

Module II: Equilibrium

Session 8

Equilibrium: A body is said to be in equilibrium if the resultant force and resultant moment of a number of forces acting on the body is zero.

Equilibrant: The force, which brings a set of forces in equilibrium, is called an equilibrant. As a matter of fact, the equilibrant is equal to the resultant force in magnitude, but opposite in direction.

General Conditions of Equilibrium

When acted upon by a system of *coplanar concurrent forces*, the body undergoes only displacement and the rotation is zero. The system is said to be in equilibrium if there is no unbalanced force acting on it, i.e., the resultant of all forces acting on the body is zero. Mathematically, for equilibrium

- i. $\sum F_x = 0$, i.e., the algebraic sum of all forces in horizontal direction in their plane is zero.
- ii. $\sum F_y = 0$, i.e., the algebraic sum of all forces in vertical direction in their plane is zero.

Graphically force polygon diagram must close.

When acted upon by a system of *coplanar non-concurrent forces*, the body undergoes only displacement due to resultant force and rotation due to resultant moment. The system is said to be in equilibrium if the algebraic sum of all forces and their moments about any point in their plane is zero. Mathematically, for equilibrium

- i. $\sum F_x = 0$, i.e., the algebraic sum of all forces in horizontal direction in their plane is zero.
- ii. $\sum F_y = 0$, i.e., the algebraic sum of all forces in vertical direction in their plane is zero.
- iii. $\sum M = 0$, i.e., the algebraic sum of all moments is zero.

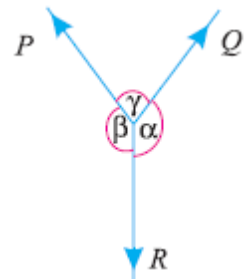
Principles of Equilibrium

1. *Two force principle.* As per this principle, if a body in equilibrium acted upon by two forces, then they must be equal, opposite and collinear.
2. *Three force principle.* As per this principle, if a body in equilibrium acted upon by three forces, then these three forces may be either concurrent or unlike parallel.

Lami's Theorem

It states, "If three coplanar forces acting at a point be in equilibrium, then each force is proportional to the sine of the angle between the other two." Mathematically,

$$\frac{P}{\sin \alpha} = \frac{Q}{\sin \beta} = \frac{R}{\sin \gamma}$$



Graphical Conditions of Equilibrium:

Triangle Law of Equilibrium: If three forces acting at a point be in equilibrium, then they can be represented in magnitude and direction by the three sides a triangle taken in order.

Polygon Law of Equilibrium: If a number of forces acting at a point be in equilibrium, then they can be represented in magnitude and direction by the sides of a closed polygon taken in order.