ENGINEERING MECHANICS

1st SEM

MECHANICAL ENGG.

Under SCTE&VT,Odisha

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Mechanics :-

Engineering mechanics is the branch of science which deals with the laws and principles of mechanics, alongwith their applications to engineering problems.

* It is classified into following two types.

(I) static
(II) Dynamic

(I) Statics:-

It is the branch of Engineering mechanics, which deals with the forces and their effects while acting upon a bodies at rest.

(II) Dynamics :-

It is the branch of engg. mechanics, which deals with the forces and their effects, while acting upon a bodies in motion.

It is of two types,

(a) Kinetics
(b) Kinematics

(a) Kinetics :-

It is the branch of dynamics, which deals with the bodies in motion due to the application of forces.

(b) Kinematics :-

It is the branch of Dynamics which deals with the bodies in motion, without any reference to the forces which are responsible for motion.

Rigid body :-

Rigid body is a solid body in which deformation is zero or negligible.

Force :-

Force is defined as an external agent which produces or tends to produce, destroy or tends to destroy the motion of a body.

Effects of a force :-

- → It may change the motion of a body.
- → It may retard the motion of a body.
- → It balance the forces already acting on a body.
- → It may give rise to the internal stresses in the body.

Characteristics of Force :-

- → Magnitude of forces
- → The direction of the line, along which the force acts. (It is also known as line of action)

→ Nature of the force (i.e Push or Pull)
→ The point at which (

Units of force :-

In M.K.S system = Kilogram-Force (kgf)
In S.I System = Newton (N)
In C.G.S system = Dyne
$1N = 10^5 dyn$ ⇒ $1 dyn = 10^{-5} N$

System of forces :-

When two or more forces act on a body, they are called to form a system of forces.

1. **Coplaner forces :-**
The forces, whose line of action lie on the same plane, are known as coplaner forces.

2. **Colinear Forces :-**
The forces, whose lines of action lie on the same line, are known as colinear forces.

(3) **Concurrent forces :-**
The forces, which meet at one point are known as concurrent forces.

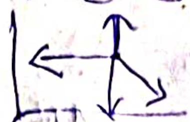
(4) **Coplanner concurrent forces :-**
The forces which meet at one point and their line of action also lie on the same plane.

(5) Coplaner non concurrent :-

The forces which don't meet at one point, but their lines of action also lie on the same plane.

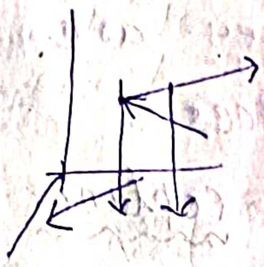
(6) Non coplaner concurrent forces :-

The forces, which meet at one point but their lines of action don't lie on the same plane.



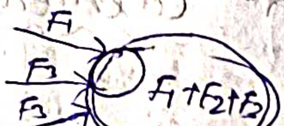
(7) Non- coplaner non- concurrent forces :-

The forces, which don't meet at one point and their lines of action don't lie on the same plane.



Principle of superposition :-

The principle of super position of forces ~~states~~ states that the combained effect of a force system acting on a particle or a rigid body is the sum of the ~~effects~~ effects of individual forces.



Freebody Diagram :- (FBD)

Freebody diagram is a sketch of an object of interest with all the surrounding objects stripped away and all of these forces acting on the body shown.

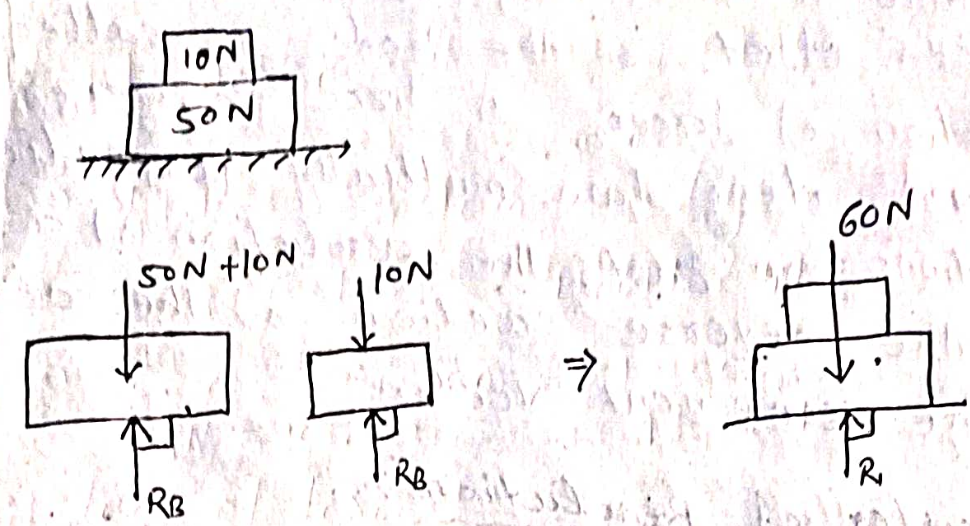
Action and Reaction of forces :-

An action force is a force that is applied to an object

-> A reaction force is a consequence of an action force which is opposite in direction

Example of FBD :-

①



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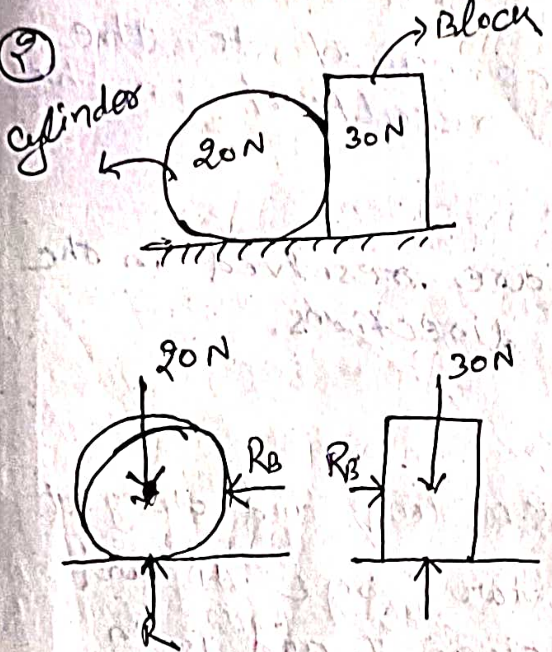

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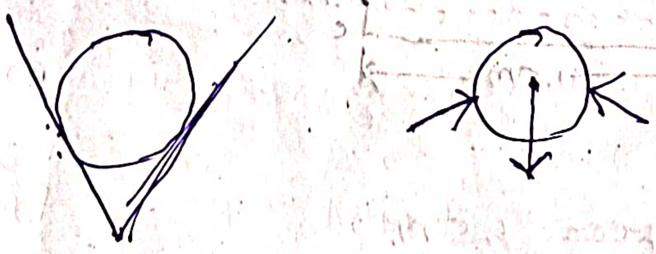


Resolution of forces:

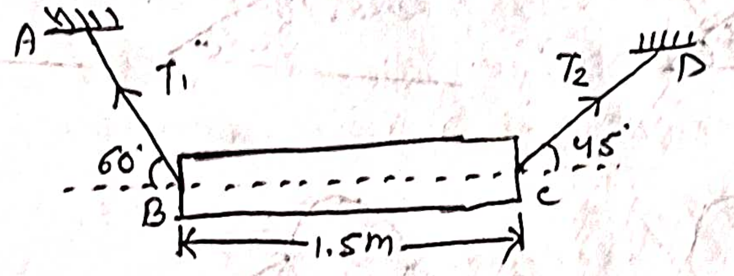
The process of spliting up the given force into a no. of components, without changing it's effect on the body is called Resolution of forces. A force is generally resolved along two mutually perpendicular directions. In fact, the resolution of a force is the reverse action of the addition of the component vectors.

Principles of Resolution:

It states that, " The algebraic sum of the resolved parts of a no. of forces in a given direction, is equal to the resolved part of their resultant in the same direction.

* In general, the forces are resolved in the vertical and horizontal directions.

Q. A machine component 1.5 m long and weight 1000N is supported by two rope AB and CD. Calculate the tensions T_1 and T_2 in the ropes AB and CD.



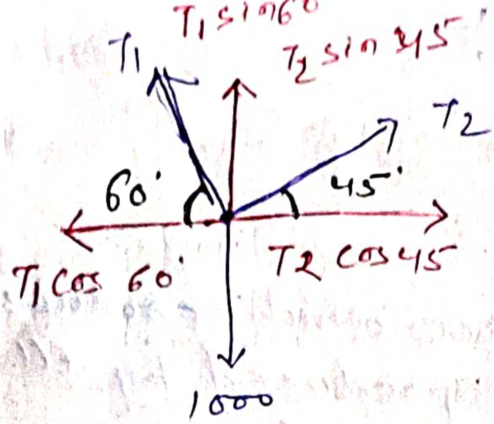
Sol?.

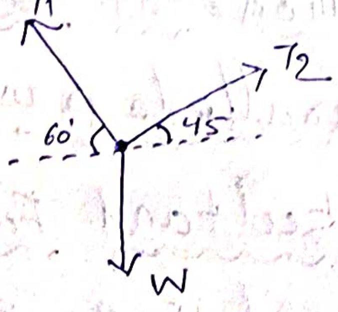
Given data,

length = ~~1000~~ 1.5 m.

weight = 1000 N

$T_1 = ?$, $T_2 = ?$





(F.B.D)

Resolving the forces horizontally, and equating the same,

$$T_1 \cos 60° = T_2 \cos 45°$$

$$\Rightarrow T_1 = T_2 \times \frac{\cos 45°}{\cos 60°} = T_2 \times \frac{0.707}{0.5}$$

$$\Rightarrow T_1 = 1.414\, T_2 \quad \text{--- (1)}$$

Now, Resolving the forces vertically,

$$T_1 \sin 60° + T_2 \cos 45° = 1000$$

$$\Rightarrow 1.414\, T_2 \sin 60° + T_2 \cos 45° = 1000$$

(From eqn (1) we get T_1)

$$\Rightarrow (1.414 \times 0.866)\, T_2 + (0.707)\, T_2 = 1000$$

$$\Rightarrow 1.224\, T_2 + 0.707\, T_2 = 1000$$

$$\Rightarrow T_2 (1.224 + 0.707) = 1000$$

$$\Rightarrow T_2 \times 1.93 = 1000$$

$$\Rightarrow T_2 = \frac{1000}{1.93} = 518.1\, N$$

From eqn (1)

$$T_1 = 1.414\, T_2$$

$$= 1.414 \times 518.1$$

$$T_1 = 732.6\, N$$

(Ans)

~~Method of Resolution~~:

Parallelogram law :-

Resultant Force :-

It is a single force which produces the same effect as produced by all the given forces acting on a body.

→ The resultant force may be determined by the following three laws of forces

(i) Parallelogram law

(ii) Triangle law

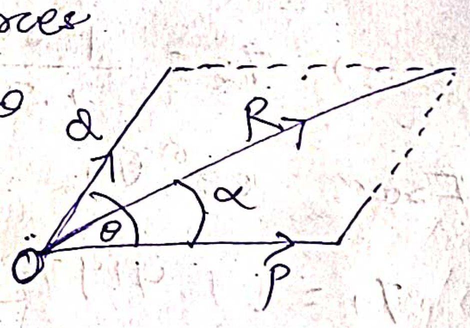
(iii) Polygon law

(1) Parallelogram law :-

It states that, if two forces acting simultaneously on a particle, be represented in magnitude and direction by the two adjacent sides of a parallelogram, then their resultant may be represented in magnitude and direction by the diagonal of a parallelogram which passes through their point of intersection.

let us consider two forces 'P' and 'Q' acting at angle θ at point 'O'.

The resultant is given by



$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

If the resultant (R) makes an angle α with the force P, then.

$$\tan \alpha = \frac{Q \sin \theta}{P + Q \cos \theta}$$

where, P, Q = Forces whose resultant is required to be found out.
θ = Angle betn P and Q
α = Angle which the resultant Force makes with one of the forces.

Note :-

1. If $\theta = 0°$ i.e when the forces act along the same line.

~~R = P+F~~

$$R = P + Q \quad (\because \cos 0° = 1)$$

2. If $\theta = 90°$ i.e when the forces at at right angle.

$$R = \sqrt{P^2 + Q^2} \quad (\because \cos 90° = 0)$$

3. If $\theta = 180°$ i.e whe the forces act along the same straight line but in opposite direction.

$(\because \cos 180° = -1)$

4. If the two forces are equal i.e $P = Q = $ Force

then, $R = \sqrt{F^2 + F^2 + 2F^2 \cos \theta}$

$$R = \sqrt{2F^2(1+\cos\theta)}$$

$$= \sqrt{2F^2 \times 2\cos^2\left(\frac{\theta}{2}\right)} \qquad \left[\because 1+\cos\theta = 2\cos^2\left(\frac{\theta}{2}\right)\right]$$

$$= \sqrt{4F^2 \times \cos^2\left(\frac{\theta}{2}\right)}$$

$$\Rightarrow R = 2F\cos\frac{\theta}{2}$$

Q. Two forces of 100N and 150N are acting simultaneously at a point. What is the resultant forces, if the angle bet' them is 45°?

Sol^n: Given data,

$P = 100N$

$Q = 150N$

$\theta = 45°$

We know that,

$$R = \sqrt{P^2+Q^2+2PQ\cos\theta}$$

$$= \sqrt{\{(100)^2+(150)^2+2\times100\times150\times\cos45°\}}\ N$$

$$= 232\ N.$$ Ans

Q. Find the magnitude of two forces, such that if they act at right angles, their resultant is $\sqrt{10}$ N. But if they act at 60°, their resultant is $\sqrt{13}$ N.

~~Given data~~

First of all, consider the two forces acting at right angles. We know that when the angle bet^n the two given forces is 90°, then the resultant force (R)

$\sqrt{10} = \sqrt{P^2+Q^2}$

$10 = P^2+Q^2$ —(1) (∵ squaring both sides.)

Similarly, when the angle betⁿ the two forces is 60°, then the resultant force (R)

$\sqrt{13} = \sqrt{P^2+Q^2+2PQ\cos 60°}$

$13 = P^2+Q^2+2PQ \times 0.5$ (∵ squaring both)

$PQ = 13-10 = 3$ (Put the value of $P^2+Q^2 = 10$)

We know that

$(P+Q)^2 = P^2+Q^2+2PQ$

$= 10+3\times 2$

$= 16$

$P+Q = \sqrt{16} = 4$ —(1)

Similarly

$(P-Q)^2 = P^2+Q^2-2PQ$

$= 10-2\times 3$

$= 4$

$\Rightarrow P-Q = \sqrt{4} = 2$ —(11)

Now solving the two eqⁿs

$P+Q = 4$

$P-Q = 2$

$2P = 6$

$\Rightarrow P = 3$

Now Put the value of P in eqⁿ (1)

$P + Q = 4$

$\Rightarrow Q = 4 - P$

$= 4 - 3$

$Q = 1N$

$\therefore P = 3N$ & $Q = 1N$

Triangle law :-

It state's that if two forces, acting simultaneously on a particle, be represented in magnitude and direction by the two sides of a triangle taken in order, then their resultant may be represented in magnitude and direction by the third side of the triangle taken in opposite order.

Polygon law :-

It states that if a no. of forces acting simultaneously on a particle, be represented in magnitude and direction by sides of a polygon taken in order, then their resultant is represented in magnitude and direction by the closing side of the polygon taken in opposite order.

Method of Resolution for the resultant force :-

1. Resolve all the forces horizontally and find the algebric sum of all horizontal components. (i.e ΣH).

2. Resolve all the forces vertically and find the algebric sum of all the vertical components (i.e. ΣV).

3. The resultant 'R' of the given forces will be given by :

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$$

4. The resultant force will be inclined with the horizontal at an angle θ, with the horizontal.

i.e.

$$\tan\theta = \frac{\Sigma V}{\Sigma H}$$

Notes:-

→ The value of angle θ will vary depending upon the values of ΣV and ΣH.

→ ΣV is +ve, the resultant makes an angle bet^n 0° and 180°. But ΣV is −ve when the the resultant makes an angle bet^n ~~90° to 270°~~ 180° to 360°.

→ ΣH is +ve, when the resultant makes an angle bet^n 0° − 90° or 270° − 360°. But

ΣH is -ve ; when resultant makes an angle betⁿ 90° – 270°.