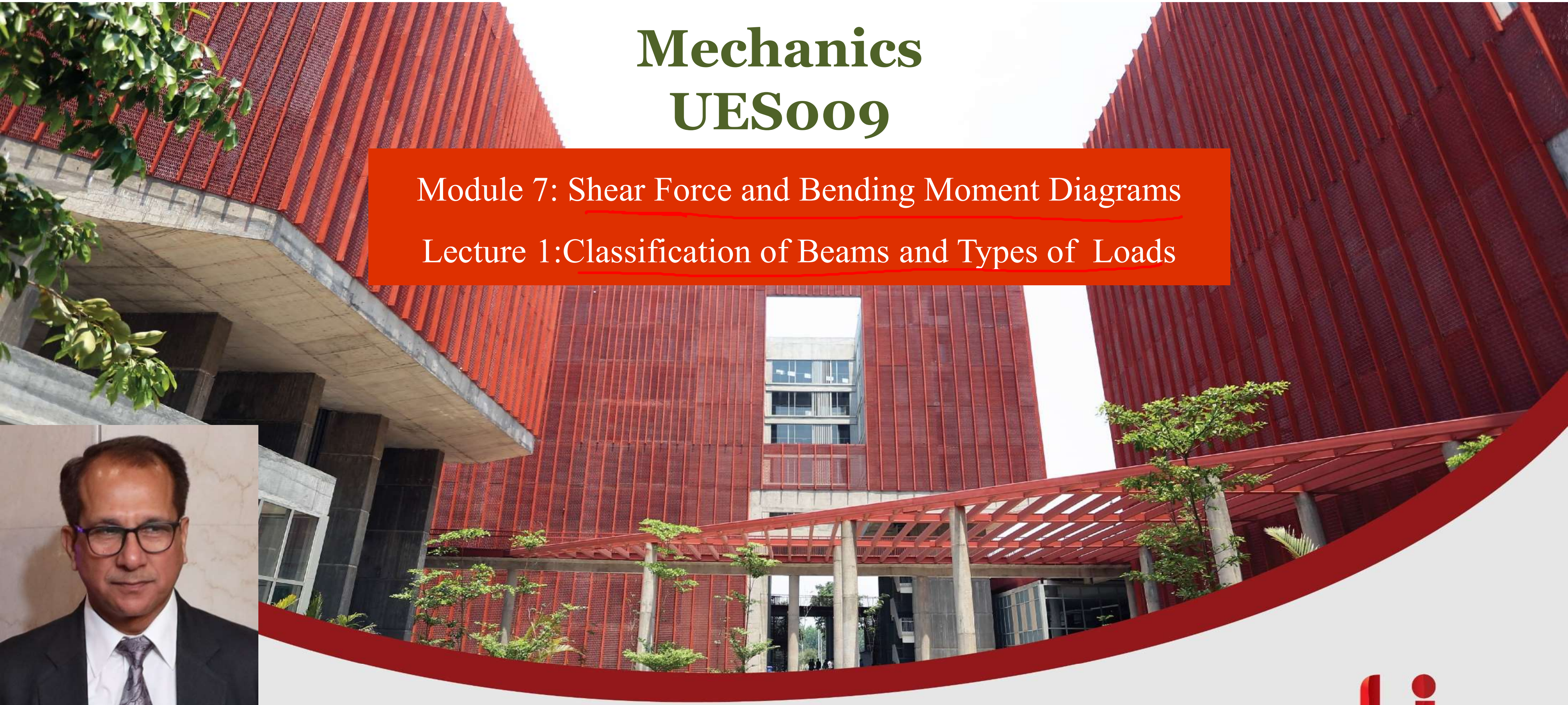

Mechanics
UES009

Module 7: Shear Force and Bending Moment Diagrams

Lecture 1:Classification of Beams and Types of Loads

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Shear Force and Bending Moment Diagrams

BEAM:

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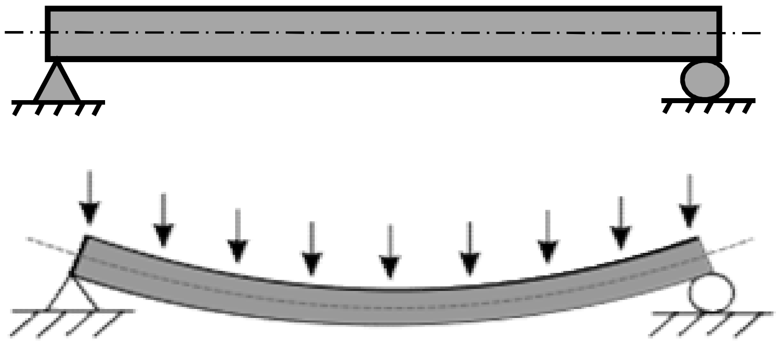
A structural member designed to resist forces acting transverse to its axis is called a beam.

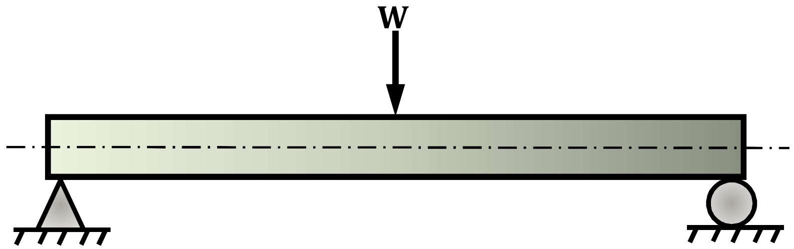
The analysis of beams involves the determination of shear force, bending moment and the deflection of beam at various sections.

Bending: The deformation of a member produced by loads acting perpendicular to its axis as well as force couple acting in a plane passes through the axis of the bar.

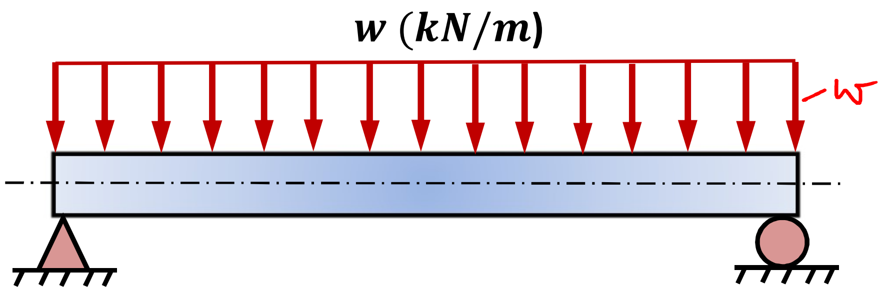


Different Types of Loads

Point load: A point load or concentrated load is one which is considered to be act at a point.



Distributed load: A distributed load is one which is distributed or spread in some manner over the length of the beam. If the spread is uniform (i.e. at the uniform rate w kN/m), it is said to be uniformly distributed load (UDL).



Uniformly Distributed load (UDL)

Different Types of Loads

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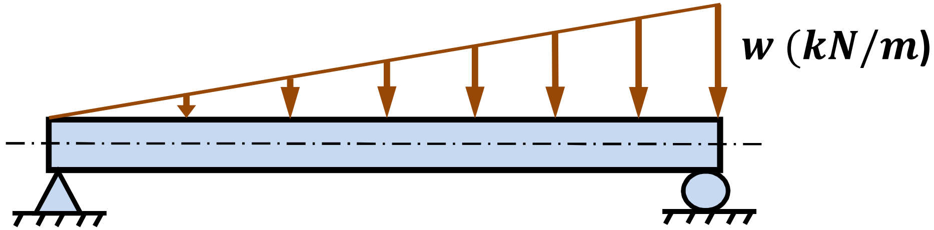
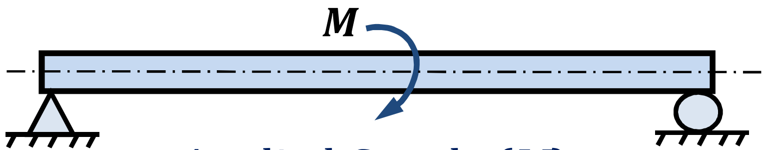
Distributed load: A distributed load is one which is distributed or spread in some manner over the length of the beam. If the spread is varying at uniform rate it is said to be uniformly varying load (UVL).



Uniformly Varying Load(UVL)

Applied Couple: Some times beams are also subjected to couples (clockwise or counter-clockwise)



Applied Couple (M)

Distributed Loads on Beams

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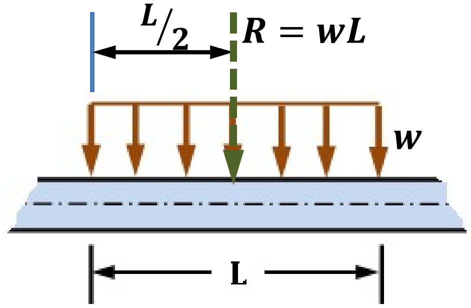
How to find the Net Force (R) acting on the beam

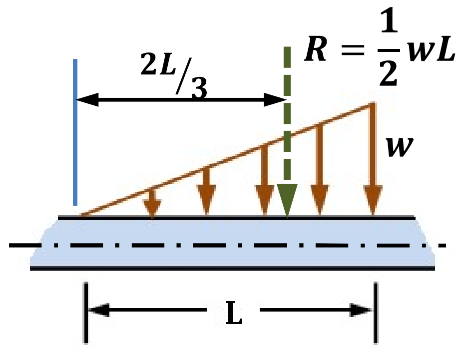
- R = Area under the loading diagram
- R acts through the centroid of the area



Uniformly distributed load (UDL)

Area under the loading diagram, $R = wL$

R, acts at $L/2$, i.e. the centroid of the area



Uniformly varying load (UVL)

Area under the loading diagram,

$R = \frac{1}{2}wL$ and R acts at $2L/3$, i.e. the centroid of the area

Distributed Loads on Beams

Combination of Uniformly distributed and varying loads

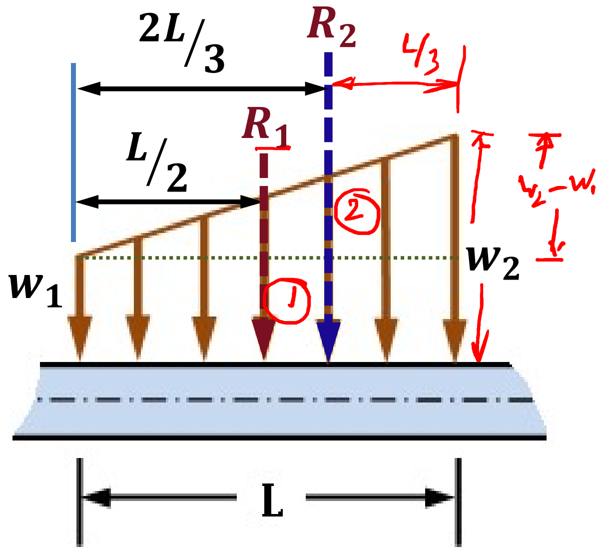
The load divided into two loads, i.e.

R_1 = rectangular load and

R_2 = triangular load

$R_1 = w_1 L$ and R_1 acts at $L/2$,
i.e. the centroid of the rectangular area

$R_2 = \frac{1}{2}(w_2 - w_1)L$ and R_2 acts at $2L/3$,
i.e. the centroid of the triangular area



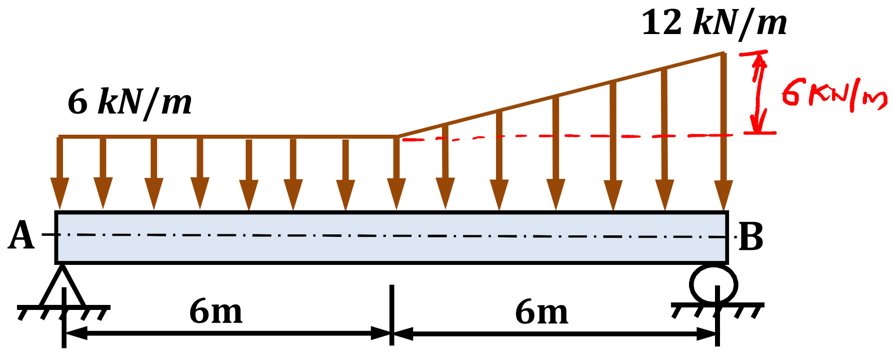
Example:

The load is divided into two loads, i.e.

R_1 = rectangular load, and R_2 = triangular load

$R_1 = w_1 L = 6 \times 12 = 72\ kN$ and

$$R_2 = \frac{1}{2}(w_2 - w_1)L = \frac{1}{2}\,(12 - 6) \times 6 = 18\ kN$$



Determine the reactions R_A and R_A

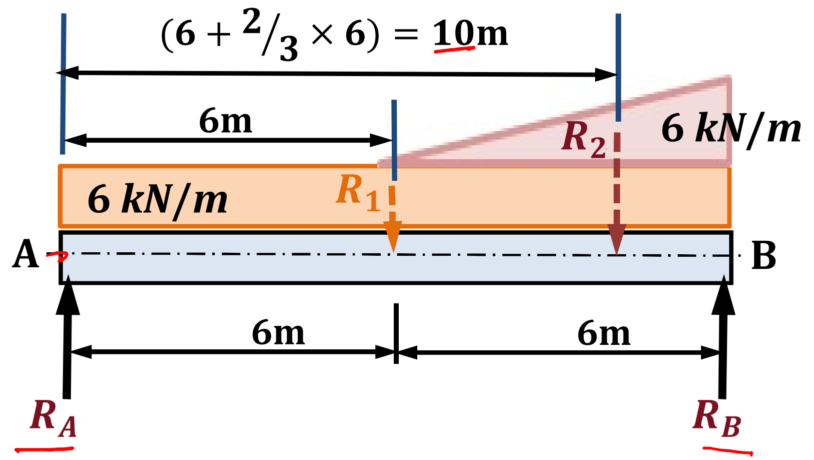
$$R_A + R_B = (6 \times 12) + (\tfrac{1}{2} \times 6 \times 6) = 90\ kN$$

$$\Sigma M_A = 0$$

$$(6 \times 12 \times 6) + \left[\left(\tfrac{1}{2} \times 6 \times 6\right) \times \left(6 + \tfrac{2}{3} \times 6\right)\right] - 12R_B$$

$$= 612\ kNm$$

$R_B = 51\ kN,\qquad R_A = 39\ kN$



Types of Supports and Support Reactions

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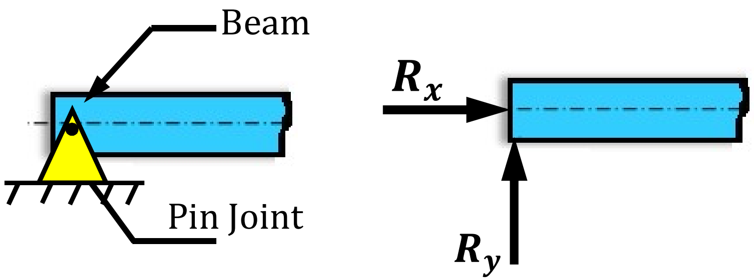
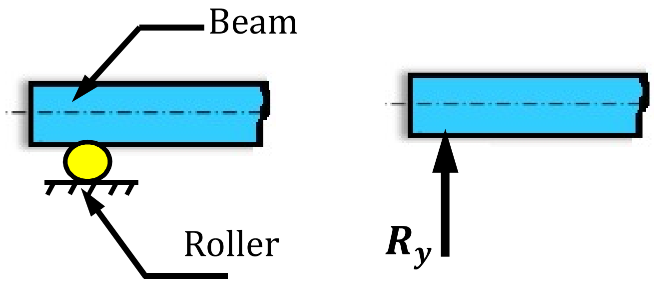
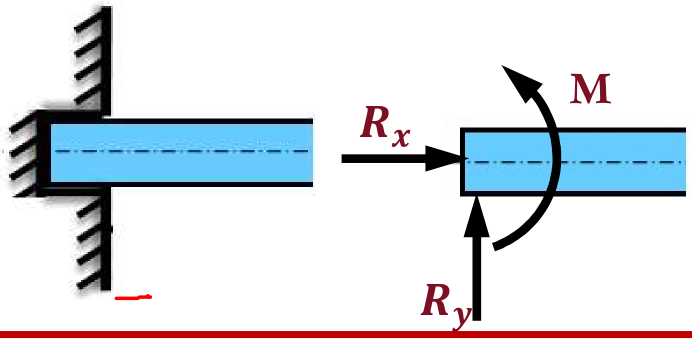


Actual Representation Diagrammatic Representation

The pin support restrains the beam from translating both horizontally and vertically, but it does not prevent rotation.



At the roller support, translation is prevented in the vertical direction but not in the horizontal direction.



At the fixed support, both translations as well as rotation are prevented.

Types of Beams on the Basis of Support Conditions

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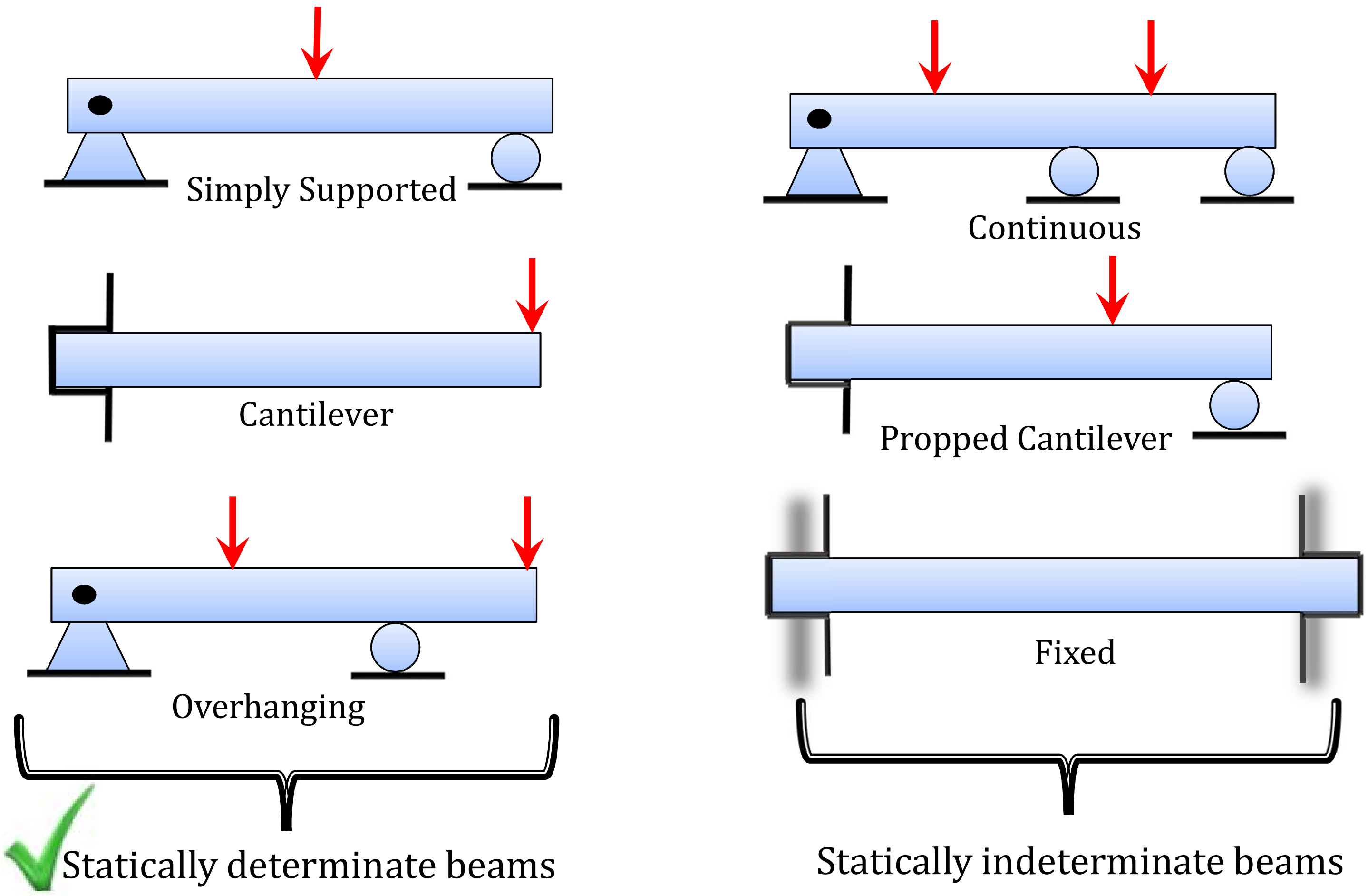


Classification of Beams

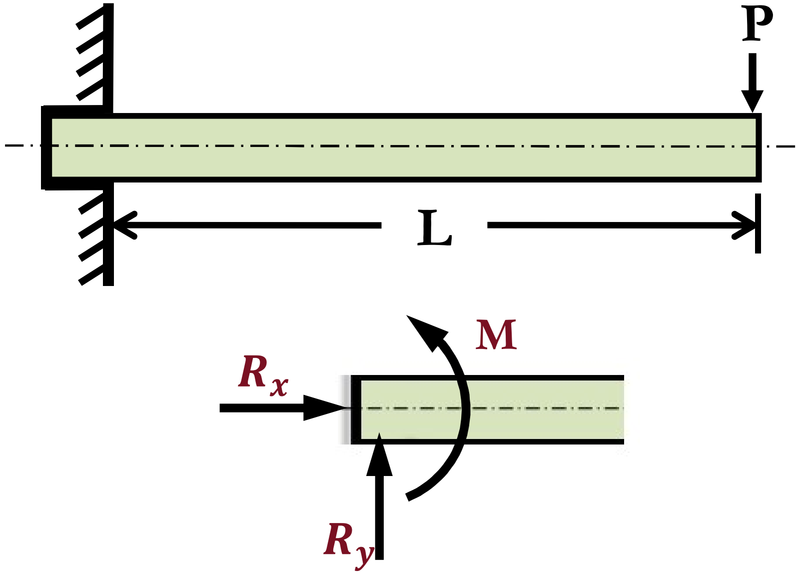
Cantilever: A cantilever beam is one whose one end is rigidly fixed and other end is free.

Disadvantage:

When the beam is loaded at one end, the moment at the fixed end is higher, if more load is applied, it can break from the support.

Applications:

- Traffic light cantilevers have a remarkable span;



Classification of Beam: Over Hang Beam

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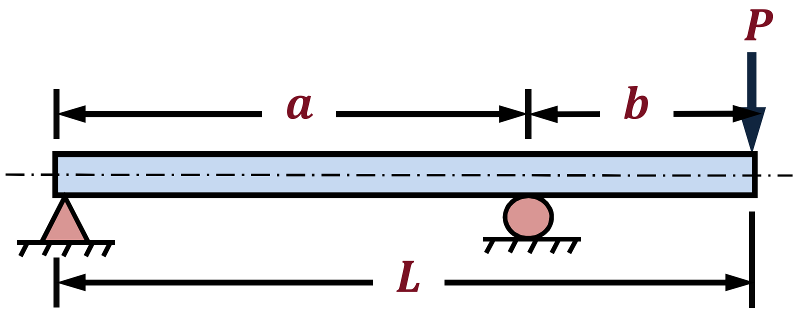
Single Over Hanging Beam:

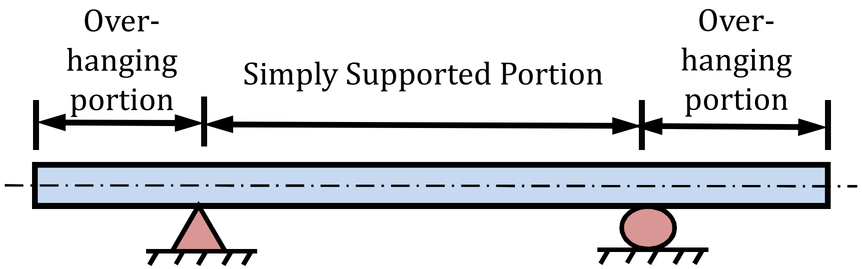
- Beam freely supported at two points and having one ends extending beyond the supports.
- It has two supports, hinged at one end, roller at other end. Overhanging portion at any one of the supports.
- Loads can be applied on overhanging portion and can be converted to equivalent moment at the support.
- Moment and Reactions are same as that of Simply Supported Beam.



Single Overhanging Beam

Classification of Beam: Over Hang Beam

Double Over Hanging Beam: Beam freely supported at two points and having both ends extending beyond these supports.

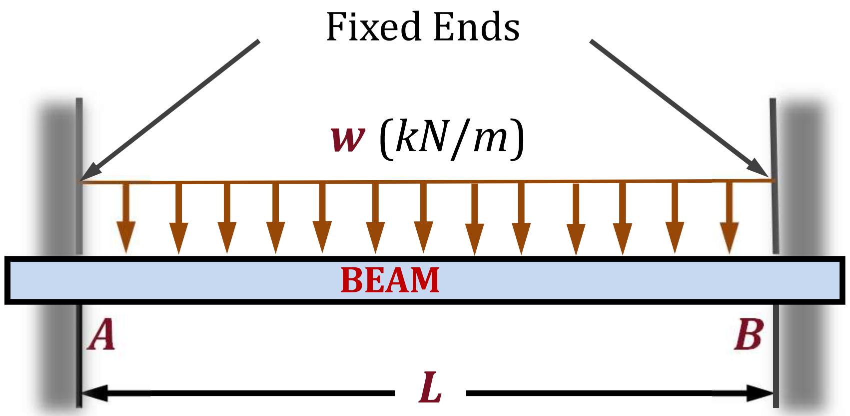


Double Overhanging Beam

Classification of Beam:

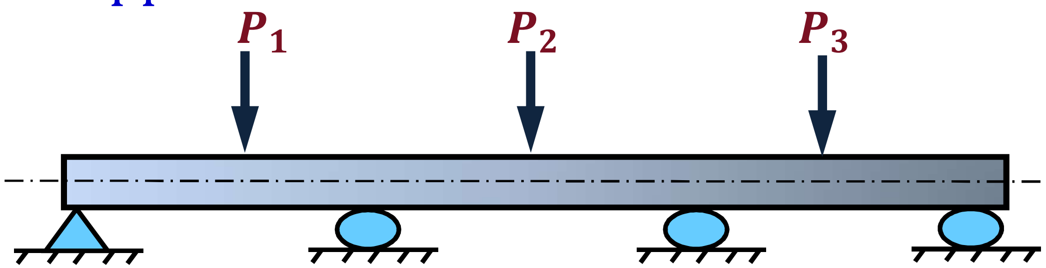
Fixed Beam:

A fixed or a build in beam has both of its ends rigidly fixed so that the slope at the ends remains zero. Such a beam is also called as the Encastre beam.



Classification of Beam:

Continuous Beam: A continuous beam is one which has more than two supports. The support at the extreme left and right are called the end supports, except the extreme, are called intermediate supports.



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Shear Force and Bending Moment Diagrams

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Shear Force and Bending Moment Diagrams

Shear Force and Bending Moment:

Shear Force: It is the algebraic sum of the vertical forces acting to the left or right of cut section along the span of the beam.

Bending Moment: It is the algebraic sum of the moment of the forces to the left or to the right of the section taken about the section.

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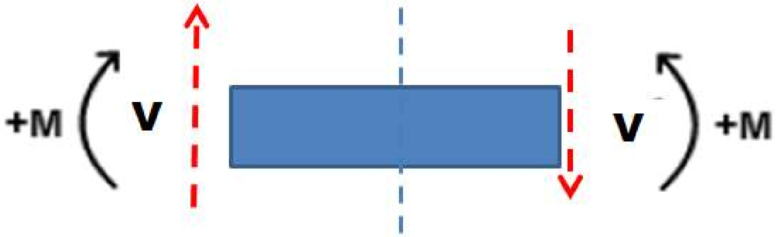
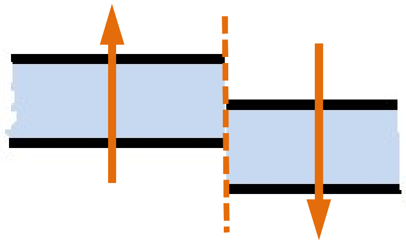
Sign Convention

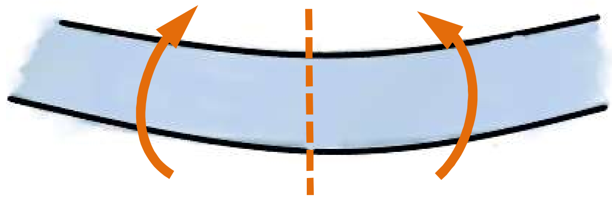


Sagging moment is positive
(beam retains water)

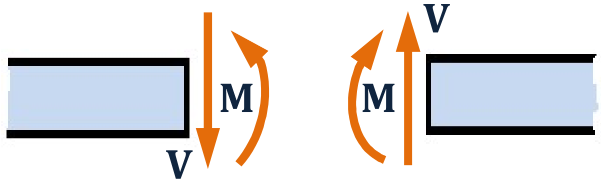
Hogging moment is negative



Effect of external forces
(positive shear)



Effect of external forces
(positive bending moment)



Internal forces at section
(positive shear and positive bending moment)

Analysis Procedure

The method of sections can be used to determine the internal loads on the cross section of a member by the procedure as below:

Support Reactions

- Determine the support reactions,

Free-Body Diagram

- Pass an imaginary section through the member perpendicular to its axis at the point where the internal loadings are to be determined.
- After the section is made, draw a free-body diagram of the segment that has the least number of loads on it, and indicate the components of the internal force and couple moment resultants at the cross section according to positive sign convention.

Analysis Procedure....

Equations of Equilibrium

Forces and moments should be summed at the section. This way the equations for shear forces and the moments can be obtained.

Shear force and Bending moment

Substitute values of $\boldsymbol{x}$ in the equations to obtain the magnitude of shear force and bending moment at various points where there is a change in the loading on the beam.

CANTILEVER BEAM

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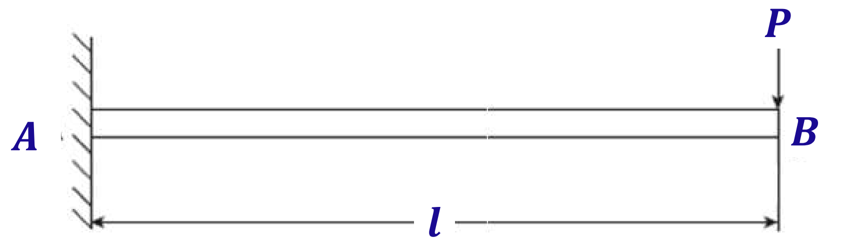
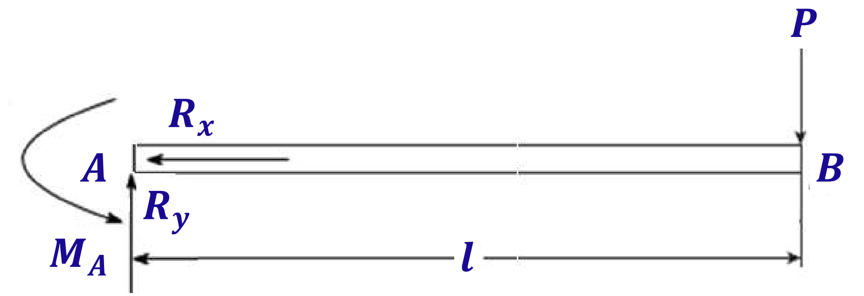
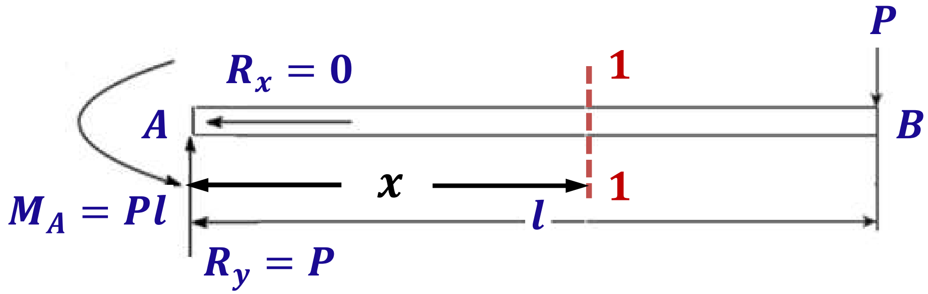
Shear Force and Bending Moment diagrams

Ex. Draw shear force and bending moment diagrams for a cantilever beam with a point load ***P*** acting at the free end.







Solution:

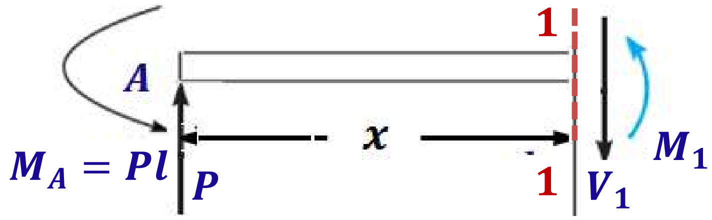
1.Draw FBD of the beam, and find reactions.

2. $R_y = P$; $R_x = 0$; $M_A = P.l$;

3.Take a section 1-1 at a distance x somewhere between **A** and **B** and draw FBD of LHS or RHS of the section.

4. $\Sigma F_y = 0$, $\boldsymbol{V_1 = P}$ ......(1)

[Eq. for S.F. for entire length of cantilever beam where ($0 \leq x \leq \boldsymbol{l}$)]



5. $\Sigma M_{1-1} = 0$, $P.x - M_A - M_1 = 0$; $\boldsymbol{M_1 = P.x - P.l}$.........(2)

[Eq. for B.M. for entire length of cantilever beam where ($0 \leq x \leq \boldsymbol{l}$)]

To find S.F. and B.M.

After obtaining equations for S.F. and B.M. , put values of $\boldsymbol{x}$ in these equations to obtain the magnitude of shear force and bending moment at all the salient points , i.e. at **A, $\boldsymbol{x}$ = 0**, at **B**, $\boldsymbol{x = l}$

From eq. (1), S.F. at A, and B, $\boldsymbol{V_A = V_B = P}$, **since $\boldsymbol{V_1}$ is independent of $\boldsymbol{x}$, it will be constant throughout.**

To plot S.F. and B.M. diagrams

$V_A = V_B = P,$

since V_1 is independent of x, it will be constant throughout.

$M_1 = P.x - P.l$ ....(2)

From eq. (2), B.M. at A,

$M_A(x=0) = P.0 - P.l = -Pl$

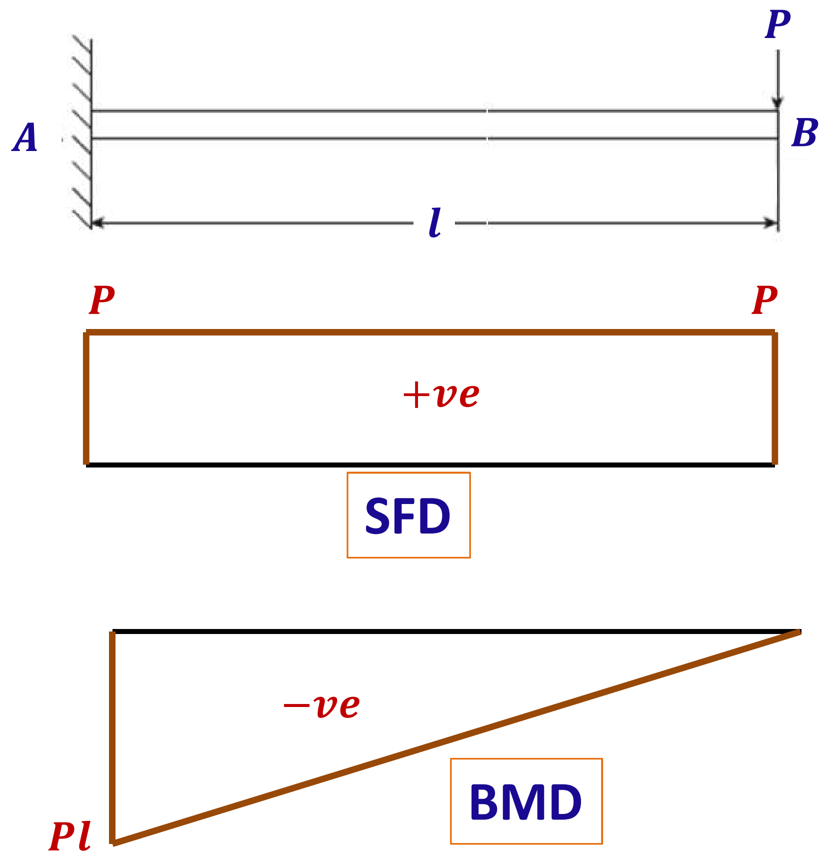
and B.M. at B,

$M_B(x=l) = P.l - P.l = 0,$

$M_A = -Pl$

$M_B = 0,$

variation of B. M. will be linear.



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SIMPLY SUPPORTED BEAM

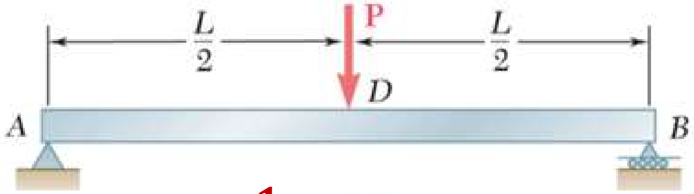
Ex. Draw shear force and bending moment diagrams for a simply supported beam with a point load **P** acting at the mid span.

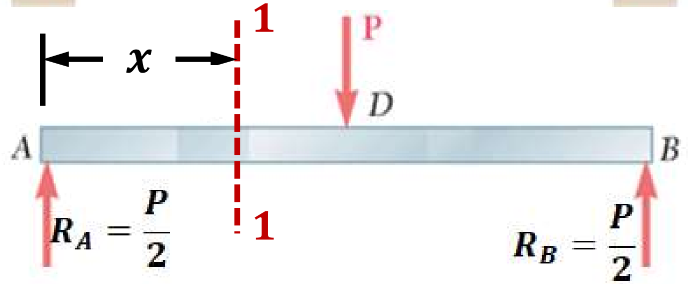
Solution:

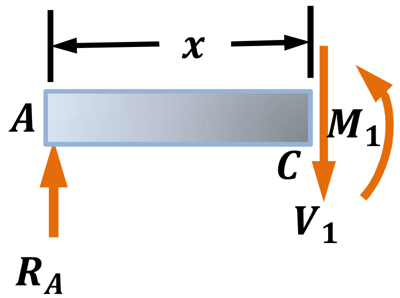
1.Draw FBD of the beam, and find reactions.

2. $R_A = R_B = \frac{P}{2}$;

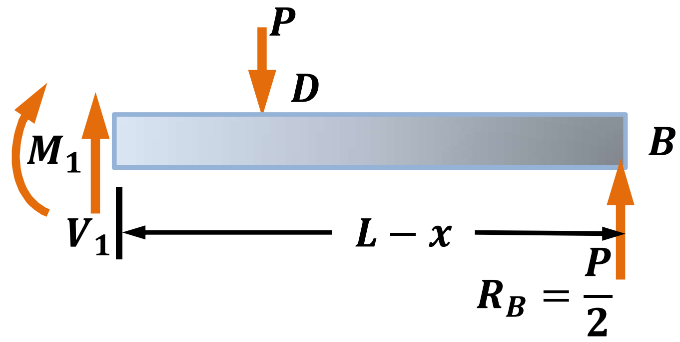
3.Take a section at a distance x somewhere between **A** and **D** and draw FBD of LHS or RHS of the section.



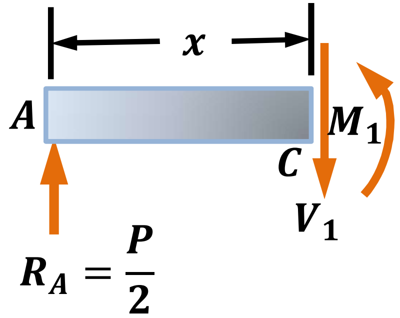




FBD of LHS of the section



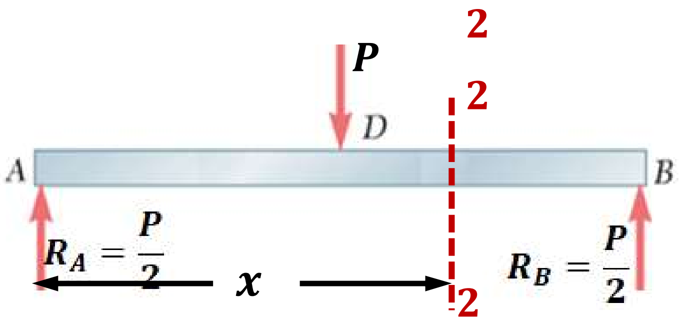
FBD of RHS of the section

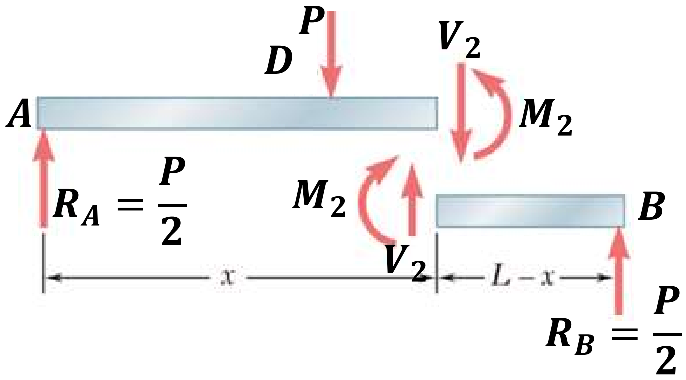


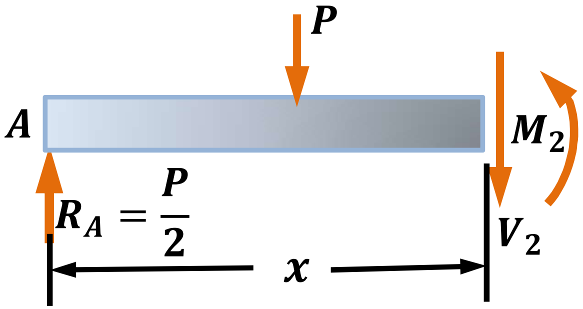
4. $\Sigma F_y = 0,$ $\boldsymbol{V_1 = \frac{P}{2}}$ ......(1) [Eq. for S.F. for the *Ist* segment of beam where ($0 \leq x \leq \frac{L}{2}$)]

5. $\Sigma M_C = 0,$ $\frac{P}{2}x - M = 0;$ $\boldsymbol{M_1 = \frac{P}{2}x}$ ....(2) [Eq. for B.M. for *Ist* segment of beam where ($0 \leq x \leq \frac{L}{2}$)]

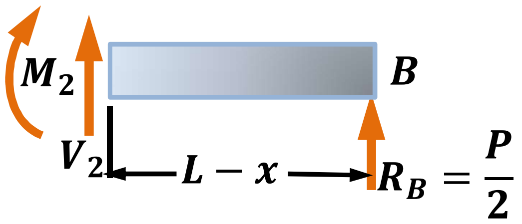
6. Similarly take another section between ***D*** and ***B*** (*IInd* segment) and draw FBD of LHS or RHS of the section.



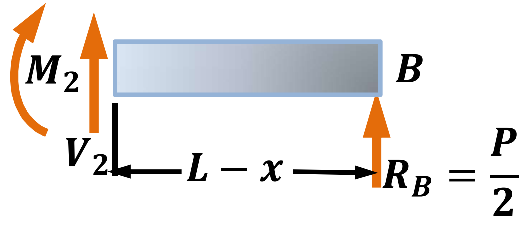




FBD of LHS of the section



FBD of RHS of the section



FBD of RHS of the section

7. $\Sigma F_y = 0,\quad V_2 + \frac{P}{2} = 0;\quad \boldsymbol{V_2 = -\frac{P}{2}}$ ......(3)

[Eq. for S.F. for the *IInd* segment of the beam, where $\left(\frac{L}{2} \leq x \leq L\right)$]

8. $\Sigma M_2 = 0,\quad M_2 - \frac{P}{2}(L - x) = 0;\quad \boldsymbol{M_2 = \frac{P}{2}(L - x)}$ ......(4)

[Eq. for B.M. for *IInd* segment of the beam, where $\left(\frac{L}{2} \leq x \leq L\right)$]

$V_1 = \frac{P}{2}$ ......(1), $M_1 = \frac{P}{2}x$ ......(2) $(0 \leq x \leq \frac{L}{2})$

$V_2 = -\frac{P}{2}$ ......(3), $M_2 = \frac{P}{2}(L - x)$ ......(4) $(\frac{L}{2} \leq x \leq L)$

To find S.F. and B.M.

After obtaining equations for S.F. and B.M. , put values of x in these equations to obtain the magnitude of shear force and bending moment at all the salient points , i.e. at **A**, $x = 0$, at **D**, $x = \frac{L}{2}$ and at **B**, $x = L$

From eq. (1), S.F. at A and at D, $V_A = V_D = \frac{P}{2}$, and from eq. (3), S.F. at D and at B,

$$V_D = V_B = -\frac{P}{2},$$

Similarly, From eq. (2), B.M. at A, $M_A = 0$, at D, $M_D = \frac{PL}{4}$

and from eq. (4), B.M. at D, $M_D = \frac{PL}{4}$, and at B, $M_B = 0$.

$V_1 = \frac{P}{2}$ ....(1) $V_2 = -\frac{P}{2}$........(3)

$V_A = V_D = \frac{P}{2}$

$V_D = V_B = -\frac{P}{2}$,

$M_1 = \frac{P}{2}x$......(2), $M_2 = \frac{P}{2}(L - x)$ ... (4)

$M_A = 0$,

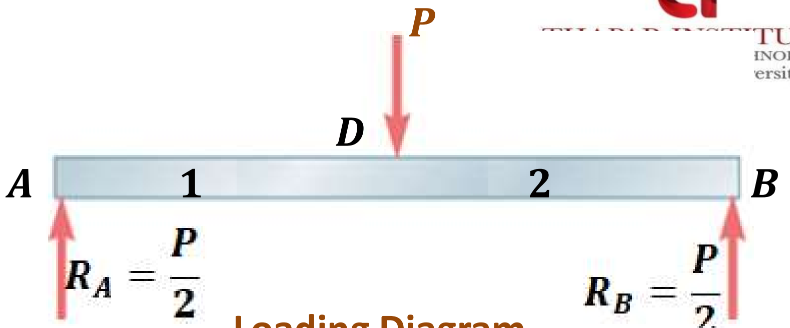
at D, $M_D = \frac{P}{2} \times \frac{L}{2} = \frac{PL}{4}$

B.M. at D, $M_D = \frac{P}{2}(L - \frac{L}{2}) = \frac{PL}{4}$,

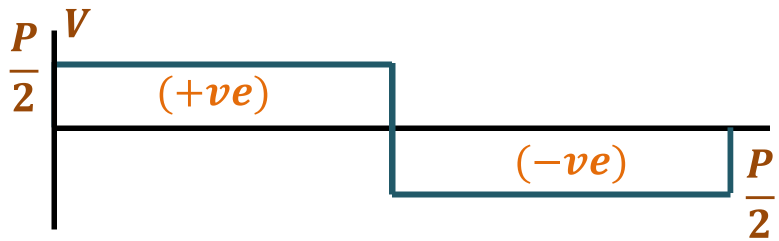
B.M. at B, $M_B = \frac{P}{2}(L - L)$;.

$M_B = 0$

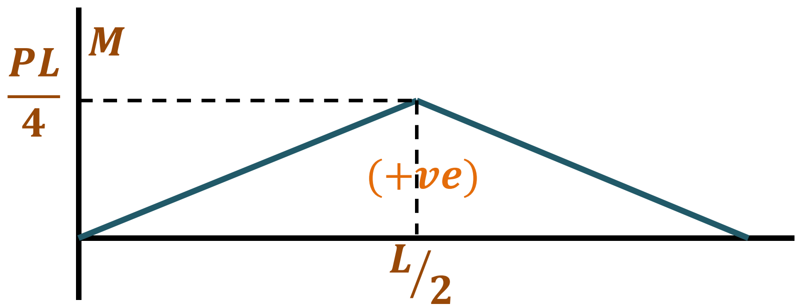
The shear force is of constant between concentrated loads, and the bending moment varies linearly;



Loading Diagram



Shear Force Diagram (SFD)



Bending Moment Diagram (BMD)