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# EQUATIONS OF EQUILIBRIUM

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Book 4



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Designer's Den

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# Definition

In statics, the equations of equilibrium are mathematical expressions that describe the conditions for an object to be in a state of equilibrium. These equations relate the forces and moments acting on an object to ensure that it remains at rest or in a state of constant motion with no acceleration. The equations of equilibrium are derived from Newton's laws of motion and are essential for analyzing the forces and moments in a static system.

## **Translational Equilibrium**

$\sum F_x = 0$ : The sum of all the horizontal (x-direction) forces acting on the object is zero.

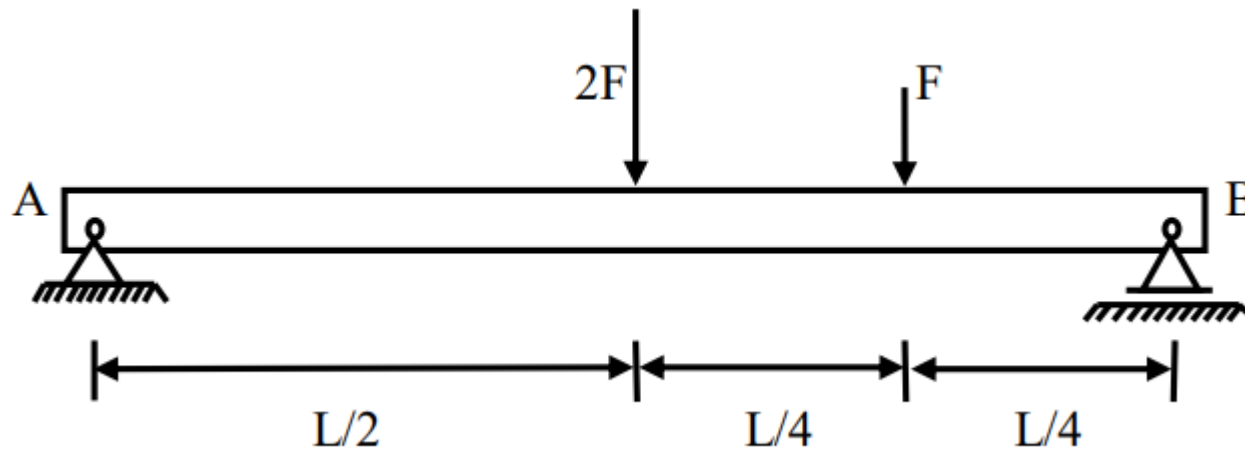
$\sum F_z = 0$ : The sum of all the vertical (z-direction) forces acting on the object is zero.

## **Rotational Equilibrium**

$\sum M = 0$ : The sum of all the moments about a reference point or axis is zero. The moments are calculated by multiplying the force magnitude by the perpendicular distance from the reference point or axis.

# Examples

**Example 1:** Calculate the reaction forces of the beam using the equations of equilibrium



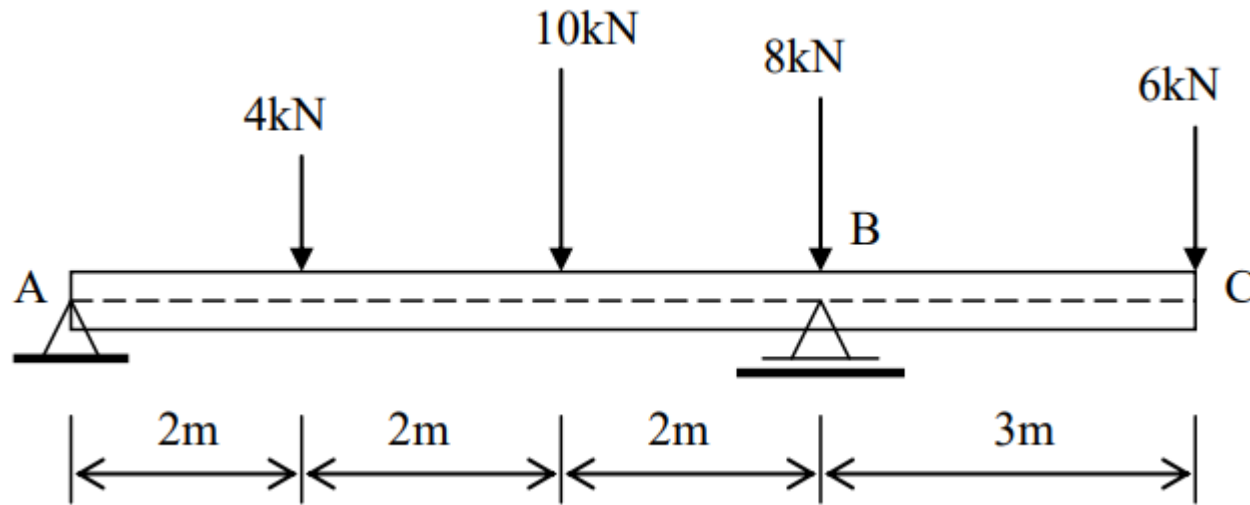
**Solution:**

$$\sum F_x = 0 \Rightarrow A_x = 0$$

$$\sum M_A = 0 = 2F \cdot \frac{L}{2} + F \cdot \frac{3L}{4} - B_y \cdot L \Rightarrow B_y = \frac{7F}{4}$$

$$\sum F_y = 0 = A_y + B_y - 2F - F \Rightarrow A_y = \frac{5F}{4}$$

**Example 2:** Calculate the reaction forces of the beam using the equations of equilibrium



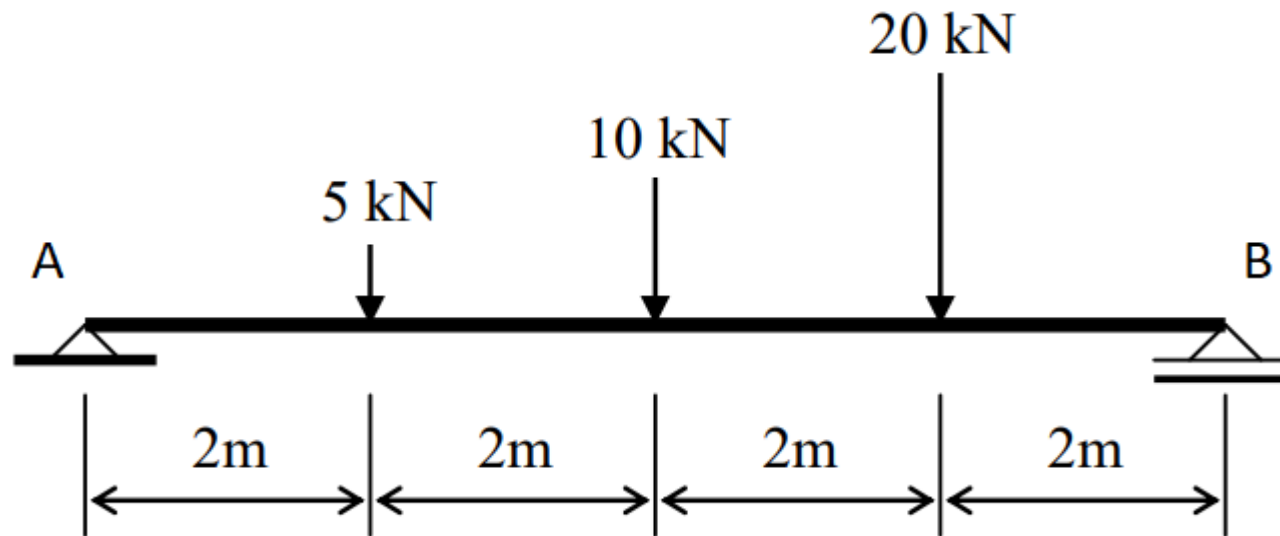
**Solution:**

$$\Sigma F_x = 0 : A_x = 0$$

$$\Sigma M_A = 0 : B_y \cdot 6 - 4 \cdot 2 - 10 \cdot 4 - 8 \cdot 6 - 6 \cdot 9 = 0 \Rightarrow B_y = (8 + 40 + 48 + 54)/6 = 25 \text{ kN}$$

$$\Sigma F_y = 0 : A_y + B_y - 4 - 10 - 8 - 6 = 0 \Rightarrow A_y = 4 + 10 + 8 + 6 - 25 = 3 \text{ kN}$$

**Example 3:** Calculate the reaction forces of the beam using the equations of equilibrium



**Solution:**

$$\Sigma M_A = 0 : B_y \cdot 8 - 5 \cdot 2 - 10 \cdot 4 - 20 \cdot 6 = 0 \Rightarrow B_y = 21,25 \text{ kN}$$

$$\Sigma F_y = 0 : A_y = 5 + 10 + 20 - 21,25 = 13,75 \text{ kN}$$

$$\Sigma F_x = 0 : A_x = 0$$