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ENG 210.2

Course Outline

1 Stress and Strain relationship consideration of equilibrium composite members.
2 General hooke's law.
3 Stress and Strain due to loading and the temperature changes, Considering elastic Constant.
4 Torsion of Circular members e.g Shafts and rectangular center.
5. Shear force, bending moment diagram and bending stress in beam of symmetrical centroid.
6. Stress and Strain transformation equation
7. Deflection of beam, Trough bending of Curve bar, thin plate and beam of elastic foundation

Stress and Strain relationship Consideration of equilibrium, Composite members.

Loading can be defined as a combined effect of external force acting on a body

Types of load.

1 Dead load
2 Live load
3 Centrifugal load

Classification of load.

1 Tensile load
2 Compressive load
3. Torsional load or twisting load
4. Bending load
5. Shearing load

Load can be

* Point load
* Distributed load
* Non-distributed load

Explain

Stress is refered to as Intensity Of existing Stress which is, force per Unit Area. i.e Stress $= \dfrac{\text{Force}(N)}{\text{Area}(m^2)}$

Stress can be considered as either total Stress or Unit Stress. Total Stress represent the total resistance of an external force and is expressed in (measured in) Newton (N), Kilonewtons (KN), Mega Newtons (MN), ... Unit Stress represent the resistance developed by a Unit area Of a Curved cross-Section and is expressed in Kilonewton per metre Square (KN/m^2), MN/m^2, N/m^2, ...

Types Of Stress

1. Combined Stress
2. Simple Stress (direct Stress)
3. Indirect Stress.

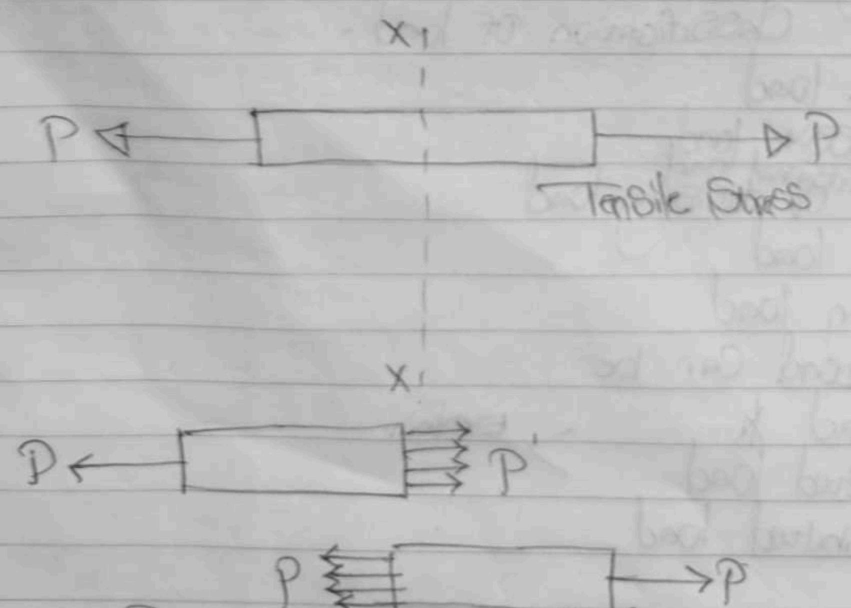
Simple / direct Stress

- Tension Stress
- Compressive Stress
- Shear Stress

Indirect Stress

- Bending Stress
- Torsion Stress

Tensile Stress.



Stress $= \dfrac{F}{A} = Kg(f)/cm^2$.

Tensile Strain.

Strain is the measure of deformation produced by the application of external force.

$$\text{Strain} = \frac{\Delta L}{\text{Original } L} = \text{Unitless (No unit)}$$

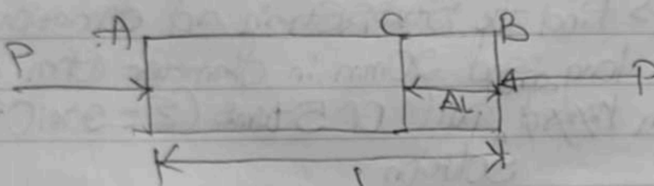
Tensile Strain

let AB = Initial length

let BC = length of the ~~compression~~ elongation $= \Delta L = (AC - AB)$

$$\text{Strain} = \frac{\text{extension}}{\text{Original length}}.$$

let AC = After ~~compression~~ elongation, final length.



Original length = AB

After compression = AC

$(AB - AC) = BC = \Delta L$ = change in length

$$\text{Compression } \cancel{\text{stress}} \text{ strain} = \frac{\text{Shortening of bar}}{\text{Original length}} = \frac{\Delta L}{AB}$$

Elasticity

When a material is gradually subjected to a gradually increasing load within a certain limit. When ~~the~~ external load is removed, the material regain its original size and shape. This property of the material is referred to as Elasticity. The strain which disappear with the removal of the load is termed / known as Elastic Strain and the body which regain its original size and shape is known as Elastic body.

Hooke's law

Read :-> Hooke's law
- Stress-Strain graph for elastic body:

Hooke's law state that provided a member remain perfectly elastic, the stress induced in it will always be directly proportional to the ~~appropriate~~ accompanied strain.

ε (Young modulus; modulus elasticity) $= \dfrac{\text{Stress}}{\text{Axial Strain}}$

$$\varepsilon = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta L/L}$$

$$\varepsilon = \frac{F}{A} \times \frac{L}{\Delta L} = \frac{FL}{\Delta L A}$$

Example :-> Find the stress, strain and elongation of a steel rod 1m long and 20mm in diameter when it is subjected to an ~~[illegible]~~ axial pull of 5 tonnes ($\varepsilon = 2\times10^6\,Kg/cm^2$)

Solution

$E = 2\times10^6\,Kg/cm^2$

Stress = ?

Strain ?

Elongation $= \Delta L = ?$

$L = 1m$

diameter $= 20mm = 20\times10^{-3} = 0.02m$

Axial pull $= 5$ tonnes $= 5\times1000 = 5000N$

$$\text{Area} = \frac{\pi d^2}{4} = \frac{3.142 \times (0.02)^2}{4} = 3.142\times10^{-4}\,m^2$$

$$\text{Stress} = \frac{F}{A}$$

$$\text{Stress} = \frac{5000}{3.142\times10^{-4}} = 1.591\times10^7\,N/m^2$$

$$\varepsilon = \frac{\text{Stress}}{\text{Strain}}$$

$$\varepsilon = 2\times10^6\,Kg/cm^2 = 2\times10^6 \times 9.81 \times 10^4\,N/m^2 = 1.962\times10^{11}$$

$$\text{Strain} = \frac{\text{Stress}}{\varepsilon} = \frac{1.591\times10^7}{1.962\times10^{11}} = 8.109\times10^{-5}$$

$$\text{Strain} = \frac{\Delta L}{L}$$

$$8.109 \times 10^{-5} = \frac{\Delta L}{1}$$

$$\underline{\Delta L = 8.109 \times 10^{-5} m}.$$

A bar of Sectional area 1250mm² and 2m in length extended 0.4mm when an axial load 50.5kN was applied. Calculate.

Solution.

Axial load = 52.5kN

$\Delta L = 0.4mm = 0.0004m$

$$\text{Stress} = \frac{F}{A}$$

$A = 1250mm^2 = 1.25 \times 10^{-3} m^2$.

$$\text{Stress} = \frac{52.5 \times 1000}{1.25 \times 10^{-3}}$$

$$= 4.20 \times 10^{7} N/m^2.$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$\text{Strain} = \frac{\Delta L}{L} = \frac{0.0004}{2} = 2 \times 10^{-4}$$

$$E = \frac{4.0 \times 10^{7}}{2 \times 10^{-4}}$$

$$\underline{E = 2.10 \times 10^{11} N/m^2}$$

Calculate the contraction in length of a ~~Shaft~~ Short Concrete column 300mm X 300mm Square Section when Carrying an axial load of 360KN, the Original Unloaded length was 3m (Assume E = ~~3000~~ 14,000N/m²).

$$\text{Strain} = \frac{\Delta L}{L}$$

$$8.109 \times 10^{-5} = \frac{\Delta L}{1}$$

$$\Delta L = \underline{8.109 \times 10^{-5} m}.$$

A bar of sectional area $1250 mm^2$ and 2m in length extended 0.4mm when an axial load 50.5KN was applied. Calculate the stress, strain and Young modulus.

Solution -

Axial load = 52.5KN

$\Delta L = 0.4mm = 0.0004m$

$$\text{Stress} = \frac{F}{A}$$

$A = 1250mm^2 = 1.25 \times 10^{-3} m^2$

$$\text{Stress} = \frac{52.5 \times 1000}{1.25 \times 10^{-3}}$$

$$= 4.20 \times 10^{7} N/m^2$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$\text{Strain} = \frac{\Delta L}{L} = \frac{0.0004}{2} = 2 \times 10^{-4}$$

$$E = \frac{4.2 \times 10^{7}}{2 \times 10^{-4}}$$

$$E = \underline{2.10 \times 10^{11} N/m^2}$$

Calculate the contraction in length of a ~~Shaft~~ short concrete column 300mm X 300mm square section when carrying an axial load of 360KN, the original unloaded length was 3m (Assume E = ~~3000~~ 14,000N/mm^2).

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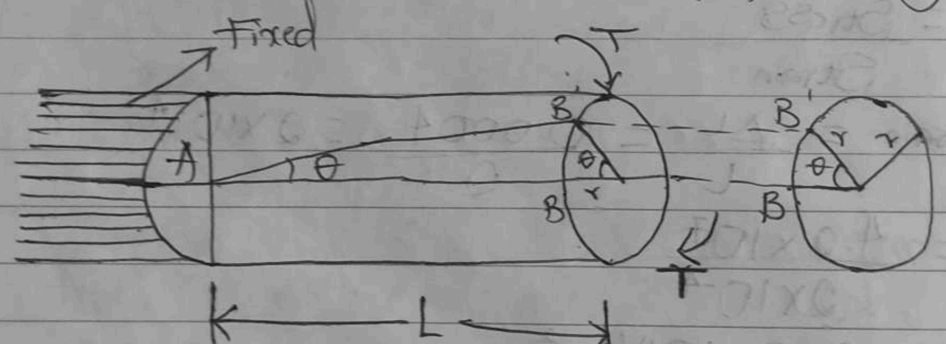
Torsion

This is the twisting Of a body by two equal and opp turns. It can also be defined as the twisting Of a part by applying equal and opposite turns While being bent due to bending moment and a Sharp twist due to torque.

A member is Said to be Under a pure tension when it is subjected to a torque without being associated to any bending moment or axial force.

The following assumptions are to be Considered When dealing With Torsion

1. The material Of the Shaft is homogeneous and isentropic
2. The Structure is elastic and also obeys Hooke's law.
3. Plane normal section Of a Circular Shaft remain plane after twisting.
4. All diameter Of the Cross Section Of the Shaft remain Straight With their length Unchanged before and after twisting.
5. The twist along the Shaft is Uniform along the length.
6. The radii line remain radii after twisting.
7. Stress do not exceed the limit Of proportionality.



T = Torque

Fs = Shear Stress

C = Modulus Of Rigidity

From the diagram above.

$$\text{Shearing Strain} = \tan\theta = \frac{BB'}{AB}$$

The Same as:

$$\theta = \frac{BB'}{AB} = \frac{r\theta}{L} \Rightarrow$$

$r\theta \Rightarrow$ tangential length.

Since Sin θ is Small

θ = angle Of twist.

$$\sin\theta = \phi$$

$$\phi = \frac{r\theta}{L}$$ ϕ = Shear Strain.

$$\text{Shearing Strain} = \frac{\text{Shear Stress}}{\text{Modulus Of Rigidity}}$$

$$\text{Shearing Strain} = \frac{fs}{C} \quad \text{——— (ii)}$$

Equating (i) and (ii) together

$$\phi = \frac{r\theta}{L} \text{——— (i)} \qquad \text{Shearing Strain} = \frac{fs}{C} \text{——— (ii)}$$

$$\therefore \frac{r\theta}{L} = \frac{fs}{C}$$

$$\frac{fs}{r} = \frac{C\theta}{L} \quad \text{——— (iii)}$$

Again $\phi = \dfrac{fs}{C} = \dfrac{r\theta}{L}$

$$fs = \frac{C\theta r}{L}$$

Polar moment Of Inertia

The moment Of Inertia Of the plane area With respect to an axis is perpendicular to the plane Of the area is Called Polar ~~momen~~ moment Of Inertia.

Circular areas

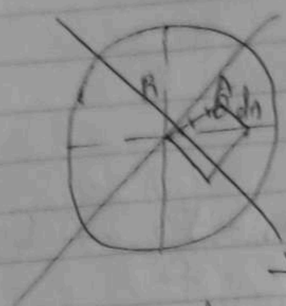
For a Circular area Of diameter D, the polar moment Of Inertia about a Centroid axis is $\pi D^4/32$, then the maximum radius is given as $r = d/2$.

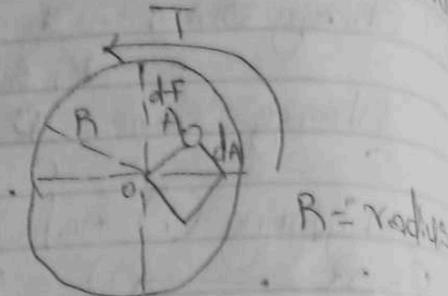
Hollow Circular Area.

A hollow Circular Area Of Outer diameter D and Inner diameter d, the polar moment Of Inertia about a Centroidal axis is $\dfrac{\pi[D^4 - d^4]}{32}$

Moment Of Resistance

Whenever a torque is applied On a Circular Shaft internal Shear Stress is induced in the Cross-Section Of the Shaft. The resultant Of this Shear Stress form a Couple about ~~the resul~~ longitudinal axis of the shaft, this couple which is numerically equal to the applied external torque is termed Torsional moment of resistance





F_S = Shear Stress
dA = elementary Area
Shear force induced = df
$df = F dA$
The moment of elementary Shear force is given as dm
$dm = r \times df$ but $df = F \cdot dA$
Substituting df into the formular below.
$dm = r \times dF$
$dm = r \times [F \cdot dA]$ —— (iv)
Note using portion

$$\frac{F_S}{r} = \frac{C\theta}{L} \text{ —— (iii)}$$

Again $F = \dfrac{C\theta r}{L}$

Substituting the value of F_S into equation (iv)

$$dm = r\,[F \cdot dA]$$

$$dm = r\left[\frac{C\theta r}{L} \cdot dA\right]$$

$$dm = \frac{C\theta r^2}{L} \cdot dA$$

Integrating $dm = \dfrac{C\theta \cdot r^2}{L} \cdot dA$

$$m = \int \frac{C\theta r^2}{L}\, dA \text{ —— (v)}$$

$$m = \frac{C\theta}{L}\int r^2 dA = \frac{C\theta J}{L}$$

Where $J = \int r^2 dA$ $\quad m = \dfrac{C\theta}{L} \cdot J$ —— (vi)

Where J is the polar moment of Inertia of the Cross Section

$$J = \int r^2 dA$$

Note

$m = T$ Where m = moment of resistance
T = applied Torque.

Using equation

$$m = T = \frac{C \cdot \theta \cdot J}{L} \quad \text{——— (vi)}$$

Again

$$\left[\theta = \frac{TL}{CJ} \right] \quad \text{——— (vii)}$$

Also, from equation (vi)

$$\theta = \frac{TL}{CJ}$$

$$\theta CJ = TL$$

Similarly $\frac{T}{J} = \frac{C\theta}{L}$

Combining both equation

$$\frac{T}{J} = \frac{C\theta}{L} = \frac{FS}{R}$$

Polar modulus

$$Z = \frac{J}{r}$$

Again $T = FS \cdot Z$

Power transmitted by Shaft

$$P = \frac{2\pi NT}{4{,}500}$$

$N \rightarrow$ rpm (S.I Unit)

Assignment.

* Determine the maximum allowable torque to which a solid circular bar 3.5m long and 11cm diameter can be subjected when specification required that shearing stress must not exceed 555Kg/cm² and twist must not exceed 3.35 in length. Assume $C = 0.68 \times 10^6 Kg/cm^2$.

Solution.

$l = 3.5m$

$d = 11cm = 11 \times 10^{-2} m = 0.11m$

$F_S = 555 Kg/cm^2 = 555 \times 9.81 \times 10^4 N/m^2$

$\theta = 3.35°$

$C = 0.68 \times 10^6 Kg/cm^2 = 0.68 \times 10^6 \times 9.81 \times 10^4 N/m^2$

$$\frac{T}{J} = \frac{F_S}{r} = \frac{C\theta}{L}$$

$$J = \frac{\pi D^4}{32}$$

$$\frac{T}{J} = \frac{F_S}{r}$$

$$T = \frac{F_S J}{r}$$

$$r = \frac{d}{2} = \frac{0.11}{2} = 0.055m$$

$$J = \frac{\pi (0.11)^4}{32}$$

$$= 1.437 \times 10^{-5} m^4$$

$$T = \frac{555 \times 9.81 \times 10^4 \times 1.437 \times 10^{-5}}{0.055}$$

$$T = \frac{782.382}{0.055}$$

$$T = 14225.124 Nm$$

$$\frac{T}{J} = \frac{C\theta}{L}$$

$$T = \frac{C\theta J}{L}$$

$$T = \frac{0.68 \times 10^6 \times 9.81 \times 10^4 \times 3.35° \times \pi \times 1.437 \times 10^{-5}}{180° \times 3.5m}$$

$$T = \frac{6.6708 \times 10^{10} \times 3.35 \times \pi \times 1.437 \times 10^{-5}}{180 \times 3.5}$$

$$= \frac{10088564.34}{630}$$

$$T = 16013.594 \text{ Nm}$$

$$\frac{F_s J}{r} < \frac{C\theta J}{L}$$

$$\frac{C\theta J}{L} > \frac{F_s J}{r}$$

$\therefore$ The Maximum allowable torque $= 16{,}013.59$ Nm

Assignment.

A 2.5cm diameter bar of gauge length 20cm found to Stretch 0.0032cm Under an axial tensile load of 160kg, When tested within the tensile elastic limit of the material. The Same bar when tested within the torsional elastic limit Suffers an angular twist of 54" at an applied torque equal to 2,400kgcm Over the gauge length of 20cm. Determine

I Modulus of elasticity.
II Modulus of Rigidity.
III Poisson ratio for the material.

Hint:-> $\left[1 + \frac{1}{m}\right] = \frac{E}{2C}$

* Modulus of elasticity (Young modulus) $= \frac{\text{Stress (tensile)}}{\text{Strain}} \rightarrow E$.

* Poisson ratio $= \frac{\Delta D}{\Delta L}$

$\frac{1}{m}$ = Poisson ratio

Modulus of Rigidity $= \frac{\text{Shear Stress}}{\text{Shear Strain}}$.

Poisson ratio $= \frac{\text{Lateral or Transverse Strain}}{\text{Longitudinal or Axial Strain}}$.

Poisson's ratio is used to measure the poisson effect, a phenomenon wherein material tends to expand in the direction perpendicular to the Compression.

A solid circular shaft of diameter 4cm and of gauge length 28cm when subjected to a torque of 10000kg.cm in a testing machine registered an angular twist of 0° 22' 0". Find the maximum shear stress induced and the value of the modulus of rigidity.

Solution

$d = 4cm = 4\times10^{-2}m$

$l = 28cm = 28\times10^{-2}m$

$T = 10000 kg.cm = 10000\times9.81\times10^{-2}Nm$

$= 981 Nm$

Shear stress $f_s = ?$

$$J = \frac{\pi d^4}{32} = \frac{\pi(4\times10^{-2})^4}{32}$$

$$J = 2.51\times10^{-7}m^4$$

$$\theta = 0° 22' = \frac{22}{60} = \frac{11}{30}°$$

$$= \frac{11°}{30}\times\frac{\pi}{180} = 6.3995\times10^{-3}rad.$$

$$\frac{T}{J} = \frac{f_s}{r}$$

$$f_s = \frac{Tr}{J}$$

$$r = \frac{d}{2} = \frac{0.04}{2} = 0.02m$$

$$f_s = \frac{981\times0.02}{2.51\times10^{-7}}$$

$$f_s = 7.817\times10^{7}N/m^2.$$

$$\frac{T}{J} = \frac{C\theta}{L}$$

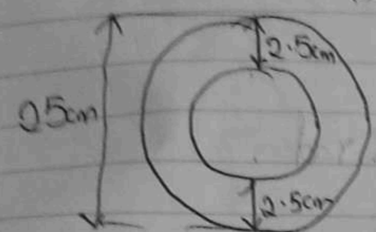
$$C = \left(\frac{J\theta}{TL}\right)^{-1} = \frac{TL}{J\theta}$$

$$C = \frac{981\times28\times10^{-2}}{2.51\times10^{-7}\times6.3995\times10^{-3}}$$

$$C = 1.71\times10^{11}N/m^2.$$

A hollow circular shaft 25cm External diameter and thickness of metal 2.5cm is transmitting power at 180 rpm. The angle of twist over a length of 3m was found to be 0.72°. Calculate the power transmitted and the maximum shear stress induced in the shaft. Take the modulus of rigidity, $C = 0.84 \times 10^6$ kg/cm².

Solution.



$d_1 = 25-(2.5+2.5)$
$= 25-5 = 20cm$

$d_2 = 25cm$ (D)

$$J = \frac{\pi(D^4-d^4)}{32} = \frac{\pi(25^4-20^4)}{32}$$

$J = 22641.56 cm^4$

$$f_s = \frac{Tr}{J}.$$

$$\frac{T}{J} = \frac{C\theta}{L}$$

$L = 3m = 300cm$

$C = 0.84 \times 10^6 kg/cm^2$

$$\theta = 0.72^\circ = \frac{0.72\pi}{180^\circ}$$

$$T = \frac{C\theta J}{L} = \frac{0.84 \times 10^6 kg/cm^2 \times 0.72\pi \times 22641.56 m^4}{180 \times 300 cm}$$

$T = 796662.26 kgcm.$

Maximum Shear Stress → External diameter

Minimum Shear Stress → Internal diameter.

$$f_s = \frac{796662.26 \times 25/2}{22641.56} \frac{kgcm \times cm}{cm^4}$$

$f_s = 439.82 kg/cm^2.$

$$P = \frac{2\pi NT}{4,500}$$

$$P = \frac{2\pi \times 180 \times 796662.2c \times 9.81 \times 10^{-2}}{4,500}$$

$P = 19,641.88$ watts

Assignment's answer.

$D = 2.5cm$

Gauge length $= 20cm$

$\Delta L = 0.0032cm$

Axial Tensile load $= 160kg$

$$\theta = 54' = \frac{54}{60} \times \frac{\pi}{180} = \frac{1}{200}\pi \text{ rad}$$

$T = 2,400kgcm$

$$\text{Tensile stress} = \frac{\text{Tensile load } (F)}{\text{Area}}$$

$$\text{Area} = \frac{\pi d^2}{4} = \frac{\pi(2.5)^2}{4}$$

$= 4.909cm^2$

$$\text{Tensile stress} = \frac{160kg}{4.909cm^2} = 32.593kg/cm^2$$

$$\text{Modulus of elasticity}, E = \frac{\text{Tensile stress}}{\text{Tensile strain}}$$

$$\text{Tensile} = \frac{\Delta L}{L} = \frac{0.0032cm}{20cm} = 1.6 \times 10^{-4}$$

$$E = \frac{32.593kg/cm^2}{1.6 \times 10^{-4}} = 203706.25kg/cm^2$$

$$\frac{T}{J} = \frac{C\theta}{L}$$

$$C = \frac{TL}{J\theta}$$

$$J = \frac{\pi d^4}{32} = \frac{\pi(2.5)^4}{32} = 3.835cm^4$$

$$C = \frac{2,400 \times 20cm}{3.835 \times \pi/200} = 796812.23kg/cm^2$$

$$\left[1 + \frac{1}{m}\right] = \frac{E}{2C}$$

$1/m = \mu =$ poisson ratio

$$1+\frac{1}{m}=\frac{203706.25}{2\times 796812.23}$$

$$1+\frac{1}{m}=\frac{203706.25}{1593624.46}$$

$$1+\frac{1}{m}=0.128$$

$$\frac{1}{m}=0.128-1$$

$$\frac{1}{m}=-0.872$$

$$\mu=-0.872 \text{ Unit}.$$

Assignment.

1a) When is a Shaft said to be in pure tension?

1b) A solid shaft 3.6m long and 75mm in diameter is fixed at both ends. A twisting moment of 22.8kN.m is applied at a distance of 1.5m from one end. Calculate the following:

i) twisting moment shared by each portion.

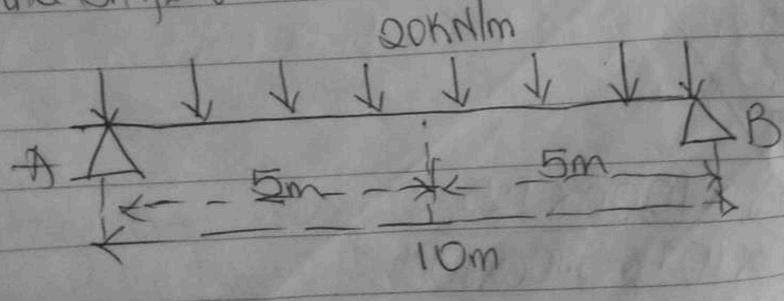
ii) the angle of twist on each ~~twist~~ sides of the plane of application of the twisting moment.

iii) The maximum Shear Stress in each side. Take C (or G) = 90GPa

2) Write a short note on beam deflection

b) When faced with a beam deflection problem, metion four (4) methods you can use to solve the challenge.

c) Determine the maximum deflection and slope of the structure in the Snapshot.



ii) $\frac{T}{J} = \frac{f_s}{r}$

$f_{s_1} = \frac{T_1 r}{J}$

$f_{s_1} = \frac{22.8 \times \left(\frac{75 \times 10^{-3}}{2}\right)}{3.106 \times 10^{-6}}$

$f_{s_1} = 275273.66\ KN/m^2$

$= 275.27\ MN/m^2$

$f_{s_2} = \frac{T_2 r}{J}$

$f_{s_2} = \frac{16.29 \times \frac{75 \times 10^{-3}}{2}}{3.106 \times 10^{-6}}$

$= 196675.79\ KN/m^2$

$= 196.68\ MN/m^2$

2. Beam deflection is the movement of a beam or node from its original position due to the forces and loads being applied to the member. It is also known as displacement and can occur from externally applied loads or from the weight of the structure itself, and the force of gravity to which this applies.

There are generally 4 main variables that determine how much beam deflections. These include:

* How much loading is on the structure.
* The length of the unsupported member.
* The material, specifically the Young's Modulus.
* The cross section size, specifically the Moment of Inertia (I)

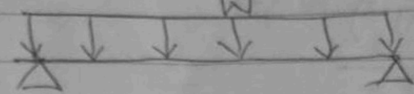
The unit of deflection, or displacement, is a length unit and is normally taken as mm (for metric) and in (imperial)

Types of beam deflection.

1. Cantilever beam deflection: cantilever beams are special type of beams that are constrained by only one support. These members would naturally deflect more as they are only supported at one end.

$\delta_{max} = WL^3/3EI$

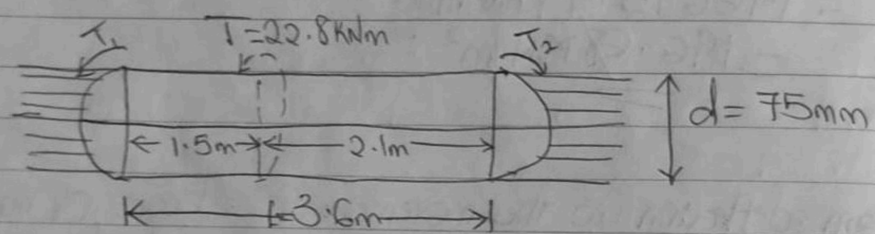
II Simply supported beam deflection:→ These beams are supported at both ends, so the deflection of a beam is generally less and follows a much different shape from that of the cantilever.



$$\frac{5WL^4}{384EI}$$

2b) Macaulay's method (Double Integration method)
II Moment-area method → VI Strain energy method
III Conjugate Beam method — applying Mohr's theorems.
IV Method of Superposition.

1b)



(ii)

$T_0 = T_1 + T_2$

$T_1 + T_2 = 22.8\text{ KNm}$ — (i)

$$\frac{T}{J} = \frac{C\theta}{L} = \frac{fs}{r}$$

$$J = \frac{\pi d^4}{32}$$

$$J = \frac{\pi (75 \times 10^{-3})^4}{32}$$

$$J = 3.106 \times 10^{-6}\,m^4$$

(i) $T \propto \frac{1}{L}$

$T_1 l_1 = T_2 l_2 \Rightarrow$ (angle of twist → same) (iii)

Proving

$$\frac{T}{J} = \frac{C\theta}{L}$$

$$\theta = \frac{TL}{CJ} \Rightarrow \frac{T_1 l_1}{\cancel{CJ}} = \frac{T_2 l_2}{\cancel{CJ}}$$

$T_1 l_1 = T_2 l_2$.

$$T_1 = \frac{T_2 l_2}{l_1}$$

$$T_1 = \frac{T_2(2.1)}{1.5}$$

$T_1 = 1.4T_2$

$T_1 + T_2 = 22.8\,kN/m$ —— (i)

$1.4T_2 + T_2 = 22.8$

$2.4T_2 = 22.8$

$$T_2 = \frac{22.8}{2.4}$$

$T_2 = 9.5\,kN/m$

$T_1 = 1.4T_2$

$T_1 = 1.4(9.5)$

$= 13.3\,kN/m$

∴ The twisting moment shared by each portion $= T_1 - T_2$

$= 13.3\,kN/m - 9.5\,kN/m$

$= 3.8\,kN/m.$

(ii)

$$\frac{T}{J} = \frac{C\theta}{l}$$

$$\frac{T_1}{J} = \frac{C\theta}{l_1}$$

$$\frac{T_1 l_1}{CJ} = \theta$$

$$\theta = \frac{13.3 \times 1000 \times 1.5}{90 \times 10^9 \times 3.106 \times 10^{-6}}$$

$\theta = 0.0714\,rad$

$= 4.09°$

∴ The angle of twist on each sides of the plane of application of the twisting moment is the same and equals to 4.09°

(iii)

$$\frac{T}{J} = \frac{f_s}{r}$$

$$f_s = \frac{T_1 r}{J} = \left(\frac{13.3 \times 1000 \times \frac{75 \times 10^{-3}}{2}}{3.106 \times 10^{-6}}\right)$$

$f_{s_1} = 1.6058 \times 10^8\,N/m^2$

$= 0.161\,GN/m^2$

$$f_{S_2} = \frac{T_2 r}{J} = \frac{9.5 \times 1000 \times \frac{75 \times 10^{-3}}{2}}{3.106 \times 10^{-6}}$$

$$f_{S_2} = 1.1470 \times 10^{8}\,N/m^2$$

$$= \underline{0.115\,GN/m^2}.$$

$$f_{s_2} = \frac{Tr_2}{J} = \frac{9.5\times1000\times\frac{75\times10}{2}}{3.106\times10^{-6}}$$

$$f_{s_2} = 1.1470\times10^{8}\,N/m^2$$
$$= 0.115\,GN/m^2$$

* What is Shear force and Bending moment?.

Types Of Beam

1. Cantilever beam
2. Simply supported beam.
3. Overhanging beam.
4. Input beam
5. Continuous beam

Types of load.

1. Point/Concentrated load
2. Uniformly distributed load (UDL)
3. Uniformly varying load (UVL)

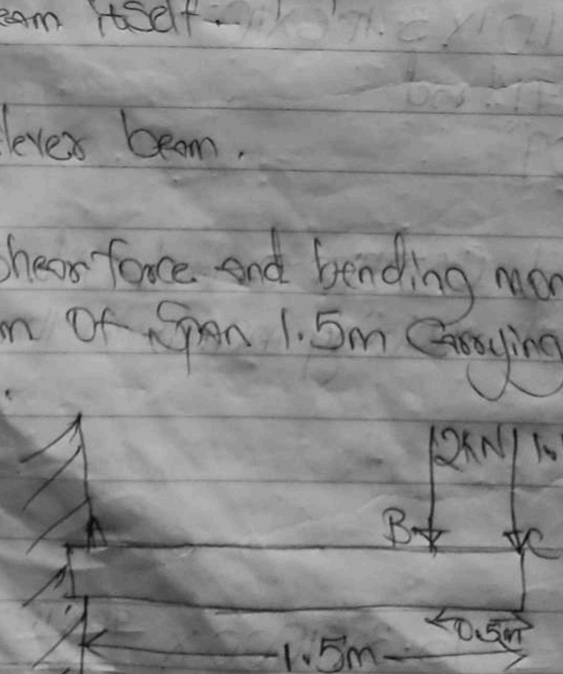
What can make a beam to deflect?.

1. load Of the Structure
2. length Of the Unsupported member
3. Elasticity Of the material (properties of the material)
4. Types Of beam itself.

Cantilever beam.

Example 1

Draw the Shear force and bending moment diagram Of a cantilever beam Of Span 1.5m Carrying a point load as Shown below.



* Study Sign Convention Of S.F and B.M

Solution

S.F

$F_C = -1.5\,KN$

$F_B = -1.5 - 2$

$= -3.5\,KN$

$F_A = -3.5\,KN$

When drawing

	S.F	B.M
Point load	Vertical	horizontal
Uniform load	Slant	Parabola
Varying load	Parabola	Quadratic

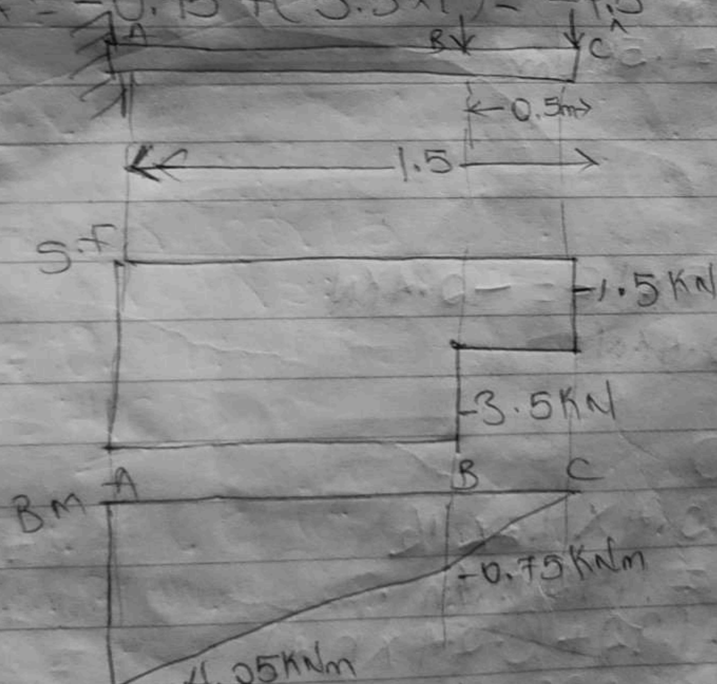
Relationship: B.M is area under the S.F & S.F is area under the load

B.M

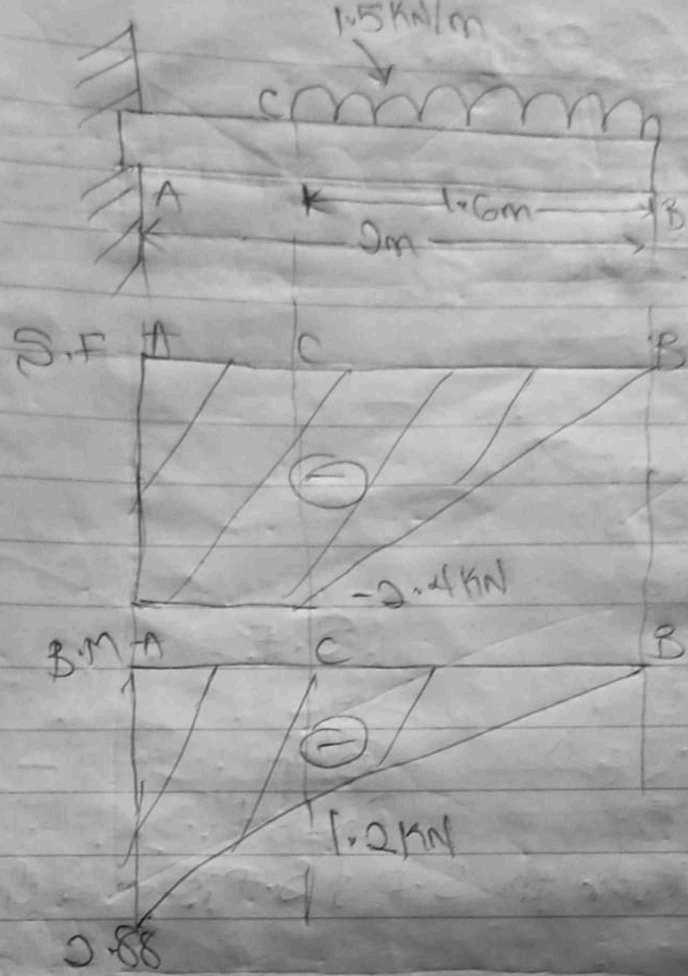
$M_C = 0$

$M_B = 0 + -(0.5 \times 1.5) = -0.75\,KNm$

$M_A = -0.75 + (-3.5 \times 1) = -4.25$



2. A cantilever beam AB 2m long carrying a uniformly distributed load of 1.5KN/m over a length of 1.6m from the free end. Draw shear force and bending moment diagram



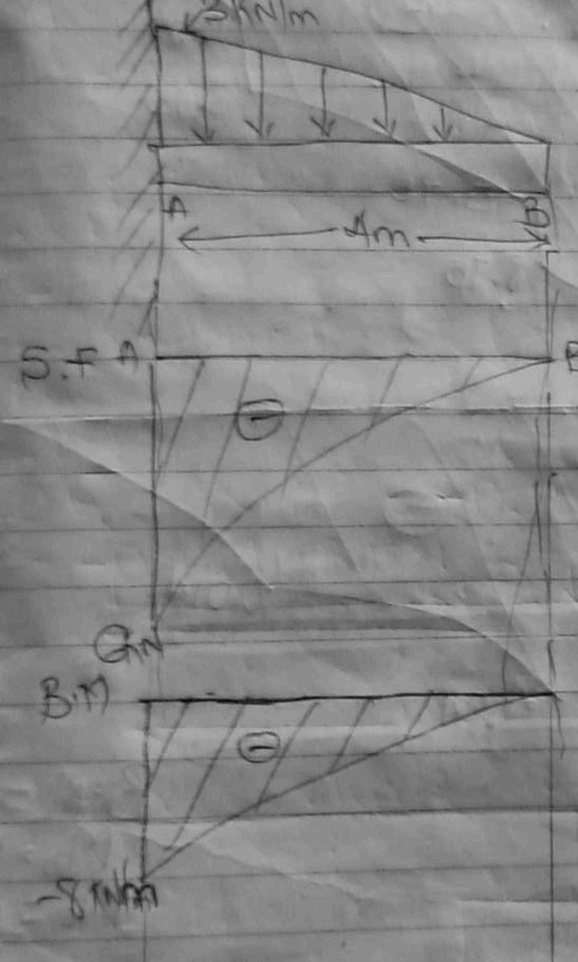
Given
Span = 2m
= 1.5KN/m

S.F
$F_B = 0$
$F_C = -1.5 \times 1.6 = -2.4KN$
$F_A = -2.4KN$
B.M
$M_B = 0$
$M_C = -2.4 \times 1.6 \times 1/2$
$= 1.92 KN m$
$M_A = -1.92 + (-2.4 \times 0.4)$
$= -2.88 KNm$

3 A cantilever beam 4m long carrying a gradual varying load zero at the free end to 3kN/m at the fixed end. Draw the shear force and bending moment diagram of the beam.

* Strength of material by Kilami

Solution.



S.F

$F_B = 0$

$F_A = -\frac{1}{2} \times 4 \times 3 = -6KN$

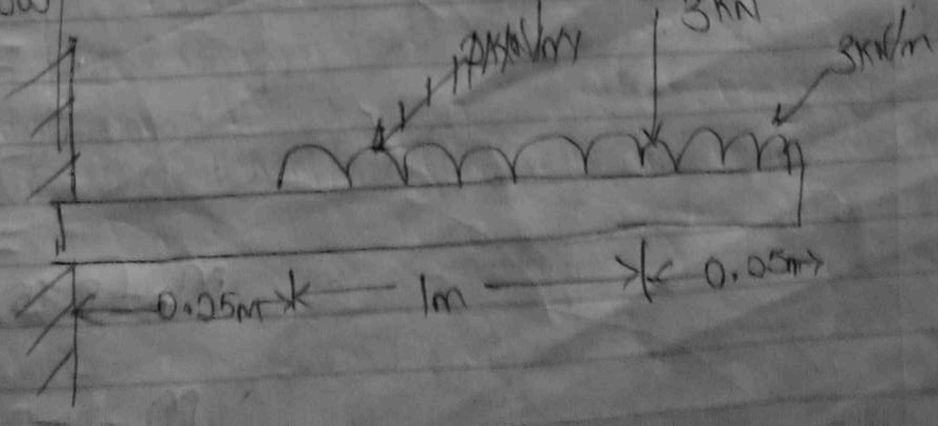
B.M

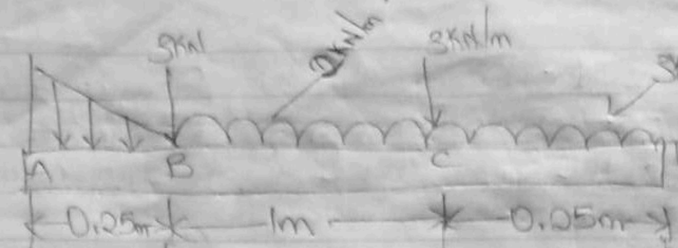
$M_B = 0$

$M_A = \frac{3 \times 4^2}{6} = 8KNm$

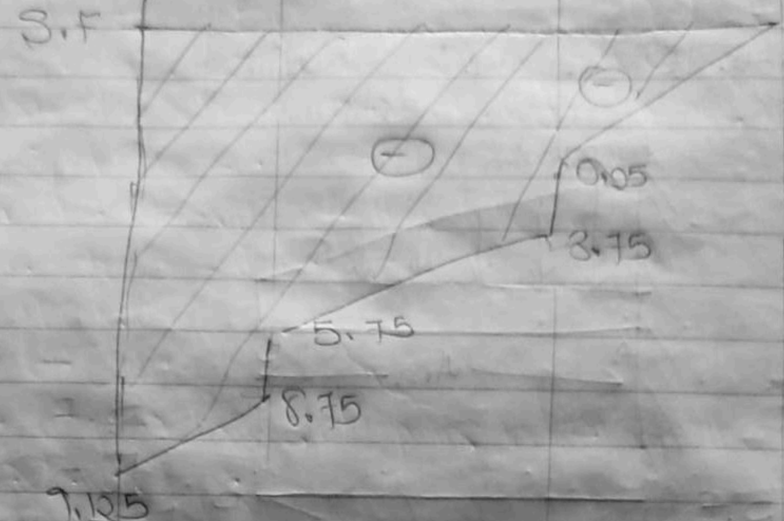
Area of parabolic $= \frac{W \times x^2}{6}$

A cantilever beam of 1.5m long is loaded with Uniform distributed load of 2KN/m and a point load of 3KN as shown below

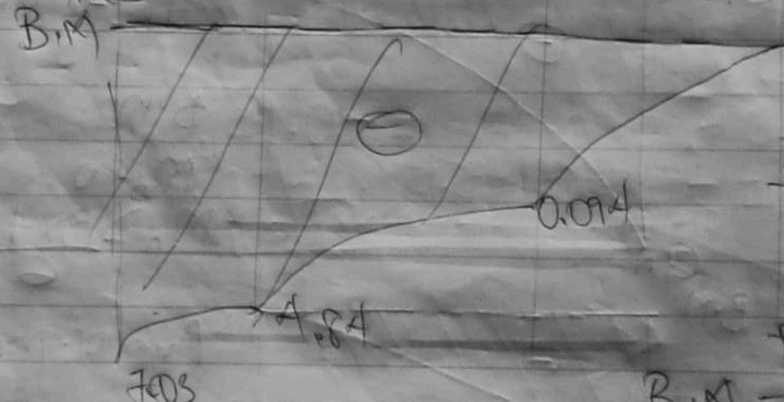




S.F



B.M



S.F

$F_D = 0$

$F_C = -(3 \times 0.25) = -0.75$

$F_C = -0.75 + (-3) = -3.75$

$F_B = -3.75 + (-2 \times 1) = -5.75$

$F_B = -5.75 - 3 = -8.75$

$F_A = -8.75 + (\frac{1}{2} \times -3 \times 0.25) = 9.88kN$

$F_A = -9.105kN$

B.M =

$M_D = 0$

$M_C = \frac{1}{2} \times -0.75 \times 0.25 = -0.094 kNm$

$M_B = \frac{1}{2}(A+B)h$

$= \frac{1}{2}(3.75 + 5.75)1 + (-0.094)$

$= -4.84 kN.m$

$M_A = (8.75 \times 0.25) + \left(\frac{-0.375 \times 0.05}{6}\right)$

$M_A = -2.194 - 0.004$

$= -2.194 - 4.84 = -7.03kNm$

1a) Write a short note of beam deflection.
b) When faced with a beam deflection problem, mention 4 methods, you can use to solve the problem.
c) Determine the maximum deflection and the slope of the structure in figure 1

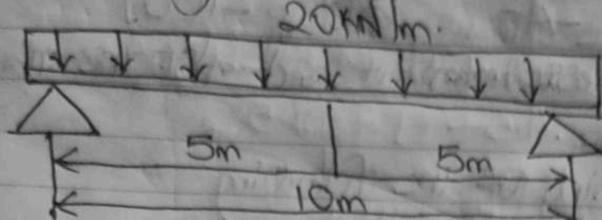


Figure 1

2a) State Hooke's law and explain the following terms:
I Stress
II Strain
III Elasticity
IV Elastic limit
V Elastic body
b) A bar of sectional area 125mm² and 2mm in length is extended by 0.4mm when an axial load of 500N was applied. Calculate the following:
I Stress
II Strain
III Young Modulus of the material.

3a) When is a shaft said to be in a pure tension?
b) A solid shaft of 3.6m long and 75mm in diameter is fixed at both ends, a twisting moment of 22.8KNm is applied at a distance of 1.5m from one end. Calculate the following:
i) Twisting moment shared by each portion.
ii) The angle of twist on each sides of the plane of application of the twisting moment.
iii) The maximum shear stress in each side. Take (C or G) = 90GPa

4a) Why is the subject Strength of material important to an engineer?
ii) Differentiate briefly between Strength of material and

Material Science.

II The State Of Stress at a point is given by the following Stress ~~tensile~~ tensor

$$T_{ij} = \begin{bmatrix} 50 & 50 & -40 \\ 50 & -30 & 30 \\ -40 & 30 & -100 \end{bmatrix}$$

Calculate the Stress invariant and also the magnitude of the principal Stress.

b Explain the meaning of the following

I Ultimate Stress

II Young modulus

III Factor Of Safety

c Draw a fully reference diagram indicating the Stress-Strain relationship.

5.

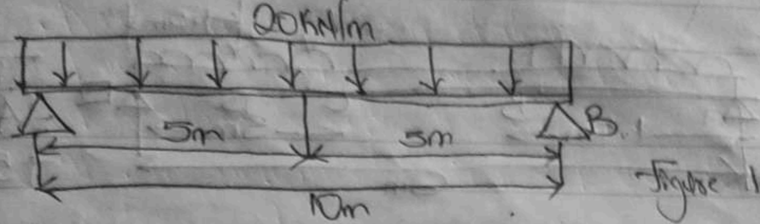


Figure 1

upward ~~mf~~ force = downward force.

20KN/m × 10m = 200KN

$R_A + R_B = 200$ ——— (i)

Considering pivot B.

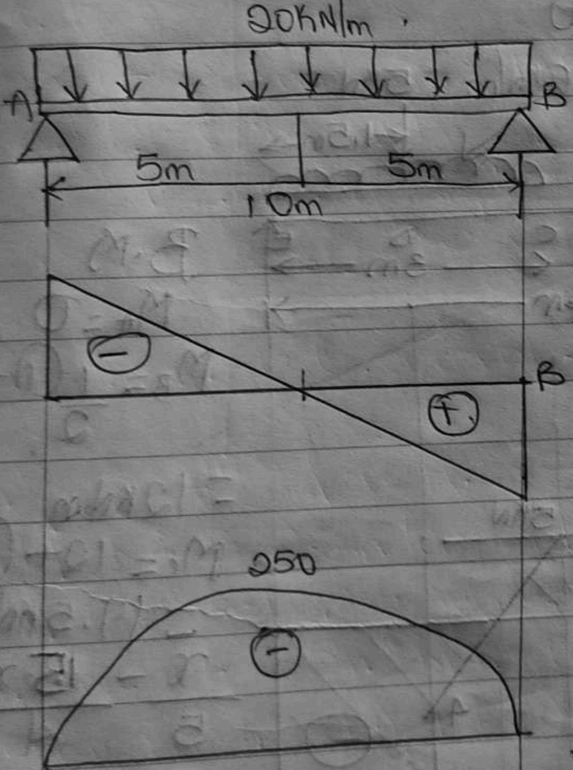
$R_A \times 10 = 200 \times 5$

$R_A = \dfrac{200 \times 5}{10} = 20 \times 5 = 100KN$

$100 + R_B = 200$

$R_B = 200 - 100$

$= \underline{100}KN$.



S.F

$F_A = -100KN$

$F_B = -100 + 200 = 100$

$\dfrac{x}{100} = \dfrac{10-x}{-100}$

$100x = 1000 - 100x$.

$200x = 1000$

$x = \dfrac{1000}{200}$

$x = 5m$

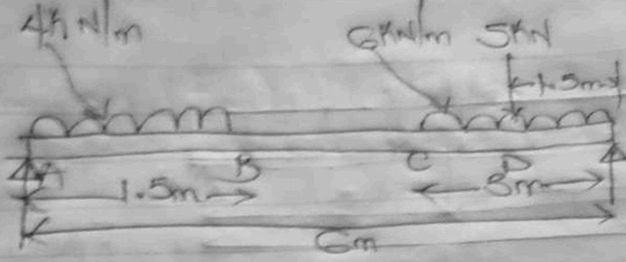
BM

$M_A = 0$

$M_c = \dfrac{1}{2} \times 100 \times 5 = 250$

$M_B = \dfrac{1}{2} \times -100 \times 5 + 250KN$

$= 0$



Total load
$= (4 \times 1.5) + (6 \times 3)$
$+ 5 = 29KN.$

Upward force = downward force,

$(R_E \times 6) - (6 \times 0.75) - (1.8 \times 4.5) - (5 \times 4.5) = 0$

$6R_E = 4.5 + 81 + 22.5$

$R_E = 18KN$

$R_A = 29 - 18 = 11KN$

S.F

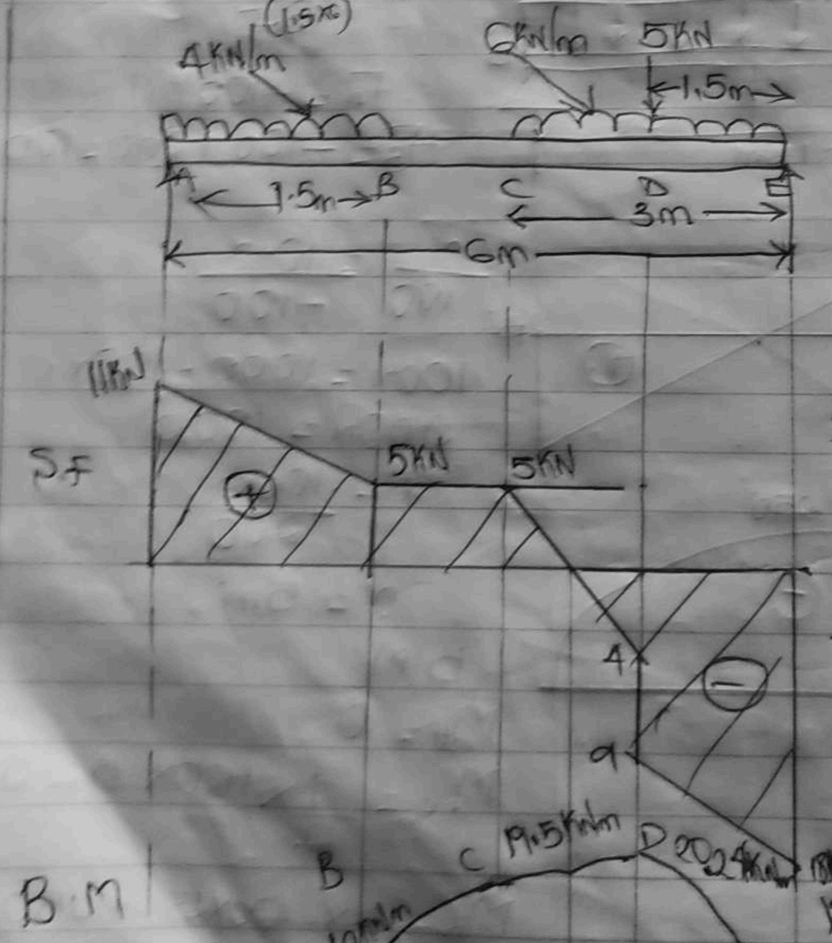
$F_A = 11KN$

$F_B = 11 - 6 = 5KN$

$F_C = 5KN$

$F_D = 5 - (1.5 \times 6) - 5 = -9KN$

$F_E = -9 - 9 + 18 = 0$



B.M

$M_A = 0$

$M_B = \frac{1}{2}(11+5)1.5$

$= 12KNm$

$M_C = 12 + (5 \times 1.5)$

$= 19.5KNm$

$\frac{x}{5} - \frac{1.5 - x}{4} = 0$

$\frac{x}{5} = \frac{1.5 - x}{4}$

$x = 0.83m$

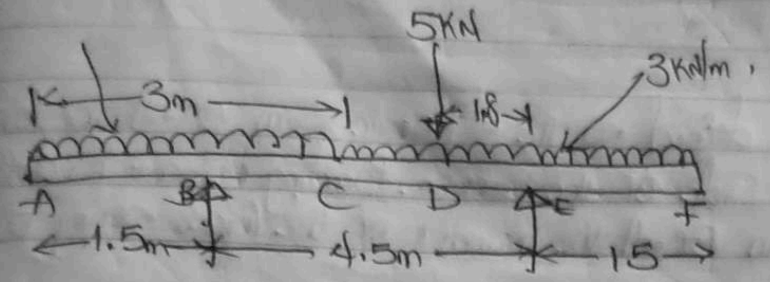
$1.5 - 0.83 = 0.67m$

$E\ M_A = 19.5 + (1/2 \times 5 \times 0.83)$

$= 21.58KNm$

$M_D = 21.58 - (1/2 \times 4 \times 0.67) = 20.24KNm$

$M_E = 20.24 - \frac{1}{2}(9+18)1.5 = 0$



Draw the S.F and B.M of the Overhanging beam in the figure above.

* Elastic limit :> is the maximum extent to which a material may be stretched without permanent alteration of size or shape.

* Strength of materials deals with various forces, stresses, moments, deformations and behaviours of various materials which in turn very much useful in designing of structures like beams, slabs, steel structures, machines, and machine parts, etc.

* Material sciences describes about a material's ability to withstand an applied load without failure or plastic deformation whereas the field of strength of materials deals with forces and deformations that result from their acting on a material. Material science deals with the property of material in designing and discovering new materials while strength of material deals with the behaviour of material under stress (loading).

* Ultimate tensile stress (UTS) refers to the maximum stress that a given material can withstand under an applied force.

* Young's modulus :> is a measure of elasticity, equal to the ratio of the stress acting on a substance to the strain produced. It tells how easily it can stretch and deform.

Factor of Safety (FoS) :-> AKA Safety Factor expresses how much stronger a System is than it needs to be for an intended load.

Shear force is defined as the algebraic Sum of all the forces acting on either Side of the Section. Bending moment is defined as the algebraic Sum of all the moment of the forces acting on either Side of the Section.