AKTU

B. Tech I-Year

Gateway Classes

Semester -I & II

Common to All Branches

Fundamentals of Mech. Engg.(BME101/201)

Unit-1 : ONE SHOT- Introduction to Mechanics

Gateway Series for Engineering

- Topic Wise Entire Syllabus
- Long - Short Questions Covered
- AKTU PYQs Covered
- DPP
- Result Oriented Content

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AKTU

B. Tech I-Year

Gateway Classes

GATEWAY CLASSES

Fundamentals of Mech. Engg.(BME101/201)

Unit-1
Introduction to Mechanics

Syallbus

Force moment and couple, principle of transmissibility, Varignon's theorem. Resultant of force system- concurrent and non-concurrent coplanar forces, Types of supports (Hinge, Roller) and loads (Point, UDL, UVL), free body diagram, equilibrium equations and Support Reactions.

Normal and shear Stress, strain, Hookes' law, Poisson's ratio, elastic constants and their relationship, stress-strain diagram for ductile and brittle materials, factor of safety.

AKTU B.TECH I-YEAR FME

FUND. OF MECHANICAL ENGG.

COMPLETE REVISION + NOTES

UNIT-1 MECHANICS

QUESTIONS तो यहीं से आएंगे !

LIVE 18 MARCH 9 PM

BY M S TOMER SIR

AKTU : B.Tech. II SEMESTER

GATEWAY CLASSES

Sem-II

Session: 2023-24

Subjects	
Maths-II	COMBO PACK
PPS/FME	
Electrical / Electronics	
Physics / Chemistry	
Soft Skills / Environment	

Courses will be available 22 March 2024

FUNDAMENTALS OF MECHANICAL ENGINEERING (FME)

UNIT-1 : Introduction to Mechanics

Th + D + Num

AKTU : Syllabus

AKTU

- Force, moment and couple, principle of transmissibility, Varignon's theorem.
- Resultant of force system- concurrent and non-concurrent coplanar forces
- Types of supports (Hinge, Roller) and loads (Point, UDL, UVL), M
- Free body diagram, equilibrium equations and Support Reactions.

W/E/G/K

- Normal and shear Stress, strain, Hookes' law
- Poisson's ratio, elastic constants and their relationship
- Stress-strain diagram for ductile and brittle materials, factor of safety.

Force

Force is an external agent which tends to change the speed or direction of a system.

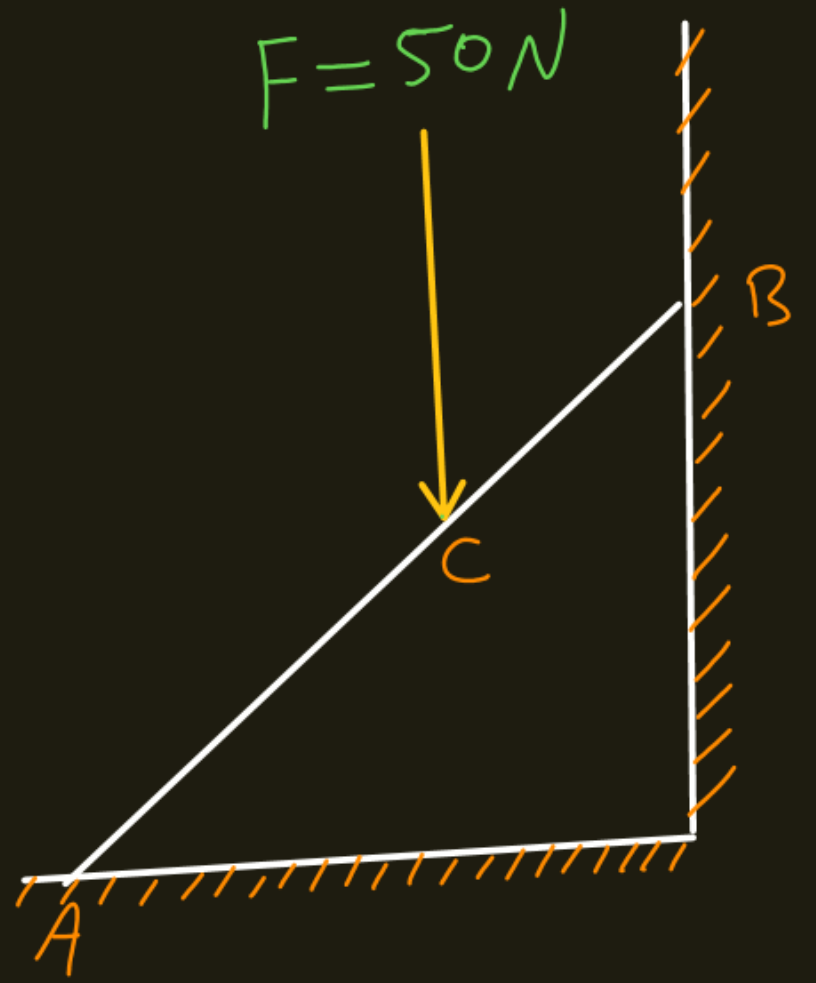
A force on a rigid body may produce the following following effects:

- Change its state of rest or motion
- Accelerate or retard its motion
- Change its shape and size
- Keep it in equilibrium.

Force

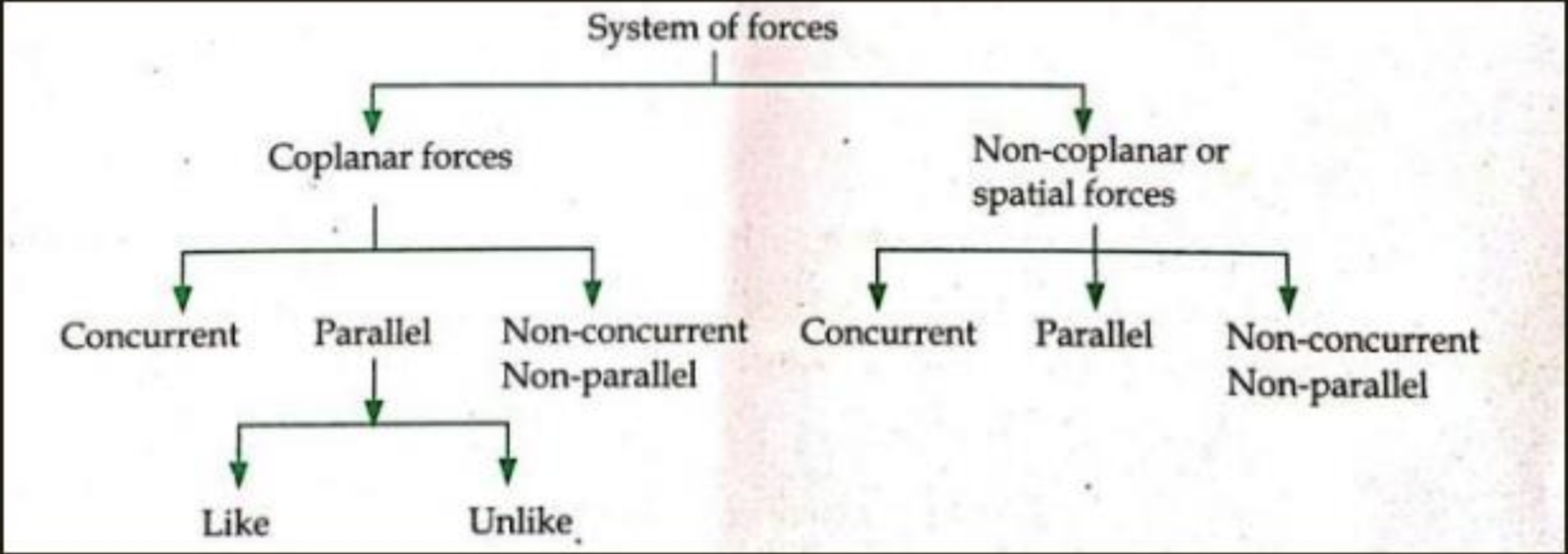
Force is a vector quantity determined completely by its

- Magnitude ⟶ 50 N
- Point of application ⟶ 'C'
- Line of action (Vertical)
- Direction (Downward)



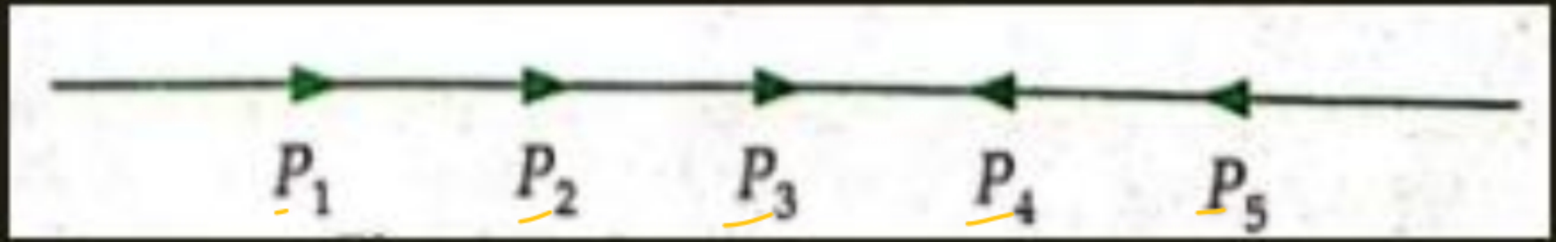
Force System

When several forces of different magnitude and direction act upon a body, they constitute a force system.

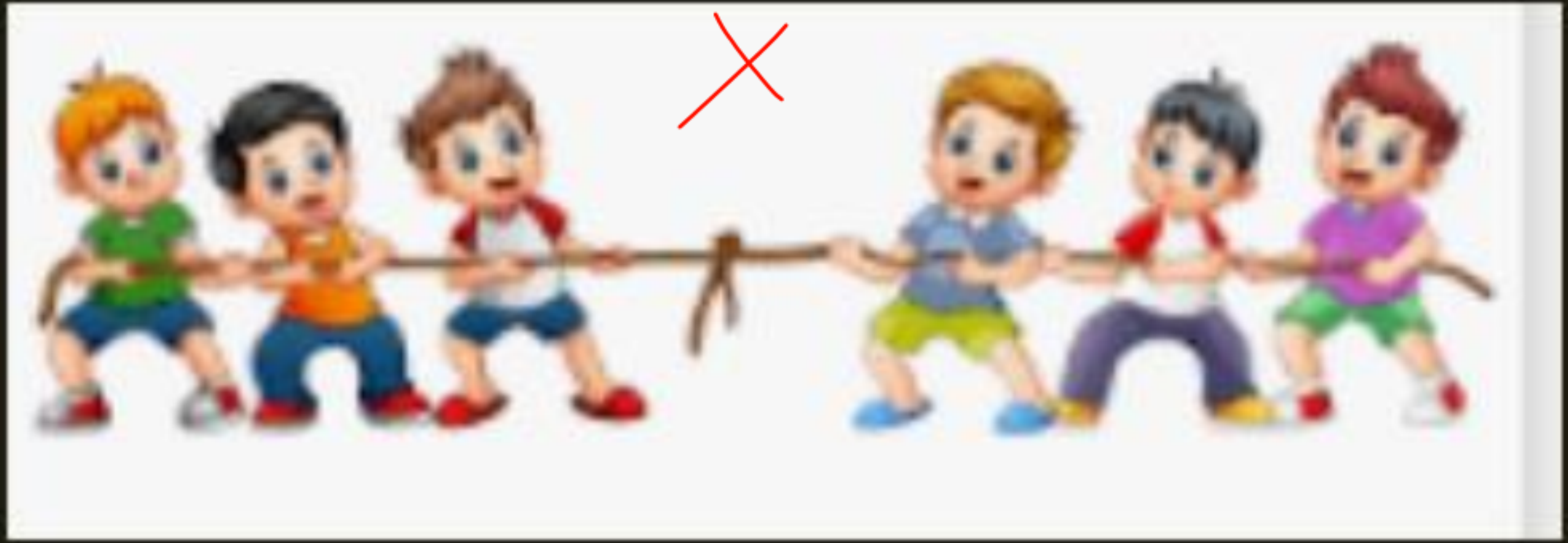


Force System

Collinear forces : The lines of action of all forces lie along the same straight line and in the same plane.

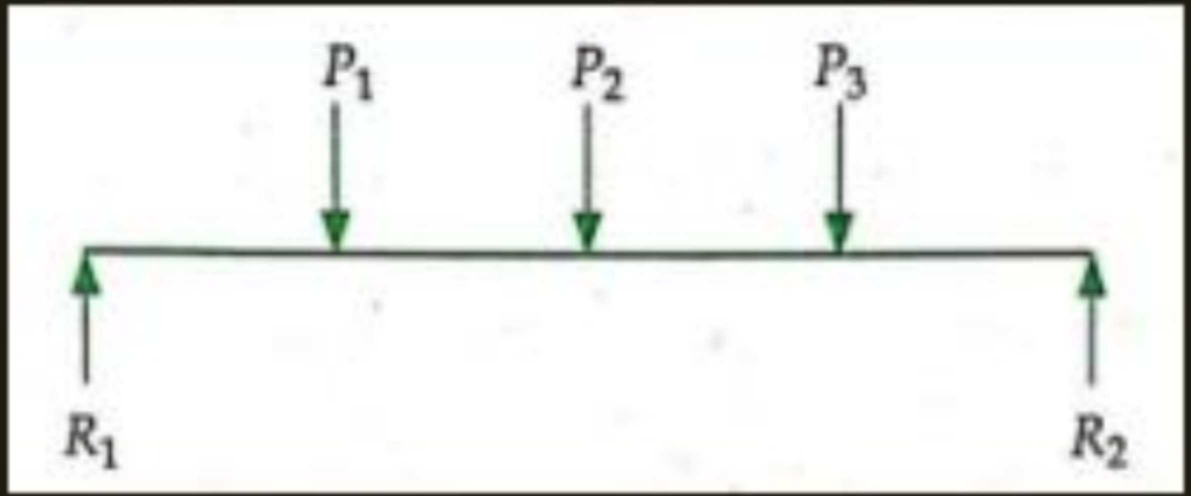


Example: Force on a rope in a tug of war.

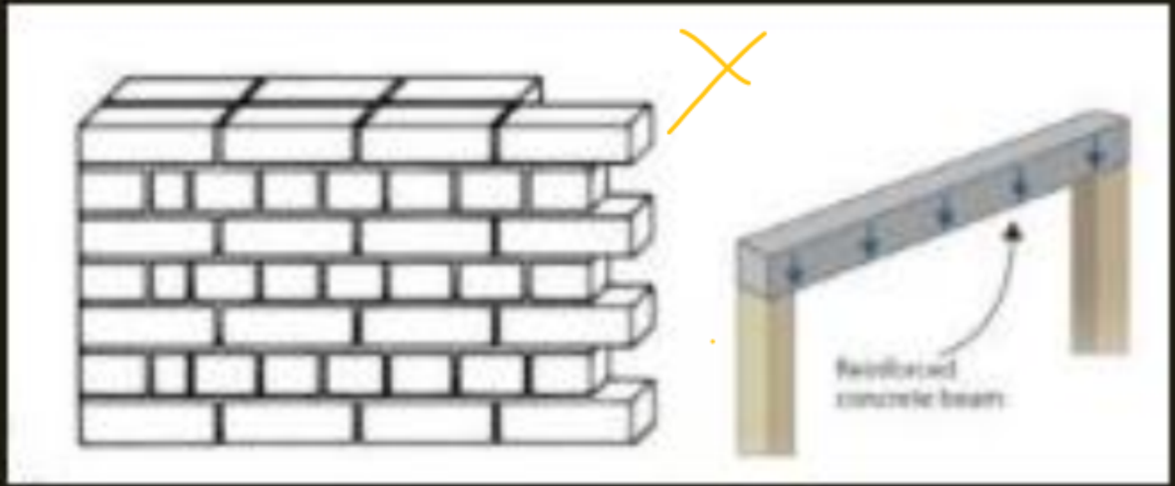


Force System

Coplanar parallel forces : The lines of action of all forces are parallel to each other and lie in a single plane.



Example: System of vertical loads acting on a beam

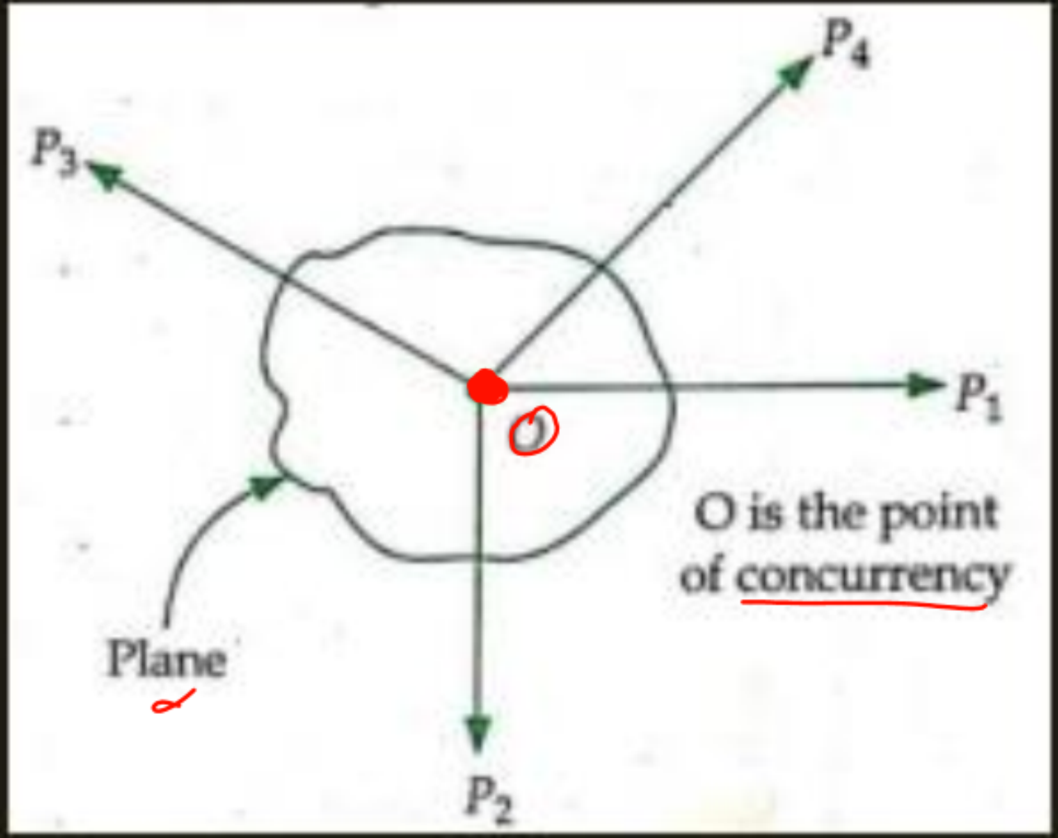


Force System

Coplanar concurrent forces : All forces lie in the **same plane**, have **different direction** but their lines of action act at one point (**pass through a single point**).

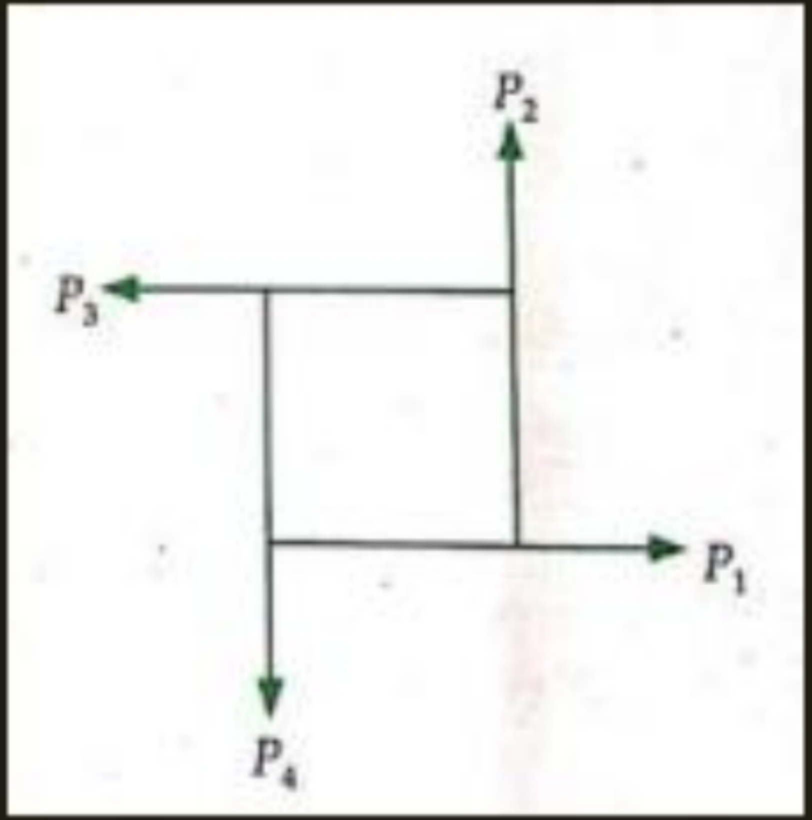
The point where the lines of action of the forces meet is known as the **point of concurrency** of the system.

Example: Forces on a rod resting against a wall.



Force System

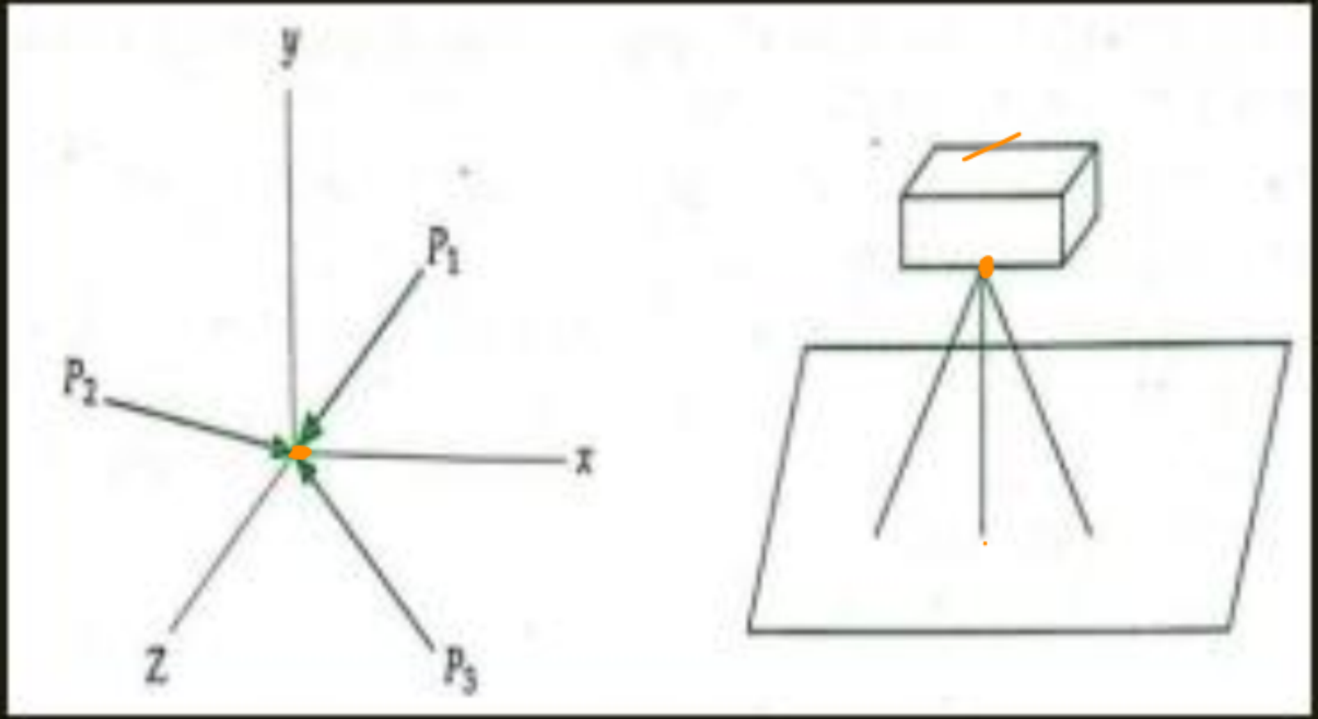
Coplanar non-concurrent forces : All forces lie in the same plane, but their lines of action do not pass through a single point.



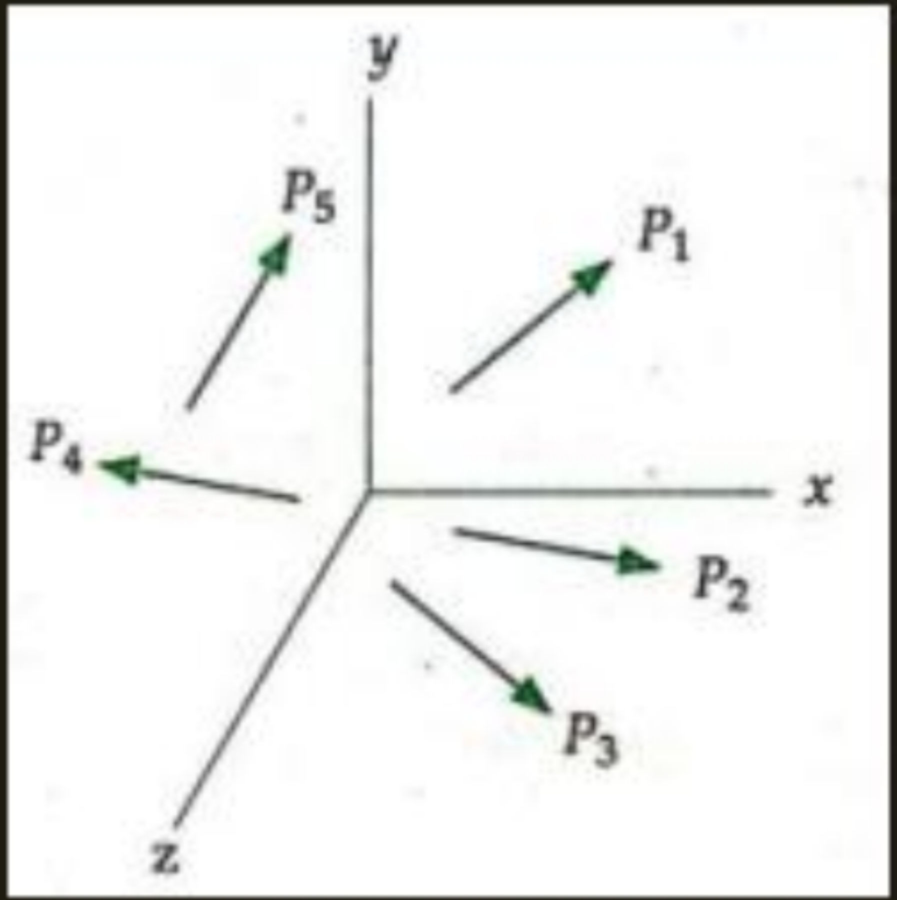
Example: Forces on a ladder resting against a wall and a person standing on a rung which is not at its centre of gravity.

Non-Coplanar concurrent forces : All forces do not lie in the same plane, but their lines of action pass through a single point.

Example: Forces on a tripod carrying a camera



Non-Coplanar non-concurrent forces : All forces do not lie in the same plane, and their lines of action do not meet at a single point.



Example: Forces acting on a moving bus.

Force System

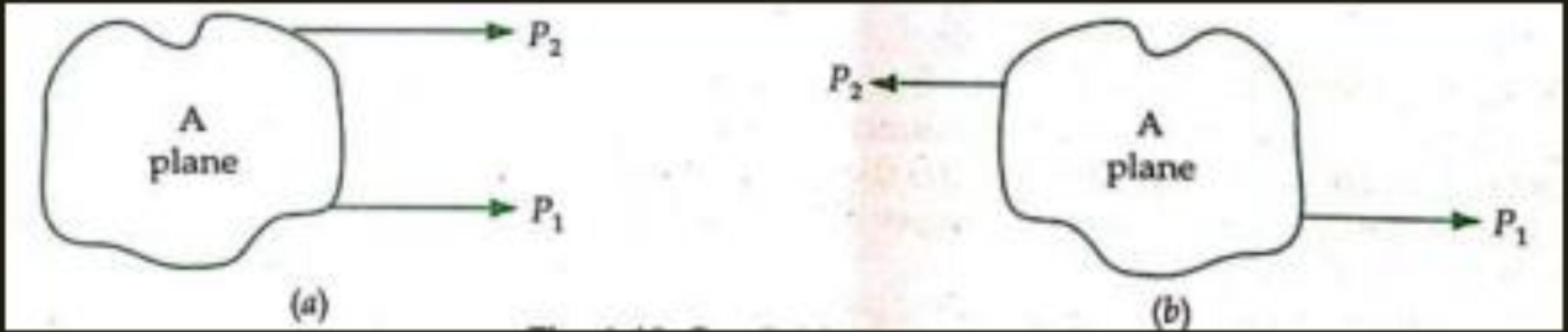
Coplanar like and unlike parallel force system:

- Same plane
- Lines of action parallel to each other

Further

(i) The system is called coplanar like parallel force system if the forces are in the same direction.

(ii) The system is called coplanar unlike parallel force system if the forces are in the opposite direction.



Moment of Force

The moment of a force about a point is the product of magnitude of the force and the perpendicular distance from the line of action of the force from the same point.

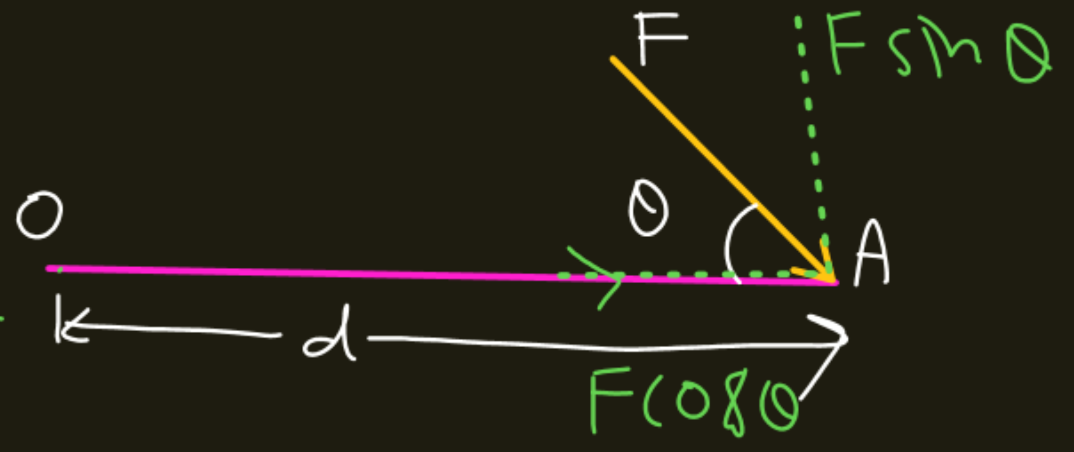
$$\boxed{M_O = F \times d}$$

$$M_O = F \times 0$$

$$\boxed{M_O = 0}$$

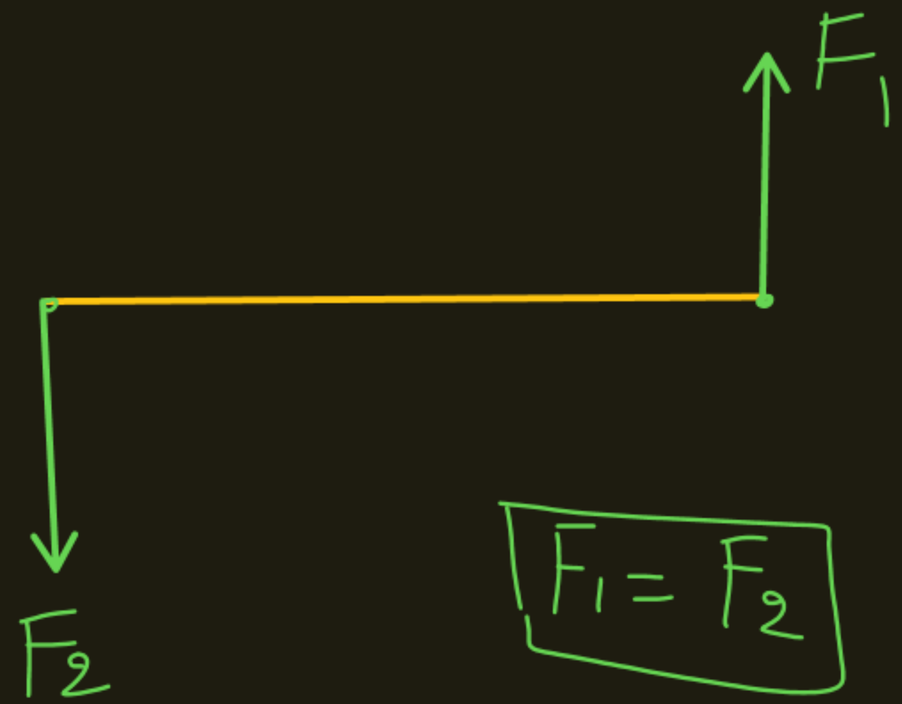
$$M_O = F\sin\theta \times d + F\cos\theta \times 0$$

$$\boxed{M_O = Fd\sin\theta}$$



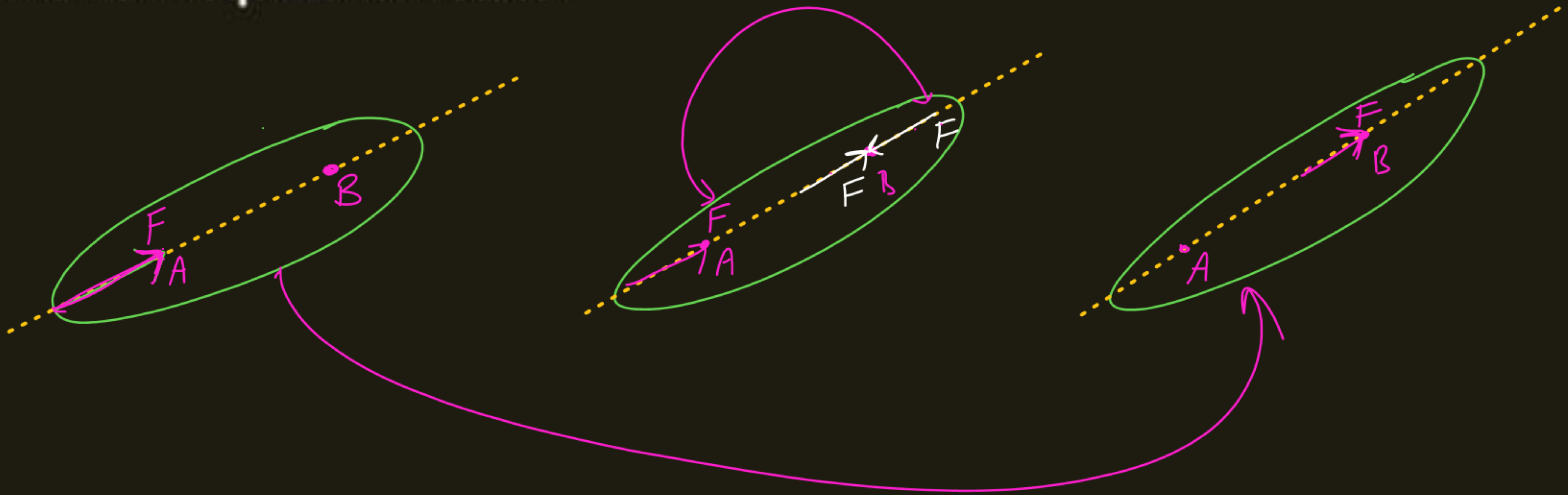
Couple

When two equal and opposite forces are applied simultaneously at different points on a body, their resultant force is zero, but both these equal and opposite forces try to rotate the body in the same direction. These two forces formed a Couple.



Principle of transmissibility of forces : AKTU-2022-23 (Odd Even)

It states that the point of application of a force may be shifted to any other point, along the line of action and in the same direction, body will remains in equilibrium state.



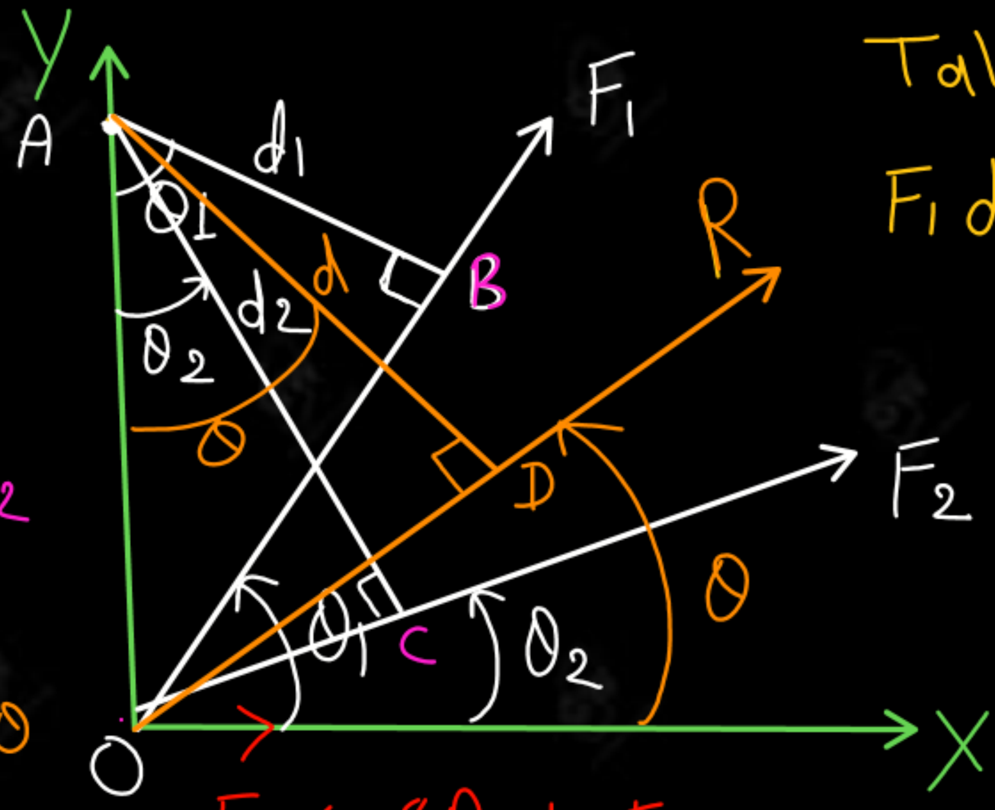
Topic : Complex Matrices

Q .1.1 **Explain the principle of transmissibility of force.** 2 marks AKTU-2022-23 (Odd Even)

Varignon's Theorem

If many coplanar forces are acting on a body, then algebraic sum of moments of all the forces about a point in the plane of the forces is equal to the moment of their resultant about the same point.

Proof: Let us consider two forces F_1 & F_2 acting on a body as shown in fig



$\triangle OBA$

$\cos\theta_1 = \frac{d_1}{OA} \Rightarrow d_1 = OA\cos\theta_1$

$\triangle OCA$

$\cos\theta_2 = \frac{d_2}{OA} \Rightarrow d_2 = OA\cos\theta_2$

$\triangle ODA$

$\cos\theta = \frac{d}{OA} \Rightarrow d = OA\cos\theta$

Taking moment of F_1, F_2 about 'A'

$F_1 d_1 = F_1\, OA\cos\theta_1$ ---- (I)

$F_2 d_2 = F_2\, OA\cos\theta_2$ ---- (II)

$R \rightarrow$ Resultant of F_1, F_2

$R \cdot d = R \cdot OA\cos\theta$ ---- (III)

$F_1\cos\theta_1 + F_2\cos\theta_2 = R\cdot\cos\theta$

$$F_1 d_1 + F_2 d_2 = F_1 \, OA \cos\theta_1 + F_2 \, OA \cos\theta_2$$

$$F_1 d_1 + F_2 d_2 = OA \left(F_1 \cos\theta_1 + F_2 \cos\theta_2 \right)$$

$$F_1 d_1 + F_2 d_2 = OA \; R \cos\theta \text{ ---- (IV)}$$

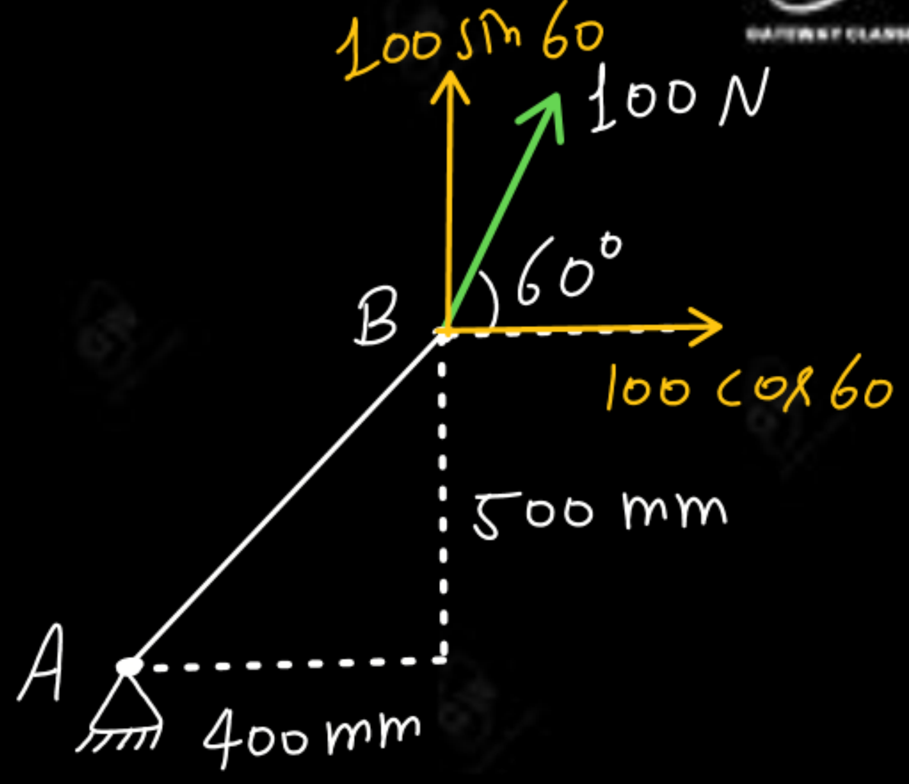
from Eq^n (III) & (IV)

$$\boxed{F_1 d_1 + F_2 d_2 = R \cdot d}$$

For 'n' no. of forces

$$\boxed{F_1 d_1 + F_2 d_2 + F_3 d_3 + \text{----} F_n d_n = R \cdot d}$$

Q.1 Find the moment of 100 N force acting at B about point A, as shown in fig. [AKTU] 2022-23



$$M_A = 100\cos 60 \times 500 - 100\sin 60 \times 400$$

$$M_A = -9641 \text{ N.mm}$$

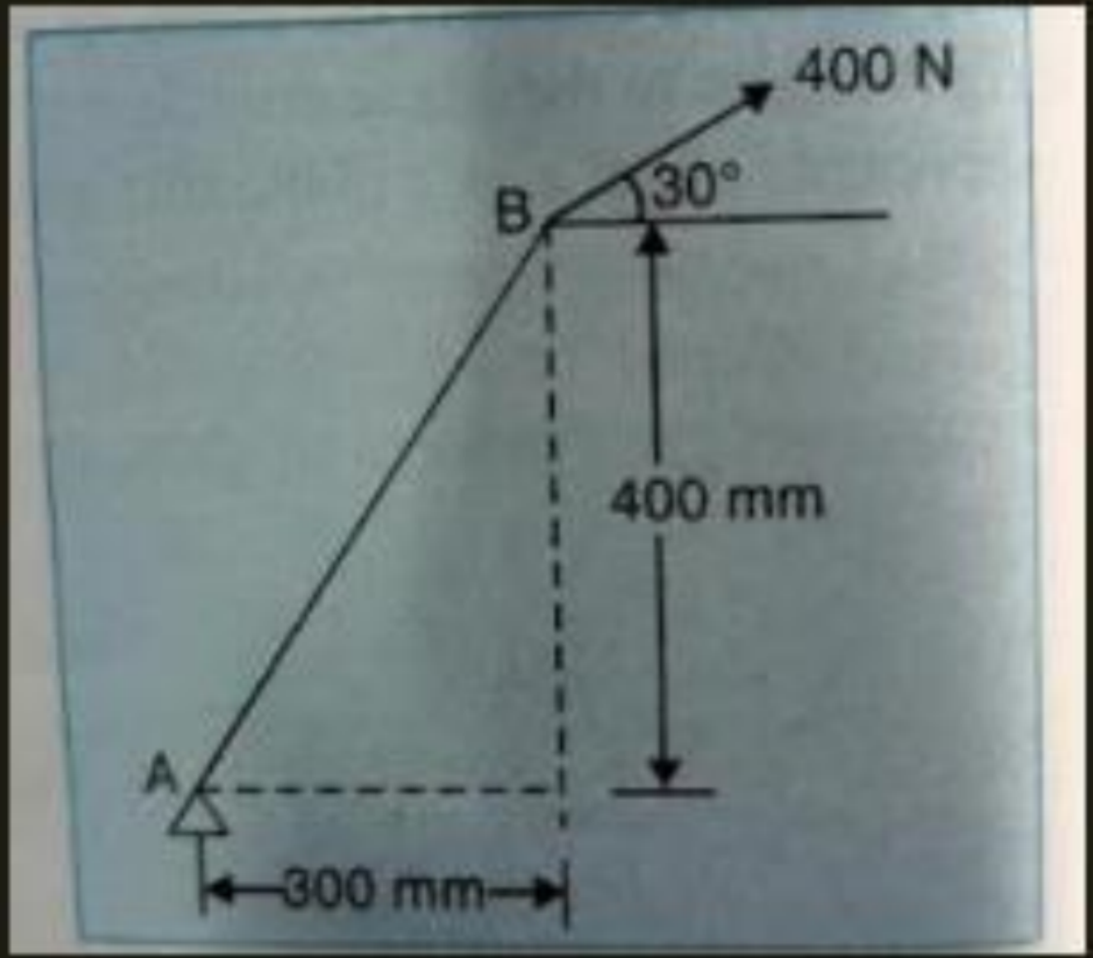
$$M_A = 9641 \text{ N.mm} \; [A.C]$$

FUNDAMENTALS OF MECHANICAL ENGINEERING

DPP

Topic : Varignon's Theorem

Q .1 Determine the moment of 400 N force acting at B in x-y plane about point A, as shown in fig.



Ans. 78564 N-mm, Clockwise moment

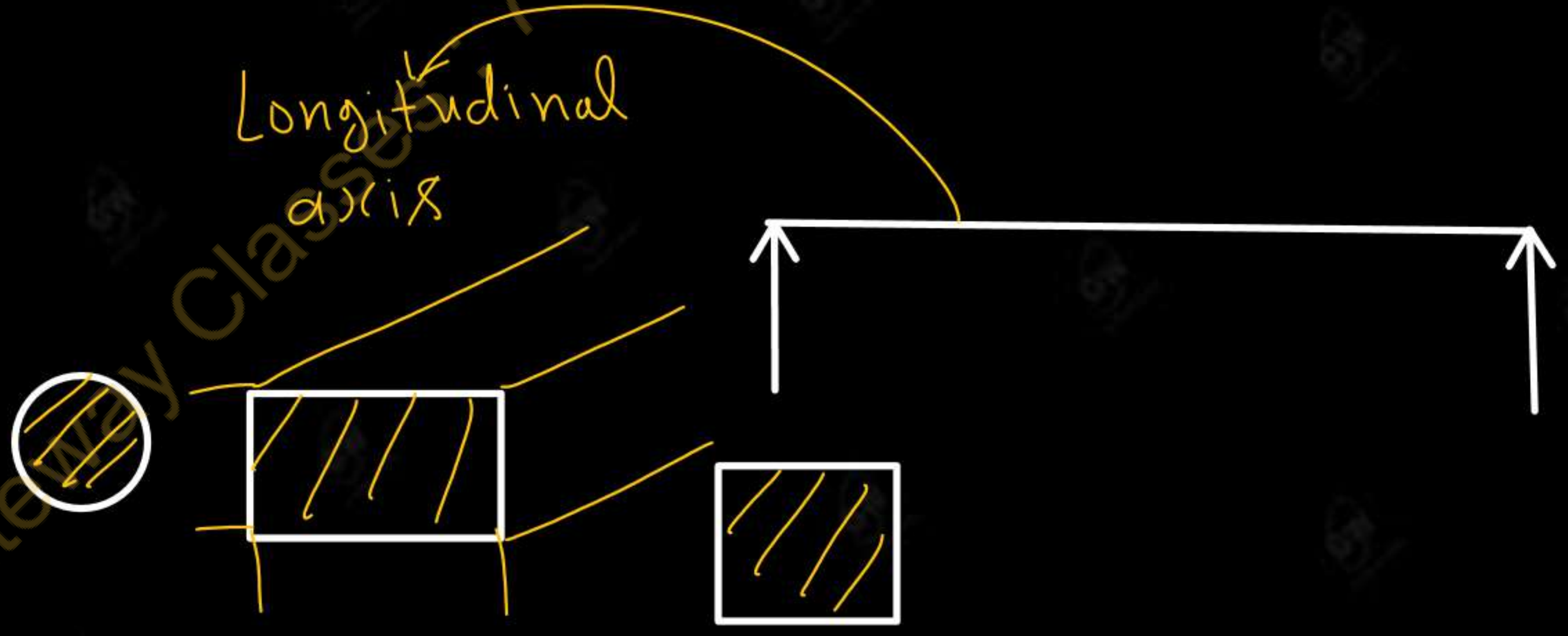
Beam

Beam is defined as a structural member whose one dimension is very large as compare other lateral dimensions.

↳ Transverse (⊥ar)

or

Beam can be defined as a structural member which is subjected to shear forces.

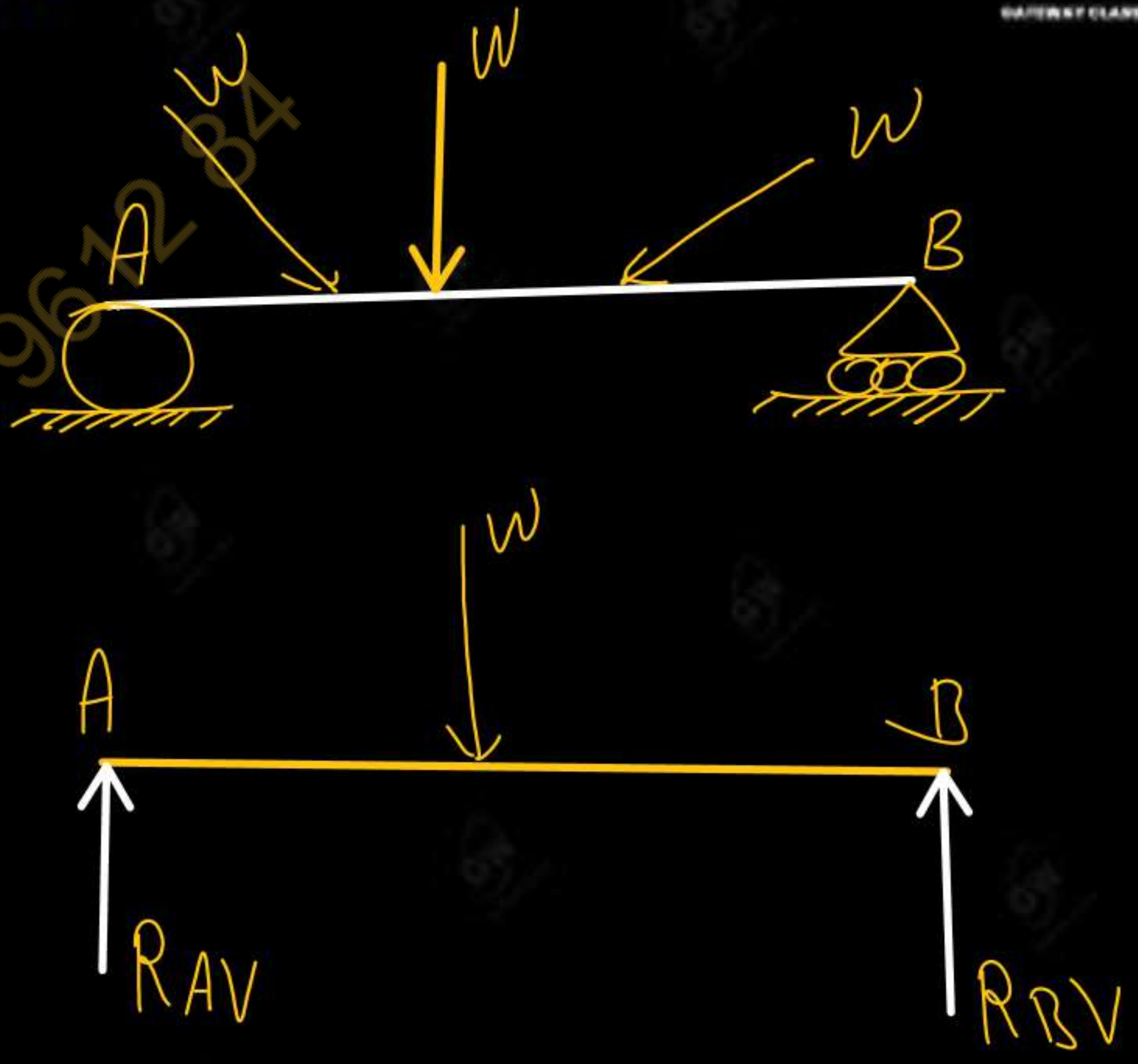


Types of Supports

1. Roller support
2. Hinge(Pin) Support
3. Fixed (Built-in) Support

1. Roller support

- Axial motion is permitted ✓
- Rotation is permitted ✓
- Only vertical motion is restricted
- No of reaction = 1, R_V

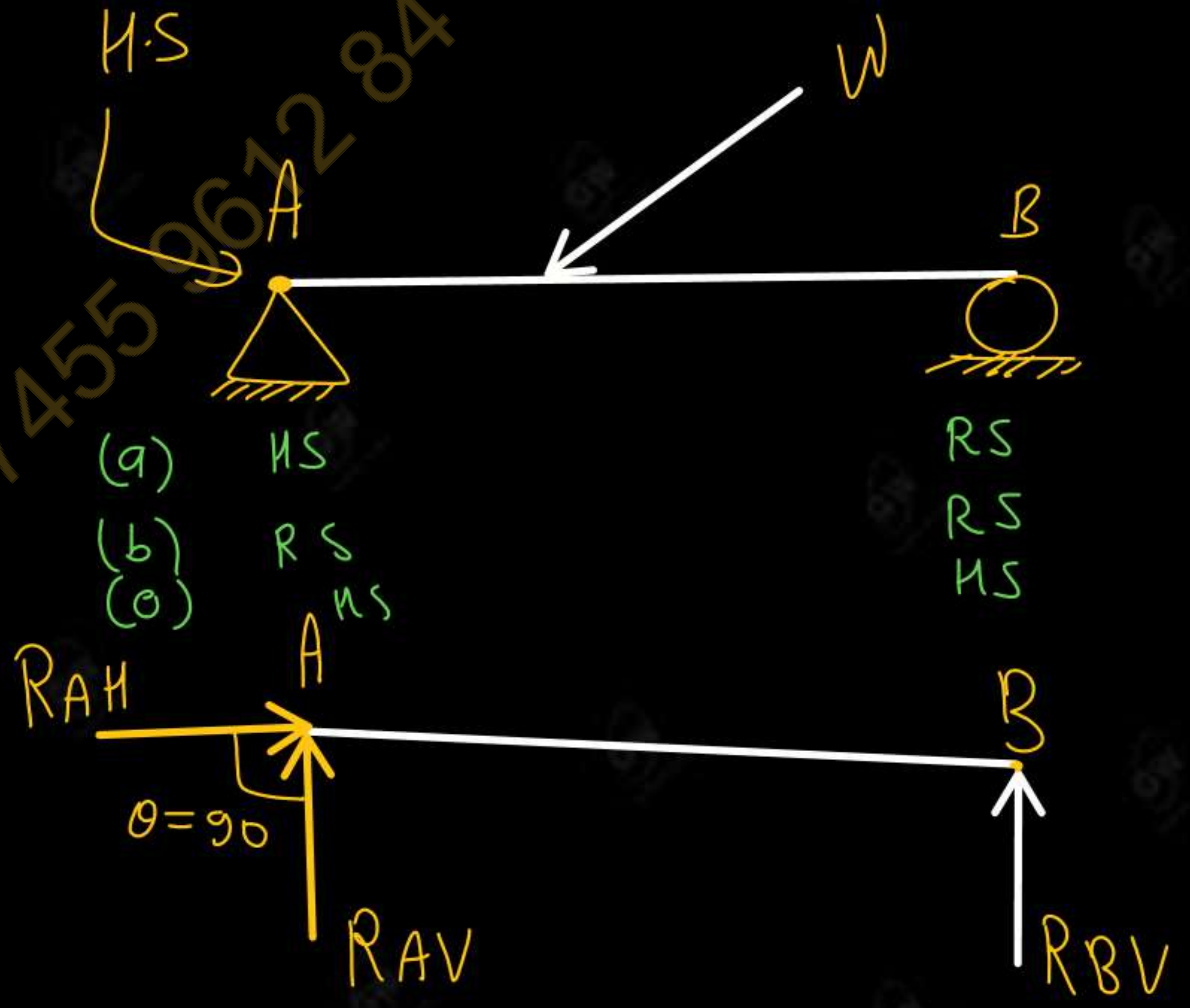


2. Pin(Hinged) support

- Vertical motion is restricted ✓
- Axial motion is restricted ✓
- Rotation is permitted
- No of reaction = 2, R_{AV} and R_{AH}

$$R_A = \sqrt{(R_{AH})^2 + (R_{AV})^2}$$

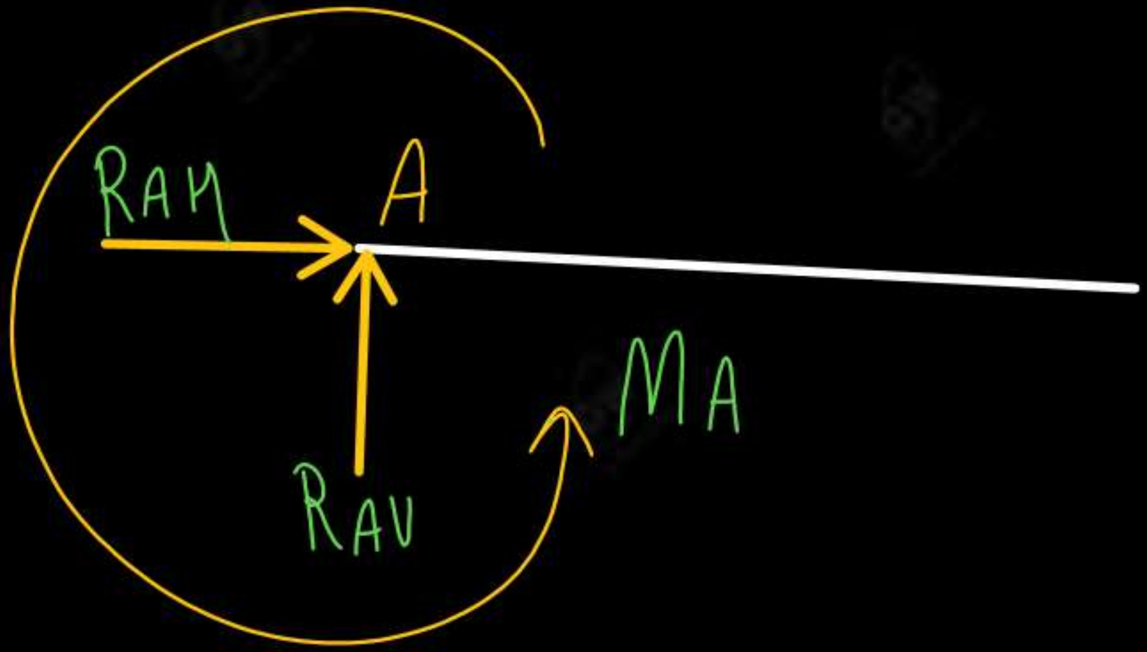
$$\alpha = \tan^{-1}\left(\frac{R_{AV}}{R_{AH}}\right)$$



3. Fixed support (Built-in)

- Vertical motion is restricted.
- Axial motion is restricted.
- Rotation is restricted.
- No of reaction = 3,
- R_{AV}, R_{AH} and M_z

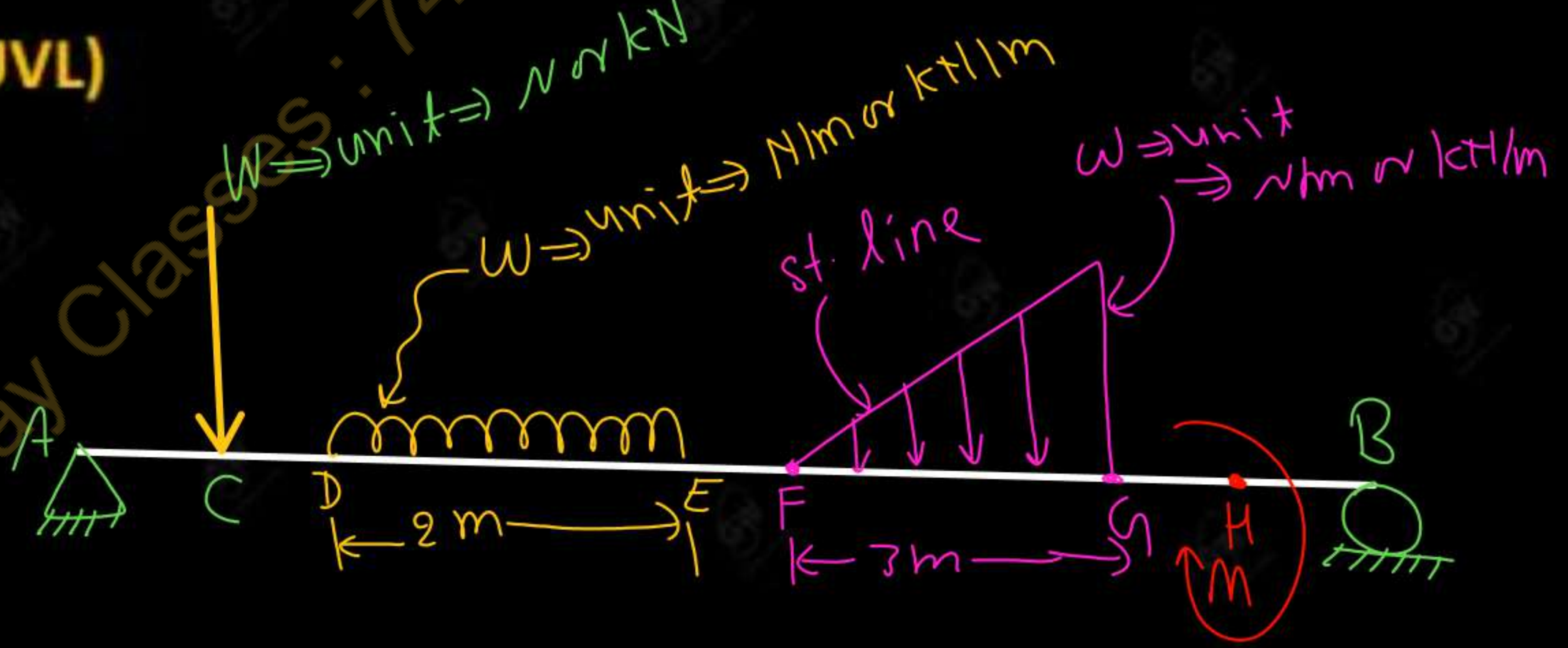
No. of Reactions = No. of motion Restricted



Type of Load subjected to beam

Following are the types of load which are subjected to a beam

1. Concentrated load(Point Load)
2. Uniformly Distributed load(UDL)
3. Uniformly Varying load(UVL)
4. External Moment (M)

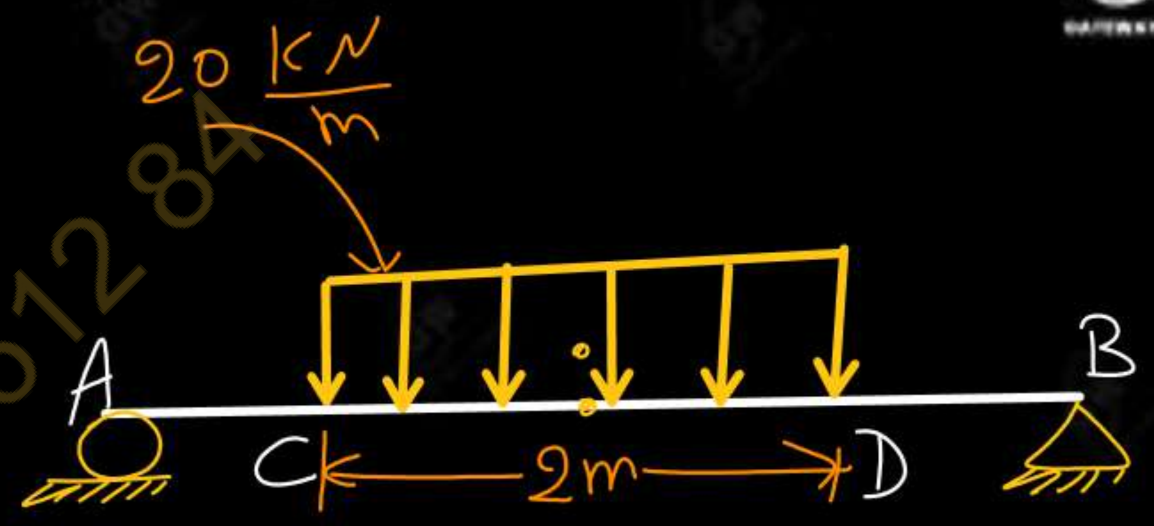


1. Concentrated load(Point load)

- This load acts at a point.
- It is represented by an arrow as shown in Fig.

2. Uniformly Distributed load(UDL)

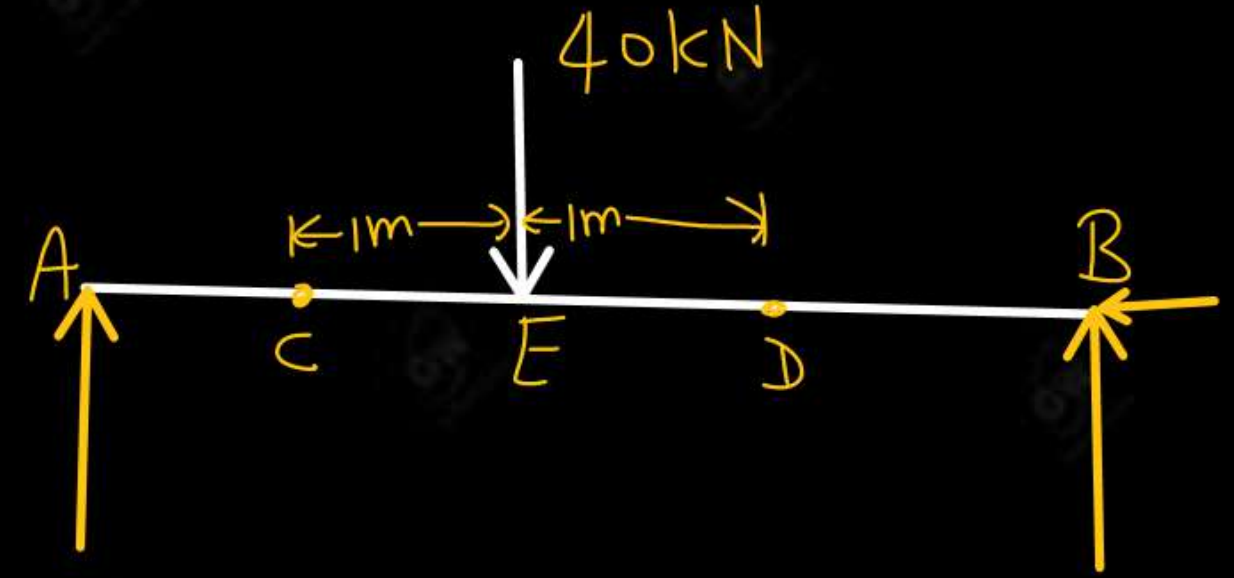
- Load acts over a certain length
- Intensity of load is uniform
- Total load = Area of plane fig (rectangle)
- Total load acts at middle of the loaded length.



Total load $= 20 \frac{kN}{\cancel{m}} \times 2 \cancel{m}$

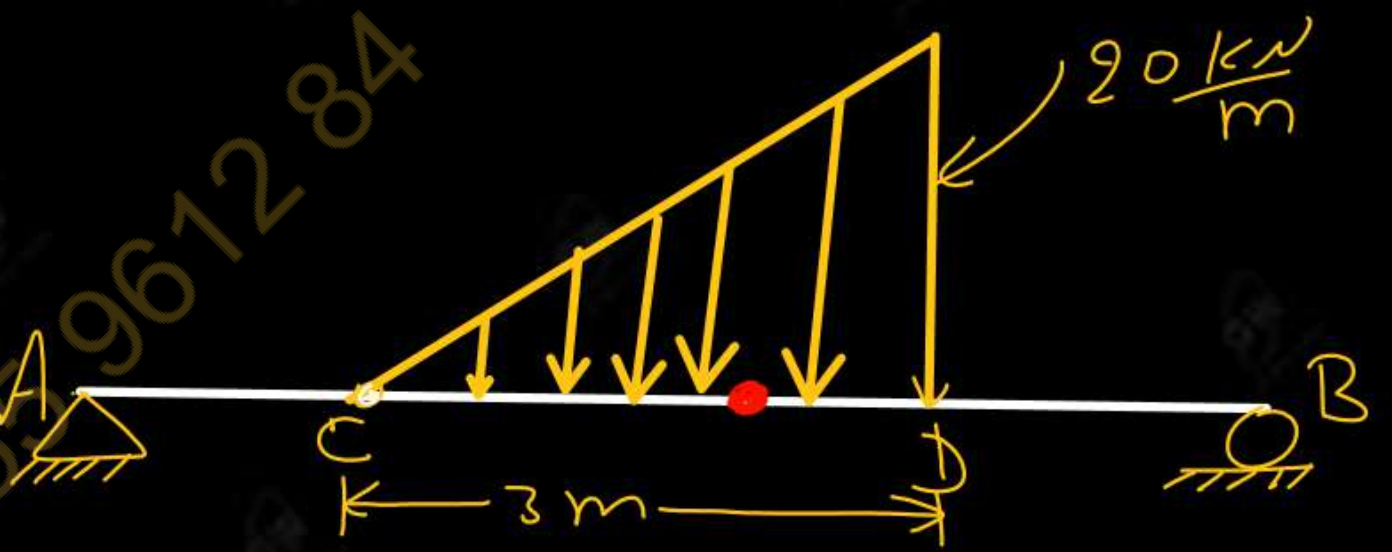
$\boxed{\text{Total load} = 40\,kN}$

Point load



3. Uniformly Varying load(UVL)

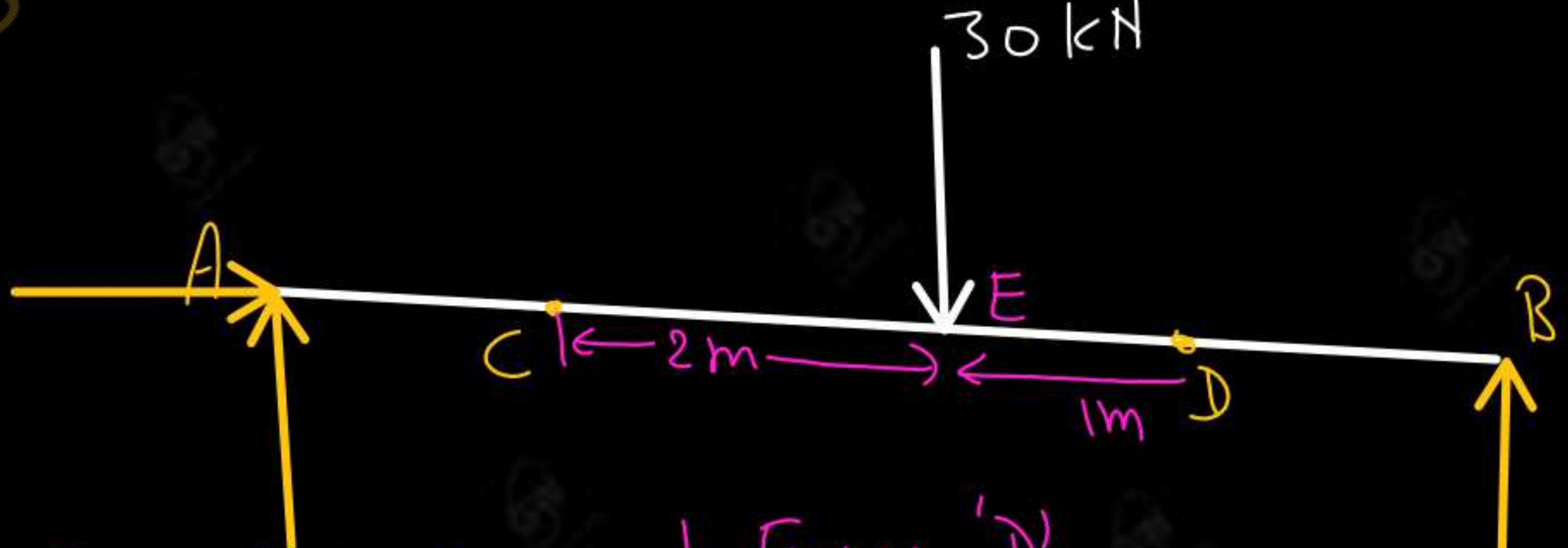
- The load varies Uniformly.
- Total load = Area of plane fig. (Triangle).
- Total load acts at Centroid of the triangle.



Total load $= \frac{1}{\cancel{2}} \times 3\cancel{m} \times \overset{10}{\cancel{20}}\, \frac{kN}{\cancel{m}}$

$\boxed{\text{Total load} = 30\,kN}$

Point load



From 'C' $= \frac{2}{3} \times 3\,m$

$= 2\,m$

From 'D'

$= \frac{1}{3} \times 3\,m$

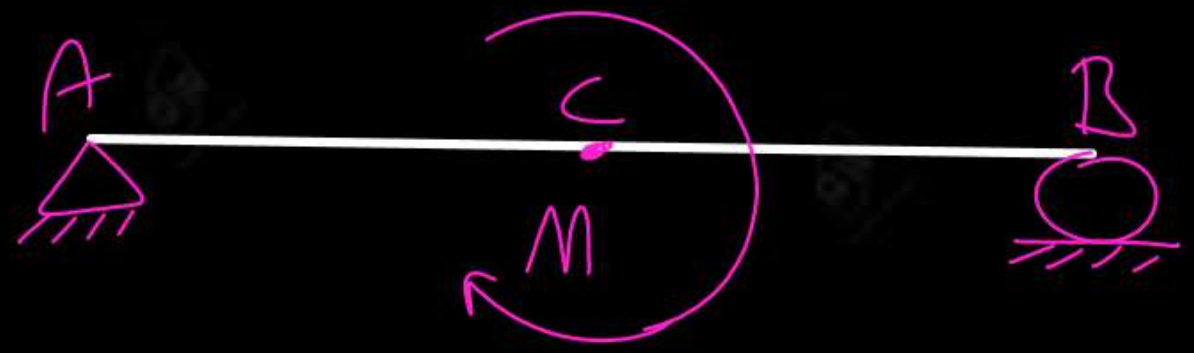
$= 1\,m$

4. Moment

- A beam may be subjected to external moment at certain points.

- Moment may be Clockwise or ~~Ani~~-clockwise.

Anti.



AKTU PYQs

Q.1	Explain the types of supports in beam. 2m
Q.2	What are types of load subjected to beams ? ⇒ 2m, 7m

Equilibrium Equations

The body is said to be in equilibrium if the resultant of all the forces acting on it is zero.

Coplanar Non-Concurrent Force System

Algebraic sum of forces in X-direction = 0 , $\boxed{\Sigma F_x = 0}$ — (I)

Algebraic sum of forces in Y-direction = 0 , $\boxed{\Sigma F_y = 0}$ — (II)

Algebraic sum of moment at any point = 0 , $\boxed{\Sigma M = 0}$ — (III)

Stress

Stress :- "It is defined as internal resisting force per unit cross-sectional area".

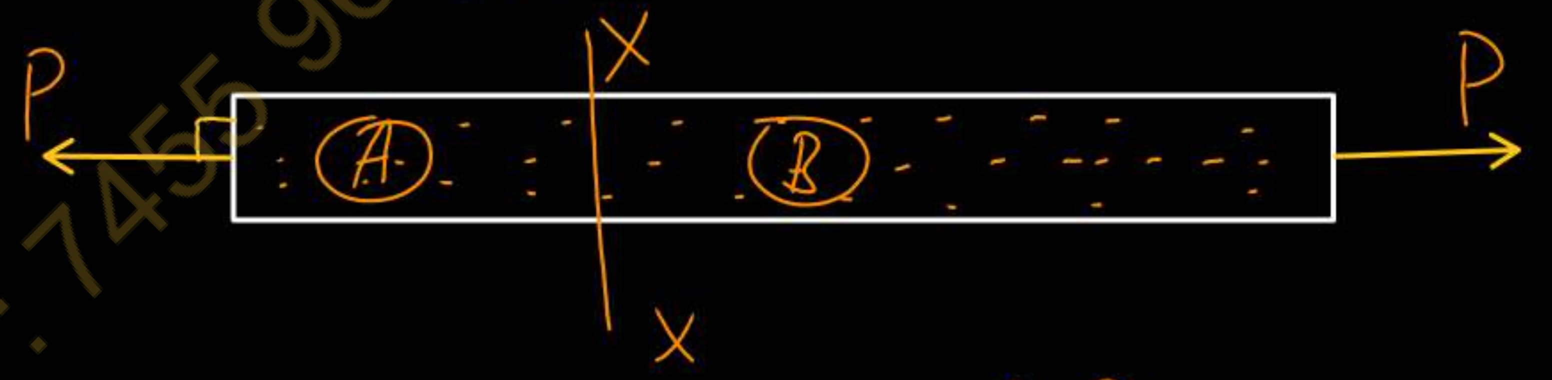
$\boxed{\sigma = \frac{R}{A}} \Rightarrow \boxed{\sigma = \frac{P}{A}}$ ***

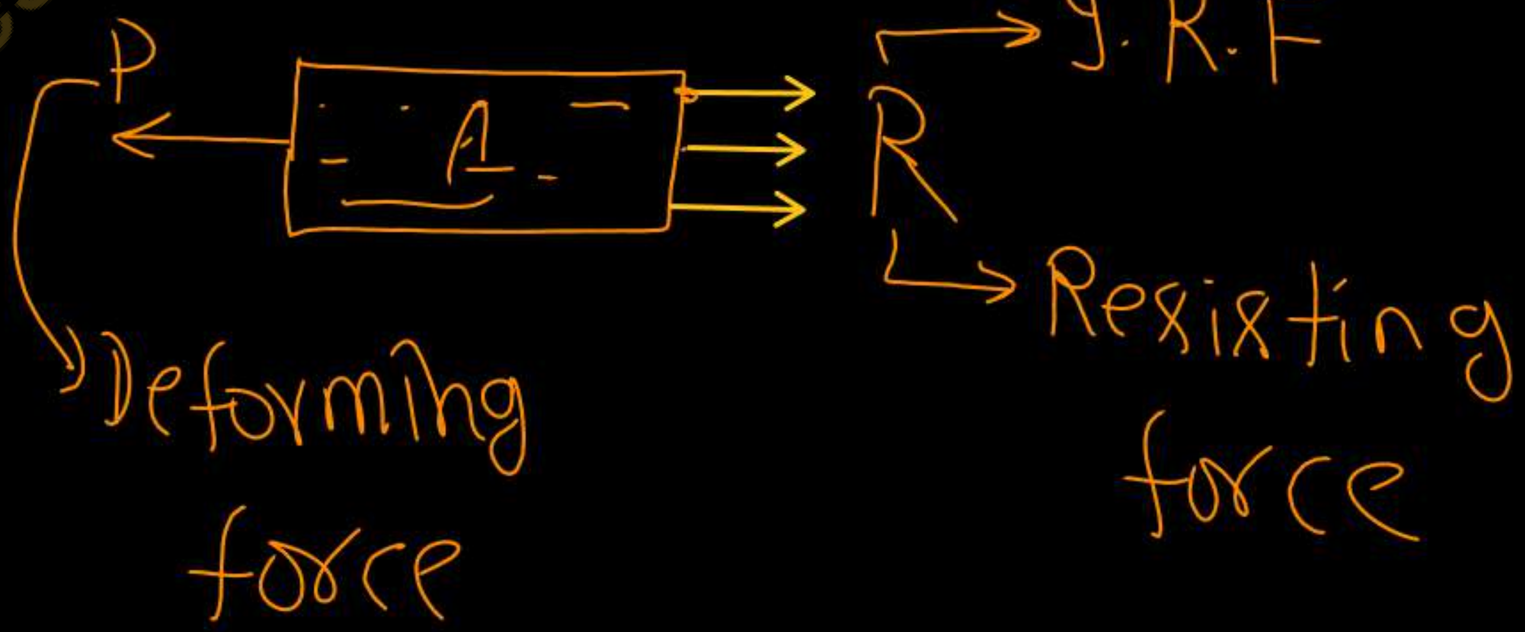
R → stress

P → N

A → m^2

deform





Unit of Stress

→ N/m^2

→ Pa [1 Pa = 1 N/m^2]

kPa, MPa, GPa | 1 MPa = 1 N/mm^2

Types of Stress

- **Stress**
  - Normal Stress (σ)
    - Longitudinal Stress (σ_{long})
      - Tensile Stress (σ_t)
      - Compressive Stress (σ_c)
    - Volumetric Stress (σ_v)
  - Shear Stress (τ)

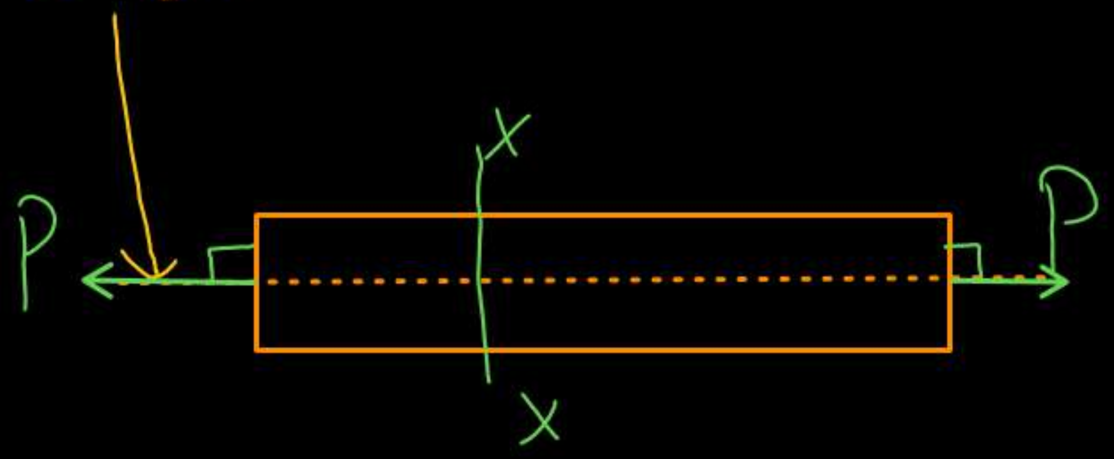
Types of Stress

⊥ar

Pull
Push

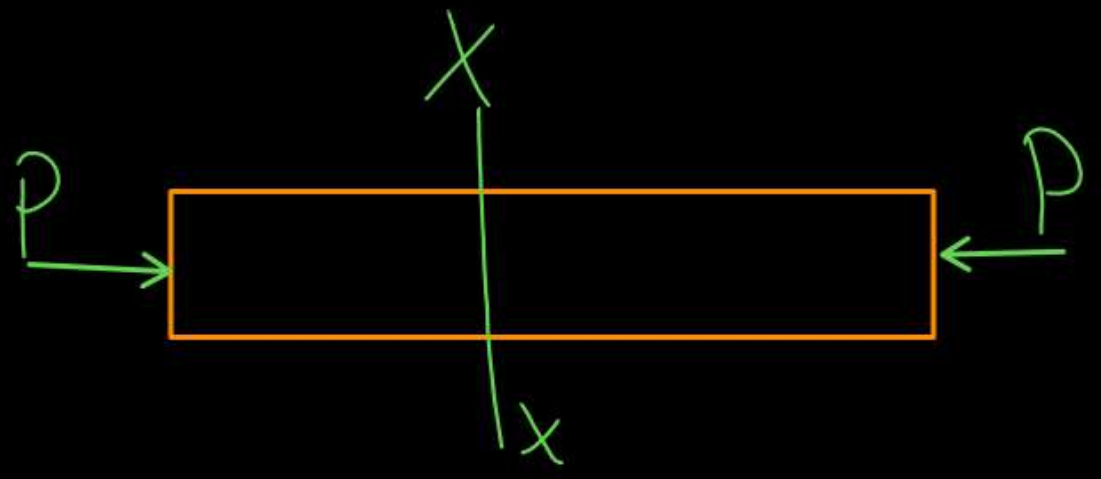
Normal Stress(σ):- Stress is said to be Normal stress when the direction of the deforming force is perpendicular to the cross-sectional area of the body.

Longitudinal axis



- **Tensile Stress(σ_t):-** When a structural member is subjected to two equal and opposite **tensile** forces , the stress produced is called tensile stress. The tensile stress at any cross-section X-X is given as

$$\boxed{\sigma_t = \frac{P}{A}}$$



- **Compressive Stress(σ_c):-** When a structural member is subjected to two equal and opposite **compressive** forces, the stress produced is called compressive stress. The compressive stress at any cross-section X-X is given as

$$\boxed{\sigma_c = \frac{P}{A}}$$

Types of Stress

➢ **Volumetric Stress(σ_v):-**

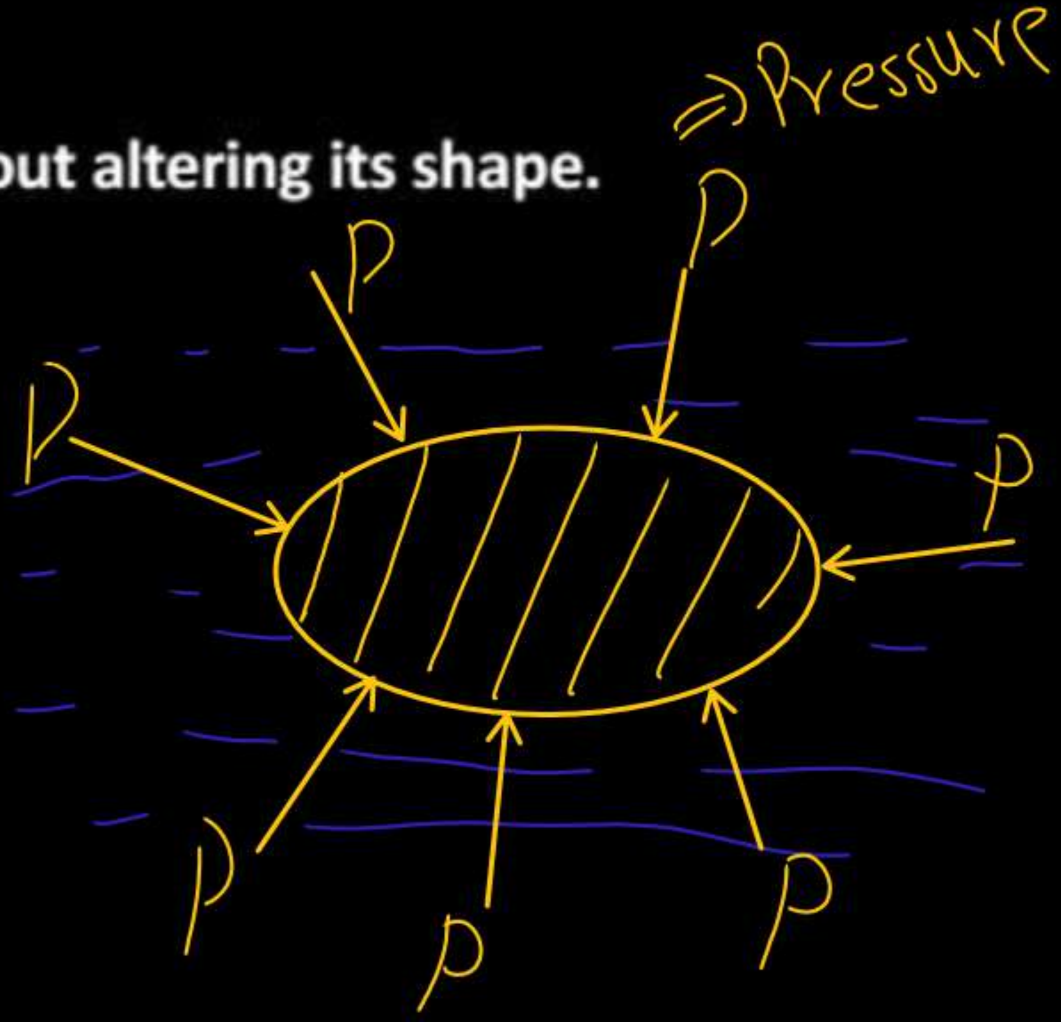
- Volumetric stress, also known as hydrostatic stress or bulk stress, is a type of stress that is associated with the uniform deformation of a material due to the application of an external force or pressure.
- Volumetric stress leads to changes in the volume of the material without altering its shape.
- Volumetric stress is typically expressed in terms of pressure.

$$\boxed{\sigma_v = -p}$$

$\sigma_v \rightarrow N/m^2$ (Pa)

$p \rightarrow$ Pressure

$p \rightarrow N/m^2$ (Pa)

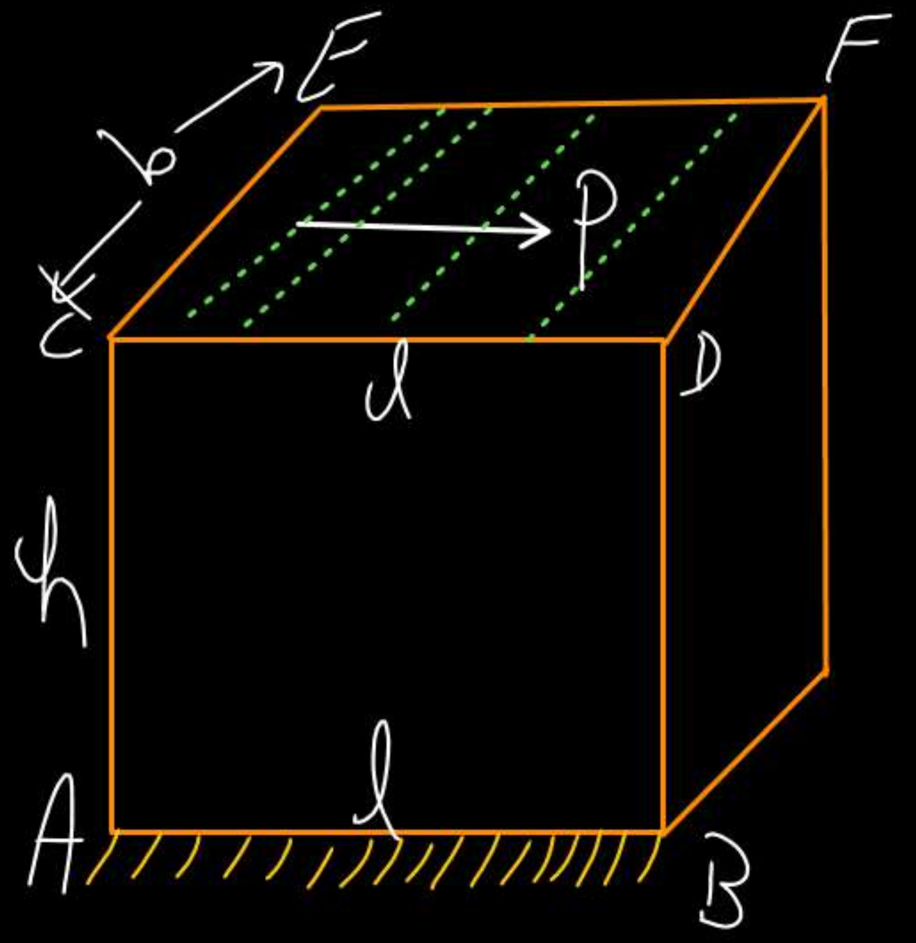


Types of Stress

Shear Stress (τ):- Stress produced by a **force tangential** to the surface of a body is known as shear stress.

It is represented by τ.

Consider a rectangular block ABCD fixed at the bottom plane and subjected to tangential force **P** at the upper plane.



Then

$$Shear\ Stress, \tau = \frac{tangential\ force}{area\ of\ face\ DCFE}$$

$$\boxed{\tau = \frac{P}{bl}}$$

Strain

- A body is said be strained when the relative position of the particles is changed due to loads acting on the member.

- This is deformation per unit original length is called strain.

- It can be defined as the ratio of change in dimension and original dimension.

Strain

$$\boxed{\cancel{Streain} = \frac{change\ in\ dimension}{original\ dimension}}$$

- **Note:** Strain is dimensionless quantity.

Types of Strain

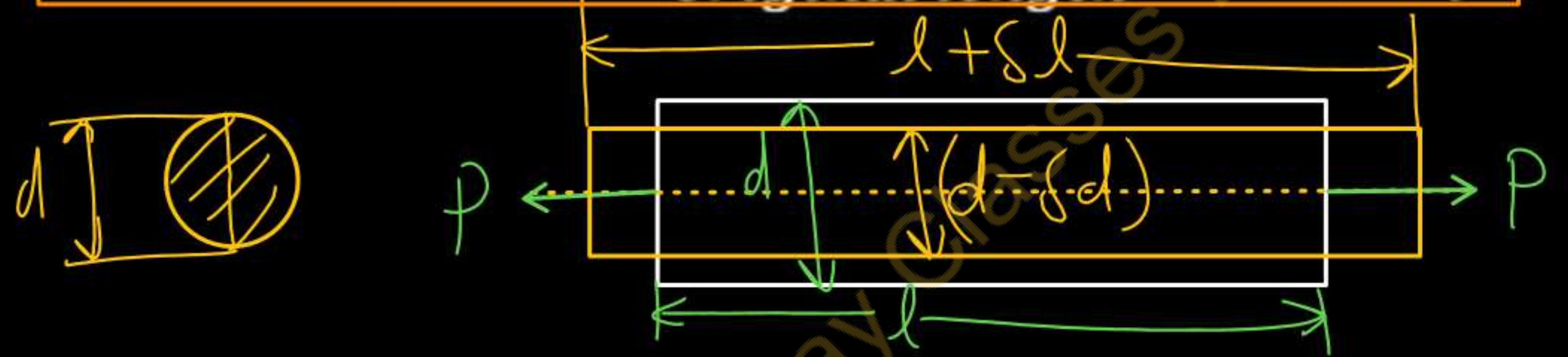
- **Strain**
  - **Normal Strain (ϵ)**
    - **Longitudinal Stain** (ε_{long})
    - **Lateral Stain** (ε_{lat})
    - **Volumetric Strain** (ε_{v})
  - **Shear Strain (ϕ)**

Types of Strain

Longitudinal strain and Lateral strain:- ? ? → Perpendicular

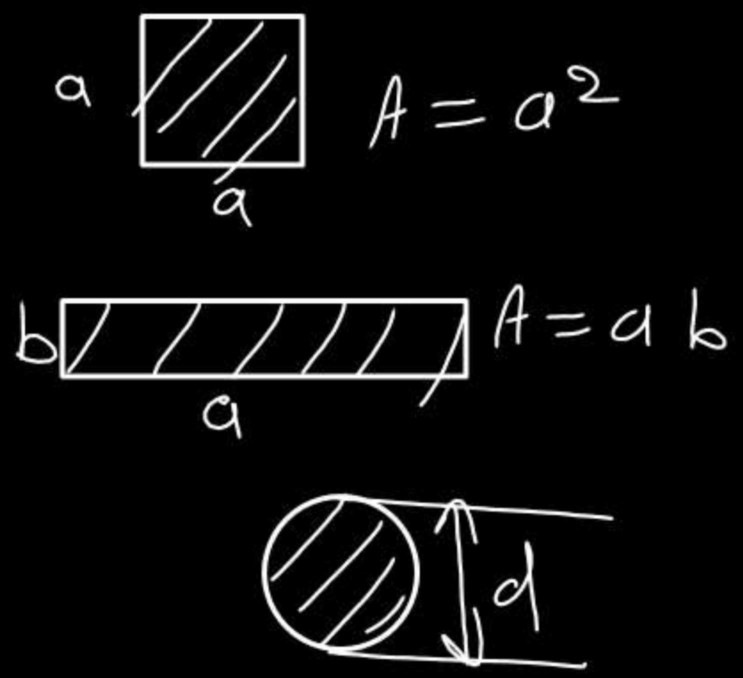
- Strain in the direction of applied load is called longitudinal strain or primary strain or linear strain.

$$\boxed{\text{longitudinal } strain = \frac{change\ in\ length}{original\ length},\quad \epsilon_{long} = \frac{\delta l}{l}}$$ → +ve



- Strain in the perpendicular direction of applied load is called lateral strain.

$$\boxed{\text{lateral strain} = \frac{change\ in\ diameter}{original\ diameter},\quad \epsilon_{lat} = \frac{\delta d}{d}}$$ → −ve



$A = \frac{\pi}{4} d^2$

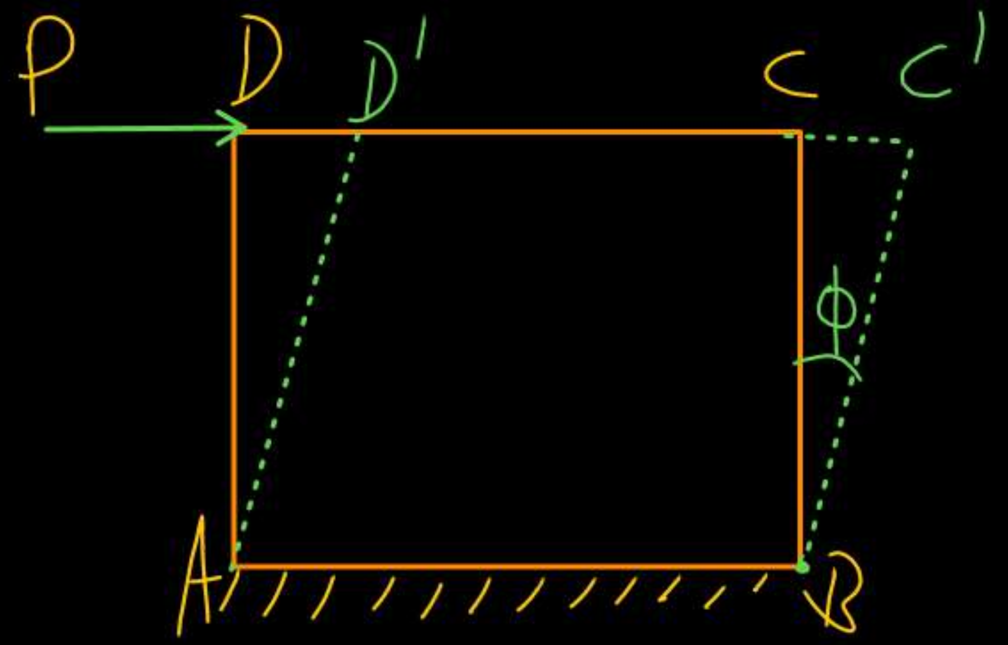
Types of Strain

- **Shear Strain(ϕ):-** Strain produced by a force, tangential to the surface of a body is known as Shear strain.
- Under the action of tangential force, the block ABCD gets distorted and takes the shape ABC'D' by deforming through an angle ϕ.

In $\Delta BCC'$

$$Tan\,\phi = \frac{CC'}{BC}$$

Because angle ϕ is very small , then $\boxed{Tan\,\phi = \phi = \frac{CC'}{BC}}$



The angular deformation ϕ in radians represents the shear strain.

Hooke's Law

(AKTU-2020-21,2021-22)

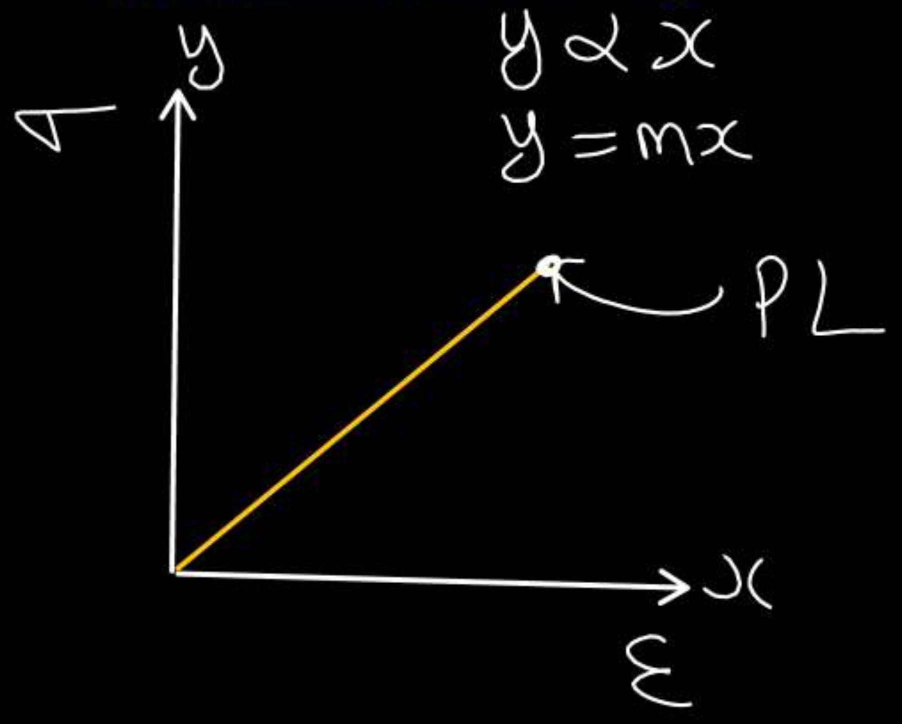
- **Hooke's Law:-** Hooke's law states that when a material is loaded within **proportional limit,** stress is directly proportional to strain.

Mathematically,

$$\sigma \propto \varepsilon$$

$$\sigma = E\varepsilon$$

$$E = \frac{\sigma}{\varepsilon}$$



- Where the constant of proportionality E is called Young's modulus or modulus of elasticity.
- Young's modulus is the property of solid material.

Elastic constants

Elastic constants:- For homogenous and isotropic material no. of elastic constants are 4 (μ, E, G, K).

- (1) Poisson's Ratio (μ) (AKTU)
- (2) Modulus Of Elasticity or Young's Modulus (E)
- (3) Modulus Of Rigidity or Shear Modulus (G) (AKTU)
- (4) Bulk Modulus (K) (AKTU)

Elastic constants

- (i) are used to determine strain theoretically
- (ii) are used obtain relationship between stress and strain

Elastic constants

(AKTU)

(1) Poisson's Ratio(μ):- It is defined as the ratio of lateral strain to longitudinal strain.

$$\boxed{Poisson's\ ratio\ \cancel{is}\ \mu = \frac{Lateral\ strain}{Longitudinal\ strain}} \Rightarrow \mu = \frac{\delta d/d}{\delta l/l}$$

- Poisson's ratio is dimensionless.
- The value of μ lies between $\boxed{0.25 \text{ to } 0.33}$ for most of the engineering materials.

Elastic constants

(AKTU)

(2) Modulus Of Elasticity or Young's Modulus(E):- It is defined as the ratio of normal stress and normal strain, when material is loaded within elastic limit.

$$E = \frac{\sigma}{\varepsilon} = \frac{\text{Normal stress}}{\text{Normal strain}}$$

- Unit of Young's modulus is same as unit of stress because strain is dimensionless quantity.
- N/m^2, Pa, Kpa, Mpa, Gpa
- E is a property of the material.

Elastic constants

(AKTU)

(C)

(3) Modulus Of Rigidity or Shear Modulus(G):- It is defined as the ratio of shear stress and shear strain, when material is loaded within elastic limit.

$$\boxed{G = \frac{Shear\ stress}{Shear\ strain}\frac{\tau}{\phi}}$$

- Unit of shear modulus is same as unit of stress because strain is dimensionless quantity.
- N/m^2, Pa, Kpa, Mpa, Gpa
- G is a property of the material.

Elastic constants

(AKTU)

(4) Bulk Modulus(K):- It is defined as the ratio of volumetric stress and volumetric strain, when material is loaded within elastic limit.

$$\boxed{K = \frac{Volumetric\ Stress}{Volumetric\ Strain} = \frac{\sigma_v}{\varepsilon_v}}$$

- Unit of Bulk modulus is same as unit of stress because strain is dimensionless quantity.
- N/m^2, Pa, Kpa, Mpa, Gpa
- K is a property of the material.

Elastic constants Derivations

(AKTU)

$\mu \rightarrow \frac{1}{m}$

$G \rightarrow C$

(I) $E = 3K(1-2\mu)$

(II) $E = 2G(1+\mu)$

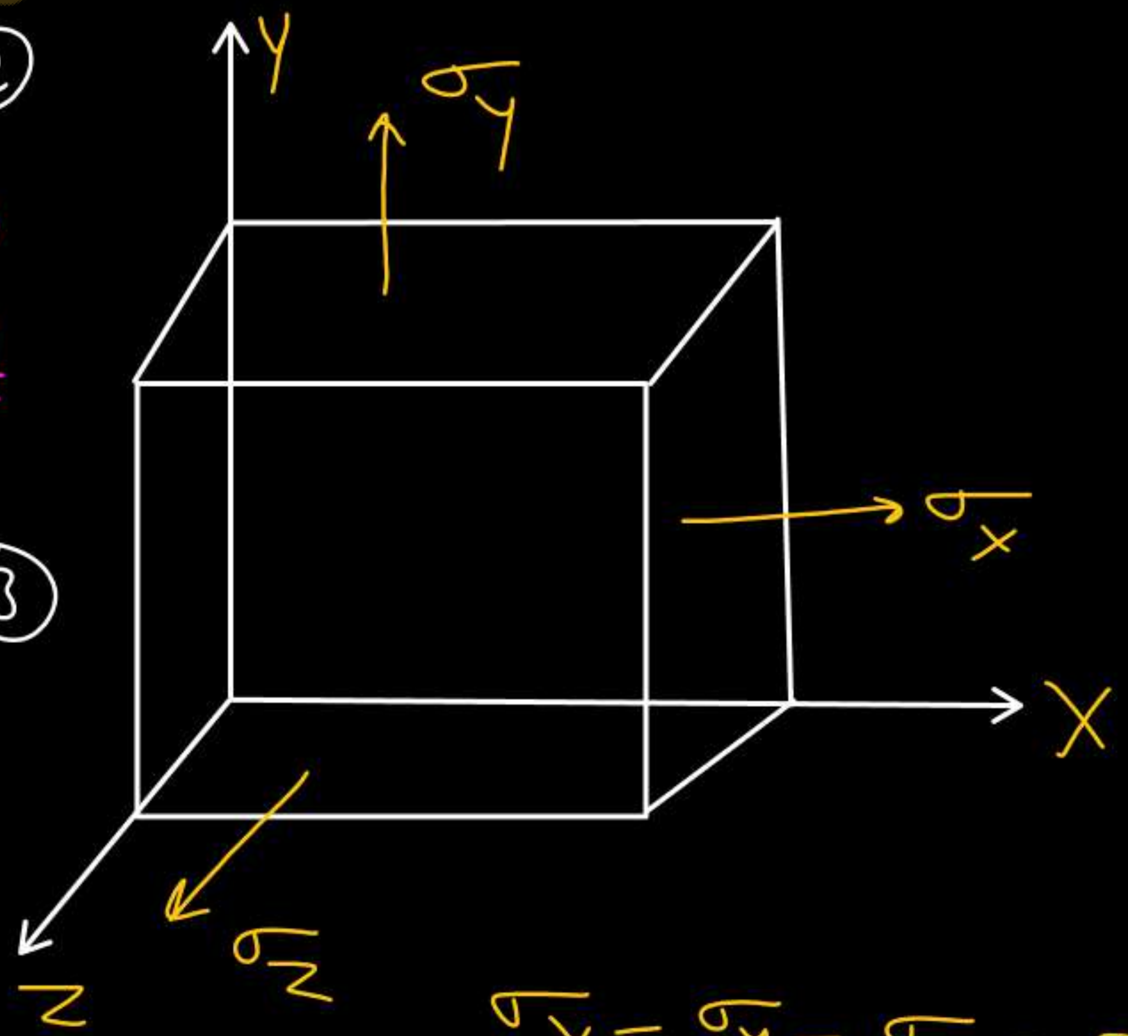
(III) $E = \frac{9KG}{3K+G}$

Elastic constants Derivations

Derivation-1 Relation between E, K and μ

$K = \frac{\sigma_v}{\varepsilon_v}$

Let us consider a cubical block subjected to direct stress σ which act simultaneously along x, y, z directions.



$\sigma_x = \sigma_y = \sigma_z = \sigma$

strain in x-direction

$\varepsilon_x = \frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} - \mu\frac{\sigma_z}{E}$

$\varepsilon_x = \frac{\sigma}{E} - \mu\frac{\sigma}{E} - \mu\frac{\sigma}{E}$

$\varepsilon_x = \frac{\sigma}{E}[1-2\mu]$ ------ (1)

Strain in y-direction

$\varepsilon_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E} - \mu\frac{\sigma_z}{E}$

$\varepsilon_y = \frac{\sigma}{E}[1-2\mu]$ ------ (2)

strain in z-direction

$\varepsilon_z = \frac{\sigma_z}{E} - \mu\frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E}$

$\varepsilon_z = \frac{\sigma}{E}[1-2\mu]$ ------ (3)

Volumetric strain

$$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z$$

$$\varepsilon_v = \frac{\sigma}{E}(1-2\mu) + \frac{\sigma}{E}(1-2\mu) + \frac{\sigma}{E}(1-2\mu)$$

$$\boxed{\varepsilon_v = \frac{3\sigma}{E}(1-2\mu)}$$

we know that

Bulk modulus, $K = \frac{\sigma_v}{\varepsilon_v} = \frac{\sigma}{\varepsilon_v}$

$$K = \frac{\cancel{\sigma}}{\frac{3\cancel{\sigma}}{E}(1-2\mu)}$$

$$\boxed{E = 3K(1-2\mu)}$$

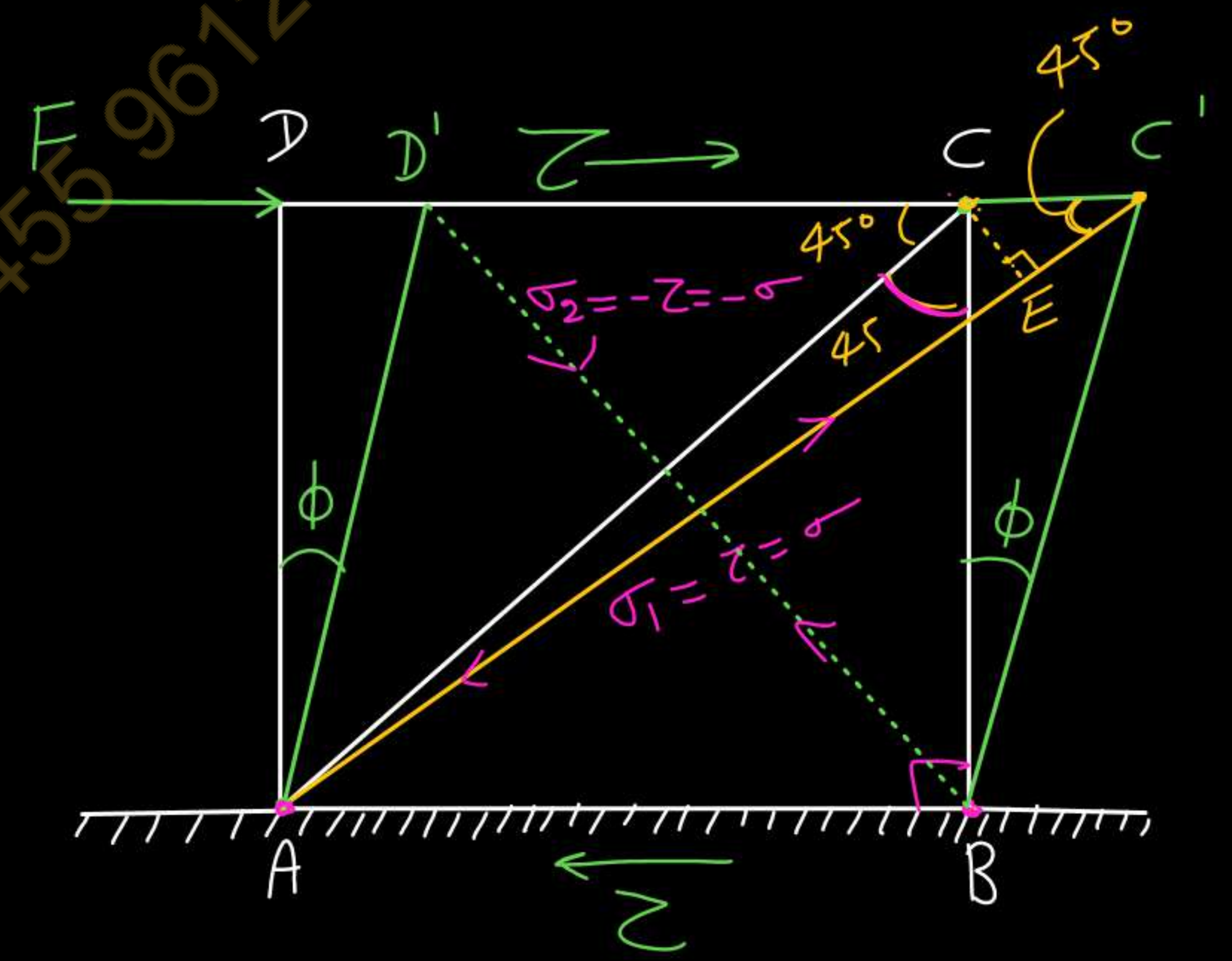
Derivation-2 : Relation between E, G and μ

$AC = AE$

Let us consider a cubical block ABCD subjected to shear force at the top face and fixed at the bottom face.

The block experiences the following effect due to shear force F

1. Shear stress is induced at the face DC and AB
2. The block distort to a new configuration ABC'D'
3. The diagonal AC elongate (Tension) and diagonal BD shorten (Compression)



$\Delta EC'C$

$\cos 45 = \frac{EC'}{CC'}$

$EC' = CC' \cos 45$

ΔABC

$\cos 45 = BC/AC$

$AC = BC/\cos 45$

$\Delta BCC'$

$$\tan\phi = \frac{CC'}{BC}$$

since ϕ is very-very small

$$\tan\phi = \phi = \frac{CC'}{BC} \text{ ---- (I)}$$

Draw $CE \perp AC'$

Linear strain in diagonal AC

$$\varepsilon = \frac{AC' - AE}{AC} = \frac{EC'}{AC}$$

$$\varepsilon = \frac{CC'\cos 45}{\frac{BC}{\cos 45}}$$

$$\varepsilon = \frac{CC'}{BC}\cos^2 45$$

$$\varepsilon = \frac{CC'}{BC}\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{CC'}{2BC}$$

$$\varepsilon = \frac{CC'}{2BC} \text{ ---- (II)}$$

from eq^n (I) & (II)

$$\varepsilon = \frac{\phi}{2}$$

we know

$$G = \frac{\tau}{\phi}$$

$$\Rightarrow \phi = \frac{\tau}{G}$$

$$\varepsilon = \frac{\tau}{2G} \text{ ---- (III)}$$

In case of Pure shear

$$\sigma = \tau \sin 2\theta \quad [\theta = 45]$$

$$\sigma = \tau \sin 90$$

$$\boxed{\sigma = \tau} \; **$$

strain in diagonal AC

$$\varepsilon = \frac{\sigma}{2G} \text{ ---- (IV)}$$

strain in diagonal AC also can be written

$$\varepsilon = \frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E}$$

$$= \frac{\sigma}{E} - \mu\left(-\frac{\sigma}{E}\right)$$

$$\varepsilon = \frac{\sigma}{E} + \mu\frac{\sigma}{E}$$

$$\varepsilon = \frac{\sigma}{E}(1+\mu) \text{ ---- (V)}$$

from eqn IV & V

$$\frac{\cancel{\sigma}}{2G} = \frac{\cancel{\sigma}}{E}(1+\mu)$$

$$\boxed{E = 2G(1+\mu)}$$

Derivation-3 : Relation between E, G and K

we know that,

$$E = 2G(1+\mu) \text{ ------ (i)}$$

$$E = 3K(1-2\mu) \text{ ----- (ii)}$$

Eliminate μ from eqn (i) and (ii)

$$E = 2G(1+\mu)$$

$$1+\mu = \frac{E}{2G}$$

$$\mu = \frac{E}{2G} - 1$$

Put value of μ in eqn (ii)

$$E = 3K\left(1 - \frac{E}{G} + 2\right)$$

$$E = 3K\left(3 - \frac{E}{G}\right)$$

$$E = 9K - \frac{3KE}{G}$$

$$E + \frac{3KE}{G} = 9K$$

$$E\left(1 + \frac{3K}{G}\right) = 9K$$

$$\boxed{E = \frac{9KG}{3K+G}}$$

AKTU - 2022-23 odd

$$\frac{1}{m},\ E,\ C,\ K$$

$$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$$

$$\mu \quad E \quad G \quad K$$

(i) $E = 2G(1+\mu)$

(ii) $E = 3K(1-2\mu)$

(iii) $E = \dfrac{9KG}{3K+G}$

$$\boxed{E = 2G(1+\mu) = 3K(1-2\mu) = \frac{9KG}{3K+G}}$$

Stress-strain diagram for ductile and brittle materials

- A stress-strain diagram is a graphical representation of the relationship between stress and strain in a material.
- It provides valuable information about a material's mechanical properties and behavior under various loading conditions.
- Ductile and brittle materials have different stress-strain behaviors, and their diagrams look distinct.

Ductile Material: [Mild steel]

- Ductile materials are capable of undergoing substantial plastic deformation before failure.

Stress-strain diagram for ductile materials (mild steel)

The stress-strain curve for a ductile material have the following characteristics:

❖ **Proportional limit(A):**

➢ Upto this limit, stress is a linear function of strain and material obeys Hook's law.

➢ 0-A is a straight line and its slope represents the value of modulus of elasticity.

$\sigma \propto \varepsilon$

$\sigma = E\varepsilon \Rightarrow \boxed{E = \frac{\sigma}{\varepsilon}}$

❖ **Elastic limit(B):**

➢ It represents maximum stress upto which material is still able to regain its original shape and size after removal of load i.e. upto this point deformation is recoverable.

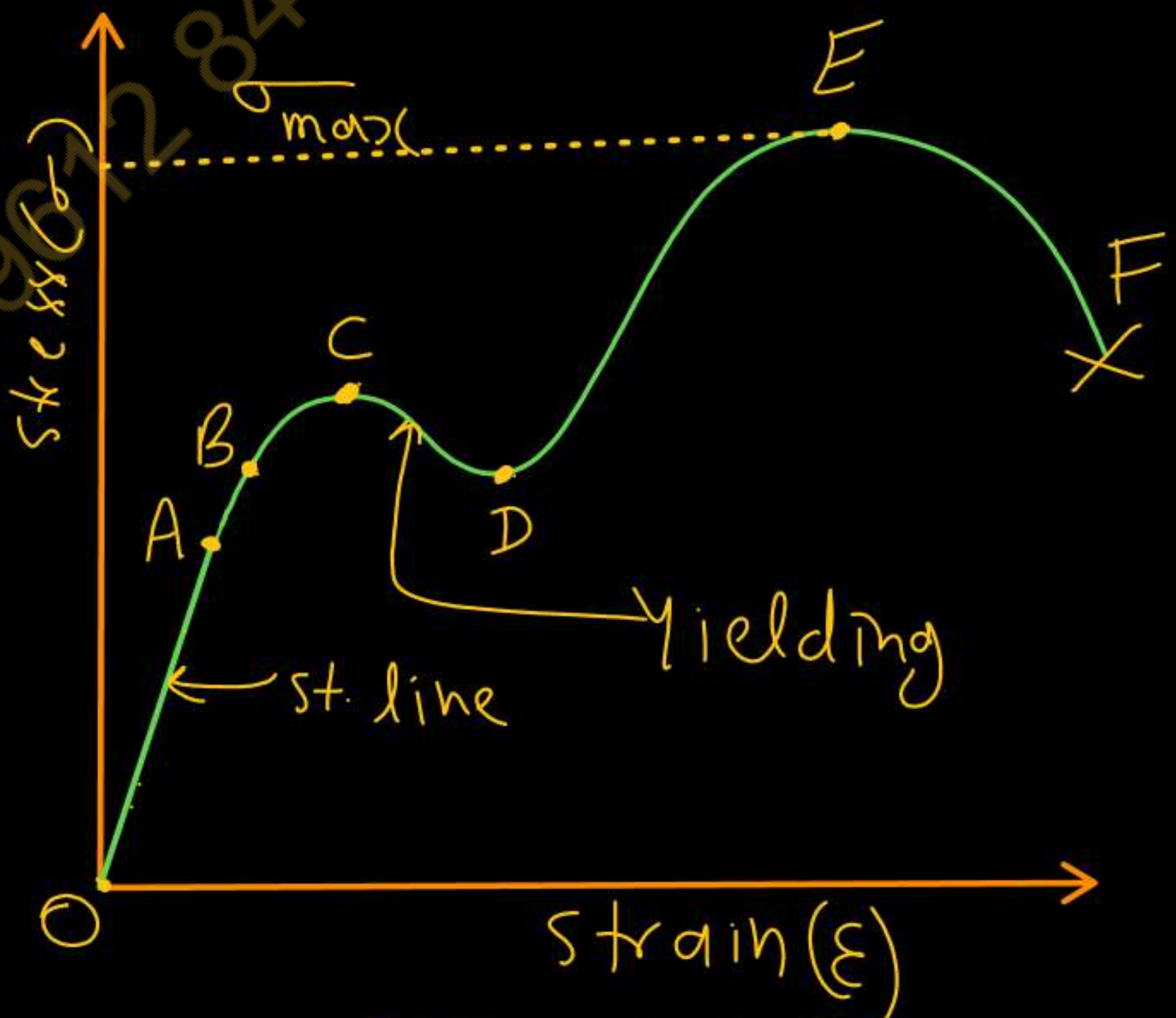


fig. Stress-strain diagram for ductile materials (mild steel)

❖ Upper yield point(C) and Lower yield point(D):

- Beyond elastic limit, the material shows considerable strain even though there is no increase in load.
- Deformation is not fully recoverable i.e. the behaviour of material is inelastic.
- This phenomenon from C to D is called yielding.

❖ Ultimate stress point(E):

- After yielding has taken place, the material becomes hardened and increase in load is required to take the material to its maximum stress at point E.
- Point E represents the maximum stress of this curve and this point is known as ultimate stress point.

❖ Breaking point(F):

- In the portion EF, there is falling off the load(stress) from the maximum until fracture takes place at F.
- The point F is known as fracture or breaking point and corresponding stress is called the breaking stress.

Stress – Strain diagram for brittle material (i.e. Cast Iron)

- For brittle materials, like cast Iron, no appreciable deformation is obtained and the failure occurs without yielding.

- Ductile materials give indication before failure.

- Brittle material fails suddenly with out any indication.

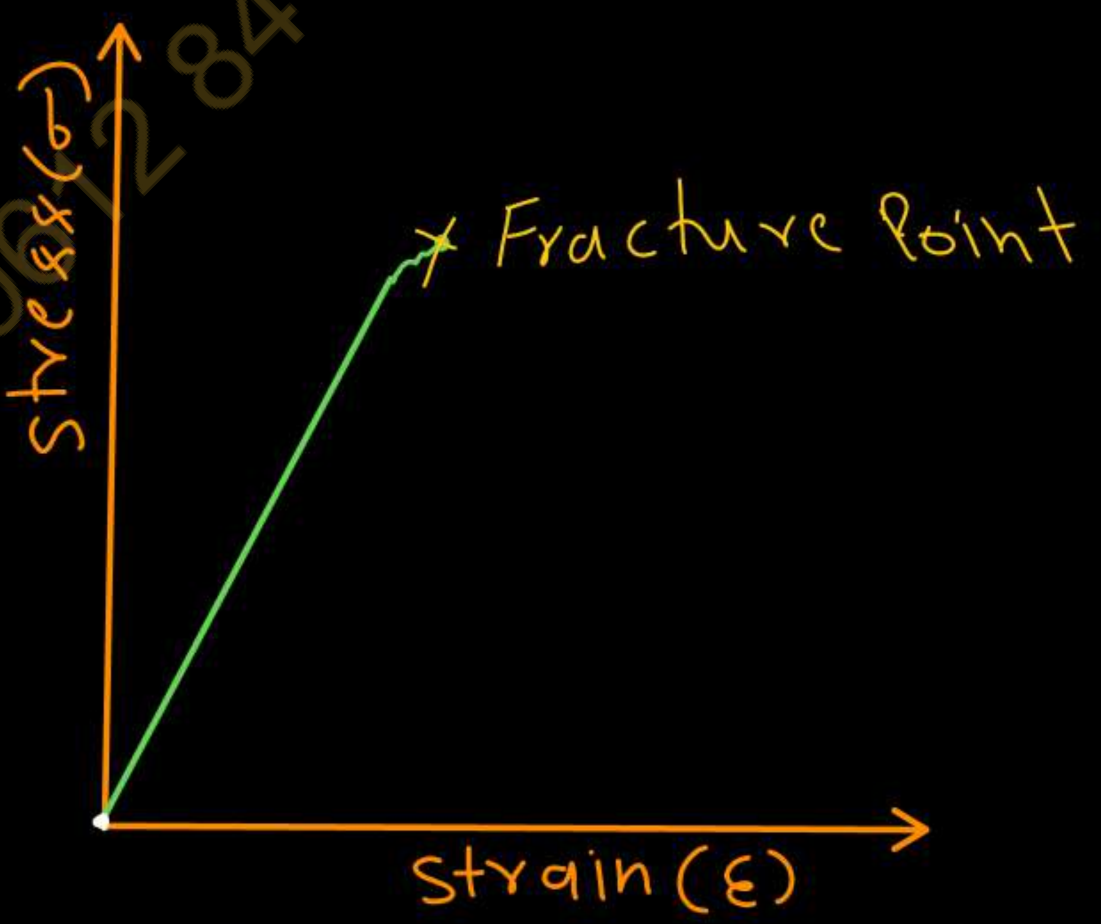


Fig. Stress – Strain diagram for brittle material (i.e. Cast Iron)

Factor of Safety

[AKTU 2020-21]

FOS is defined as Ultimate stress to working stress.

$$FOS = \frac{\textit{Ultimate stress}}{\textit{Working stress}} = \frac{\textit{Ultimate stress}}{\textit{Allowable stress}}$$

- For safe design FOS must be greater than unity. $FOS > 1$
- How much FOS is required depends on-
- Materials Properties , Design, Loading Conditions , Uncertainties, Applications etc.

$FOS \uparrow \Rightarrow cost \uparrow$

- **For example,** civil engineering structures like bridges and buildings may have a factor of safety around 1.5 to 2, while aerospace and nuclear engineering applications may require factors of safety that are much higher, often exceeding 3 or 4.
- As the FOS increases, the cost of the product also increases therefore cost is also a considerable parameter.

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Thank You