Kurdistan Region
Salahaddin University-Erbil
College of Engineering
Mechanic & Mechatronics Engineering Department

Fundamentals of design

For Second Stage Students
In Mechanic & Mechatronics Dept.

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Shear Force and Bending Moment

The algebraic sum of the vertical forces at any section of a beam to the right or left of the section is known as shear force. It is briefly written as S.F. the algebraic sum of the moment of all the forces acting to the right or left of the section is known as bending moment. It is written as B.M.

Shear Force and Bending Moment Diagram

A shear force diagram is one which shows the variation of the shear force along the length of the beam. And a bending moment diagram is one which shows the variation of the bending moment along the length of the beam.

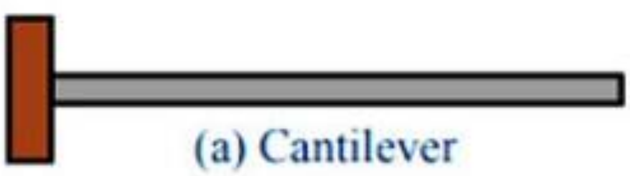
Before drawing the force and bending moment diagrams, we must know the different types of beams and different types of load acting on the beam.

Types of Beams

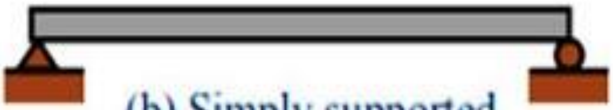
The following are the important types of beams:

1- Cantilever beam.
2- Simply supported beam.
3- Overhanging beam.
4- Continuous beam.
5- Fixed beams.

1- Cantilever Beam. A beam which is fixed at one end and free at the other end, is known as cantilever beam. Such beam is shown in figure (a).



2- **Simply Supported Beam.** A beam supported or resting freely on the supports at its both ends, is known as simply supported beam. Such beam is shown in figure (b).

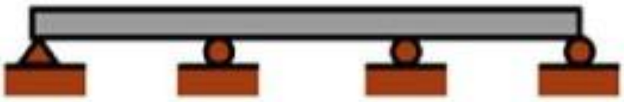


(b) Simply supported

3- **Overhanging Beam.** If the end portion of a beam is extended beyond the support, such beam is known as overhanging beam. Overhanging beam is shown in figure (c).

(c) Overhanging

4- **Continuous beam.** A beam which is provided more than two supports as shown in figure (d), is known as continuous beam.



(d) continuous

5- **Fixed Beam.** A beam whose both ends are fixed or built-in walls, is known as fixed beam. Such beam is shown in figure.

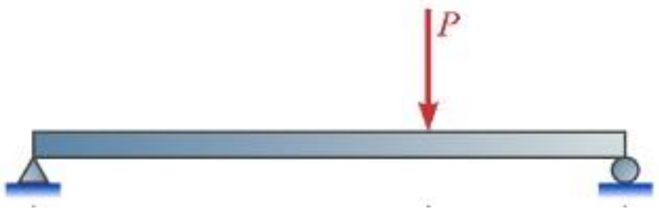
(e) Fixed ended

Types of Load

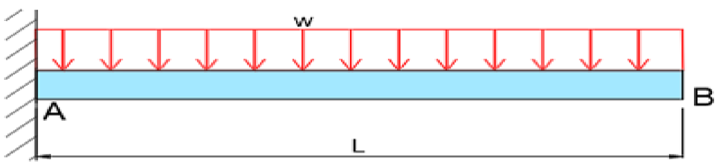
A beam is normally horizontal and the loads acting on the beams are generally vertical. The following are the important types of load acting on a beam.

1- Concentrated or Point Load.
2- Uniformly Distributed Load, and
3- Uniformly Varying Load.

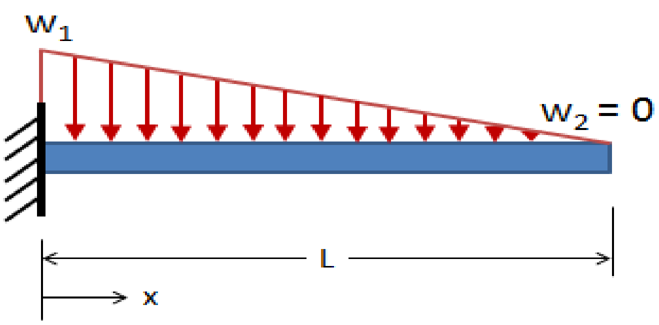
1- Concentrated or Point Load. A concentrated load is one which is considered to act at a point, although in practice it must really be distributed over a small area. As shown in figure



2- Uniformly Distributed Load. A uniformly distributed load is one which is spread over a beam in such a manner that rate of loading is uniform along the length (each unit length is loaded to the same rate) as shown in figure.

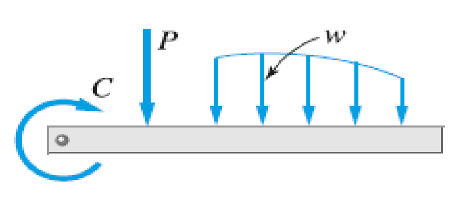
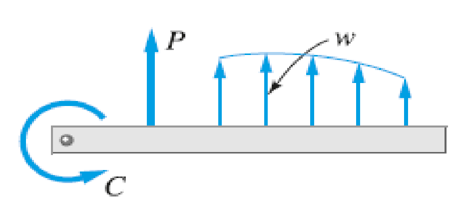
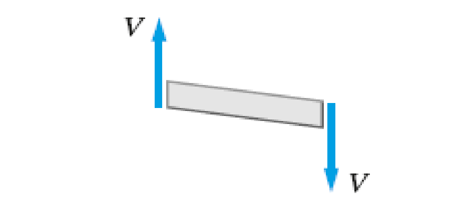
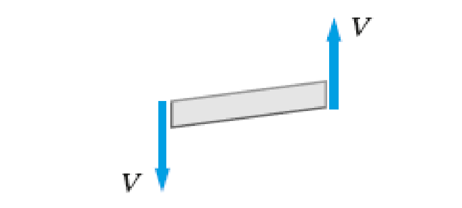
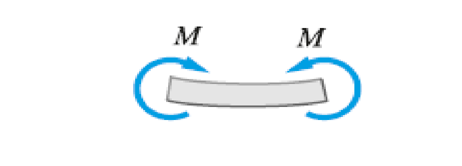
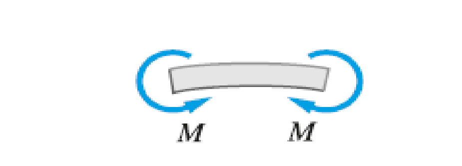


3- Uniformly Varying Load. A uniformly varying load is one which is spread over a beam in such a manner that rate of loading varies from point to point along the length as shown in figure, in which the load is zero at one end and increases uniformly to the other end such load is known as triangular load.



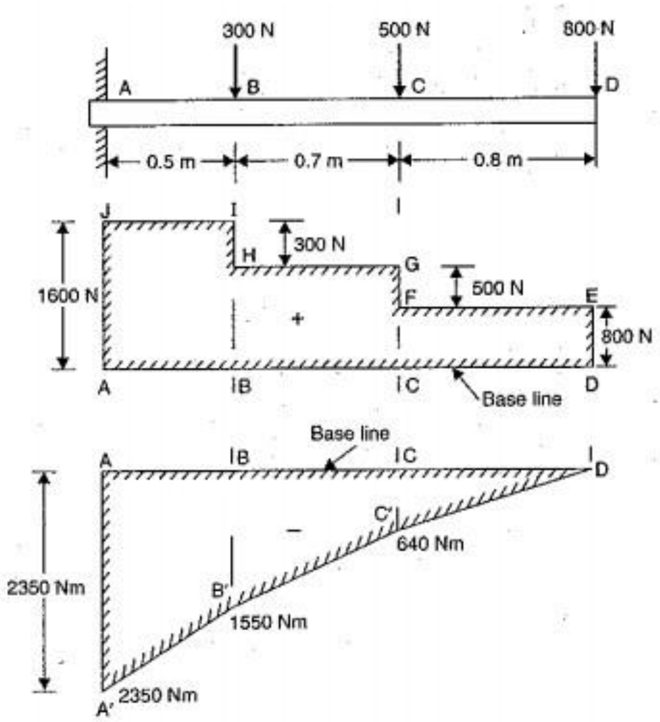
For solving numerical problems, the total load is equal to the area of the triangle and this total load is assumed to be acting at the center of gravity of the triangle at a distance of 2/3 of total length of beam.

Sign Conventions for Shear Force and Bending Moment

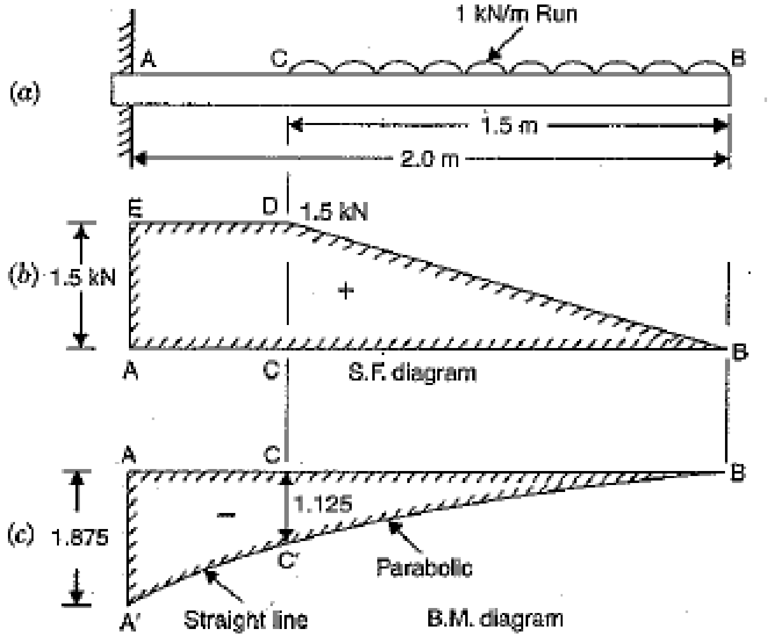
	Positive	Negative
External loads		
Shear force		
Bending moment		

Problem 1. A cantilever beam of length 2 m carries the point loads as shown in figure. Draw the shear force and bending moment diagrams for the cantilever beam.

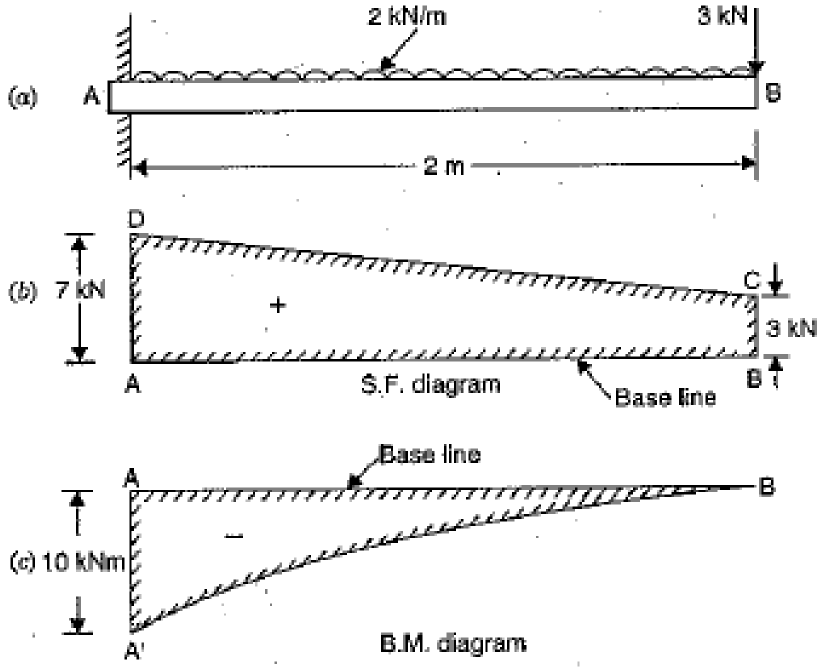
Solution:



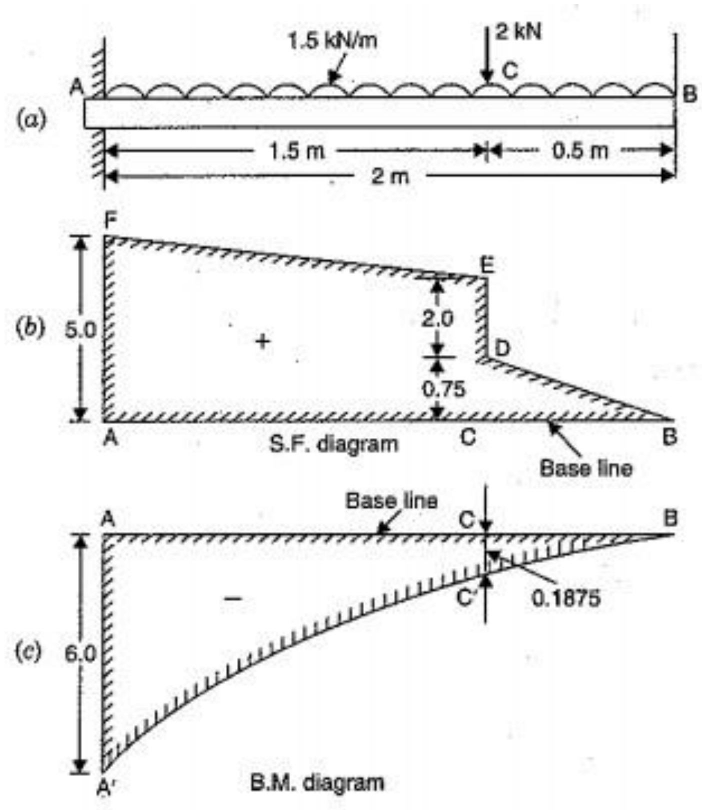
Problem 2. A cantilever of length 2 m carries a uniformly distributed load of 1 kN/m run over a length of 1.5 m from the free end. Draw the shear force and bending moment diagrams for the cantilever.



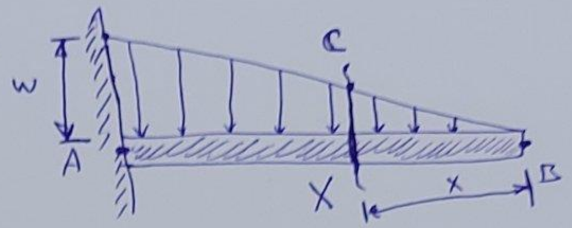
Problem 3. A cantilever of length 2 m carries a uniformly distributed load of 2 kN/m length over the whole length and a point load of 3 kN at the free end. Draw the shear force and bending moment diagrams for the cantilever.



Problem 4. A cantilever of length 2 m carries a uniformly distributed load of 1.5 kN/m run over the whole length and a point load of 2 kN at a distance of 0.5 m from the free end. Draw the shear force and bending moment diagrams for the cantilever.



Take a section X at a distance x from the free end B.



let F_x = Shear force at section X

M_x = Bending moment at the section X.

$$CX = \frac{w * x}{L} \qquad \left(\frac{CX}{w} = \frac{x}{L} \right)$$

$$CX * L = w * x$$

$$CX = \frac{w * x}{L}$$

F_x = Total load on the Cantilever for a length x from the free end B.

= Area of triangle BCX

$$= \frac{XB * XC}{2} = \frac{x * \left[\frac{w * x}{L}\right]}{2}$$

$$\boxed{= \frac{w * x^2}{2L}}$$

Shear force At B ⇒ x = 0 $\quad F_B = \frac{w * 0^2}{2L} = \boxed{\text{Zero}}$

At A ⇒ x = L $\quad F_A = \frac{w * L^2}{2L} = \boxed{\frac{w \cdot L}{2}}$

$M_x = -$ Area of triangle (BCX) * Distance of C.G of the triangle from X

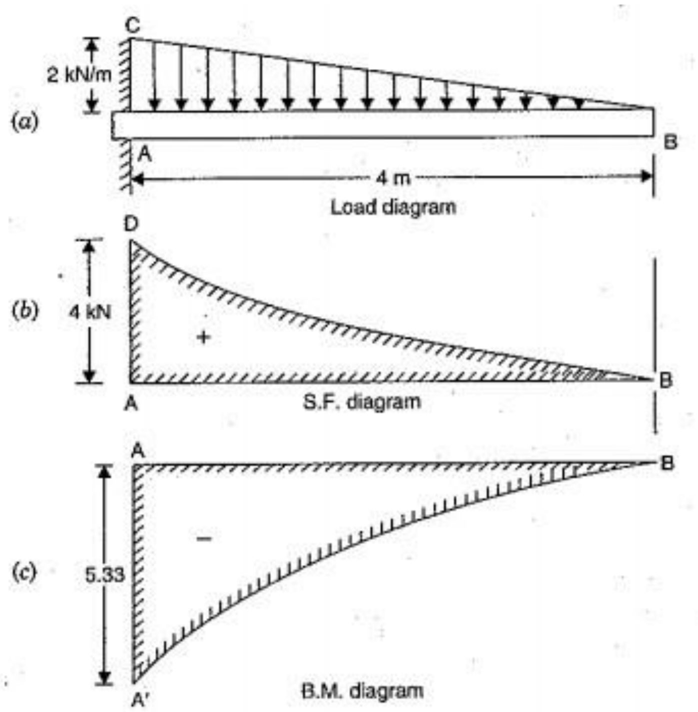
$$M_x = -\left[\frac{w.x^2}{2L}\right] * \frac{x}{3} = -\frac{w * x^3}{6L}$$

B.M at B ⇒ $x = 0$ B.M at B $= -\frac{w * 0^3}{6.L} =$ **zero**

B.M at A ⇒ $x = L$ B.M at A $= -\frac{w.L^3}{6.L} = -\frac{w.L^2}{6}$

(2)

Problem 5. A cantilever of length 4 m carries a gradually varying load, zero at the free end to 2 kN/m at the fixed end. Draw the shear force and bending moment diagrams for cantilever.



Problem 6

A simply supported beam of length 6 m, carries point load of 3 kN and 6 kN at distances of 2 m and 4 m from the left end. Draw the shear force and bending moment diagrams for the beam.

(P)

Solution

Calculate the Reactions R_A and R_B

Taking moments of the force about A, we get

$$R_B * 6 = 3 * 2 + 6 * 4$$

$$R_B * 6 = 30 \Rightarrow R_B = \frac{30}{6} = 5 \text{ kN}$$

R_A = total load on beam − R_B = (3 + 6) − 5 = 4 kN

Shear force Diagram

Shear force at A, $F_A = +R_A = +4$ kN

Shear force between A and C is constant = 4 kN

Shear force at C, $F_C = +4 - 3 = +1$ kN

Shear force between C and D is constant = +1 kN

Shear force at D, $F_D = +1 - 6 = -5$ kN

Shear force between D and B is constant = − 5 kN

Shear force at B, $F_B = -5$ kN

(2)

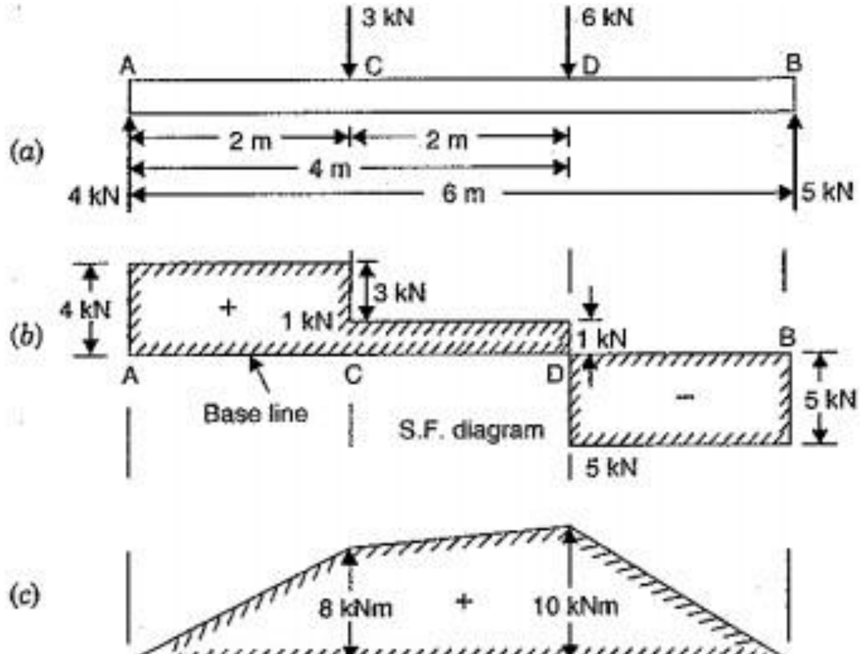
Bending moment

B.M. at A, $B.M_{at\,A}$ = Zero

B.M. at C, $B.M_{at\,C} = R_A * 2 = 4 * 2 = +8$ kN.m

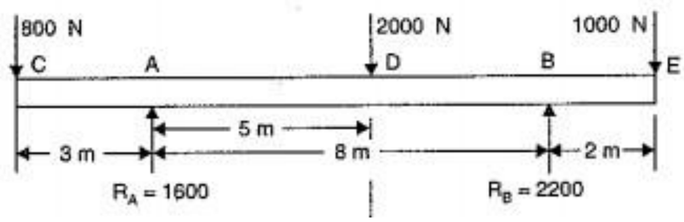
B.M. at D $= R_A * 4 - 3 * 2 = 4 * 4 - 3 * 2 = +10$ kN.m

$B.M_{at\,B}$ = Zero



Problem 7

Draw the shear force and bending moment diagram for the beam which is loaded as shown in figure.



Solution:-

First calculate the Reactions RA and RB

$\Sigma F_y = 0$

$RA + RB - 800 - 2000 - 1000 = 0$

$RA + RB - 3800 = 0$

$RA + RB = 3800 \Longrightarrow \boxed{RA = 3800 - RB}$

$\Sigma M_A = 0$

$RB * 8 + RA * \text{Zero} + 800 * 3 - 2000 * 5 - 1000 * (8+2) = 0$

$RB * 8 + 800 * 3 = 2000 * 5 + 1000 * 10$

$RB = \dfrac{20000 - 2400}{8} = \dfrac{17600}{8} = \boxed{2200\ N = RB}$

$\therefore RA = 3800 - 2200 = \boxed{1600\ N = RA}$

Shear force Diagram.

$S.F_{at\,C} = -800\ N$

S.F between C and A remains constant $= -800\ N$

$S.F_{at\,A} = -800 + RA = -800 + 1600 = +800\ N$

S.F between A and D remains constant = +800 N

$S.F_{at\ D} = +800 - 2000 = -1200$ N

S.F between D and B remains constant = -1200 N

$S.F._{at\ B} = -1200 + R_B = -1200 + 2200 = +1000$ N

S.F between B and E remains constant = +1000 N

Bending Moment Diagram.

$B.M._{at\ C} = 0$

$B.M._{at\ A} = -800 * 3 = -2400$ N.m

$B.M_{at\ D} = -800 * (3+5) + RA * 5$

$= -800 * 8 + 1600 * 5 \Rightarrow B.M_{at\ D} = +1600$ N.m

$B.M_{at\ B} = -2000$ N.m

$B.M_{at\ E}$ = Zero