January : 2016 (CBCS)

Note : **Max. marks : 60**

(i) Attempt any five questions.

(ii) All questions carry equal marks.

(iii) Assume suitable data or dimensions, if necessary, clearly mentioned it.

Q.1 (a) What is engineering mechanics? Classify the Engineering mechanics and briefly explain them.

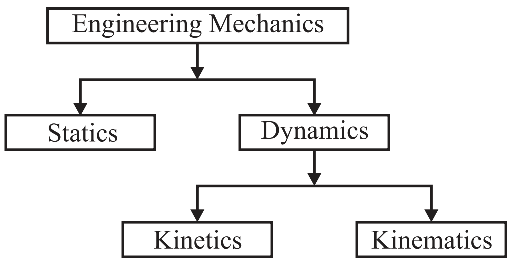
Ans. **Engineering mechanics :** ***"Engineering mechanics describes the behavior of a body, in either a beginning state of rest or of motion of rigid body, subjected to the action of forces".***

Of course, engineering mechanics is an integral component of the education of engineers whose disciplines are related to the mechanical behavior of bodies or fluids. Such behavior is of interest to aeronautical, civil, chemical, electrical, mechanical, metallurgical, mining and textile engineers. A sound training in engineering mechanics continues to be one of the most important aspects of engineering education due to the interdisciplinary character of many engineering applications (e.g. spaceship, robotic and manufacturing). It is appropriate to conclude that the subject of engineering mechanics is the core of all engineering analysis.

Classification of engineering mechanics :

Engineering mechanics may be divided into following two main branches :

1. Statics
2. Dynamics



1. **Static :** It is that branch of engineering mechanics, which deals with the forces and their effects, while acting upon the bodies at rest.
2. **Dynamics :** It is that branch of engineering mechanics, which deals with forces and their effects, while acting upon body in motion.

   Dynamics may be further subdivided into the following sub-branches :

   (i) **Kinetics :** It is that branch of dynamics which deals with the bodies in motion due to the application of forces.

   (ii) **Kinematics :** It is that branch of dynamics which deals with the bodies in motion. Without any reference to the forces which are responsible for the motion.

   The study of kinematics assimilates terms such as displacement, velocity, acceleration, retardation etc. which are important to an engineer in the design of moving part of a machine.

Q.1 (b) The resultant of the two forces, when they act an angle of 60^0 is 14 N. If the same forces are acting at right angles, their resultant is 12 N. Determine the magnitude of two forces.

Ans. **Given :** $R_1 = 14\,\text{N}, \quad R_2 = 12\,\text{N}$

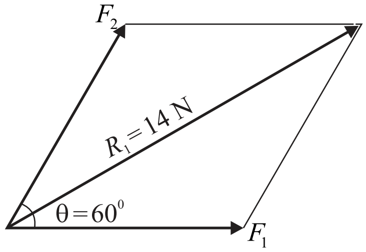


Fig.(a)

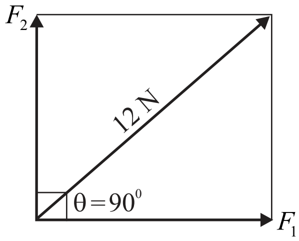


Fig.(b)

When force acts at 60^0 with each other resultant is 14 N :

Applying law of parallelogram, from Fig.(a), we get

$$R_1^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$$

$$14^2 = F_1^2 + F_2^2 + 2F_1F_2\cos 60^0$$

$$F_1^2 + F_2^2 + F_1F_2 = 196 \qquad \ldots\text{(i)}$$

When force acts at 90^0 with each other their resultant is 12 N :

Applying law of parallelogram, from Fig.(b),

$$R_2^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$$

$$12^2 = F_1^2 + F_2^2 + 2F_1F_2\cos 90^0$$

$$F_1^2 + F_2^2 = 144 \qquad \ldots\text{(ii)}$$

From equation (ii) and (i), we get

$$144 + F_1F_2 = 196$$

$$F_1F_2 = 52 \qquad \ldots\text{(iii)}$$

Also, we can write,

$$(F_1 + F_2)^2 = F_1^2 + F_2^2 + 2F_1F_2 \qquad \left[\because (a+b)^2 = a^2 + b^2 + 2ab\right]$$

From equation (ii) and (iii), we get

$$(F_1 + F_2)^2 = 144 + 2\times 52$$

$$(F_1 + F_2)^2 = 248$$

$$F_1 + F_2 = \sqrt{248} \qquad \ldots\text{(iv)}$$

Also, we can write,

$$(F_1 - F_2)^2 = F_1^2 + F_2^2 - 2F_1F_2 \qquad \left[\because (a-b)^2 = a^2 + b^2 - 2ab\right]$$

$$(F_1 - F_2)^2 = 144 - 2\times 52$$

$$(F_1 - F_2)^2 = 40$$

$$F_1 - F_2 = \sqrt{40} \qquad \ldots\text{(v)}$$

Adding equation (iv) and equation (v), we get

$$F_1 + F_1 = \sqrt{248} + \sqrt{40}$$

$$2F_1 = 22.073$$

$$F_1 = 11.036\,\text{N} \qquad \textbf{Ans.}$$

From equation (iv), we get

$$F_2 = \sqrt{248} - 11.036$$

$$F_2 = 4.712\,\text{N} \qquad \textbf{Ans.}$$

Q.2 **(a)** State the law of parallelogram of forces and show that the resultant, $R = \sqrt{P^2 + Q^2}$ when the two forces P and Q are acting at right angles to each other. Find the value of R if the angle between the forces is zero.

Ans. **Law of parallelogram of forces :**

If two force acting at a point are represented in magnitude and direction by the adjacent sides of a parallelogram then the diagonal passing through their point of intersection represents the resultant in both magnitude and direction.

Proof :

Let the forces $\vec{P}$ and $\vec{Q}$ act at O. Let OA and OB represent the forces P and Q acting at an angle θ.

Complete the parallelogram $OACB$.

Draw CD perpendicular to OA.

Let $\angle COA = \alpha$, $OC = R$ denote the magnitude of the resultant and α is the direction of resultant.

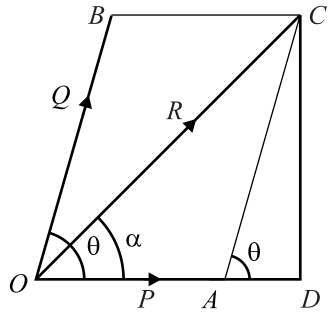


Fig.

From ΔADC,

$$\cos\theta = \frac{AD}{AC}$$

$$AD = AC\cos\theta$$

$$AD = Q\cos\theta$$

Now, $OD = OA + AD = OA + AC\cos\theta$

$OD = P + Q\cos\theta$ $\quad [\because AC = OB = Q]$

Also, $DC = AC\sin\theta = Q\sin\theta$

Resultant : $OC^2 = OD^2 + DC^2$

$$R^2 = (P + Q\cos\theta)^2 + (Q\sin\theta)^2$$

i.e. $R^2 = P^2 + Q^2 + 2PQ\cos\theta$

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta} \quad \text{...(i)}$$

Direction of resultant :

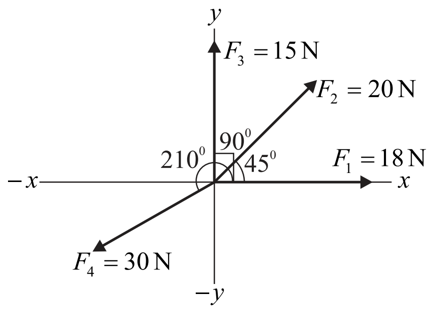
$$\tan\alpha = \frac{CD}{OD} = \frac{Q\sin\theta}{P + Q\cos\theta} \quad \text{...(ii)}$$

Equation (i) and equation (ii) give the required magnitude and direction of the resultant.

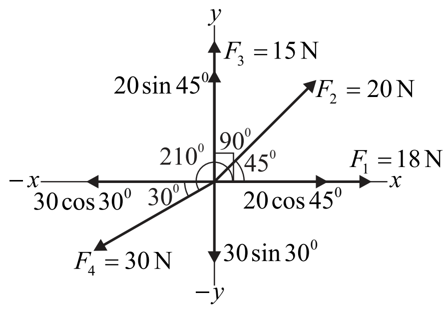
Q.2 **(b)** The four forces F_1, F_2, F_3 and F_4 of magnitudes 18 N, 20 N, 15 N and 30 N and directions 0^0, 45^0, 90^0, 210^0 (counter clock wise from horizontal) respectively acting at a point on a body. Determine the magnitude and direction of the force for equilibrium condition of the body.

Ans. **Given :** F_1, F_2, F_3 and F_4 of magnitudes 18 N, 20 N, 15 N and 30 N and directions 0^0, 45^0, 90^0, 210^0 (counter clockwise from horizontal).

FBD :



Resolving the forces :



Magnitude and direction of the force for equilibrium condition = Equilibrant

$$\Sigma F_x = 18 + 20\cos 45^0 - 30\cos 30^0 = 6.161\text{ N}$$

$$\Sigma F_y = 15 + 20\sin 45^0 - 30\sin 30^0 = 14.14\text{ N}$$

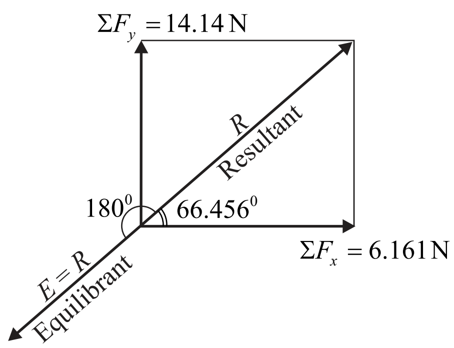
Magnitude of resultant force (R) = Magnitude of equilibrant (E)

$$E = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = 15.424\text{ N}$$

Direction of resultant,

$$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = \tan^{-1}\left(\frac{14.14}{6.161}\right)$$

$$\theta = 66.456^0$$



So, direction of equilibrant $= 180^0 + 66.456^0 = 246.456^0$ **Ans.**

Q.3 **(a)** Define and explain the terms principal of equilibrium, forces law of equilibrium and moment law of equilibrium.

Ans. The body is said to be in equilibrium if the resultant of all forces acting on it is zero. There are two major types of static equilibrium, namely, translational equilibrium i.e. $\Sigma F_x = 0$, $\Sigma F_y = 0$ (also known as, forces law of equilibrium) and rotational equilibrium i.e. $\Sigma M = 0$ (also known as, Moment law of equilibrium)

1. **For coplanar concurrent forces (translational equilibrium) :**

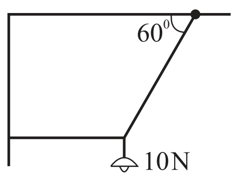
$$\Sigma F_x = 0,\ \Sigma F_y = 0$$

2. **For coplanar non-concurrent forces (translational and rotational equilibrium) :**

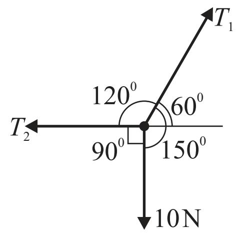
$$\Sigma F_x = 0,\ \Sigma F_y = 0,\ \Sigma M = 0$$

Q.3 (b) A lamp weighing 10 N is suspended from the ceiling by a chain. It is pulled a side by a horizontal cord until the chain makes an angle of 60^0 with the ceiling. Find the tension in the chain and the cord by applying Lami's theorem.

Ans. **Given :** Weight of lamp = 10 N



Applying Lami's theorem :



$$\frac{T_1}{\sin 90^0} = \frac{T_2}{\sin 150^0} = \frac{10}{\sin 120^0}$$

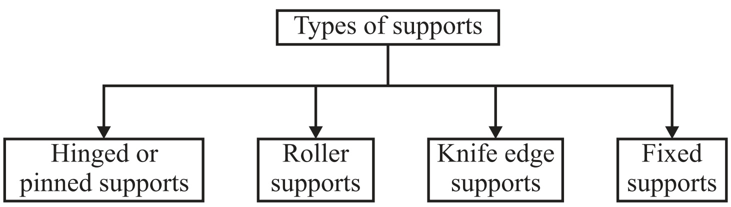
$$T_1 = \frac{10}{\sin 120^0} \times \sin 90^0 = 11.547\text{ N}$$ **Ans.**

$$\frac{T_2}{\sin 150^0} = \frac{10}{\sin 120^0}$$

$$T_2 = \frac{10}{\sin 120^0} \times \sin 150^0 = 5.773\text{ N}$$ **Ans.**

Q.4 (a) Explain the various types of beams. What are the different types of support and loading on a beam explain in brief?

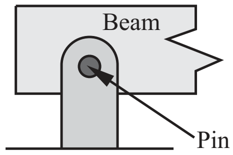
Ans.



(i) Hinged or Pinned support : The essential feature of a pinned support is to prevent translation at the end of a beam but does not prevent rotation. Thus, an end carrying hinged or pinned support cannot move in vertical or horizontal direction but, it can rotate around the hinged.

A pin or thin support is capable of developing a reaction force with horizontal and vertical components (R_x and R_y), but cannot develop a moment reaction.

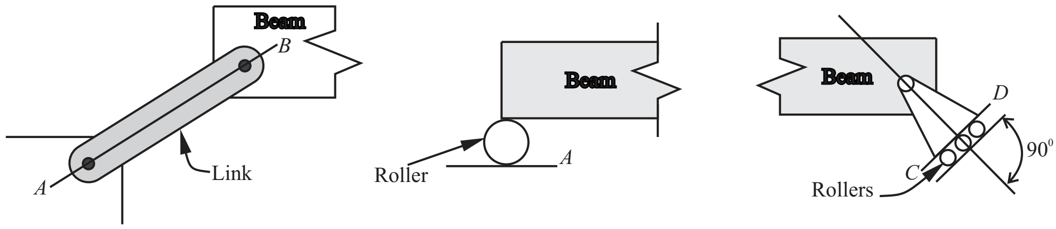
Hence it can resist force acting in any direction of plane but cannot resist rotation.



Hinged or pinned support

Fig.1 : Hinged or Pinned support

(ii) Roller support or Link support : A roller support is capable of resisting force only in one specified line of action.



(a) (b) (c)

Fig.2 : Roller support or Link support

The link shown in Fig.2(a) can resist force only along direction AB.

Roller in Fig.2(b) can resist force only in vertical direction. Whereas roller in Fig.2(c) can resist forces acting perpendicular to line *CD*.

It should be noted that a roller support is capable of resisting a force in either directions (i.e. upward and downward) i.e. a beam is not allowed to lift off from a support.

(iii) Knife edge support : The function of knife edge support is similar to roller support. It is also capable of resisting force in only one specified line of action, but here beam can be lifted up or it may leave the support.

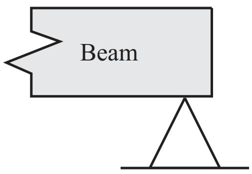


Fig.3 : Knife edge support

(iv) Fixed support : Fixed support is a support which resists translation of beam as well as rotation of beam.

Fig.4 : Fixed support

Support reaction is the force which is offered by the support, against the loads acting on the beam. The support reaction for various types of supports is shown below.

(i) Hinged or pinned support :

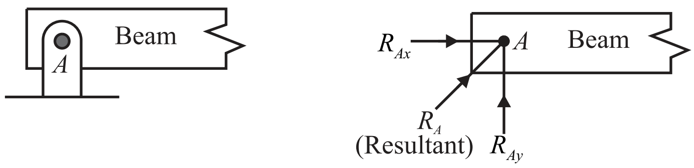


Fig.(a) : Hinged or pinned support

(ii) Roller support :

Fig.(b) : Roller support

(iii) Knife edge support :

Fig.(c) : Knife edge support

(iv) Fixed support :

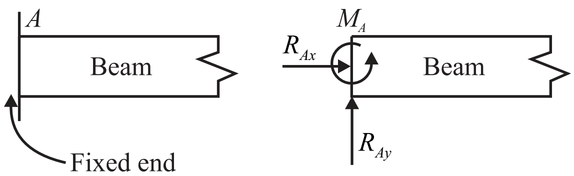


Fig.(d) : Fixed support

Note : ***Number of reaction at any support = Number of restricted motion.***

Example : As hinged support can resist force acting at any direction in a given plane, therefore it has two component of that reaction force $(R_x \text{ and } R_y)$.

Beam is classified into different categories depending upon the types of support as below :

(i) Simply supported beam : Simply supported beam is a beam which is supported at its two ends by either two roller support or two hinge support or one roller and one hinged support.

Fig.(a) : Simply supported beam

(ii) Overhanging beam : An overhanging beam is a beam, simply supported at any two point within the span of beam but it also projects beyond one or both the support.

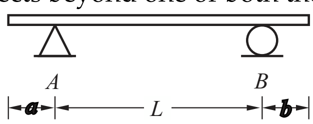


Fig.(b) : Overhanging beam

(iii) Cantilever beam : Cantilever beam is a beam which is fixed at one end and free at other. At fixed support beam can neither translate nor rotate, whereas at free end it may do both.

Fig.(c) : Cantilever beam

(iv) Fixed beam : When the both ends of the beam are built in or fixed, such beam is called as fixed beam.

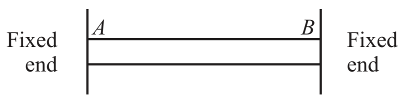


Fig.(d) : Fixed beam

(v) Continuous beam : It is a beam which expands over more than two supports.

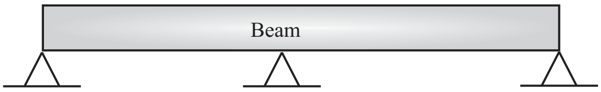


Fig.(e) : Continuous beam

(vi) Propped cantilever beam : A cantilever beam which has a support between fixed end and free end is called propped cantilever beam.

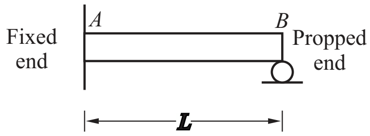
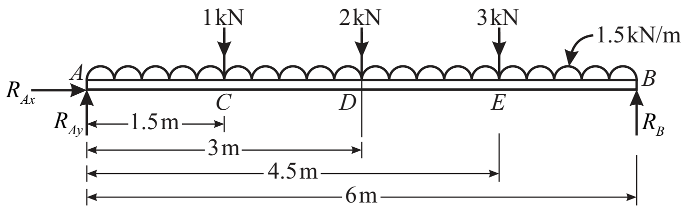


Fig.(f) : Propped cantilever beam

Q.4 (b) A beam of 6 m long in simply supported at the ends and carries a uniformly distributed load of 1.5 kN/m and three concentrated loads 1 kN, 2 kN and 3 kN acting respectively at a distance of 1.5 m, 3 m and 4.5 m from the left end. Determine the reacting at both ends.

Ans. FBD :



Calculation for reaction :

Applying condition of equilibrium,

Consider, R_A and R_B are the reactions at support A and B respectively.

$\Sigma F_x = 0,$

$$R_{Ax} = 0 \text{ (No horizontal force on beam)}$$

$\Sigma F_y = 0,$

$$R_{Ay} + R_B = 1.5 \times 6 + 1 + 2 + 3$$

$$R_{Ay} + R_B = 15 \qquad \ldots\text{(i)}$$

Taking moments about support A, we get

$\Sigma M_A = 0,$

$$R_B \times 6 = 1 \times 1.5 + 2 \times 3 + 3 \times 4.5 + 1.5 \times 6 \times \frac{6}{2}$$

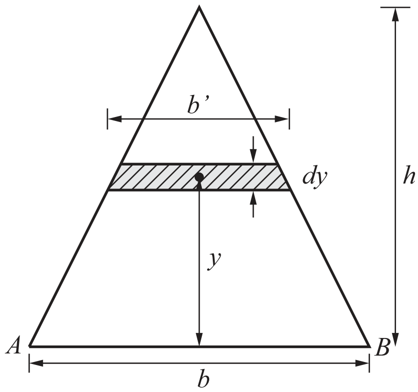
$$R_B = 8 \text{ kN}$$ **Ans.**

From equation (i), we get

$$R_{Ay} = 15 - 8 = 7 \text{ kN}$$ **Ans.**

Q.5 (a) Derive an expression for the moment of inertia of a triangular section about an axis passing through the C.G. of the section and parallel to the base.

Ans. Moment of inertia of a triangle with base width b and height h is to be determined about the base AB.



Consider an elemental strip at distance y from the base AB. Let dy be the thickness of the strip and dA its area. Width of this strip is given by :

$$b' = \frac{(h-y)}{h} \times b$$ [By similarity of triangle] …(i)

Moment of inertia of this strip about *AB*

$$I_{AB} = \int_0^h y^2 dA = \int_0^h y^2 b' dy$$

From equation (i), we get

$$I_{AB} = \int_0^h y^2 \frac{(h-y)}{h} \times b \times dy$$

$$I_{AB} = \int_o^h y^2 \frac{(h-y)bdy}{h} = \int_o^h \left(y^2 - \frac{y^3}{h} \right) bdy$$

$$I_{AB} = b\left[\frac{y^3}{3} - \frac{y^4}{4h} \right]_o^h$$

$$I_{AB} = b\left[\frac{h^3}{3} - \frac{h^4}{4h} \right]$$

$$I_{AB} = \frac{bh^3}{12}$$ **Ans.**

It is clear that the centroidal axis will be parallel to base hence from parallel axis theorem,

$$I_{AB} = I_{xx} + Ay^2$$

Here, y is the distance between base AB and centroidal axis x-x and is equal to $\frac{h}{3}$.

$$\frac{bh^3}{12} = I_{xx} + \frac{1}{2} bh \left(\frac{h}{3} \right)^2 = I_{xx} + \frac{bh^3}{18}$$

Moment of inertia about centroidal axis

$$I_{xx} = \frac{bh^3}{12} - \frac{bh^3}{18} = \frac{bh^3}{36}$$ **Ans.**

Q.5 (b) Determine the Center of gravity of the L-section shown in Fig.1.

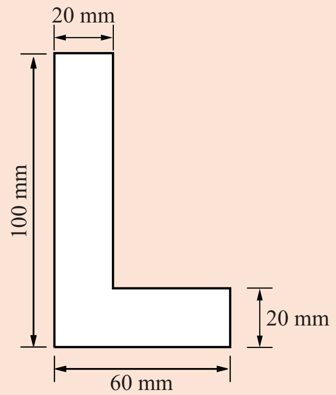
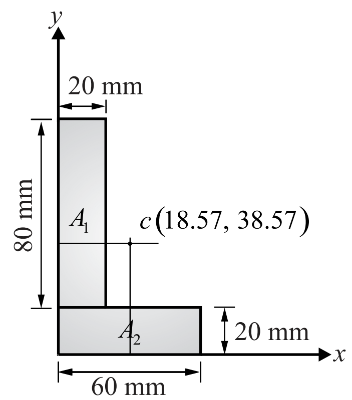


Fig.1

Ans. The given composite figure can be divided into two rectangles. Selecting the reference axis x and y as shown is figure.



$$A_1 = 80 \times 20 = 1600 \text{ mm}^2, \quad x_1 = 10 \text{ mm}, \quad y_1 = 20 + \frac{80}{2} = 60 \text{ mm}$$

$$A_2 = 60 \times 20 = 1200 \text{ mm}^2, \quad x_2 = 30 \text{ mm}, \quad y_2 = 10 \text{ mm}$$

***x*-coordinate of centroid :**

$$\bar{x} = \frac{A_1 x_1 + A_2 x_2}{A_1 + A_2} = \frac{1600 \times 10 + 1200 \times 30}{1600 + 1200} = 18.57 \text{ mm}$$

***y*-coordinate of centroid :**

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{1600 \times 60 + 1200 \times 10}{1600 + 1200} = 38.57 \text{ mm}$$

Hence, the centroid is $c(18.57, 38.57)$ as shown in figure above.

Q.6 (a) State the Newton's law of motion and Gravitation, also explain the various terms used in dynamics.

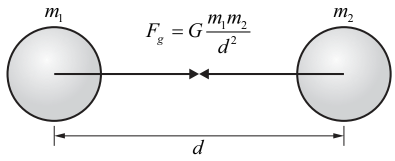
Ans. According to Newton's law of gravitation,

1. Every mass attracts every other mass.
2. Attraction is directly proportional to the product of their masses.

$$F_g \propto m_1 m_2 \quad \text{...(i)}$$

3. Attraction is inversely proportional to the square of the distance between their centers.

$$F_g \propto \frac{1}{d^2} \quad \text{...(ii)}$$



Gravitational force,

$$F = G\frac{m_1 m_2}{d^2}$$

Where, G is known as universal gravitational constant.

The value of G is $6.673\times10^{-11}\,\text{m}^3/\text{kg-s}^2$, mass of the earth $m_1 = 5.9736\times10^{24}\,\text{kg}$ and distance of the earth $d = 12.74202\times10^6\,\text{m}$, we obtain $g = 9.82242\ \text{m/s}^2$.

Newton's laws consist of "the law of inertia", "the law of motion", and "the law of action and reaction."

Newton's first law (the law of inertia) : The law states that; *"A body will remain at rest or in uniform motion in a straight line unless it is compelled to change this state by forces impressed upon it."*

The first law depicts that if there is no external effect, an object must be still or moving at a constant velocity, which leads to a concept of the net force.

Newton's second law (the law of motion) : This law states that; *"A body acted upon by an external unbalanced force will accelerate in proportion to the magnitude of this force in the direction in which this force acts."*

The second law quantifies the force in terms of acceleration and mass of the object.

$$F = ma$$

Newton's third law (the law of action and reaction) : This law states that, "*For every action (or force) there is an equal and opposite reaction (or force)*".

The third law illustrates the existence of the counter force which is related to normal forces, tension, etc.

Various terms related to dynamics :

1. **Displacement :** It is the shortest distance from the initial to the final position of a point. It is a vector quantity.

   Displacement = Final position – Initial position

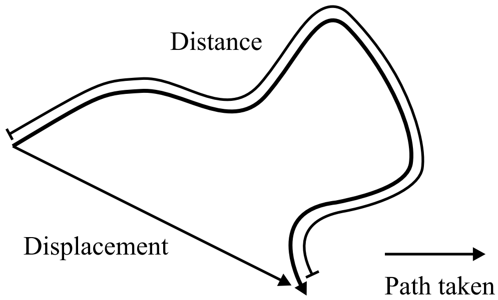


Fig. : Displacement

2. **Distance travelled :** It is the length of path travelled by a particle or body. It is a scalar quantity.
3. **Velocity :** Velocity is the rate of displacement of a body with respect to time.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time interval}}$$

4. **Acceleration :** Acceleration is the rate of change of velocity of a body with respect to time.

$$\text{Acceleration} = \frac{\text{Velocity}}{\text{Time interval}}$$

5. **Average velocity :** It is the average value of the given velocities. Average velocity is displacement over total time.

$$\text{Average velocity } = \frac{\Delta x}{\Delta t}$$

6. **Instantaneous velocity :** It is the velocity at a particular instant of time. It can be obtained from the average velocity by choosing the time interval Δt and the displacement Δx. Instantaneous velocity, (or velocity)

$$v = \underset{\Delta t \to 0}{\text{limit}} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

The unit of velocity is m/s.

7. **Average acceleration :** Let v be the velocity of the particle at any time t. If the velocity becomes $(v + \Delta v)$ at a later time $(t + \Delta t)$ then,

$$\text{Average acceleration } = \frac{\Delta v}{\Delta t}$$

8. **Instantaneous acceleration :** It is the acceleration of a particle at a particular instant of time and can be calculated by choosing the time interval Δt and the velocity Δv.

$$\text{Acceleration } a = \underset{\Delta t \to 0}{\text{limit}} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2 x}{dt^2}.$$

Acceleration is position if the velocity is increasing. The unit of acceleration is m/s^2.

$$a = \frac{dv}{dt} \quad \text{as} \quad v = \frac{dx}{dt}$$

So, $$a = \frac{d^2 x}{dt^2}$$

Also, $$a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} \quad \text{and as } \frac{dx}{dt} = v$$

So, $$a = v\frac{dv}{dx}$$

9. **Uniform motion :** A particle is said to have a uniform motion when its acceleration is zero and its velocity is constant with respect to time. It also called **uniform velocity**.

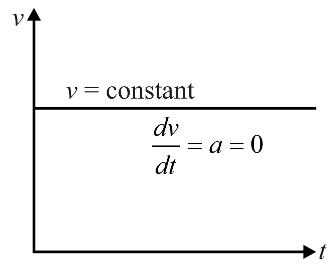


Fig. : Uniform Motion

10. **Uniformly accelerated motion :** A particle moving with a constant acceleration $(a = \text{constant}$ with respect to time) is said to be in uniformly accelerated motion.

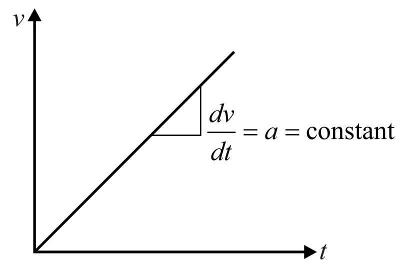


Fig. : Uniformly Accelerated Motion

Q.6 **(b)** Determine the force in members *BD*, *CD* and *CE* of the truss shown in Fig.2.

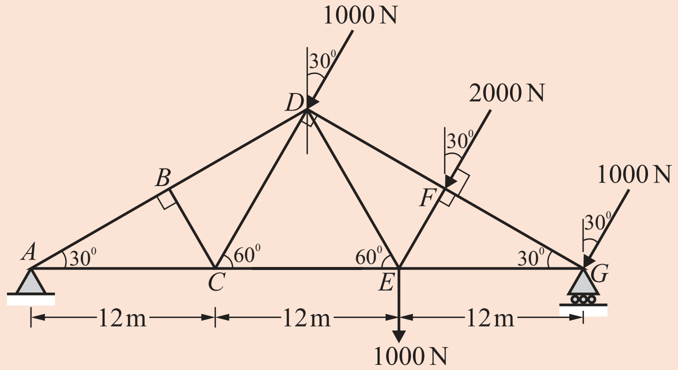
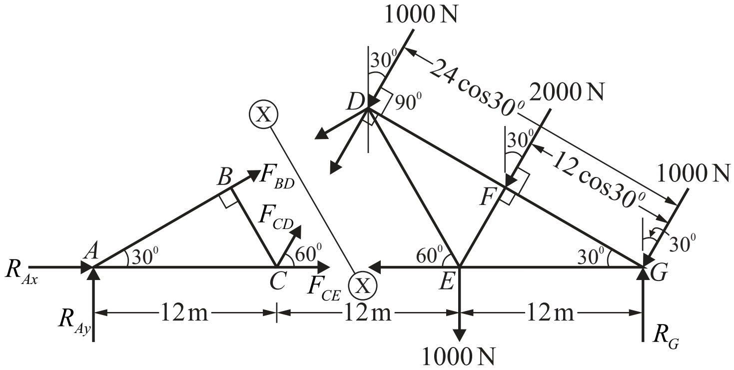


Fig.2

Ans. **FBD :**



Calculation for reactions :

Applying condition of equilibrium,

$\Sigma F_y = 0,$

$$R_{Ay} + R_G = 1000\cos 30^0 + 2000\cos 30^0 + 1000\cos 30^0 + 1000$$

$$R_{Ay} + R_G = 4464.102\text{ N} \qquad \ldots\text{(i)}$$

$\Sigma F_x = 0,$

$$R_{Ax} = 1000\sin 30^0 + 2000\sin 30^0 + 1000\sin 30^0$$

$$R_{Ax} = 2000\text{ N}$$

Taking moment about *G*,

$$R_{Ay} \times 36 = 1000 \times 24\cos 30^0 + 2000 \times 12\cos 30^0 + 1000 \times 12$$

$$R_{Ay} = 1488.033\text{ N}$$

From equation (i), we get

$$R_G = 4464.102 - 1488.033$$

$$R_G = 2976.069\text{ N}$$

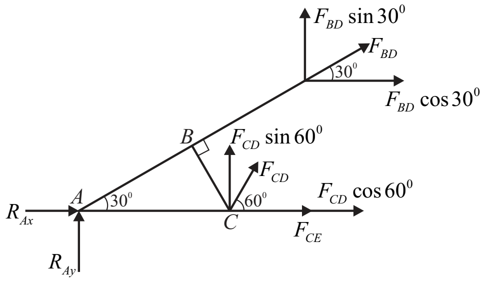
Using method of section :

Initially consider all the members under tension. If the value of forces comes negative after calculation, it means the force in members are compressive, but we will not change their sense in any of the FBD (let it look like a tensile force) during solving, instead of doing this we will put negative values of respective forces in the equations.

Cutting a section passing through BD, CD, CE, consider left portion

In ΔABC,

$$\frac{BC}{AC} = \sin 30^0$$
$$BC = 12\sin 30^0$$
$$BC = 6\,\text{m}$$



Taking moment about C,

$$F_{BD}\times BC + R_{Ay}\times AC = 0$$
$$F_{BD} = \frac{-R_{Ay}\times 12}{6} = -1488.033\times 2$$
$$F_{BD} = -2976.066\,\text{N (Compressive)}$$ **Ans.**

$\Sigma F_x = 0$,

$$F_{BD}\cos 30^0 + F_{CD}\cos 60^0 + R_{Ax} + F_{CE} = 0$$
$$F_{CD}\cos 60^0 + F_{CE} = 2976.066\cos 30^0 - 2000$$
$$F_{CD}\cos 60^0 + F_{CE} = 577.348 \quad \ldots\text{(ii)}$$

$\Sigma F_y = 0$,

$$F_{BD}\sin 30^0 + F_{CD}\sin 60^0 + R_{Ay} = 0$$
$$F_{CD} = \frac{2976.066\sin 30^0 - 1488.033}{\sin 60^0}$$
$$F_{CD} = 0$$ **Ans.**

From equation (ii), we get

$$F_{CE} = 577.348\ \text{N (Tensile)}$$ **Ans.**

Member	Force	Magnitude (N)	Nature
BD	F_{BD}	2976.066	Compressive
CD	F_{CD}	0	–
CE	F_{CE}	577.348	Tensile

Q.7 **(a)** Explain and define the term free body diagram. Draw the free body diagram of a ball of weight W placed on a horizontal surface.

Ans. ***If a body consist of more than one element and support, each then element and support can be isolated from the system, such diagram is called free body diagram.***

One of the most useful aids for solving a statics problem is the free body diagram (FBD). A free body diagram is a graphic, dematerialized, symbolic representation of the body (structure, element or segment of an element) in which all connecting "pieces" have been removed. A FBD is a convenient method to model the structure, structural element, or segment that is under scrutiny. It is a way to conceptualize the structure, and its composite elements, so that an analysis may be initialized.

To draw **FBD** of a body we remove all the supports (like wall, floor, hinge or any other body) and replace them by the reactions which these supports exert on the body.

Example : Consider a ball of weight W resting on a horizontal plane as shown in Fig.(a).
The steps to draw the FBD are :

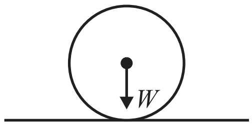


Fig.(a) : Ball resting on a plane

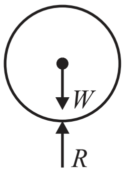


Fig.(b) : Free body diagram of ball

Step 1 : First draw the object :

Here our object is a ball.

Step 2 : Remove all supports :

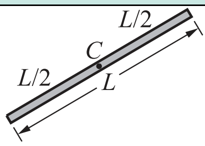
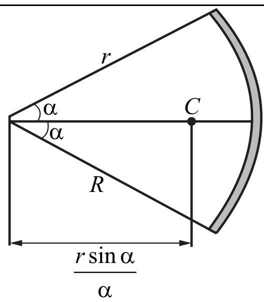
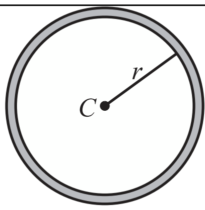
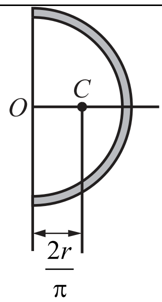
Remove surface, here surface will give reaction force.

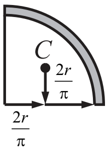
Step 3 : Show all the forces :

Show body forces as well as external forces as shown in Fig. (b).

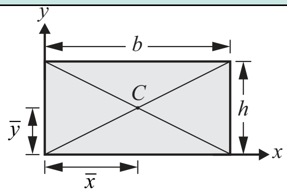
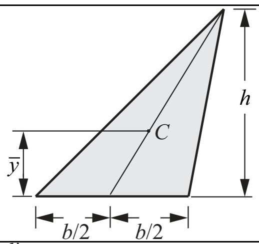
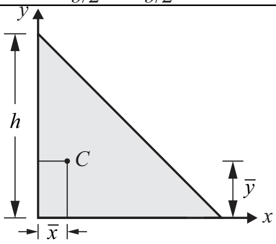
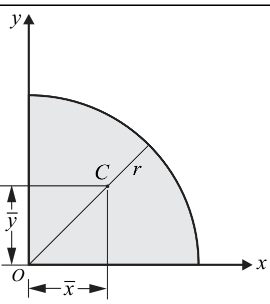
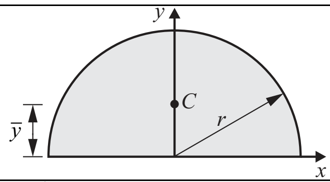
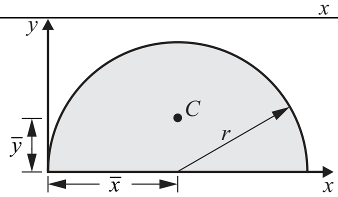
Q.7 (b) Give the position of centroid of the following standard sections :
(i) Rectangle (ii) Triangle
(iii) Uniform rod (iv) Semicircle

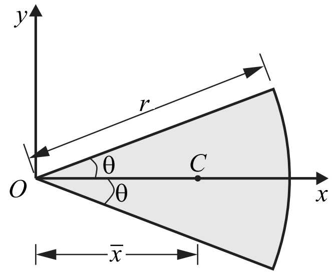
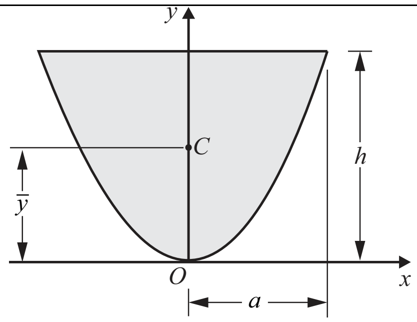
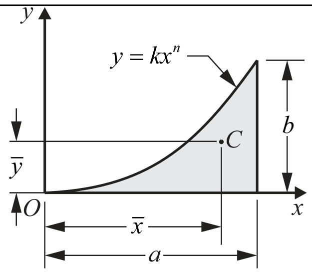
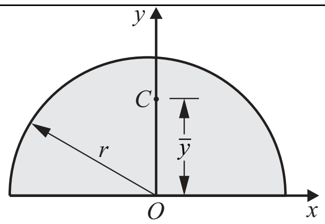
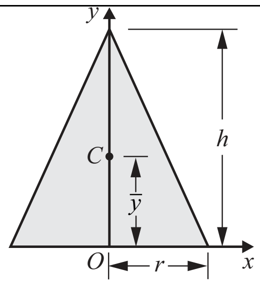
Ans. Centroids of various line segments :

S. No.	Basic line segment		Length	Location of centroids
	Description	Figure		
1.	Straight line or uniform rod		L	Centre of the line $= \frac{L}{2}$
2.	Arc of a circle of radius r and inscribed angle 2α		$2\alpha r$	On the line of symmetry at a distance of $\frac{r\sin\alpha}{\alpha}$ from the centre of arc.
3.	Circle of radius r		$2\pi r$	Centre of the circle.
4.	Semicircular arc of radius r		πr	On the line of symmetry at a distance of $\frac{2r}{\pi}$ from the centre.

S. No.	Basic line segment		Length	Location of centroids
	Description	Figure		
5.	Quarter circular arc of radius r		$\frac{\pi r}{2}$	A distance $\frac{2r}{\pi}$ from centre along one radius and then $\frac{2r}{\pi}$ from that point perpendicular to that radius.

Centroids of area of various shapes :

Plane	Shape	Area	$\bar{x}_c$	$\bar{y}_c$
Rectangle		ab	$\frac{b}{2}$	$\frac{h}{2}$
Triangle		$\frac{bh}{2}$	–	$\frac{h}{3}$
Right angle triangle		$\frac{bh}{2}$	$\frac{b}{3}$	$\frac{h}{3}$
Quarter-circle		$\frac{\pi r^2}{4}$	$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$
Semi-circle		$\frac{\pi r^2}{2}$	0	$\frac{4r}{3\pi}$
		$\frac{\pi r^2}{2}$	r or $\frac{d}{2}$	$\frac{4r}{3\pi}$

Plane	Shape	Area	$\bar{x}_c$	$\bar{y}_c$
Circular-Sector		$r^2\theta$	$\frac{2r\sin\theta}{3\theta}$	0
Parabola		$4\frac{ah}{3}$	0	$\frac{3h}{5}$
General curve		$\frac{ab}{n+1}$	$\left(\frac{n+1}{n+2}\right)a$	$\left(\frac{n+1}{2n+1}\right)\frac{b}{2}$
Hemisphere		$\frac{2}{3}\pi r^3$	0	$\frac{3}{8}r$
Right circular cone		$\frac{1}{3}\pi r^2 h$	0	$\frac{h}{4}$