Module 1 : Introduction : Review of Basic Concepts in Mechnics
Lecture 2 : Equilibrium

Objectives

In this course you will learn the following

- Review of the concepts of equilibrium.
- Static equilibrium equations in 3-D and 2-D.
- Concept of free body diagrams.

1.2 Equilibrium

The concept of equilibrium is the most central one in the subject of Statics. When the net effect or the resultant of all the forces (and couples) acting on a system is zero, the system is said to be in equilibrium. Thus, based on the resultant of all the forces ***R*** , and the resultant of all the moments (couples) ***M*** , the vector equations of equilibrium are

$$R = \sum F = \mathbf{0} \quad \text{and} \quad M = \sum M = \mathbf{0} \qquad \textbf{(1.1)}$$

The two vector equations of equilibrium can be expressed alternatively as scalar equations of equilibrium for a system of forces in 3 dimensions (*x* , *y* & *z*), as

$$\sum F_x = 0, \quad \sum F_y = 0, \quad \sum F_z = 0 \qquad \textbf{(1.2)}$$

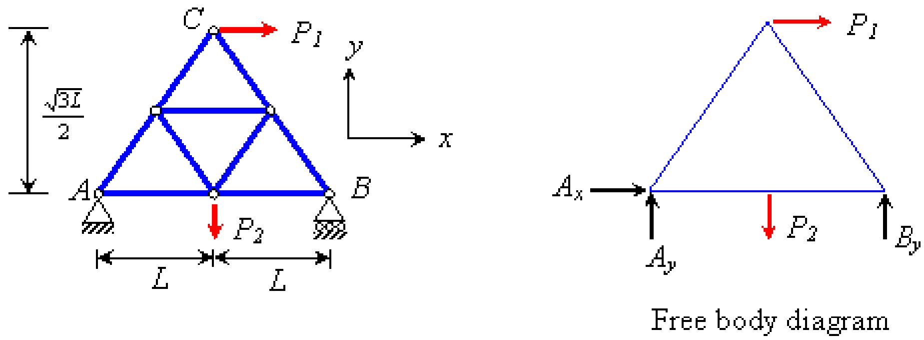
$$\sum M_x = 0, \quad \sum M_y = 0, \quad \sum M_z = 0 \qquad \textbf{(1.3)}$$

Here, $\sum F_x$ represents the algebraic summation of components of all the forces in x-direction. This summation is same as the resultant (net effect) of all the forces in x-direction.

This set of six equilibrium equations can be narrowed down to three scalar equations in case of a planer force system (forces acting in two dimensions only)

$$\sum F_x = 0, \quad \sum F_y = 0, \quad \sum M_z = 0 \qquad \textbf{(1.4)}$$

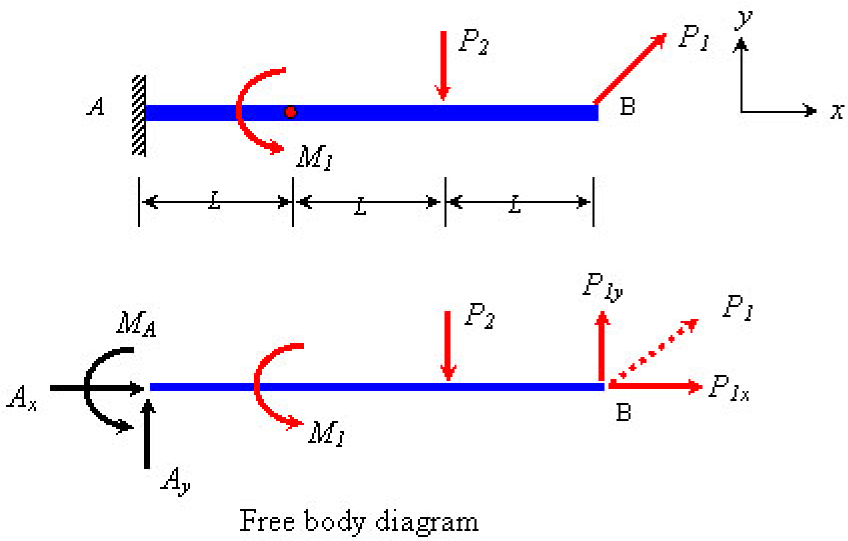
Figures 1.7 & 1.8 illustrate how resultants are obtained for a two-dimensional (planer) force system.



$$\sum F_x = A_x + P_1$$

$$\sum F_y = A_y + B_y - P_2 \qquad \sum M_z = B_y(3L) - P_1\left(\frac{\sqrt{3}L}{2}\right) - P_2(L)$$

Figure. 1.7 Obtaining resultants for a truss



$$\sum F_x = A_x + P_{1x}$$
$$\sum F_y = A_y + P_{1y} - P_2$$
$$\sum M_z = -A_y(3L) + M_A + P_2(L) + M_1$$

Figure 1.8 Obtaining resultants for a cantilever system

These equations provide the necessary and sufficient forces to keep a system in equilibrium. The omission of a force that is acting on a system or the inclusion of a force that is not acting on the system produces erroneous results in analyzing the behaviour of the system. Hence, it is of utmost importance to understand exactly what the mechanical system under consideration is and the forces that are acting on the specific system. A system is a body or a combination of connected bodies. The bodies can be either rigid or deformable (even fluids can be treated as body). For Structural Mechanics, we will restrict ourselves to the study of rigid and deformable solids only. For the important task of identifying the forces (and couples) acting on a system, we take the help of Free Body Diagrams. Thus, drawing a free body diagram becomes the first and foremost task in solution of problems in mechanics.

The free body diagram of a body (or its part, or a connected system of bodies) is obtained by isolating it from the all *other* surrounding bodies. The diagram detaches the system in consideration from all mechanical contacts with *other* bodies and sets it *free* . The *other* bodies are not shown in the diagram, but they are replaced by the forces (and couples) that they apply on the system for which we are drawing a free body diagram. The following examples show how to obtain the free body diagram for a system and also the equilibrium equations for the same system.

Recap

In this course you have learnt the following

- Review of the concepts of equilibrium.
- Static equilibrium equations in 3-D and 2-D.
- Concept of free body diagrams.