Subject Code- 21CIV14

Model Question Paper-I/II with effect from 2021 (CBCS Scheme)

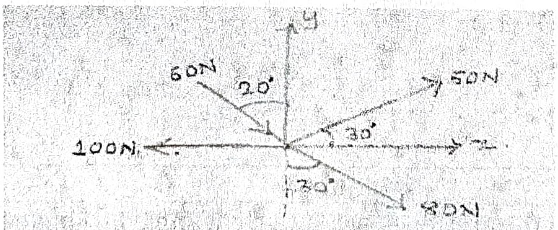
USN | | | | | | | | | | |

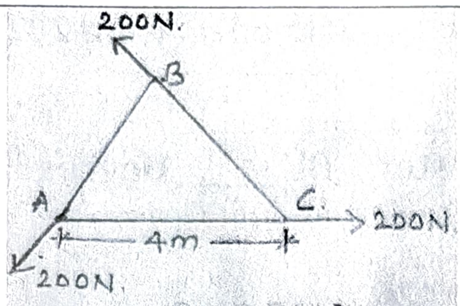
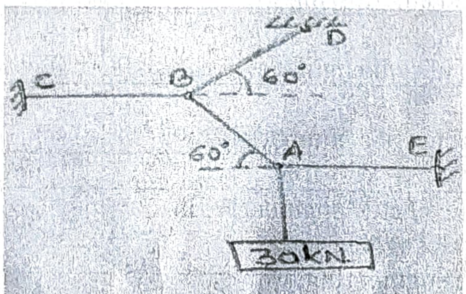
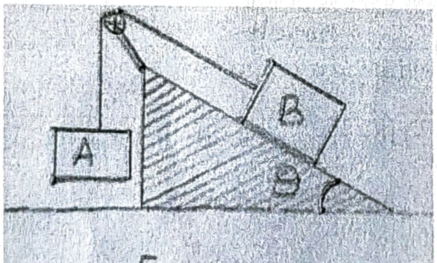
First Semester _BE_____ Degree Examination

Subject Title Elements of civil Engineering and Mechanics

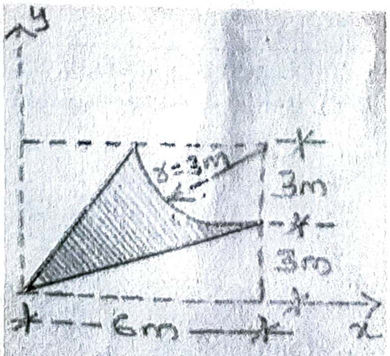
TIME: 03 Hours **Max. Marks: 100**

Note: 01. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE.**
02. Any missing data may suitable be assumed.
03.

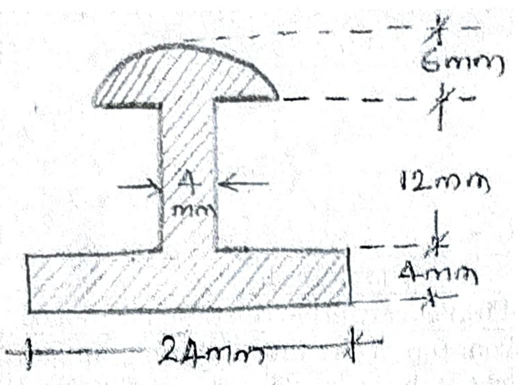
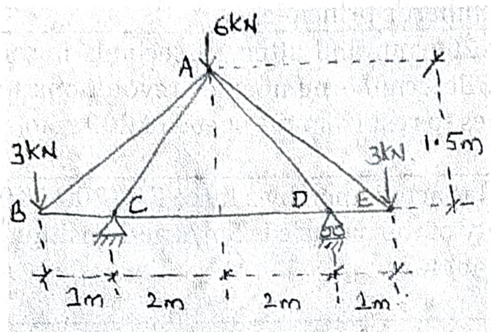
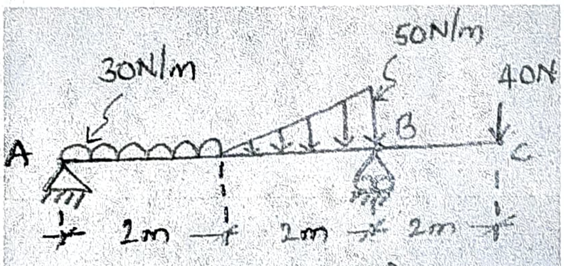
		Module -1	**Marks**
Q.01	a	Explain briefly the scope of civil engineering in i) Environmental and sanitary engineering ii) Construction engineering	8
	b	Explain briefly the role of civil engineers in the development of the nation	6
	c	What are the requirements of a good brick?	6
		OR	
Q.02	a	Explain briefly the scope of civil engineering in i) Geotechnical engineering ii) Earthquake engineering	8
	b	Explain briefly different types of cement.	6
	c	Explain the classification of steel	6
		Module-2	
Q. 03	a	State and prove parallelogram law of forces	6
	b	Determine the resultant of the force system shown in fig. Q3 (b).  Fig. Q3(b)	6
	c	Three forces of magnitude 200N each are acting along the sides of an equilateral triangle as shown in fig Q 3 (c). Determine the resultant in magnitude and direction with reference to point B.	8

		 Fig. Q 3 (c)	
OR			
Q.04	a	State and Prove Lami's theorem	6
	b	A vertical load of 30kN is supported at A by a system of cables as shown in fig. Q4 (b). Determine force in each cable for equilibrium.  Fig. Q 4 (b).	6
	c	Knowing that W_A = 80N and θ = 40^0, determine the smallest and largest value of W_B for which the system is in equilibrium, refer fig. Q4 (c). Take μ_s = 0.35 and μ_k = 0.25.  Fig. Q 4 (c)	8

Module-3

Q. 05	a	Find the centroid of the area enclosed by a right angled triangle from first principle.	10
	b	Locate the centroid of the shaded area as shown in fig. Q 5(b)  Fig. Q5 (b)	10

OR

Q. 06	a	State and prove parallel axes theorem	6
	b	Derive an expression for moment of inertia of a rectangle from first principle about its vertical centroidal axis.	6
	c	Find the polar radius of gyration for the area as shown in fig. Q 6 (c)  Fig. Q 6 (c)	8
		Module-4	
Q. 07	a	Explain different types of supports and reactions.	8
	b	Analyse the truss as shown in fig Q 7(b), by methods of joints.  Fig. Q 7 (b).	12
		OR	
Q. 08	a	What are the assumptions made in analysis of a truss.	4
	b	Find the support reactions for the beam as shown in fig Q 8 (b).  Fig. Q 8 (b).	8
	c	A floor truss is loaded as shown in fig Q 8 (c), determine the forces in members CF, EF and EG.	8

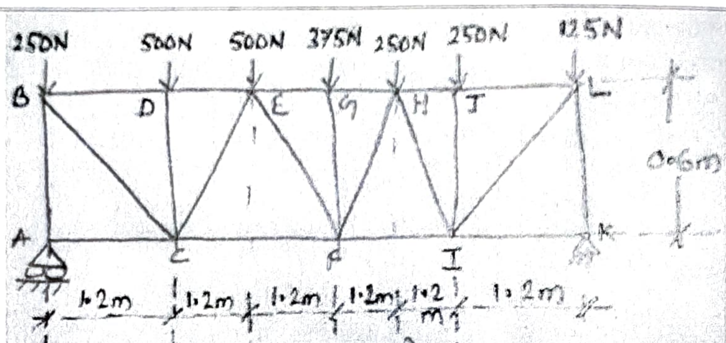


Fig Q 8(c).

		Module-5	
Q. 09	a	Define i) Displacement ii) Velocity iii) Acceleration iv) Speed	4
	b	A stone is released from top of the tower, during the last second of its motion, it covers 1/4th of the height of the tower. Find the height of the tower.	8
	c	A target is fired with an initial velocity of 180m/s at a target located 500m above the gun and at a horizontal distance of 2100m. Neglecting air resistance, determine the value of the firing angle.	8
		OR	
Q. 10	a	State and explain D' Alembert's principle.	6
	b	A fly wheel rotates at 200rpm and after 10 seconds it rotating at 160rpm. If the retardation is uniform determine number of revolutions made and time taken by flywheel before it-.comes to rest from the speed of 200 rpm.	6
	c	A particle of mass 100N is acted upon by a force $F = (20t^2 - 40)N$, where 't' is time in second. At $t = 0s$, velocity of the particle is 5m/s and position $x = 0$. Find velocity and position of the particle at $t = 2s$.	8

FIRST SEMESTER B.E DEGREE EXAMINATION
ELEMENTS OF CIVIL ENGINEERING AND MECHANICS [21CIV14]

MODEL QUESTION PAPER SOLUTION SET-2

Q1 a.

i] The scope of civil engineering in Environmental and sanitary engineering is as follows:

This discipline deals with study of the natural environment/ ecosystems, inter-relation between biotic and abiotic factors, safety of people against different types of pollution and treatment as well as disposal of wastes.

Considering the increase in population and rapid rate of urbanisation, all types of pollution have increased and hence environmental impact assessment for industries, factories and control /eradication / prevention of pollution have become very essential areas for study and research / development.

The applications involve:

- Measurement of pollutants.
- Water treatment for supplying potable water.
- Waste water treatment
- Determining standards for effluents
- Monitoring different types of pollution
- Environmental Impact Assessment

-4M

ii] The scope of civil engineering in Construction engineering is as follows:

This discipline deals with different types of constructions of structures with requisite economy, efficiency and factor of safety. It also includes excavation, construction of foundations and footing, concreting, finishing, building of walls, bridges, tunnels, underground and underwater constructions with different techniques, construction machinery. etc.

The applications involve:

- Construction management
- Maximization and optimization of resources
- Use of modern and effective methods / techniques
- Scheduling and phasing of works

-4M

Q.1 b] The role of civil engineers in the development of the nation is as follows:

- To conceive, plan, estimate, get approval, create and maintain all civil engineering infrastructure activities.
- To carry out research and training programmes to improve the technology.
- Development of infrastructures like:
  → Town and city planning
  → Build suitable structures for the rural and urban areas for various utilities.
  → Build tanks, dams to exploit water resources.
  → Purify the water and supply water to needy areas like houses, schools, offices and agriculture field.
  → Provide good drainage system and purification plants.
  → Provide and maintain communication systems like roads, railways, harbours and airports. -6M
  → Monitor land, water and air pollution and take measures to control them.

Q.1 c. The requirements of good bricks are as follows:

- Bricks should be uniformly and thoroughly burnt with uniform colour and straight edges.
- Bricks should be hard, giving metallic ringing sound when struck together or by trowel and no stratch is made on its surface by finger-nail.
- Bricks should be free from cracks, flaws, lumps and holes.
- An average building brick should have a minimum compressive strength of $3.5\ N/mm^2$.
- Bricks should not break into pieces when dropped freely from a height of about 1m on to the ground. -6M
- Brick should not absorb water more than 20% of its dry weight.

Q.2 a.

i] The scope of civil engineering in Geotechnical engineering is as follows:

This discipline deals with study of soil properties and engineering behaviour of soil under the action of particular loads and moisture content. It includes soil mechanics, aspects of geology and foundation engineering.

The applications of the discipline are as follows:

- Sub-soil exploration
- Design and construction of foundations for water structures, buildings and machines.
- Effective, efficient and economical type of foundation for load transfer on wider area.
- Estimation of bearing capacity of soil.
- Maintenance of foundations to avoid failure.
- Design of retaining walls, earthern dams / embankments
- Ascertaining stability of ground slopes.

–4M

ii] The scope of civil engineering in Earthquake engineering is as follows:

This discipline deals with designing and analysing of structures to make them more resistant to earthquake. It also involves,

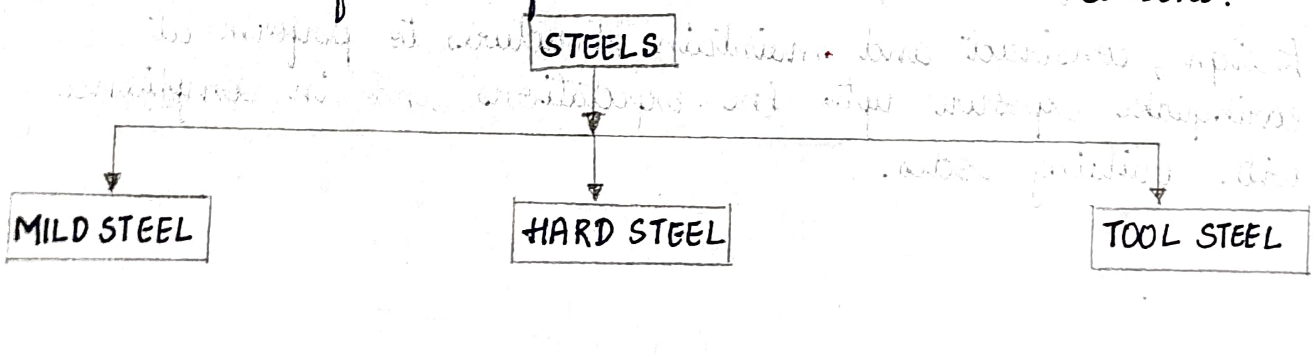
- Post-earthquake investigations of causative mechanisms resulting in structural damage, failure or collapse.
- Earthquake planning and risk mitigation which includes identification, quantification and mitigation of risk through optimal repair strategies, performance-based upgrades etc.
- Foresee the potential consequences of strong earthquakes on urban areas and civil infrastructure.
- Design, construct and maintain structures to perform at earthquake exposure upto the expectations and in compliance with building codes.

- 4M

Q. 2 b The different types of cement are as follows :

- ORDINARY PORTLAND CEMENT – It is general purpose cement ordinarily used for usual construction works like masonry, plaster, cement concrete. etc. Specific weight is about 14.4 kN/m³.
- RAPID HARDENING CEMENT – It contains higher percentage of tricalcium silicate. It is finer than OPC hence attains greater strength in shorter time. As it hardens quickly, it is used for roads, bridges and underwater constructions where time of construction should be less.
- POZZOLONA CEMENT – It is a mixture of OPC and a volcanic substance called pozzolona so that cement withstands the chemical attacks and sea water action. Used in marine construction.
- LOW HEAT CEMENT – It produces low heat of hydration. It is used for massive structures like dams where heat of hydration cannot be dissipated which would result in shrinkage cracks. ANY 6 1 M each
- SULPHATE RESISTING CEMENT – It contains higher percentage of silicates and used to resist sulphate attack eg. canal lining
- HYDROPHOBIC CEMENT – It contains water repellent chemicals and does not absorb moisture.
- WATER-PROOF CEMENT – During mixing, water proofing agents are added to ordinary cement. Used for water retaining structures.
- COLOURED CEMENT – Suitable pigments are added to prepare coloured cements, used for decorative works.
- GRADE CEMENT – These are categorised based on compressive strength after 28 days of curing as 33 grade, 43 grade and 53 grade. – 6M

c Steel is classified as follows, based on carbon content.



- Mild steel also known as low carbon steel, has carbon content less than 0.2 % [carbon < 0.2 %] and is very ductile.
- Hard steel also known as medium carbon steel, has carbon content < 0.25 % to 0.7 % and possesses medium ductility.
- Tool steel also known as high carbon steel, has carbon content < 0.7 % and possesses less ductility.
- Alloys of steel like high strength steel and stainless steel are also in use.
- Cold twisted steel bars having rough surface or protrusions are called Tor steel bars or deformed [high yield strength deformed] bars having yield strength upto 500 or 550 N/mm². −6M
- Thermo - Mechanically Treated [TMT] bars are cooled rapidly after hot rolling so higher strength is obtained.

Forms of mild steel used are as follows:

MILD STEEL
- BARS
  - Square
  - Plain circular
  - Thermo - Mechanically Treated [TMT]
  - High Yield Strength Deformed [HYSD] or TOR
- WIRES OR CABLES
- OTHER SECTIONS

Q 3 a. PARALLELOGRAM LAW OF FORCES

STATEMENT : "If two forces are represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant is represented in magnitude and direction by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces." −2M

PROOF :

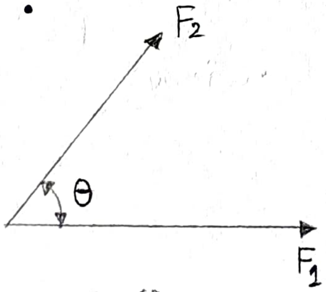


fig (i)

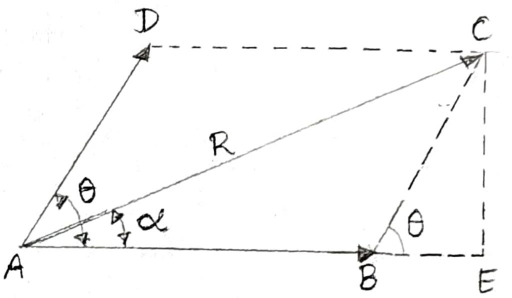


fig (ii)

Consider the two forces F_1 and F_2 acting on a particle as shown in fig (i). Let the angle between the two forces be θ. If parallelogram ABCD is drawn with AB representing F_1 and AD representing F_2, according to parallelogram law of forces, AC represents the resultant R. Drop perpendicular CE to AB.

The resultant R of F_1 and F_2 is given by:

$$R = AC = \sqrt{AE^2 + CE^2} = \sqrt{(AB+BE)^2 + CE^2}$$

But $AB = F_1$

$BE = BC\cos\theta = F_2\cos\theta$

$CE = BC\sin\theta = F_2\sin\theta$

$$\therefore R = \sqrt{(F_1 + F_2\cos\theta)^2 + (F_2\sin\theta)^2}$$

$$= \sqrt{(F_1^2 + 2F_1F_2\cos\theta + F_2^2\cos^2\theta + F_2^2\sin^2\theta)}$$

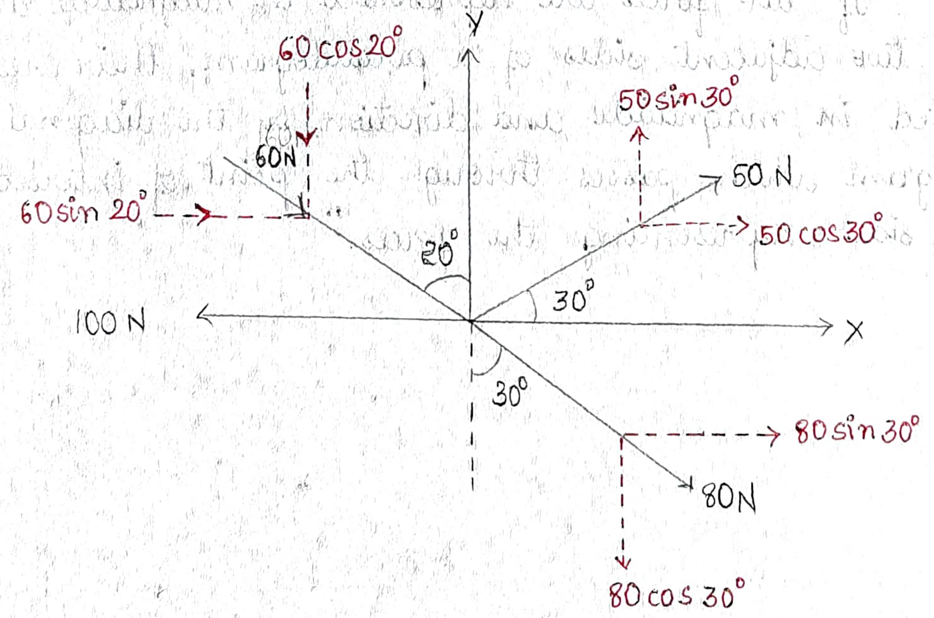
$$\therefore \boxed{R = \sqrt{(F_1^2 + 2F_1F_2\cos\theta + F_2^2)}} \qquad [\because \sin^2\theta + \cos^2\theta = 1]$$

The inclination of the resultant to the direction of the force F_1 is given by α -4M

$$\tan\alpha = \frac{CE}{AE} = \frac{CE}{AB+BE} = \frac{F_2\sin\theta}{F_1 + F_2\cos\theta}$$

$$\therefore \boxed{\alpha = \tan^{-1}\frac{F_2\sin\theta}{F_1 + F_2\cos\theta}}$$

Q 3 b.



-2M

Fig: Resolution of forces into x and y components

$\Sigma F_x = 50\cos 30^\circ + 80\sin 30^\circ + 60\sin 20^\circ - 100$

$= 43.30 + 40 + 20.52 - 100$

$\Sigma F_x = 3.82\ N$ -1M

$\Sigma F_y = -80\cos 30^\circ + 50\sin 30^\circ - 60\cos 20^\circ$

$= -69.28 + 25 - 56.38$

$\Sigma F_y = -100.66\ N$ -1M

$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$

$= \sqrt{(3.82)^2 + (-100.66)^2}$

$= \sqrt{10147.028}$ -1M

$\therefore \boxed{R = 100.73\ N}$

$\tan\alpha = \dfrac{|\Sigma F_y|}{|\Sigma F_x|} = \dfrac{100.66}{3.82} = 26.35$

$\alpha = \tan^{-1}(26.35)$ -1M

$\therefore \boxed{\alpha = 87.82^\circ}$

Q 3 c.

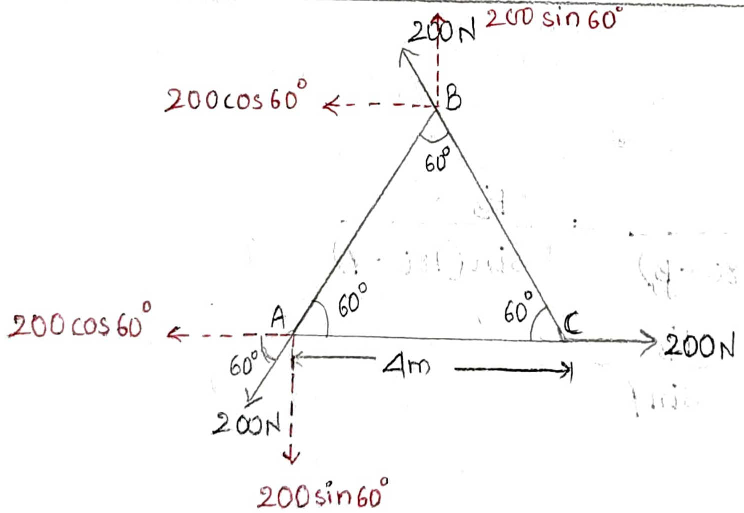


Fig: Resolution of forces into x and y components

$\Sigma F_x = -200\cos 60^\circ - 200\cos 60^\circ + 200$

$= 0$

$\Sigma F_y = -200\sin 60^\circ + 200\sin 60^\circ$

$= 0$

$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = 0$

$\therefore$ The resultant force is 0.

Q. 4 a. LAMI'S THEOREM :

STATEMENT : If three concurrent forces are in equilibrium, the ratio of magnitude of any force to the sine of angle between the other two forces is constant.

For the three concurrent forces F_1, F_2 and F_3 as shown in figure,

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$ -3M

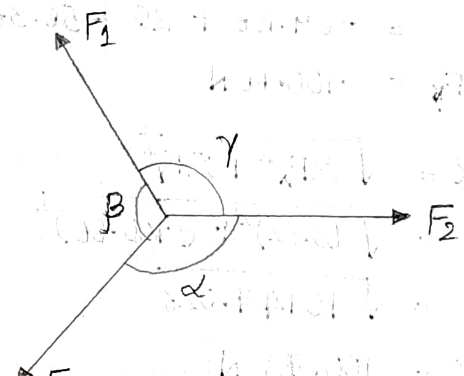


fig 1

PROOF : As the three forces are in equilibrium, they will form a closed triangle when drawn one after the other as shown in figure 2.

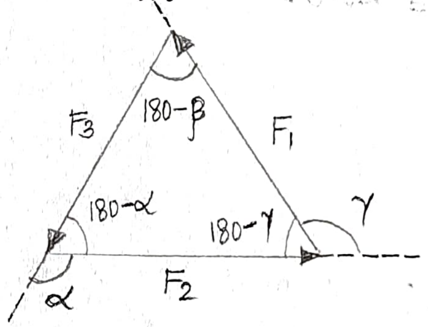


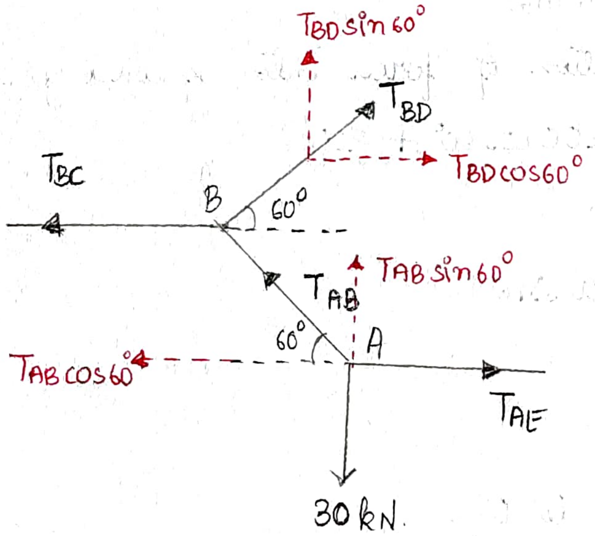
fig 2

Using sine rule,

$$\frac{F_1}{\sin(180-\alpha)} = \frac{F_2}{\sin(180-\beta)} = \frac{F_3}{\sin(180-\gamma)}$$ -3M

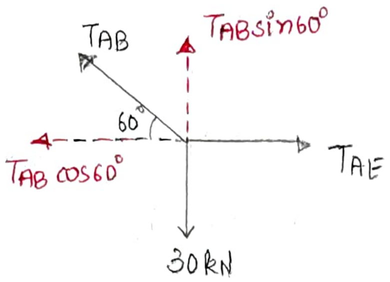
$$\therefore \frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

4 b.



FBD for the system of cables

FBD of point A :



$\Sigma F_x = 0$

$T_{AE} - T_{AB}\cos 60^\circ = 0$

$T_{AE} = T_{AB}\cos 60^\circ$ —— (i)

$\Sigma F_y = 0$

$-30 + T_{AB}\sin 60^\circ = 0$

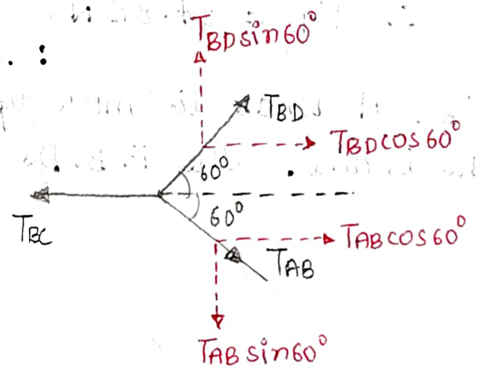
$\therefore \boxed{T_{AB} = 34.64\text{ kN [T]}}$ —— (ii)

substituting (ii) in (i)

$\therefore \boxed{T_{AE} = 17.32\text{ kN}}$ [T]

-3M

FBD of point B. :



$\Sigma F_x = 0$

$-T_{BC} + T_{AB}\cos 60^\circ + T_{BD}\cos 60^\circ = 0$

$-T_{BC} + 34.64\cos 60^\circ + T_{BD}\cos 60^\circ = 0$

$-T_{BC} + T_{BD}\cos 60^\circ = -17.32$ —— (iii)

$\Sigma F_y = 0$

$-T_{AB}\sin 60^\circ + T_{BD}\sin 60^\circ = 0$

$-34.64\sin 60^\circ + T_{BD}\sin 60^\circ = 0$

$\therefore \boxed{T_{BD} = 34.64\text{ kN [T]}}$ —— (iv)

substituting (iv) in (iii)

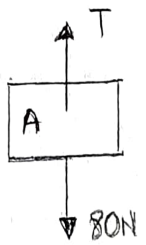
$-T_{BC} + 34.64\cos 60^\circ = -17.32$

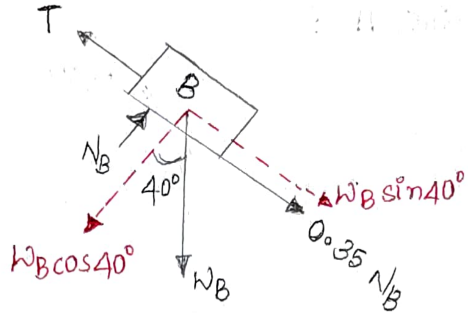
$-T_{BC} = -34.64\text{ kN}$

$\therefore \boxed{T_{BC} = 34.64\text{ kN [T]}}$

-3M

Q. 4 c] For smallest value of W_B, A tends to move down and B tends to move upward along the incline. The free body diagrams are as follows :





From FBD of A:

$\Sigma F_y = 0$

$T - 80 = 0$

$\therefore\ T = 80\,N$

From FBD of B:

$\Sigma F_y = 0$

$N_B - W_B \cos 40° = 0$

$\therefore\ N_B = W_B \cos 40°$

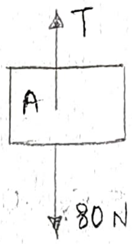
$\Sigma F_x = 0$

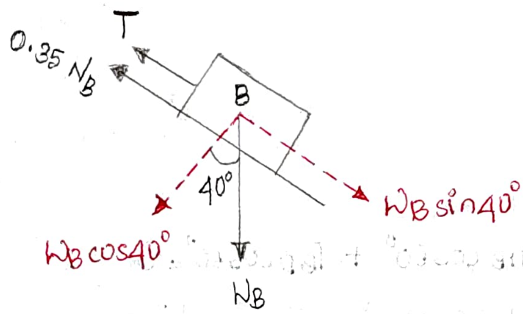
$W_B \sin 40° + 0.35\,N_B - T = 0$

$\therefore\ W_B \sin 40° + 0.35 \times W_B \cos 40° - 80 = 0$ -4M

$\therefore\ \boxed{W_B = 87.82\,N}$

For largest value of W_B, A tends to move up and B tends to move down along the incline. The F.B.Ds are shown below:





From F.B.D of A:

$\Sigma F_y = 0$

$T - 80 = 0$

$\therefore\ T = 80\,N$

From F.B.D of B:

$\Sigma F_y = 0$

$N_B - W_B \cos 40° = 0$

$\therefore\ N_B = W_B \cos 40°$

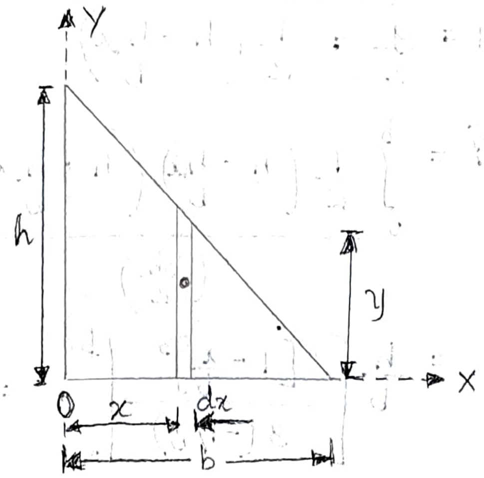
$\Sigma F_x = 0$

$W_B \sin 40° - 0.35\,N_B - T = 0$

$W_B \sin 40° - 0.35 \times W_B \cos 40° - 80 = 0$ -4M

$\therefore\ \boxed{W_B = 213.52\,N}$

Q. 5 a] Consider a right-angle triangle of base b and height h as shown in figure.



Consider an elementary strip of width dx and height y parallel to Y-axis as shown. As dx is very small, it is approximately a rectangular area. Its area is

$$dA = y\,dx$$

By similar triangles,

$$\frac{y}{b-x} = \frac{h}{b}$$

$$\therefore \quad y = \frac{h}{b}(b-x)$$

$$\therefore \quad y = h - \frac{h}{b}x$$

$$\therefore \quad dA = \left(h - \frac{h}{b}x\right)dx$$

$$A = \int dA = \int_0^b \left(h - \frac{h}{b}x\right)dx$$

$$= \left[hx - \frac{h}{b}\cdot\frac{x^2}{2}\right]_0^b$$

$$= hb - \frac{h}{b}\cdot\frac{b^2}{2} = hb - \frac{hb}{2}$$

$$\therefore \quad A = \frac{bh}{2}$$

$$\bar{x} = \frac{\int x\,dA}{A} = \frac{\int_0^b x\left(h - \frac{h}{b}x\right)dx}{(bh/2)}$$

$$= \frac{2}{b}\int_0^b \left(x - \frac{x^2}{b}\right)dx = \frac{2}{b}\left[\frac{x^2}{2} - \frac{x^3}{3b}\right]_0^b$$

$$= \frac{2}{b}\left[\frac{b^2}{2} - \frac{b^3}{3b}\right] = 2b\left[\frac{1}{2} - \frac{1}{3}\right] = 2b\left[\frac{1}{6}\right]$$

$$\therefore \quad \boxed{\bar{X} = \frac{b}{3}}$$

- 5M

$$\bar{Y} = \frac{\int y\,dA}{A}$$

where y is the centroidal distance of area dA from x-axis

$$\therefore\ y = \frac{y}{2} = \frac{1}{2}\left(h - \frac{h}{b}x\right)$$

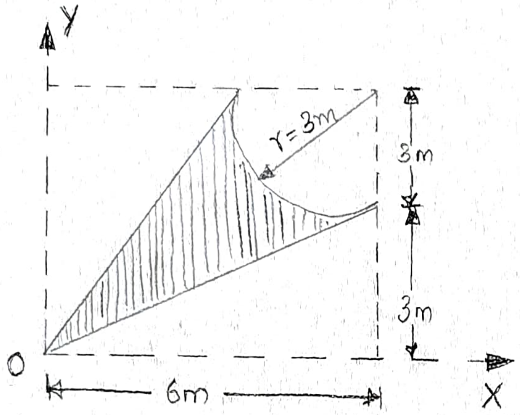
$$\therefore\ \bar{y} = \frac{\int_0^b \frac{1}{2}\left(h - \frac{hx}{b}\right)\left(h - \frac{h}{b}x\right)dx}{\left(\frac{bh}{2}\right)} = \frac{h}{b}\int_0^b \left(1 - \frac{x}{b}\right)^2 dx$$

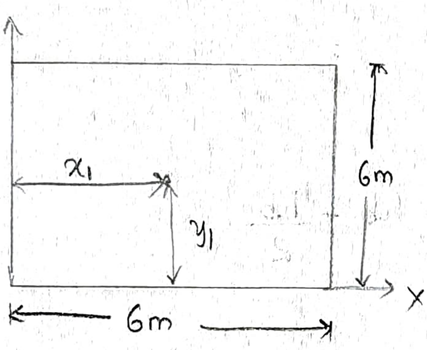
$$= \frac{h}{b}\left[\frac{\left[1 - \frac{x}{b}\right]^3}{3(-1/b)}\right]_0^b = \frac{-h}{3}\left[\left(1 - \frac{b}{b}\right)^2 - (1-0)^3\right] = -\frac{h}{3}(-1)$$

-5M

$$\therefore\ \boxed{\bar{y} = \frac{h}{3}}$$

Q.5 b]



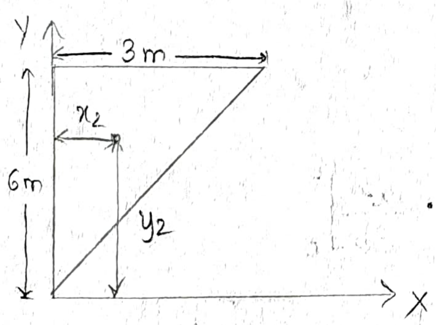


$A_1 = 6 \times 6 = 36\,m^2$

$x_1 = \frac{6}{2} = 3\,m$

$y_1 = \frac{6}{2} = 3\,m$

-1.5M

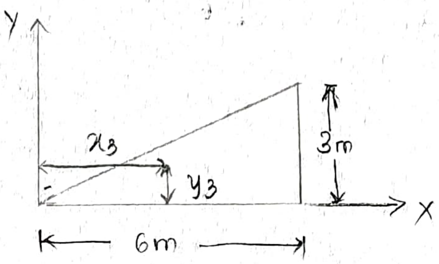


$A_2 = \frac{1}{2} \times 3 \times 6 = 9\,m^2$

$x_2 = \frac{1}{3} \times 3 = 1\,m$

$y_2 = \frac{2}{3} \times 6 = 4\,m$

-1.5M

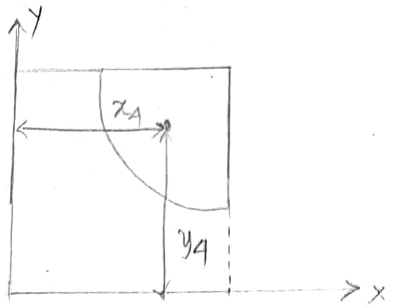


$A_3 = \frac{1}{2} \times 6 \times 3 = 9\,m^2$

$x_3 = \frac{2}{3} \times 6 = 4\,m$

$y_3 = \frac{1}{3} \times 3 = 1\,m$

-1.5M



$$A_4 = \frac{\pi r^2}{4} = \frac{\pi (3)^2}{4} = 7.068 m^2$$

$$x_4 = 6 - \frac{4r}{3\pi} = 6 - \frac{4(3)}{3\pi} = 4.73 m$$ - 1.5M

$$y_4 = 6 - \frac{4r}{3\pi} = 6 - \frac{4(3)}{3\pi} = 4.73 m$$

$$\therefore \bar{x} = \frac{A_1 x_1 - A_2 x_2 - A_3 x_3 - A_4 x_4}{A_1 - A_2 - A_3 - A_4}$$ - 2M

$$= \frac{(36 \times 3) - (9 \times 1) - (9 \times 4) - (7.068 \times 4.73)}{36 - 9 - 9 - 7.068}$$

$$\therefore \boxed{\bar{x} = 2.7 m}$$

$$\therefore \bar{y} = \frac{A_1 y_1 - A_2 y_2 - A_3 y_3 - A_4 y_4}{A_1 - A_2 - A_3 - A_4}$$ - 2M

$$= \frac{(36 \times 3) - (9 \times 4) - (9 \times 1) - (7.068 \times 4.73)}{36 - 9 - 9 - 7.068}$$

$$\boxed{\bar{y} = 2.7 m}$$

$\therefore$ Centroid, $C[\bar{x}, \bar{y}] = [2.7m, 2.7m]$

1.6 a] PARALLEL AXIS THEOREM

STATEMENT: Moment of Inertia about any axis in the plane of an area is equal to the sum of moment of inertia about a parallel centroidal axis and the product of area and square of the distance between the two parallel axes.

$$I_{AB} = I_{GG} + A y_c^2$$ - 3M

where,

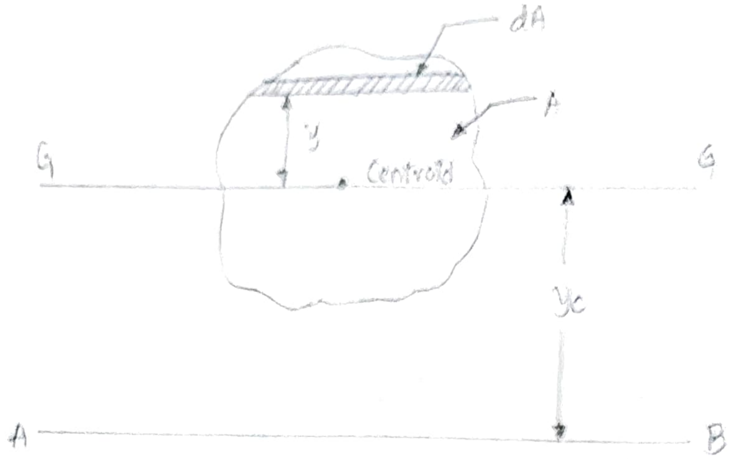
I_{AB} = moment of inertia about axis AB.

I_{GG} = moment of inertia about centroidal axis GG parallel to AB.

A = the area of plane figure given

y_c = the distance between the axis AB and the parallel centroidal axis GG

PROOF:



Consider an elemental parallel strip dA at a distance y from the centroidal axis.

Then, $I_{AB} = \Sigma (y + y_c)^2 dA$

$$= \Sigma (y^2 + 2yy_c + y_c^2) dA$$

$$= \Sigma y^2 dA + \Sigma 2yy_c dA + \Sigma y_c^2 dA$$

But, $\Sigma y^2 dA =$ Moment of inertia about the axis GG

$$= I_{GG}$$

$$\Sigma 2yy_c dA = 2y_c \Sigma y dA$$

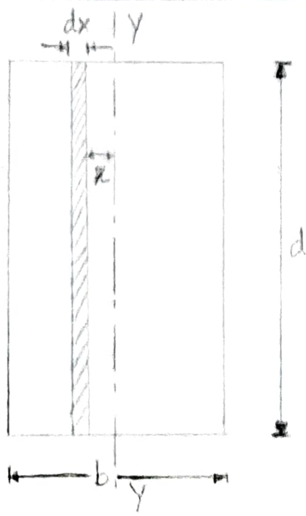
$$= 2y_c A \frac{\Sigma y dA}{A}$$

Term $2y_c A$ is constant and $\frac{\Sigma y dA}{A}$ is the distance of centroid from the reference axis GG. Since GG is passing through the centroid itself $\frac{y dA}{A}$ is zero and hence the term $\Sigma 2yy_c dA$ is zero. -3M

$$\Sigma y_c^2 dA = y_c^2 \Sigma dA = Ay_c^2$$

$$\therefore I_{AB} = I_{GG} + Ay_c^2$$

Q. 6 b]



Consider a rectangle of width b and depth d. Moment of inertia about the centroidal axis y-y parallel to the longer side is required.

Consider an elemental strip of width dx at a distance x from the axis. Moment of inertia of the elemental strip about the centroidal axis y-y is :

$= x^2 dA$

$= x^2 d\,dx$

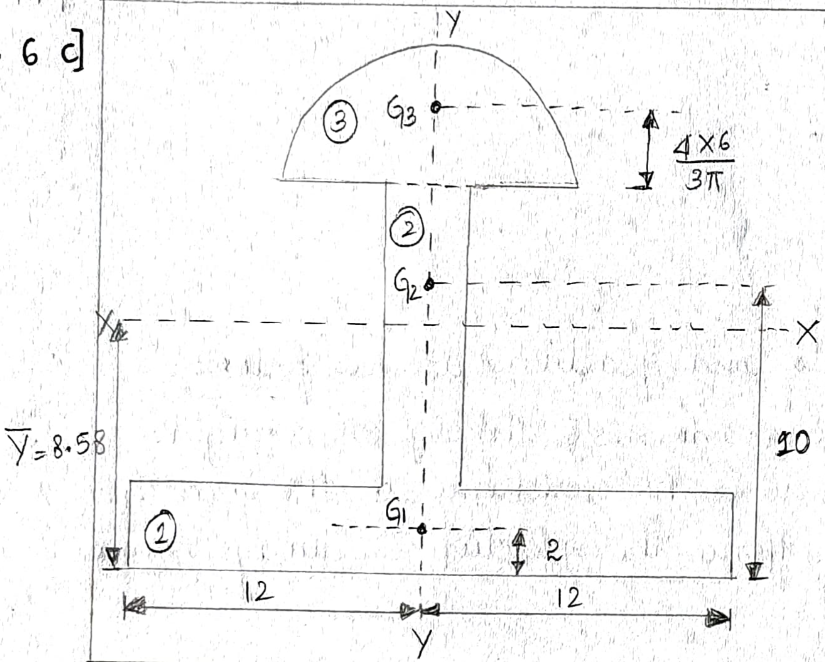
$$I_{yy} = \int_{-b/2}^{b/2} x^2 d\,dx$$

$$= d\left[\frac{x^3}{3}\right]_{-b/2}^{b/2}$$

$$= d\left[\frac{b^3}{24} + \frac{b^3}{24}\right]$$ −6M

$$\boxed{I_{yy} = \frac{db^3}{12}}$$

Q. 6 c]



Component Area A (mm^2)	y (mm)	I_G		$r_x = \bar{Y} - y$ (mm)
		I_x (mm^4)	I_y (mm^4)	
1. 24×4	2	$\frac{24\times4^3}{12}$	$\frac{4\times24^3}{12}$	6.58
2. 4×12	10	$\frac{4\times12^3}{12}$	$\frac{12\times4^3}{12}$	−1.42
3. $\frac{\pi\times6^2}{2}$	$16 + \frac{4\times6}{3\pi}$	0.11×6^4	$\frac{\pi\times6^4}{8}$	−9.9665

−3M

$\Sigma A = 200.55\ mm^2$

$$\bar{Y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$= \frac{(24\times4)(2) + (4\times12)(10) + \left(\frac{\pi\times6^2}{2}\right)\left(16 + \frac{4\times6}{3\pi}\right)}{24\times4 + 4\times12 + \pi\times6^2/2}$$

$\bar{Y} = 8.58mm$ -1m

$I_{xx} = \Sigma (I_x + A r_x^2)$

$= \left[\frac{24 \times 4^3}{12} + (24 \times 4) \times 6.58^2\right] + \left[\frac{4 \times 12^3}{12} + (4 \times 12) \times 1.42^2\right] +$

$\left[0.11 \times 6^4 + \left(\frac{\pi \times 6^2}{2}\right) \times 9.9665\right]^2$ -1m

$I_{xx} = 10716.84 \ mm^4$

$I_{yy} = \frac{4 \times 24^3}{12} + \frac{12 \times 4^3}{12} + \frac{\pi \times 6^4}{8}$ -1m

$I_{yy} = 5180.94 \ mm^4$

$\therefore I_{zz} = I_{xx} + I_{yy} = 10716.84 + 5180.94$

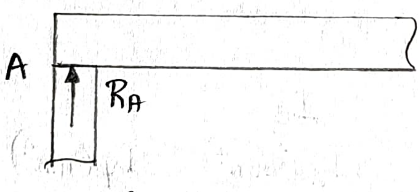
$I_{zz} = 15897.78 \ mm^4$ -2M

$K = \sqrt{\frac{I_{zz}}{\Sigma A}} = \sqrt{\frac{15897.78}{200.55}}$

$\therefore \boxed{K = 8.903 mm}$

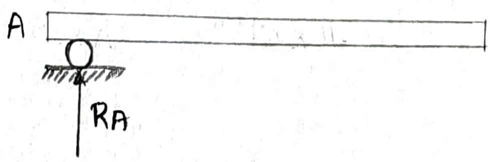
Q. 7 a] The different types of supports and reactions are as follows:

- SIMPLE SUPPORT: The end of the beam rests simply on a rigid support. In this support, there is no resistance to the force in the direction of the support. Hence the reaction is always normal to the support.



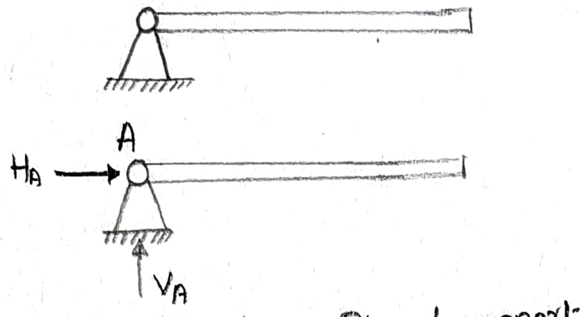
Simple Support -2M

- ROLLER SUPPORT: In this case, beam end is supported on rollers. In such cases, reaction is always normal to the support, since rollers are free to roll along the supports.



Roller support -2M

- HINGED OR PINNED SUPPORT: In such cases, the position of the end of the beam is fixed but the end is free to rotate. At such supports the reaction can be in any direction which is usually represented by its components in two mutually perpendicular directions. This type of support permits rotation freely at the end.

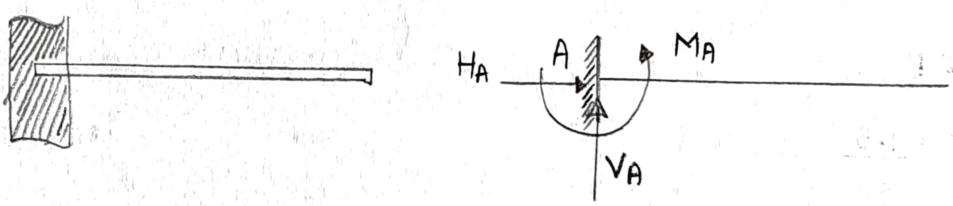


Hinged or Pinned support

-2M

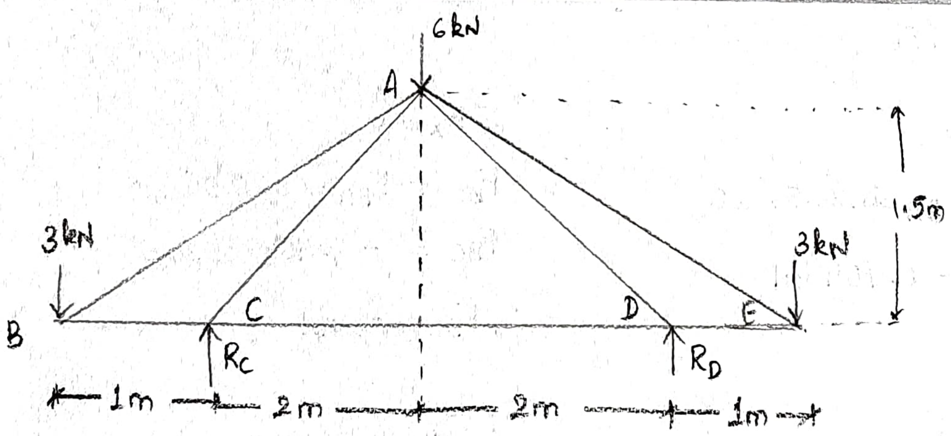
- FIXED SUPPORT: At fixed support the end of the beam is neither permitted to move in any direction nor allowed to rotate. Hence support reactions are a force in any direction and the resisting moment.

-2M



Fixed supports

Q 7 b]



Considering equilibrium of entire truss.

$\Sigma M_D = 0$

$-3\times5 + R_C\times4 - 6\times2 + 3\times1 = 0$

$\therefore \boxed{R_C = 6\text{ kN}}$

$\Sigma F_H = 0$ gives $H_C = 0$

$\therefore$ Reaction at C is vertical.

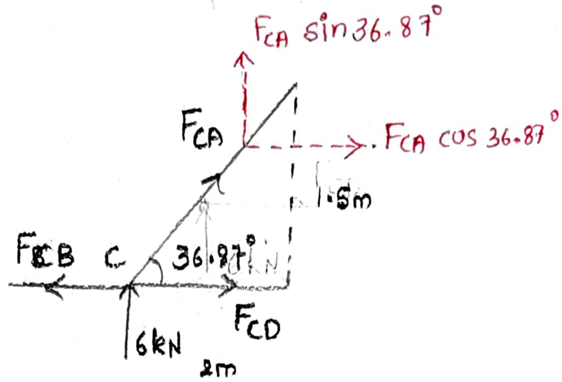
$\Sigma F_y = 0$

$-3 - 6 - 3 + R_c + R_D = 0$ — 2M

$-3 - 6 - 3 + 6 + R_D = 0$

$\therefore \boxed{R_D = 6\ kN}$

Joint C



$\tan\theta = \frac{1.5}{2}$

$\theta = \tan^{-1}(0.75)$

$\theta = 36.87°$

$\Sigma F_y = 0$

$6 + F_{CA} \sin 36.87° = 0$

$\therefore \boxed{F_{CA} = -10\ kN}$

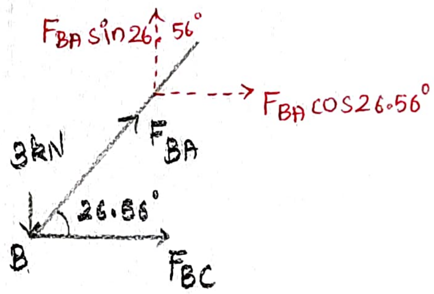
$\Sigma F_x = 0$

$-F_{CB} + F_{CD} + F_{CA} \cos 36.87° = 0$ — 2M

$-F_{CB} + F_{CD} - 10 \cos 36.87° = 0$

$-F_{CB} + F_{CD} = 8\ kN.$

Joint B



$\tan\theta = \frac{1.5}{3}$

$\theta = \tan^{-1}(0.5)$

$\theta = 26.56°$ — 2M

$\Sigma F_y = 0$

$-3 + F_{BA} \sin 26.56° = 0$

$\therefore \boxed{F_{BA} = 6.709\ kN}$

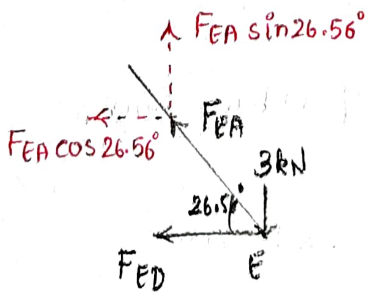
$\Sigma F_x = 0$

$F_{BC} + F_{BA} \cos 26.56° = 0$

$F_{BC} = -6.709 \cos 26.56°$

$\therefore \boxed{F_{BC} = -6\ kN}$

Joint E



— 2M

$\Sigma F_y = 0$

$-3 + F_{EA} \sin 26.56° = 0$

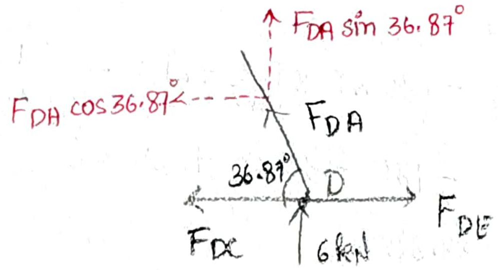
$\therefore \boxed{F_{EA} = 6.709\ kN}$

$\Sigma F_x = 0$

$-F_{ED} - F_{EA} \cos 26.56° = 0$

$\therefore \boxed{F_{ED} = -6\ kN}$

Joint D



$\Sigma F_y = 0$

$6 + F_{DA} \sin 36.87^\circ = 0$

$\therefore \boxed{F_{DA} = -10 \text{ kN}}$

$\Sigma F_x = 0$

$-F_{DC} + F_{DE} - F_{DA} \cos 36.87^\circ = 0$ -2M

$-F_{DC} - 6 + 10 \cos 36.87^\circ = 0$

$-F_{DC} + 2 = 0$

$\therefore \boxed{F_{DC} = 2 \text{ kN}}$

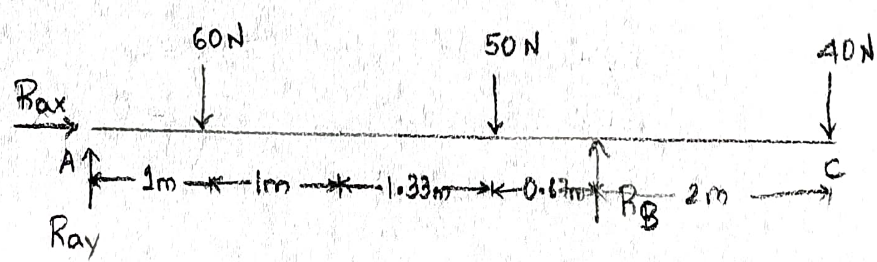
Forces	Nature	magnitude
F_{CA}	compression	10 kN
F_{BA}	tension	6.709 kN
F_{BC}	compression	6 kN
F_{EA}	tension	6.709 kN
F_{ED}	compression	6 kN
F_{DA}	compression	10 kN
F_{DC}	tension	2 kN

-2M

Q.8 a] The assumptions made in analysis of truss are as follows:

- The ends of the members are pin connected [hinged].
- The loads act only at the joints.
- Self weight of the members are negligible. -4M
- Members are having either uniform cross-sections throughout or if they are have varying cross-section the centroid is located along the same longitudinal line.

Q.8 b] The F.B.D of beam is as follows:



-2M

$\Sigma M_B = 0$

$R_{ay} \times 4 - \left(30 \times 2 \times \left[\frac{2}{2} + 2\right]\right) - \left(\frac{1}{2} \times 2 \times 50 \times \frac{1}{3} \times 2\right) + (40 \times 2) = 0$

$R_{ay} \times 4 - 180 - 33.33 + 80 = 0$ -2M

$\therefore \boxed{R_{ay} = 33.33\ N}$

$\Sigma F_y = 0$

$R_{ay} - 60 - 50 - 40 + R_B = 0$

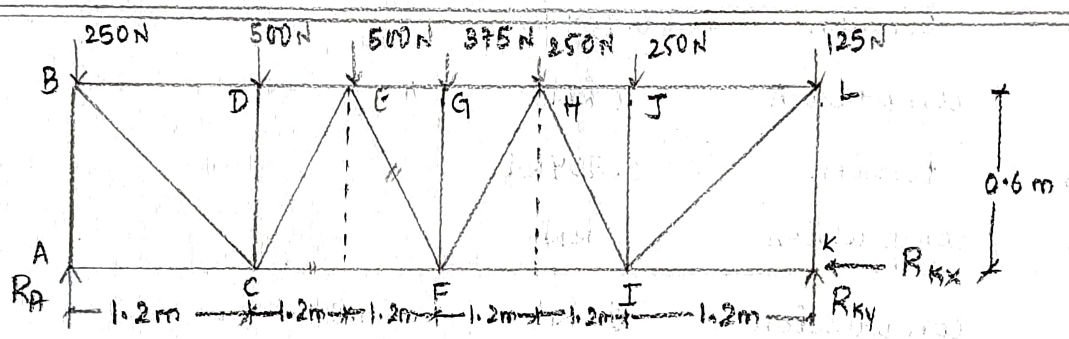
$33.33 - 60 - 50 - 40 + R_B = 0$ -2M

$\boxed{R_B = 116.67\ N}$

$\Sigma F_x = 0$

$\boxed{R_{ax} = 0}$ -2M

Q. 8 c)



$\Sigma M_K = 0$

$R_A \times 7.2 - (250 \times 7.2) - (500 \times 6) - (500 \times 4.8) - (375 \times 3.6) - (250 \times 2.4)$
$- (250 \times 1.2) = 0$

$\therefore \boxed{R_A = 1312.5\ N}$

$\Sigma F_y = 0$ -1M

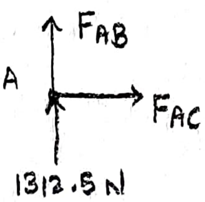
$R_A - 250 - 500 - 500 - 375 - 250 - 250 - 125 + R_{Ky} = 0$

$\therefore \boxed{R_{Ky} = 937.5\ N}$

$\Sigma F_x = 0$

$\therefore \boxed{R_{Kx} = 0}$

Joint A



$\Sigma F_y = 0$

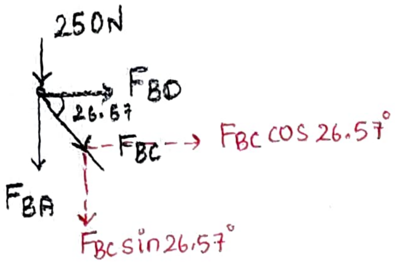
$1312.5 + F_{AB} = 0$

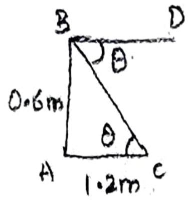
$\boxed{F_{AB} = -1312.5\ N}$

$\Sigma F_x = 0$

$\boxed{F_{AC} = 0}$ -1M

Joint B





$\tan\theta = \frac{0.6}{1.2}$

$\theta = \tan^{-1}(0.5)$

$\theta = 26.57°$

$\Sigma F_y = 0$

$-250 - F_{BA} - F_{BC}\sin 26.57° = 0$

$-250 + 1312.5 = F_{BC}\sin 26.57°$

$\therefore \boxed{F_{BC} = 2375.41\ N}$

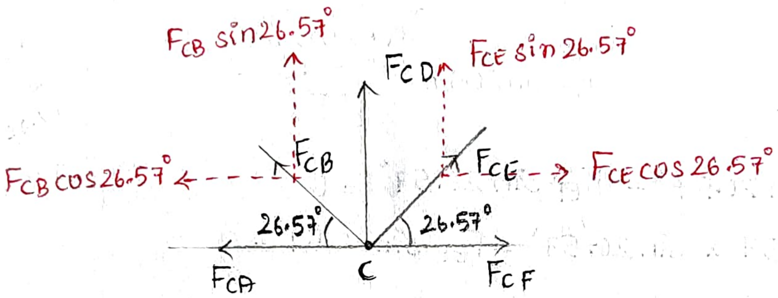
$\Sigma F_x = 0$

$F_{BD} + F_{BC}\cos 26.57° = 0$

$F_{BD} = -F_{BC}\cos 26.57°$ - 1M

$\therefore \boxed{F_{BD} = -2124.5\ N}$

Joint C



$\Sigma F_y = 0$

$F_{CD} + F_{CB}\sin 26.57° + F_{CE}\sin 26.57° = 0$

$F_{CD} + 2375.41 \times \sin 26.57° + F_{CE}\sin 26.57° = 0$

$F_{CD} + F_{CE}\sin 26.57° = -1062.5$ ——— (i) - 1M

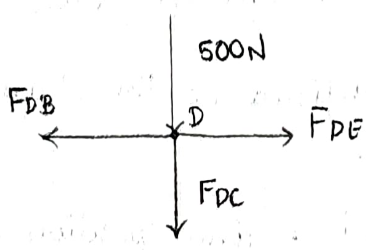
$\Sigma F_x = 0$

$-F_{CA} + F_{CF} + F_{CE}\cos 26.57° - F_{CB}\cos 26.57° = 0$

$0 + F_{CF} + F_{CE}\cos 26.57° - 2375.41\cos 26.57° = 0$

$F_{CF} + F_{CE}\cos 26.57° = 2124.5$ ——— (ii)

Joint D



- 1M

$\Sigma F_y = 0$

$-500 - F_{DC} = 0$

$\therefore \boxed{F_{DC} = -500\ N}$

$\Sigma F_x = 0$

$F_{DE} - F_{DB} = 0$

$\therefore \boxed{F_{DE} = -2124.5\ N}$

substituting value of F_{DC} in (i)

$$-500 + F_{CE}\sin 26.57^\circ = -1062.5$$

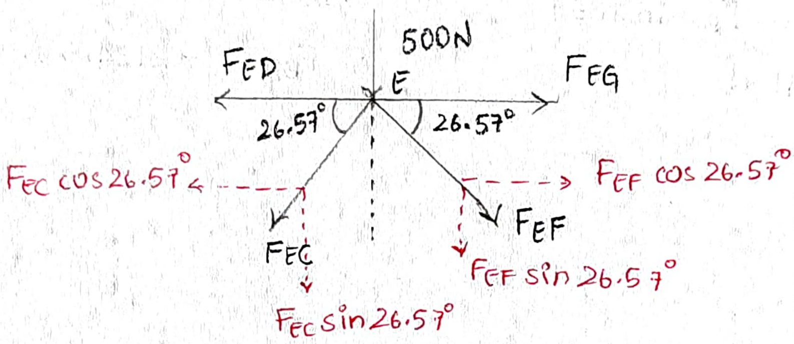
$$\therefore \boxed{F_{CE} = -1257.57 \text{ N}}$$

substituting value of F_{CE} in (ii) -1M

$$F_{CF} - 1257.57\cos 26.57^\circ = 2124.5$$

$$\therefore \boxed{F_{CF} = 3249.25 \text{ N}}$$

Joint E



$$\Sigma F_y = 0$$

$$-500 - F_{EC}\sin 26.57^\circ - F_{EF}\sin 26.57^\circ = 0$$

$$-500 + 1257.57 \times \sin 26.57^\circ - F_{EF}\sin 26.57^\circ = 0$$

$$\therefore \boxed{F_{EF} = 139.73 \text{ N}}$$

-2M

$$\Sigma F_x = 0$$

$$F_{EG} - F_{ED} + F_{EF}\cos 26.57^\circ - F_{EC}\cos 26.57^\circ = 0$$

$$F_{EG} + 2124.5 + 139.73\cos 26.57^\circ + 1257.57\cos 26.57^\circ = 0$$

$$\therefore \boxed{F_{EG} = -3374.23 \text{ N}}$$

∴ The forces in members are as follows:

Member CF 3249.25 N [Tensile force]

Member EF 139.73 N [Tensile force]

Member EG 3374.23 N [Compressive force]

Q.9 a] i] DISPLACEMENT : It is defined as the change in position. It is a vector quantity.

Displacement = final position − initial position -1M

ii] VELOCITY : The rate of change of displacement with respect to time is called as velocity. It is a vector quantity.

If s is the displacement in interval t, the average velocity v is given by $\frac{s}{t}$.

Velocity of a particle at a given instant is called instantaenous velocity and is given by, -1M

$$v = \lim_{\delta t \to 0} \frac{\delta s}{\delta t}$$

iii] ACCELERATION : Rate of change of velocity with respect to time is called acceleration. It is given by, -1M

$$a = \frac{dv}{dt}$$

iv] SPEED: The rate of change of distance with respect to time is defined as speed. -1M

Q.9 b] Since the initial velocity, $u = 0$

Let the height covered in the last second be $\frac{1}{4}h$

Let the height of the tower be 'h'.

Suppose it takes 'n' second to reach the ground.

Thus, in n^{th} second the body covers a height $\frac{h}{4}$.

$$S_n = u + \left(\frac{a}{2}\right)(2n-1)$$

$$\frac{h}{4} = 0 + \left(\frac{9.8}{2}\right)(2n-1)$$

$$\frac{h}{4} = 4.9\,(2n-1) \quad \text{———} \quad (i)$$ -2M

The distance travelled in 'n' second is,

$$h = 0 + \frac{1}{2}gn^2$$

$$h = \left(\frac{9.8}{2}\right)n^2$$

$$h = 4.9n^2 \quad \text{———} \quad (ii)$$ -2M

From (i) & (ii),

$$\frac{4.9n^2}{4} = 4.9\,(2n-1)$$

$$\frac{4.9n^2}{4.9} = 4\,(2n-1)$$

$$n^2 = 8n - 4$$

$n^2 - 8n + 4 = 0$ 2M

$\therefore n = 0.536$ or 7.46.

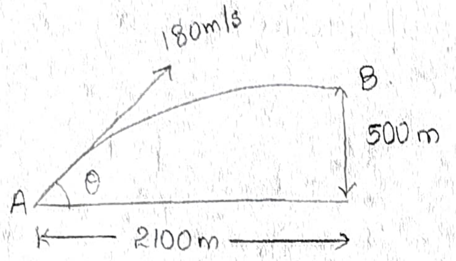
Here $n = 0.536$ is not possible.
So, the time in which the body hits the ground is 7.46 s.
Putting value of n in eq^n (ii), we get

$h = 4.9 n^2$

$= 4.9 (7.46)^2$ -2M

$\therefore h = 272.69$ m.

Q.9 c]



$y = 500$ m

$x = 2100$ m

Equation of trajectory:

$$y = x \tan\theta - \frac{g x^2}{2 u^2 \cos^2\theta}$$

$$500 = 2100 \tan\theta - \frac{(9.8)(2100)^2}{2(180)^2 \cos^2\theta}$$

$$500 = 2100 \tan\theta - \frac{666.94}{\cos^2\theta}$$

$$500 = 2100 \tan\theta - 666.94 \sec^2\theta$$

$$500 = 2100 \tan\theta - 666.94 [1 + \tan^2\theta]$$

$$500 = 2100 \tan\theta - 666.94 - 666.94 \tan^2\theta$$

$$666.94 \tan^2\theta - 2100 \tan\theta + 1166.94 = 0$$

$\tan\theta = 2.428$ or $\tan\theta = 0.7206$ -8M

$\theta = 67.61^\circ$ or $\theta = 35.77^\circ$

Q.10 a] D'Alembert's principle states that "the system of forces acting on a moving body is in dynamic equilibrium with the inertia force of the body."

The equation $R = ma$ can be written as,

$R - ma = 0$ -3M

The term '$-ma$' is a force of magnitude $m \times a$, applied in the opposite direction of motion and is termed as inertia force or reverse effective force.

Let the body shown in fig (i) be subjected to a system of forces causing the body to move with an acceleration a in the direction of the resultant. Then apply a force equal to 'ma' in the reversed direction of acceleration as shown in fig. According to D'Alembert's principle, the equations of equilibrium $\Sigma F_x = 0$ and $\Sigma F_y = 0$ may be used for the system of forces.

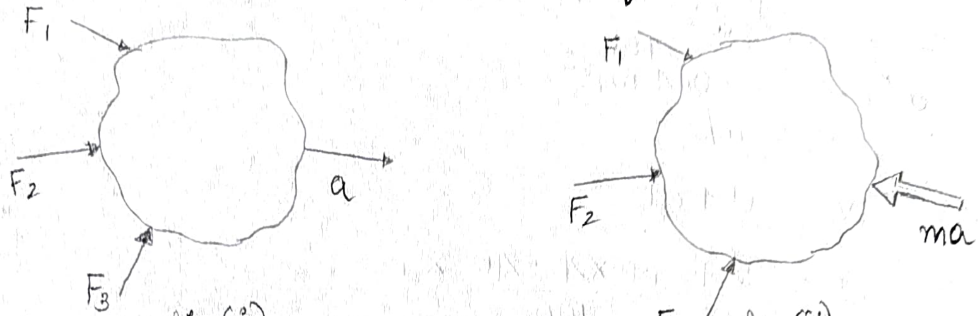


fig (i) fig (ii)

-3M

Q. 10 b] $\omega_i = 200 \text{ rpm} = \frac{200}{60} \text{ rps} = 3.33 \text{ rps}$

$\omega_f = 160 \text{ rpm} = \frac{160}{60} \text{ rps} = 2.67 \text{ rps}$

$t = 10 \text{ secs}$

$\omega_f = \omega_i + \alpha t$

$2.67 = 3.33 + \alpha(10)$

$\alpha = \frac{2.67 - 3.33}{10} = \frac{-0.66}{10} = -0.066 \text{ rad/sec}^2$ -2M

$\omega_f^2 - \omega_i^2 = 2\alpha\theta$ [at rest $\omega_f = 0$]

$0 - (3.33)^2 = 2 \times (-0.066)\theta$

$-11.0889 = -0.1320\theta$

$\therefore \theta = 84$ revolutions -2M

$\omega_f = \omega_i + \alpha t$ [at rest $\omega_f = 0$]

$0 = 3.33 + (-0.066)t$

$-3.33 = -0.066t$

$\therefore t = \frac{-3.33}{-0.066} = 50.45 \text{ sec.}$ -2M

Q. 10 c] Given: mass = 100 N

$$F = (20t^2 - 40)\ N$$

at $t = 0$, $V = 5\ m/s$, $x = 0$

at $t = 2s$, $V = ?$, $x = ?$

at $t = 0s$, $V = u + at$

$$= 5 + \frac{F}{m} \times t$$

$$= 5 + \frac{20 \times 0 - 40 \times 0}{100}$$

$$= 5\ m/s$$

at $t = 2s$, $V = u + at$

$$= 5 + \frac{20 \times 4 - 40}{100} \times 2$$

$$= 5 + 0.8$$

$$v = 5.8\ m/s$$

$$x = ut + \frac{1}{2} at^2$$

$$= 5 \times 2 + \frac{1}{2} \times \frac{F}{m} \times 2^2$$

$$= 10 + \frac{1}{2} \frac{[20 \times 2^2 - 40]}{100} \times 4$$

$$x = 10.8\ m$$

$\therefore$ at $t = 2s$, $v = 5.8\ m/s$ and $x = 10.8\ m$.

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