac{2\xi r}{1-r^2}$$

$$r = \frac{\omega}{\omega_n}$$

Now, amplitude ratio, $$\frac{x_0}{x_i} = \frac{r^2}{\sqrt{\left(1-r^2\right)^2 + (2\xi r)^2}}$$ Ans.

(ii)

Given : m = 0.05 kg; k = 5000 N/m; C = 30 N-s/m; x_i = 5 sin(100t) mm

Steady state relative displacement,

$$x_r(t) = x_r \sin(\omega t + \phi)$$

where,
$$x_r = \frac{x_i r^2}{\sqrt{(1-r^2) + (2\xi r)^2}}$$

Now,
$$x_i = 5,\ \omega = 100,\ \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{5000}{0.05}} = 316.22 \text{ rad/s}$$

$$r = \frac{\omega}{\omega_n} = \frac{100}{316.22}$$

$$r = 0.3162$$

$$C_c = 2\sqrt{km} = 2\sqrt{5000 \times 0.05} = 31.62 \text{ N.s/m}$$

∴
$$\xi = \frac{C}{C_c} = \frac{30}{31.62} = 0.948$$

∴
$$x_r = \frac{5 \times 0.3162^2}{\sqrt{(1-0.3162^2)^2 + (2 \times 0.948 \times 0.3162)^2}}$$

$$= 0.462 \text{ mm}$$

Now,
$$\tan\phi = \frac{2\xi r}{1-r^2} = \frac{2 \times 0.948 \times 0.3162}{1-0.3162^2}$$

∴
$$\phi = 33.66°$$

∴
$$x_r(t) = 0.462 \sin(100t + 33.66°)$$ Ans.

End of Solution

Q.7 (a) (i) An engine is to be designed to have a minimum reliability of 0.8 and minimum availability of 0.98 over a period of 2 × 10^3 hours. Determine MTTR and frequency of failures of engine.

(ii) Explain the mechanism of chip formation. What are the conditions that results in the formation of

I. Continuous chips without built up edge,

II. Continuous chips with built up edge,

III. Discontinuous chips?

[8+12=20 marks : 2023]

Solution:

(i)

Given : Reliability, R = 0.8; Availability, A = 0.98; Time, t = 2 × 10^3 hours

$$\text{Reliability, } R = e^{-\lambda t}$$

⇒
$$0.8 = e^{-\lambda \times 2 \times 10^3}$$

⇒
$$\lambda = 1.1157 \times 10^{-4} \text{ failures/hour}$$

Frequency of failures of engine, $\lambda = 1.1157 \times 10^{-4}$ failures/hour **Ans.**

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{1.1157 \times 10^{-4}} = 8962.84 \text{ hours}$$

$$\text{Availability } (A) = \frac{MTBF}{MTBF + MTTR}$$

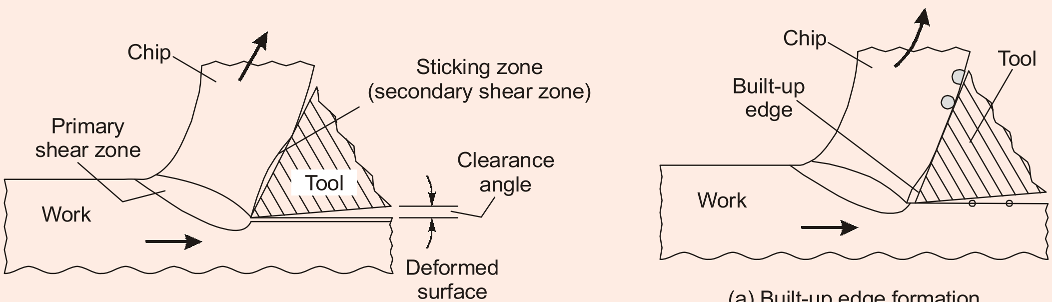
$$\Rightarrow \quad 0.98 = \frac{8962.84}{8962.84 + MTTR}$$

$$\Rightarrow \quad \text{MTTR} = 182.9 \simeq 183 \text{ hours}$$ **Ans.**

(ii)

Mechanism of chip formation

When the zone under the cutting action is carefully examined, the following observations can be made. The uncut layer deforms into a chip after it goes through a severe plastic deformation in the primary shear zone (as shown in figure).



Material deformation and associated phenomena in machining

Just after its formation, the chip flows over the rake surface of the tool and the strong adhesion between the tool and the newly formed chip surface results in some sticking. Thus, the chip material at this surface (and the adjacent layers) undergoes a further plastic deformation since, despite the sticking, it flows. This zone is referred to as the secondary shear zone. Under suitable conditions, the machining operation is smooth and stable and produces continuous ribbon-like chips. As a result, the surface produced is smooth and the power consumption is not unnecessarily high.

At a somewhat high speed, the temperature increases and the tendency of the plastically deformed material to adhere to the rake face increases and a lump is formed at the cutting edge. This is called a built-up edge (BUE); it grows up to a certain size but ultimately breaks due to the increased force exerted on it by the adjacent flowing material. After it breaks, the broken fragments adhere to the finished surface and the chip surface results in a rough finish. With a further increase in the cutting speed or when a cutting fluid is used, the built-up edge disappears.

When the machining is performed at a very low speed or the work material is brittle, the shearing operation on the work material does not continue without causing a fracture. The ruptures occur intermittently, producing discontinuous chips. Figure below shows the progress of the formation of discontinuous chips. The resulting surface is rough.

MADE EASY

ESE 2024 : PRELIM EXAM

Online Test Series

TOTAL
34 Tests
Newly Designed
2206 Quality Questions

An early start gives you an extra edge!!

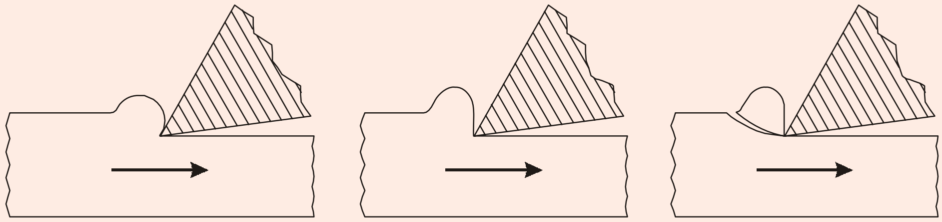
Test series is live.

Scan to enroll

Key Features :

- Newly designed quality questions as per standard of ESE
- Due care taken for accuracy
- Error free comprehensive solutions.
- Comprehensive and detailed analysis report of test performance
- Including tests of Paper-I (General Studies & Engineering Aptitude) and Paper-II (Technical syllabus)
- All India Ranking
- Available on android, iOS (Desktop & Laptop)
- **Streams Offered : CE, ME, EE, E&T**

www.madeeasy.in 9021300500



Formation of discontinuous chips

The conditions for the various types of chips are:

(i) Continuous chips without BUE:

(a) Ductile material

(b) Small uncut thickness

(c) High cutting speed

(d) Large rake angle

(e) Suitable cutting fluid

(ii) Continuous chips with BUE:

(a) Stronger adhesion between chips and tool face

(b) Low rake angle

(c) Large uncut thickness

(iii) Discontinuous chips:

(a) Low cutting speed

(b) Brittle work material

(c) Small rake angle

(d) Large uncut thickness

End of Solution

Q.7 (b) Explain with the working principle a suitable Non-Destructive Testing (NDT) technique to be used for detecting surface as well as fully embedded defects for a wide range of materials including polymers. Also, list the other NDT techniques with reasoning that are not suitable for inspection of above described requirements.

[20 marks : 2023]

Solution:

NDT technique which can be used for detecting surfaces as well as fully embedded defects is ultrasonic testing.

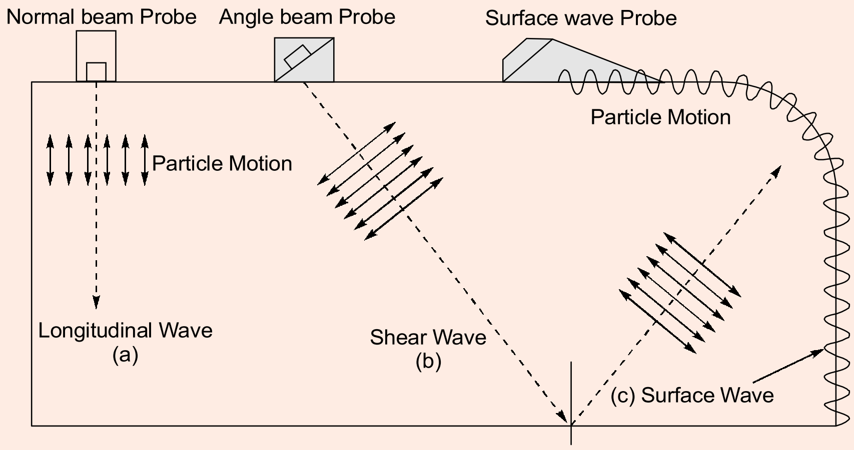
Ultrasonic testing uses high-frequency sound energy to detect defects. Ultrasonic waves in the frequency range from 100 kHz to 50 MHz are used for non-destructive testing and thickness gauging. Ultrasonic waves can transmit through any material, though the transmission characteristics depend on the acoustical impedance of such materials. These ultrasonic waves can propagate through any material as a longitudinal wave, shear wave, surface (Rayleigh) wave, or Plate (Lamb) wave.

A longitudinal wave is a compression wave in which the particle moves in the same direction as the propagation of the wave. A shear wave is a wave motion in which the particle motion is perpendicular to the direction of the propagation.

Shear waves have an elliptical particle motion and travel across the surface of a material. The velocity is approximately 90% of the shear wave velocity of the material type and their depth of penetration is approximately equal to one wavelength.

Plate waves have a complex vibration occurring in materials where thickness is less than the wavelength of ultrasound introduced in it.

Various types of ultrasonic probes are available for such testing. A dual-type transducer uses separate transmitting and receiving elements to create a pseudofocus, which is advantageous for inspecting parts with rough back-wall surfaces. Applications of such probes include remaining wall thickness measurements, corrosion monitoring, and high-temperature applications.



Common ultrasonic probes

Other common NDT techniques are:

1. Visual Inspection Test : It is used for inspection of defects on the surfce only. It is not used for internal defects and embedded defects.
2. Magnetic Particle Test : This test is conducted to check for very small voids and cracks at or just below the surface of a casting of a ferromagnetic material.
3. Dye-Penetrant Inspection : The Dye-Penetrant method is used to detect invisible surface defects in a non-magnetic casting. It is not possible to identify the exact size and shape of the defect.
4. Radiographic examination : The radiograph method is expensive and is used only for subsurface exploration.

End of Solution

Q.7 (c) (i) A 12-bit Analog-to-Digital Converter operating at a sampling rate of 5 kHz is used with a sensor. What is the size of computer memory (in bytes) required to store 20 seconds of sensor data? What will be the memory size in case a 8-bit Analog to Digital Converter is used? Why is it not possible to connect sensors such as accelerometers, strain gauges and thermocouple directly to a microprocessor or computer?

(ii) A CNC machine tool table is powered by a servo motor, lead screw and optical encoder. The lead screw has a pitch of 5 mm and is connected to the motor shaft with a gear ratio of 16 : 1. The optical encoder connected directly to the lead screw generates 200 pulses per revolution of the lead screw. The table moves a distance of 100 mm at a feed rate of 500 mm/min. Determine the pulse count received by the control system to verify that the table has moved exactly 100 mm.

[12+8=20 marks : 2023]

Solution:

(i)

- The most naturally occurring phenomena are analog in nature, which are continuous function, with respect to time. The output of a transducer like thermocouple, strain gauge and accelerometer are in analog form. In order to feed this analog output of transducer to a digital system like microprocessor or a computer, it must be converted into digital form.
- An ADC (Analog to digital converter) is used to convert the analog quantity into digital value based on various types. Before it is converted, it is more important to sample the analog signal at a frequency rate which is atleast twice the frequency of input signal and more than that, so that the original signal can be reconstructed to have minimum error. This approach is known as sampling/Nyquist rate for sampling,

$$\text{Sampling frequency, } f_s \geq 2f_i \text{(input analog frequency)}$$

A sample and hold circuit in required to achieve the sample of input signal such that it is recognized by the ADC to generate the corresponding digital output.

Examples: A 3 bit ADC can have a resolution of $\frac{1}{2^3}$.

$$\text{Number of levels} = 2^n - 1 [\text{i.e. } 0 - (2^3 - 1) \text{ or } 0 - 7]$$

More the number of bits for representing the analog quantity in digital (i.e. binary), more is the resolution.

Examples of ADCs is are (1) Flash type (2) Counting type, (3) Successive approximation register type, (4) Dual storage ADC.

- Quantization and encoding are two important features for an ADC.
- If more bits are used for ADC, then more resolution is obtained and the quantization error in also reduced such that the input signal in encoded to its nearest level.
- On the other hand, if more bits are used for representing a single sample, obviously more memory space in required for storing the sampled data in the computer.

As per given data, a 12 bit ADC operating at sampling rate of 5 kHz requires 5000 samples for second.

For 1 second $\Rightarrow$ 5000 samples

For 20 seconds $\Rightarrow$ 100000 samples i.e. 5000×20

Each sample requires 12 bits.

$\therefore$ For 100000 samples, $12 \times 100000 \Rightarrow 1200000$ bits

$$\text{Number of bytes} = \frac{1200000}{8} = 150000 \text{ bytes}$$

or atleast 256 kB of memory is required

If 8 bits ADC is used,

$$1 \text{ sample} = 8 \text{ bits}$$

100000 samples = 800000 bits or 100000 bytes is required or minimum 128 kB is required.

(ii)

Given : $P = 5$ mm; Gear ratio = 16 : 1

Distance travelled by table for 1 revolution of lead screw = 5 mm

So, number of revolution of lead screw for 100 mm distance travelled by table = $\frac{100}{5} = 20$ revolution

Number of pulses required for 1 revolution of lead screw = 200

So, total number of pulses required for 20 revolution of lead screw = $20 \times 200 = 4000$ pulses

As lead screw is connected to motor shaft then number of revolution turned by motor shaft = $16 \times 20 = 320$ revolution

So, total number of input pulses required = 320×200

$= 64000$ pulses **Ans.**

End of Solution

Q.8 (a) An automatic door is designed to open the door when a person approaches and close automatically after five seconds. The door is operated by an electric motor-based actuator, responsible for sliding the door on rail.

(i) Explain the working mechanism assuming a microprocessor based control using a schematic diagram of the control system used. Also, specify the primary components of the control system.

(ii) If a microcontroller based system is used, what would be the merits and demerits of such system?

[20 marks : 2023]

Solution:

(i)

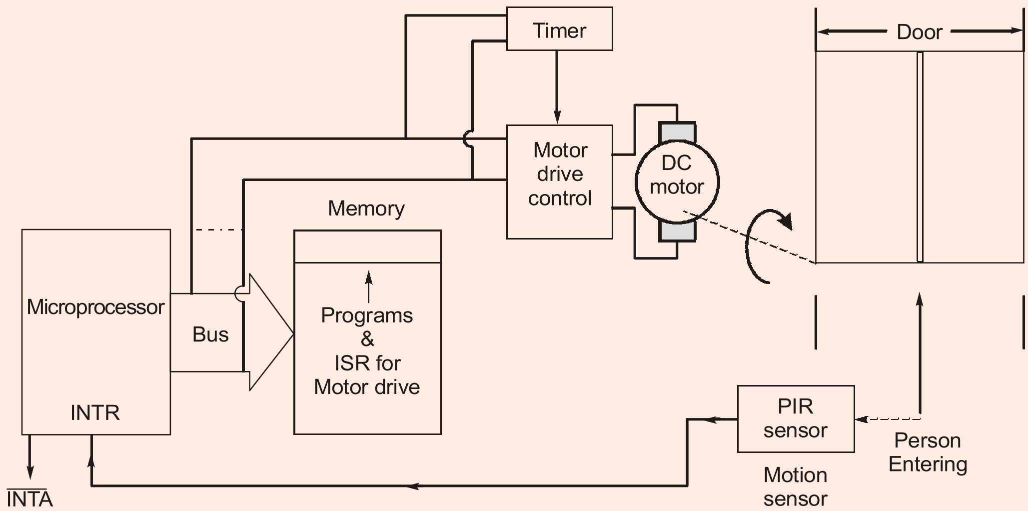
Microprocessor based automatic door opening system using a PIR sensor and DC motor.

Primary components used

1. PIR sensor (Passive Infrared) for motion detection.
2. Driver circulatory for D.C motor to generate the pulses for rotation.

3. D.C. motor to operate the door sliding on rail.
4. Timer IC (optional) for generating a delay and producing an o/p signal after the prescribed time.
5. The door to be opened (process)/controlled system.

A microprocessor (Ex. 8085) to receive the interrupt from the densor.



- Considering open loop control system, the following application in designed:

Operation of the system as per schematic shown.

1. When a person approaches near the door, the PIR sensor captures the motion or senses the motion and rises an o/p which acts like an interrupt to the microprocessor. The sensor is connected to INTR (Interrupt request pin) of microprocessor.
2. The microprocessor always polls (enquires) the INTR pin in every instruction which is known as polling.
3. If an interrupt in recognised or INTR pin, the microprocessor responds with INTA (interrupt acknowledgement) and the corresponding ISR (interrupt service routine) is executed from the memory.
4. ISR (Interrupt service routine)

- To trigger the Drive control mechanism to run the motor for particular direction (i.e. clockwise) to open the door.
- A program to generate a delay of 5 seconds

  or

  To turn on an external timer circuit for 5 seconds delay, which is optional.
- After delay of 5 seconds an other o/p would initiate motor driver circuitary respective pulse for anticlockwise rotation to close the door.
- The sensitivity of the PIR sensor can be set by varrying the potentiometer sensor itself.
- By using the microprocessor based system more hardware logic is required as memory and timer circuits are outside the processor.

MADE EASY

GATE 2024 ONLINE TEST SERIES

Streams:
CE, ME, EE, EC, CS, IN, PI, CH

Tests are live

Quality Questions — Throughly researched, quality questions as per standard & orientation of GATE consisting MCQs, NATs & MSQs

GATE Interface — Test series interface is exactly similar to actual GATE

Anywhere, Anytime — Facility to appear in test anywhere & anytime (24 x 7)

Video Solution — Get video solutions by senior faculties for proper understanding of concepts

Ask an Expert — Ask your doubt to our experts, Get answer of your queries on chat window

Step by Step Solutions — Detailed, step by step and well illustrated solutions, For user's better understanding

Smart Report — Comprehensive and detailed analysis of test-wise performance. Evaluate yourself and get All India Rank

Virtual Calculator Embedded — Make yourself conversant in use of embedded virtual calculator

Available on android, iOS (Desktop & Laptop)

48 TESTS
1584 + Newly Designed Questions

Scan to enroll

Queries : 9021300500 | queryots@madeeasy.in | Enroll now www.madeeasy.in

(ii)

By using the microcontroller based system for the same application following merits and demerits are noted.

Merits:

1. The hardware logic (circuitary required is reduced as the microcontroller e.g. 8051 of Intel) would have built in timer (16 bit) for generating delay.
2. Flexibility is obtained as microcontroller has many parts like 32 I/O pins w,r,t, 8051 which can be programmed as I/P or O/P.
3. In some microcontrollers the PWM (Pulse Width Modulation) pulses for controlling the motor can be directly generated there by avoiding additional circuitary.
4. Memory is an inbuilt part of controller so delay in operation in reduced.
5. Cost is reduced due to less hardware and system becomes more compact.
6. System can be more reliable as less hardware is affected by external noise.
7. Low power consumption due to less hardware.

Demerits:

1. If more memory space is required for the applications, then external memory can be connected, which would resemble like a lap circulatory.
2. Few interupts would be possible as compared to microprocessor.

End of Solution

Q.8 (b) (i) It is desired to measure the angular position of a motor shaft with a set-up using two Hall Sensors A and B and a permanent magnet muti-pole wheel. Explain the logic that is used for measuring the position as well as direction of the motor shaft based on states of output signals from Hall Sensors A and B.

(ii) With the help of a schematic diagram, explain the working principle of a resolver. How does the output for resolver differ from that of an encoder?

[10+10=20 marks : 2023]

Solution:

(i)

The principle of hall-effect is when a conductor or semiconductor with current flowing in one direction when introduced perpendicular to a magnetic field a voltage could be measured at right angles to the current path. This same principle allows for accurate angle measurement and to develop a complete hall sensor and magnet-based system. Based on the degree range and resolution needed, one or more linear hall sensors can be used for angular measurement.

The linear hall effect sensor measures the magnetic flux density vector component and output a linearly proportional signal. As the magnet in figure (a) rotates, it produces a sinusoidal variation in magnetic flux density at every point in space around it, in 2 or 3 of the axes. Therefore, a linear Hall sensor that is placed nearby will produce a sine wave output as the magnet turns.

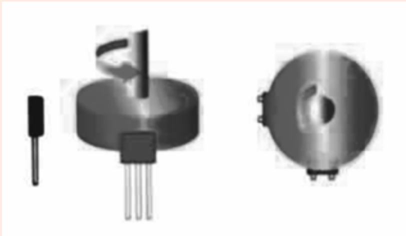


Fig (a) : Proposed system

The complete 360° rotation can be recorded when two linear hall sensor are used with a 90° phase offset to produce sine and cosine waveforms, as shown in figure (b).

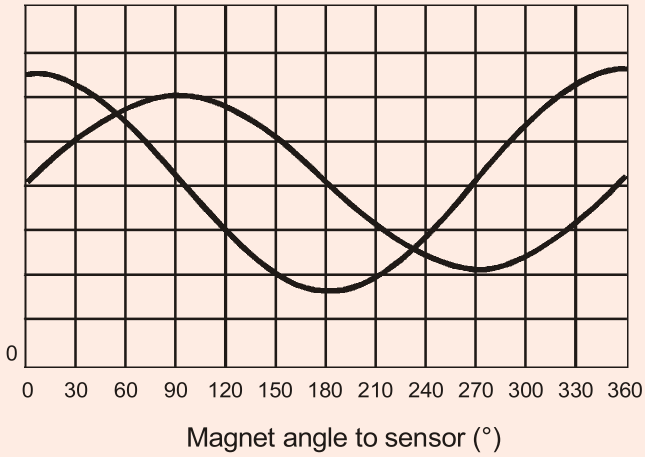


Fig (b) : Phase shifted sinusoidal output of the sensors

The sensors are orthogonally placed to measure the X-axis and Y-axis directions of the rotating magnetic field. The projections of the external magnetic field give the sine and cosine of the rotation angle. The angular position information (i.e., α) is extracted from those two signals using Arduino Uno microcontroller.

The stepper motor here acts as a reference system. The stepper motor rotates proportional to the number of pulses and the speed of rotation is relative to the frequency of those pulses. The step of stepper motor used in this system corresponds to 0.8°. The rotating magnetic system is mounted through an acrylic sheet on the motor which provides the base for electronics and also calibration.

(ii)

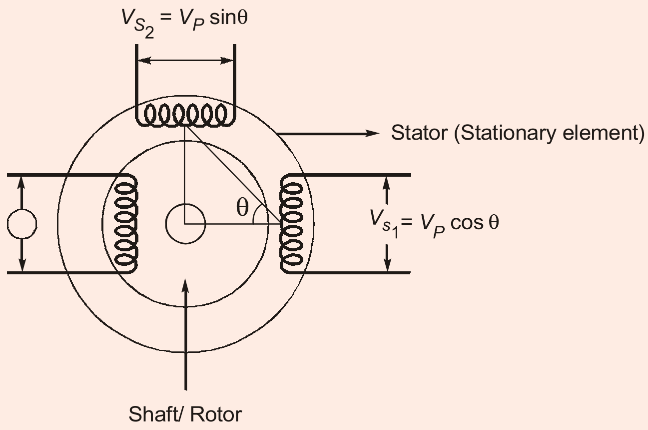
Optical Resolver

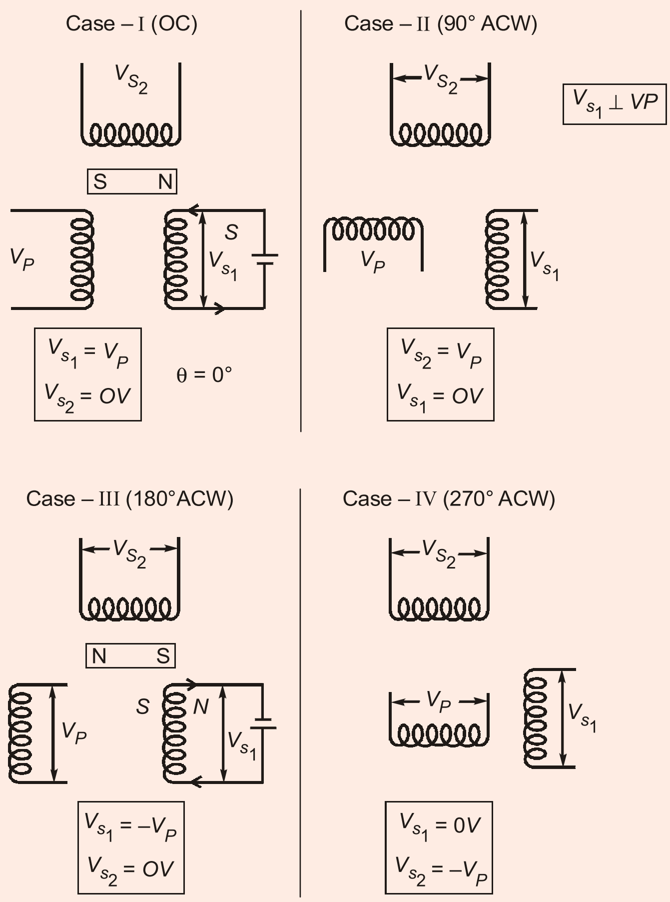
- This is the best angular measuring device.
- You can measure even parts of rotation with accuracy and precision.
- It is an analog sensor i.e. we have to use an ADC.

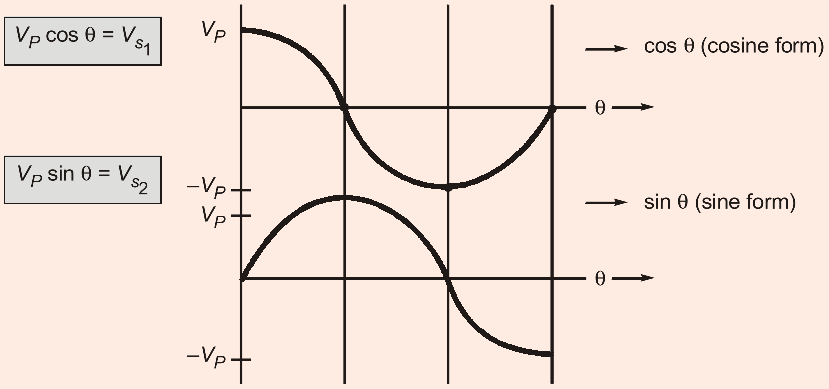
1. It works on the principle of EMI and mutual inductance.
2. It has 1 Primary coil & 2 Secondary coils.

$$\frac{V_{s_1}}{N_{s_1}} = \frac{V_p}{N_p}$$

If
$$N_{s_1} = N_p$$
$$V_{s_1} = V_p$$
$$V_{s_2} = 0 \text{ (Due to no magnetic field)}$$







End of Solution

Q.8 (c) What are the fundamental arm architecture of a basic robot arm on the basis of geometric work envelope? How can these fundamental arm architecture be derived from one another? What arm configurations do Gantry and SCARA robots correspond to? Also, show the geometric work envelope and arm configuration of Gantry and SCARA robots with a suitable figure.

[20 marks : 2023]

Solution:

The four basic configurations are:

(i) Cartesian (rectangular) configuration - all three *P* joints.
(ii) Cylindrical configuration - one *R* and two *P* joints.
(iii) Polar (spherical) configuration - two *R* and one *P* joint.
(iv) Articulated (Revolute or Jointed-arm) configuration - all three *R* joints.

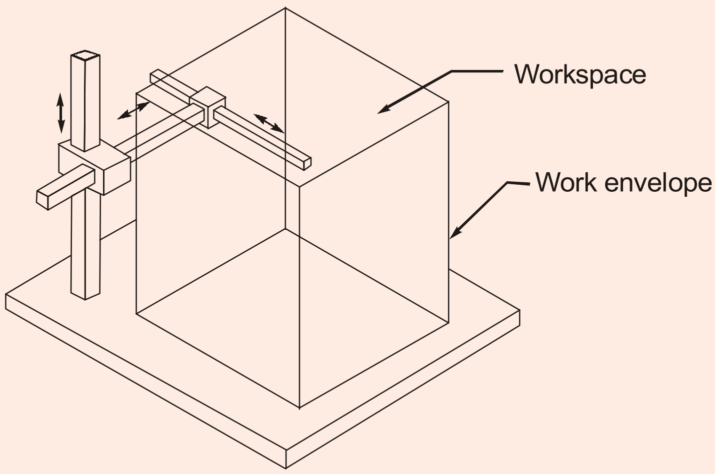


Fig: A 3-DOF Cartesian arm configuration and its workspace

The workspace of Cartesian configuration is cuboidal and is shown in above figure. Two types of constructions are possible for Cartesian arm: a Cantilevered Cartesian, as shown above, and a Gantry or box Cartesian. The latter one has the appearance of a gantry-type crane and is shown below. Despite the fact that Cartesian arm gives high precision and is easy to program, it is not preferred for many applications due to limited manipulatability [Gantry configuration is used when heavy loads must be precisely moved. The Cartesian configuration gives large work volume but has a low dexterity.]

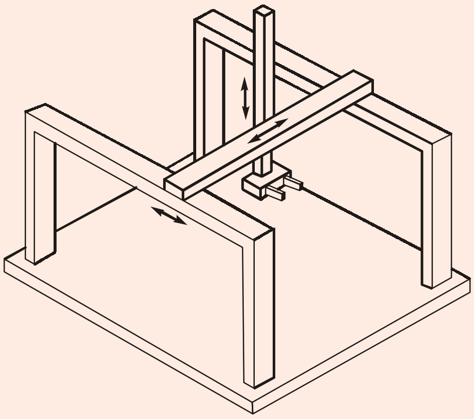


Figure: Gantry or box configuration Cartesian manipulator

The SCARA configuration has vertical major axis rotations such that gravitational load, Coriolis, and centrifugal force do not stress the structure as much as they would if the axes were horizontal. This advantage is very important at high speeds and high precision. This configuration provides high stiffness to the arm in the vertical direction, and high compliance in the horizontal plane, thus making SCARA congenial for many assembly tasks. The SCARA configuration and its workspace are presented pictorially in figure below.

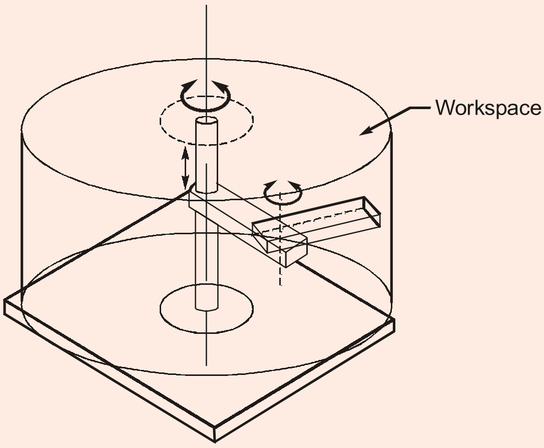


Figure: The SCARA configuration and its workspace

End of Solution

NEXT IAS

BIG LEARNINGS MADE EASY

Learn from India's top faculties

General Studies

Foundation Course for CSE

OFFLINE & LIVE-ONLINE | 1 YEAR & 2 YEARS COURSES

- Comprehensive coverage of both Prelims & Mains syllabus
- Current based teaching curriculum as per latest UPSC Exam Pattern
- Systematic subject sequence & well-framed modules
- Academic Coach for personal mentorship
- Weekly classes for Current Affairs and newspaper analysis
- Provision of additional online lectures for backup & revision
- Latest, updated and well-researched study material
- Performance assessment by mandatory weekly class tests
- Online and Offline All India Test Series for Prelims & Mains

DELHI OFFLINE BATCHES

LIVE-ONLINE BATCHES

BHOPAL OFFLINE BATCHES

Scan to Enroll

Optional

Foundation Course

- **ECONOMICS** by VIBHAS JHA SIR
- **GEOGRAPHY** by ALOK RANJAN SIR
- **HISTORY** by HEMANT JHA SIR
- **PSIR** by PIYUSH CHAUBEY SIR
- **SOCIOLOGY** by RAJ RAI SIR
- **ANTHROPOLOGY** by SUDHIR KUMAR SIR
- **MATHEMATICS** by AVINASH SINGH SIR

Scan to Enroll

Delhi Centre :
27-B, Pusa Road, Metro Pillar No. 118,
Near Karol Bagh Metro, New Delhi-110060
8081300200

www.nextias.com

Bhopal Centre :
Plot No. 46, ZONE - 2,
M.P. Nagar, Bhopal - 462011
8827664612