

## Forces

### Force

#### Principal of transmissibility of Forces:

If a force acts at any point on a rigid body it may also be considered to act at any other point on its line of action.

#### Parallelogram Law of Forces:

It stated that “it two forces acting simultaneously at a point be represented in magnitude and direction by the two adjacent sides of parallelogram, then the resultant of these two forces is represented in magnitude and direction by the diagonal of that parallelogram originating from that point “.

Mathematically,  $R = \sqrt{P^2 + Q^2 + (2PQ \cos \theta)}$

#### Triangle law of forces:

It stated that “If two forces acting at a point are represented by the two sides of a triangle taken in order, then their resultant force is represented by the third side taken in opposite order”.

#### System of forces:

##### Force:

Force is an agent which changes or tends to change the state of rest or of uniform motion of a body upon which it acts. A Force represents the action of one body on another. Force is a vector quantity (i.e, Force has got both magnitude and direction)

#### Characteristics of a force:

A Force is characterized by

1. Magnitude

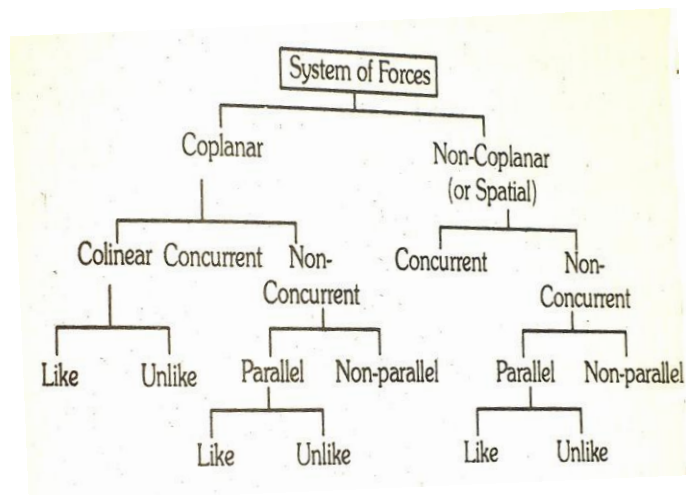
2. Line of action

3. Direction

The magnitude of a force is denoted by a certain number of units.

#### System of Forces:

A body with two or more forces acting simultaneously on it constitutes a system of forces. Force system is classified into subdivisions as shown in the line diagram given below.



#### Coplanar Forces:

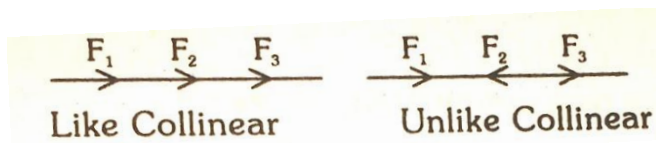
In Coplanar force system, the forces do not act in one plane. This system is also called as “Forces in Plane”.

#### Non – Coplanar Force:

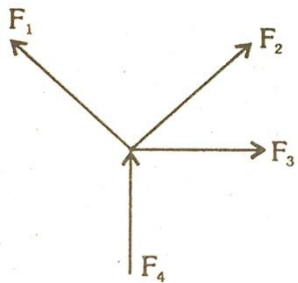
In Non – Coplanar force system, the forces do not act in one plane. This system is also called as “Forces in Space”.

**Collinear Forces:**

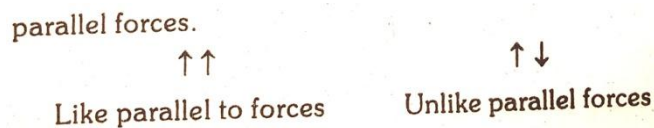
The Forces which acts on a common line of action are called collinear forces. If they act in same direction, they are called the collinear and if they act in opposite direction, they are called “unlike collinear”.

**Concurrent Forces:**

In concurrent force system, forces intersect at a common point.

**Parallel Forces:**

In parallel force system line of action of forces are parallel to each other. Parallel forces acting in same direction are called like parallel forces and the parallel forces acting in opposite direction are called unlike parallel forces.

**Like Collinear Coplanar Forces:**

Forces acting in same direction lie on a common line of action and acts in a single plane.

**Unlike Collinear Coplanar Forces:**

Forces acting in opposite direction, lies on a common line of action and acts in a single plane.

**Coplanar Concurrent Forces:**

Forces intersect at a common point and lies in a single plane.

**Coplanar Noncurrent Forces:**

Forces which do not intersect at a common point, but acts in one plane. They may be either parallel or non-parallel.

**Non- Coplanar Concurrent forces:**

Forces intersect at one point, but their lines of action do not lie on the same plane.

**Non Coplanar non –concurrent forces:**

Forces do not intersect at one point and also their line of action does not lie on the same plane.

**Resultant Force:**

If a number of forces acting on a particle simultaneously are replaced by a single force, which could produce the same effect as produced by the given forces, that single force is called Resultant force. It is an equivalent force of all the given forces.

Resultant force of all the force systems can be determined by two methods.

1. Analytical method
2. Graphical method.

**Q. Find the resultant force of the collinear forces shown below:**



Resultant Force  $R = 8 + 10 + 12 = 30\text{N}$



**Q. Find the resultant force of the collinear forces shown below.:**



Magnitude of Resultant force

$$R = 2 - 3 + 6 - 11 = -6\text{N}$$

As  $R$  is negative measure, Resultant force acts in the negative directions. i.e. towards left.

**Resultant force of concurrent forces:**

In order to find the resultant force of concurrent forces, we shall take.

- i) Resultant force of two concurrent forces and
- ii) Resultant forces of more than two concurrent forces.

**Resultant force of two concurrent forces:**

The analytical method of finding out the resultant of two concurrent forces can be developed from the parallelogram law of forces.

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

Q. Two concurrent forces of 12N and 18N are acting at an angle of  $60^\circ$ . Find the resultant force.

Let  $p = 12\text{N}$  and

$Q = 18\text{N}$  and

$\theta = 60^\circ$

Resultant force,

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

$$R = \sqrt{12^2 + 18^2 + (2 \times 12 \times 18 \times \cos 60^\circ)}$$

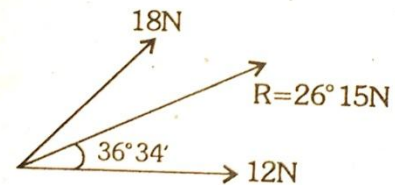
$$= \sqrt{684} = 26.15\text{N}$$

Inclination of Resultant force with the force  $P$ ,

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

$$= \frac{18 \sin 60^\circ}{12 + (18 \cos 60^\circ)} = 0.742$$

$$\alpha = \tan^{-1}(0.742) = 36^\circ 34'$$



Q. Two concurrent forces acts at an angle of  $30^\circ$ . The resultant force is 15N and one of the forces is 10N. Find the other force.

Let  $R = 15\text{N}$ .  $P = 10\text{N}$ ,  $\theta = 30^\circ$ ,  $Q = ?$

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

$$15^2 = 10^2 + Q^2 + (2 \times 10 \times Q \cos 30^\circ)$$

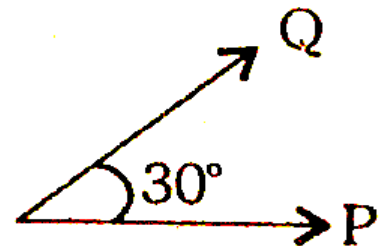
$$15^2 = 100 + Q^2 + 17.32 Q$$

$$\text{or } Q^2 + 17.32 Q - 125 = 0$$

$$Q = \frac{-17.32 \pm \sqrt{(17.32)^2 - (4 \times 1 \times -125)}}{2 \times 1}$$

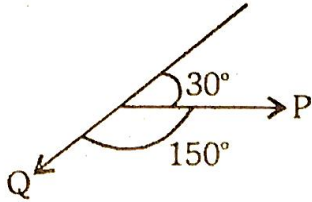
$$= \frac{-17.32 \pm 28.28}{2}$$

$$= -22.8\text{N or } 5.48\text{N}$$



Reject  $-22.8\text{N}$  force, because, if the force is reversed the included angle will be  $150^\circ$  not  $30^\circ$ .

Hence  $Q = 5.48\text{N}$



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