INTERNAL FORCES

Book 5

Designer's Den

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Definition

Internal forces refer to the forces that act within a structure or object, rather than on its external surfaces. These forces develop as a result of the external loads applied to the structure or object and are distributed throughout its interior. Understanding internal forces is crucial for analyzing the structural behavior and integrity of various engineering systems. These forces are denoted N, V and M and are usually represented in diagrams to help visualize the distribution and magnitude of internal forces within a structural member. Engineers use these diagrams to analyze and design structural elements.

N – Diagram

N (Axial Force): "N" represents the axial force, also known as the normal force or axial load, acting along the longitudinal axis of a structural member. It is a force that causes the member to either be in compression (contracting) or tension (stretching). The positive sign convention is typically used, where "N" is positive for tension and negative for compression. The axial force is represented by a straight arrow pointing along the axis of the member.

V – Diagram

V (Shear Force): "V" represents the shear force acting parallel to the cross-section of a structural member. It induces a sliding or shearing effect within the material. Shear forces arise due to unequal distribution of external loads across the cross-section of the member. The shear force is represented by an arrow perpendicular to the longitudinal axis of the member, indicating the direction and magnitude of the force.

M – Diagram

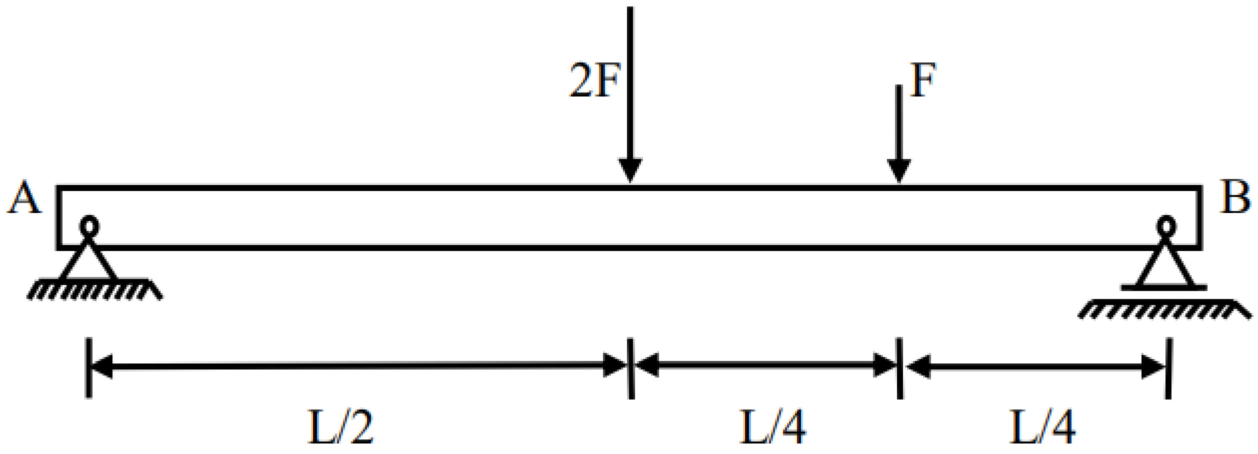
M (Bending Moment): "M" represents the bending moment, which is a measure of the internal bending action within a structural member. Bending moments occur due to the application of external forces that cause the member to bend. The bending moment is represented by curved arrows, with the direction of the arrows indicating the rotational effect on the member. The magnitude of the bending moment is typically represented by the length of the arrows.

Calculation procedure

1. Identify the Member and Supports: Determine the structural member for which you want to create the internal force diagrams. Identify the type of member (e.g., beam, column) and the supports or connections at its ends.
2. Draw the Member: Sketch a clear and accurate representation of the member, including its length and any applied loads or moments. Label the relevant dimensions.
3. Calculate External Forces: Determine all the external loads acting on the member, such as point loads, distributed loads, and moments. Analyze the structure to find the magnitudes and positions of these loads.
4. Determine Reactions: Calculate the reactions at the supports or connections based on the applied loads and the equilibrium conditions of the member.
5. Intersect the Member: Start from one end of the member and move along its length, section by section. At each section, calculate the axial force (N), shear force (V) and bending moment (M) by considering the applied loads and reactions.
6. Plot: Create a plot of each diagram with reaction symbols to mark the direction of the internal forces. The moment diagram is drawn on the tension side of the section.

Examples

Example: Calculate the internal forces for this system and draw their diagrams

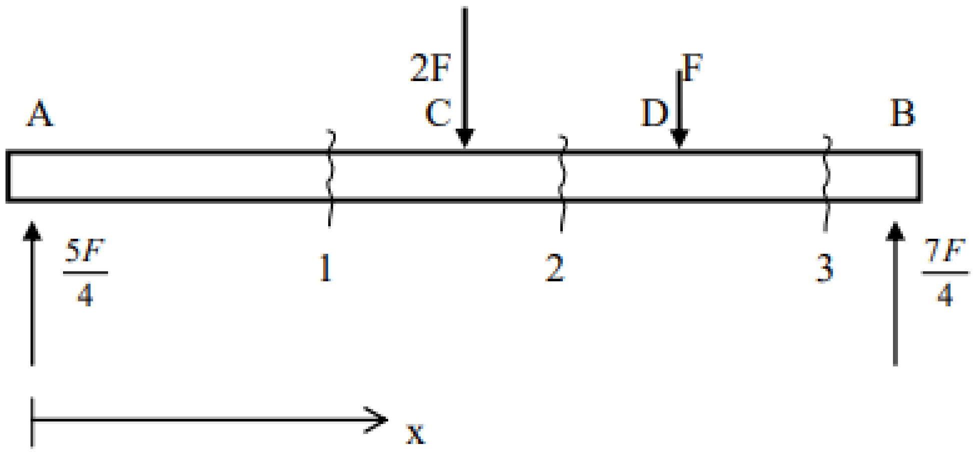


Solution:

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

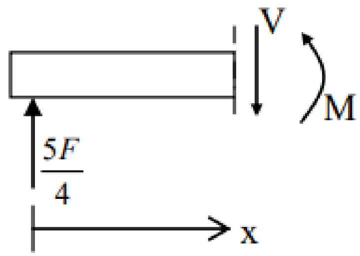
$$\sum M_A = 0 = 2F \cdot \frac{L}{2} + F \cdot \frac{3L}{4} - B_y \cdot L \Rightarrow B_y = \frac{7F}{4}$$

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



Section 1:

$$0 \le x \le \frac{L}{2}$$

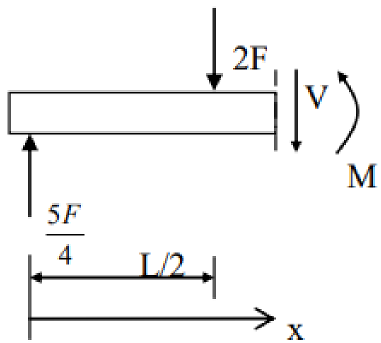


$$\sum F_y = 0 = \frac{5F}{4} - V \Rightarrow \underline{V = \frac{5F}{4}}$$

$$\sum M = 0 = -M + \frac{5F}{4} \cdot x \Rightarrow M = \frac{5F}{4} \cdot x$$

Section 2:

$$\frac{L}{2} \le x \le \frac{3L}{4}$$

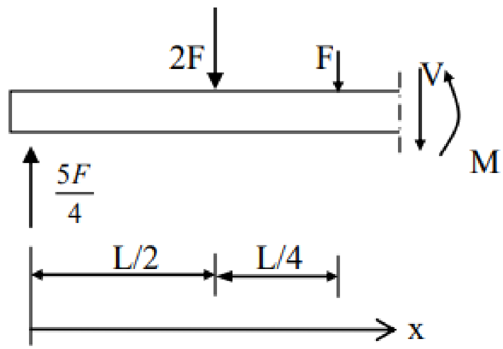


$$\sum F_y = 0 = \frac{5F}{4} - 2F - V \Rightarrow \underline{V = -\frac{3F}{4}}$$

$$\sum M = 0 = -M - 2F \cdot (x - \frac{L}{2}) + \frac{5F}{4} \cdot x \Rightarrow M = FL - \frac{3F}{4} \cdot x$$

Section 3:

$$\frac{3L}{4} \le x \le L$$



$$\sum F_y = 0 = V - \frac{5F}{4} + 2F + F \Rightarrow \underline{V = -\frac{7F}{4}}$$

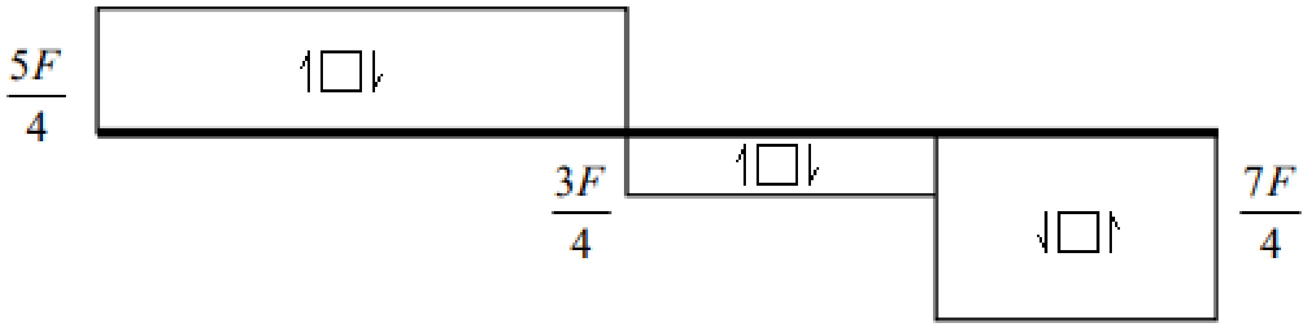
$$\sum M = 0 = -M + \frac{5F}{4} \cdot x - 2F \cdot (x - \frac{L}{2}) - F \cdot (x - \frac{3L}{4})$$

$$\Rightarrow M = \frac{7FL}{4} - \frac{7F}{4} \cdot x$$

N – Diagram:

There are no axial forces in this system

V – Diagram:



M – Diagram: