University School of Automation and Robotics
GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY
East Delhi Campus, Surajmal Vihar
Delhi - 110092

USAR
UNIVERSITY SCHOOL OF AUTOMATION AND ROBOTICS

Engineering Mechanics

By: Dr. Divya Agarwal

- **UNIT- I**

- **Force system:** Introduction, force, principle of transmissibility of force, resultant of a force system, resolution of a force, moment of force about a line, Varigon's theorem, couple, resolution of a force into force and a couple, properties of couple and their application to engineering problems.
- **Equilibrium:** Force body diagram, equations of equilibrium, and their applications to engineering problems, equilibrium of two force and three force members.
- **Distributed forces:** Determination of centre of gravity, centre of mass and centroid by direct integration and by the method of composite bodies., mass moment of inertia and area moment of inertia by direct integration and composite bodies method, radius of gyration, parallel axis theorem, polar moment of inertia.

- **UNIT- II**

- **Structure:** Plane truss, perfect and imperfect truss, assumption in the truss analysis, analysis of perfect plane trusses by the method of joints, method of section, graphical method.
- **Friction:** Static and Kinetic friction, laws of dry friction, co-efficient of friction, angle of friction, angle of repose, cone of friction, frictional lock, friction in pivot and collar bearing, friction in flat belts.

- **UNIT-III**

- **Kinematics of Particles:** Rectilinear motion, plane curvilinear motion, rectangular coordinates, normal and tangential coordinates
- **Kinetics of Particles:** Equation of motion, rectilinear motion and curvilinear motion, work energy equation, conservation of energy, concept of impulse and momentum, conservation of momentum, impact of bodies, co-efficient of restitution, loss of energy during impact.

- **UNIT-IV**

- **Kinematics of Rigid Bodies:** Concept of rigid body, type of rigid body motion, absolute motion, introduction to relative velocity, relative acceleration (Corioli's component excluded) and instantaneous center of zero velocity, velocity and acceleration.
- **Kinetics of Rigid Bodies:** Equation of motion, translatory motion and fixed axis rotation, application of work energy principles to rigid bodies conservation of energy.
- **Beam:** Introduction, types of loading, methods for the reactions of a beam, space diagram, types of end supports, beams subjected to couple

- **UNIT-III**

- **Kinematics of Particles:** Rectilinear motion, plane curvilinear motion, rectangular coordinates, normal and tangential coordinates
- **Kinetics of Particles:** Equation of motion, rectilinear motion and curvilinear motion, work energy equation, conservation of energy, concept of impulse and momentum, conservation of momentum, impact of bodies, co-efficient of restitution, loss of energy during impact.

- **UNIT-IV**

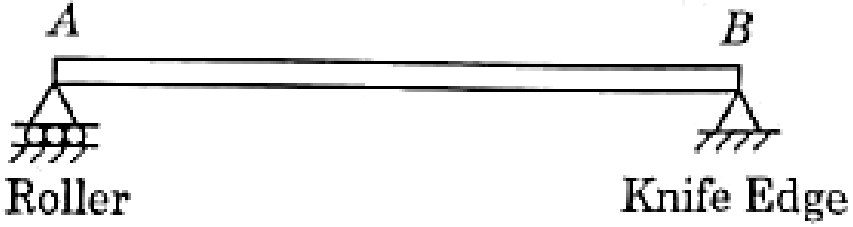
- **Kinematics of Rigid Bodies:** Concept of rigid body, type of rigid body motion, absolute motion, introduction to relative velocity, relative acceleration (Corioli's component excluded) and instantaneous center of zero velocity, velocity and acceleration.
- **Kinetics of Rigid Bodies:** Equation of motion, translatory motion and fixed axis rotation, application of work energy principles to rigid bodies conservation of energy.
- **Beam:** Introduction, types of loading, methods for the reactions of a beam, space diagram, types of end supports, beams subjected to couple

WHAT IS A BEAM AND SHEAR FORCE?

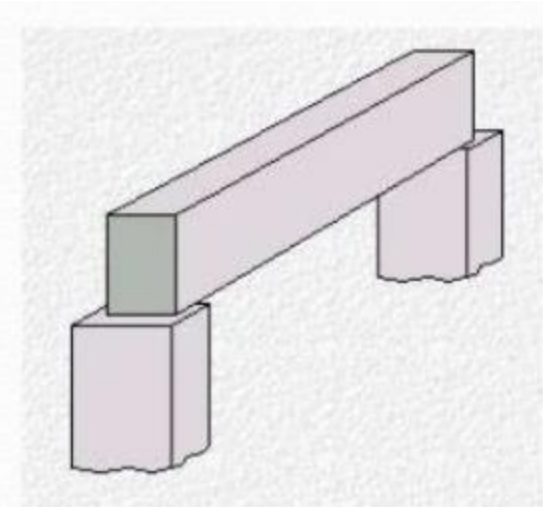
- **Beam -** Structural member whose longitudinal dimension is large compared to its transverse dimension.
- It is supported along its length and is acted upon by a system of loads transverse at right angles to its longitudinal axis. It may also be acted upon by some couples.
- Shear force is an internal force in any material which is usually caused by any external force acting perpendicular to material, or a force which has a component acting tangent to material.
- Shearing forces are unaligned forces pushing one part of a body in one direction, and another part in opposite direction. When forces are aligned into each other, they are called compression forces.
- Effect of loading results in developing shearing force and bending moment at any section of the beam.
- For designing a beam, information about shear force and bending moment is required.
- Shearing force and bending moment developed depends upon combination of loading and support conditions of the beam.

TYPES OF BEAMS

1. **Cantilever beam.** It is a beam which is fixed at one end (A) and free at other end (B). There is no deflection or rotation at the fixed end.

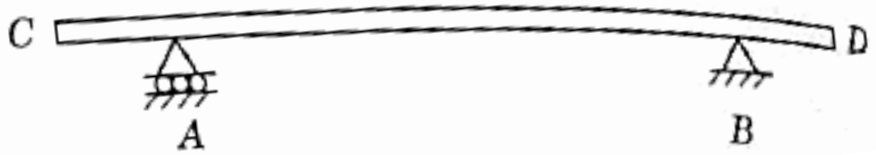


2. **Simply supported beam.** A beam supported freely on supports which may be a knife edge or a roller. There is no deflection or displacement of the beam at the ends. In this type of support, the beam is allowed to rest freely on a support (see figure). Here, we can observe that the beam is free to move in any direction and also to rotate about the support..

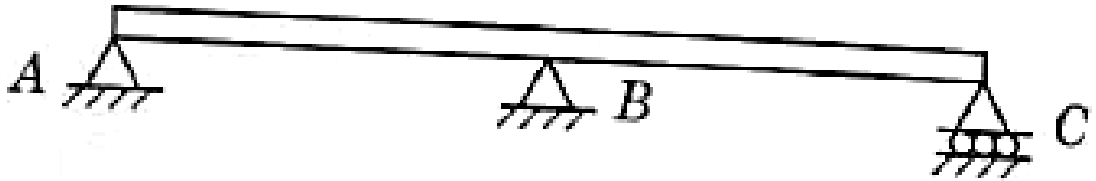


TYPES OF BEAMS

3. **Fixed beam**. A beam whose both ends are fixed. This support keeps the ends of the beam fixed. i.e., the beam end resists to take any kind of translation or bending moment.
4. **Overhanging beam.** A beam with one or both ends extended beyond the supports.



5. **Continuous beam.** A beam with more than two supports is a continuous beam. Such a beam may or may not have an overhang.



TYPES OF BEAMS – REAL LIFE EXAMPLES

Fixed beam

Cantilever beam

Simply supported beam

TYPES OF BEAMS – REAL LIFE EXAMPLES

Overhanging beam

Continuous beam

INTRODUCTION TO SUPPORT REACTIONS

- When we apply a force on a body, it exerts a reaction,
- e.g., when a ceiling fan is hung from a girder, it is subjected to the following two forces:
  1. Weight of the fan, acting downwards, and
  2. Reaction on the girder, acting upwards.
- As the fan is in equilibrium therefore, the above two forces must be equal and opposite.
- Similarly, if we consider the equilibrium of a girder supported on the walls, we see that total weight of fan and girder is acting through supports of the girder on walls.
- i.e., walls must exert equal and upward reactions at the supports to maintain the equilibrium.
- Upward reactions, offered by walls, are known as *support reactions*.
- Support reaction depends upon type of loading and support.

METHODS FOR THE REACTIONS OF A BEAM

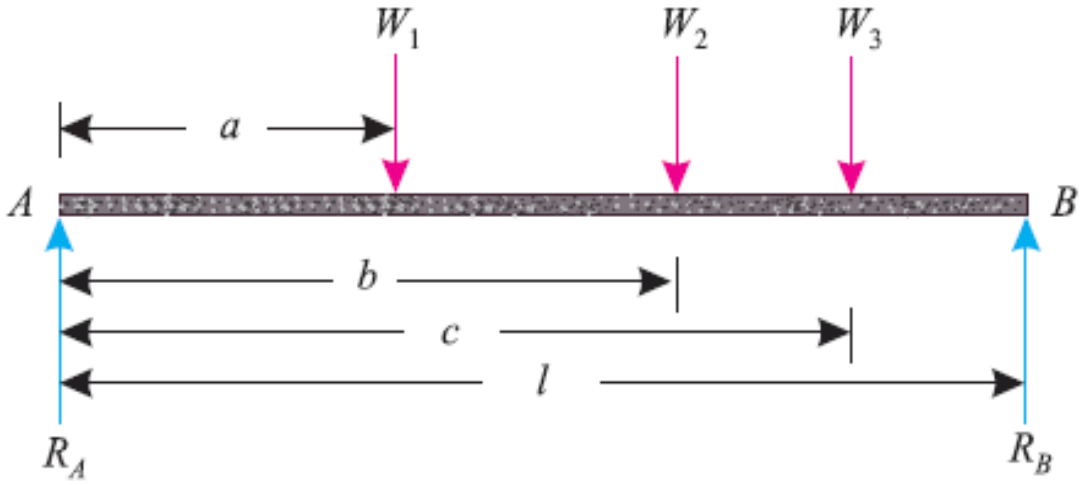
- Reactions at two supports of a beam may be found out by:

1. Analytical method

2. Graphical method.

ANALYTICAL METHOD FOR THE REACTIONS OF A BEAM

- Consider a simply supported beam *AB* of span *l*, subjected to point loads W_1, W_2 and W_3 at distances of *a*, *b* and *c*, respectively from support *A*.



- Let R_A and R_B = Reaction at *A* and *B*, respectively.
- Sum of clockwise moments due to loads about *A*

  $= W_1a + W_2b + W_3c$ ...(*i*)

- Sum of anticlockwise moment due to reaction R_B about *A* = $R_B\,l$ ...(*ii*)
- Equate clockwise and anticlockwise moments about *A*,

$$R_B\,l = W_1a + W_2b + W_3c \quad \ldots (As, \Sigma M = 0)$$

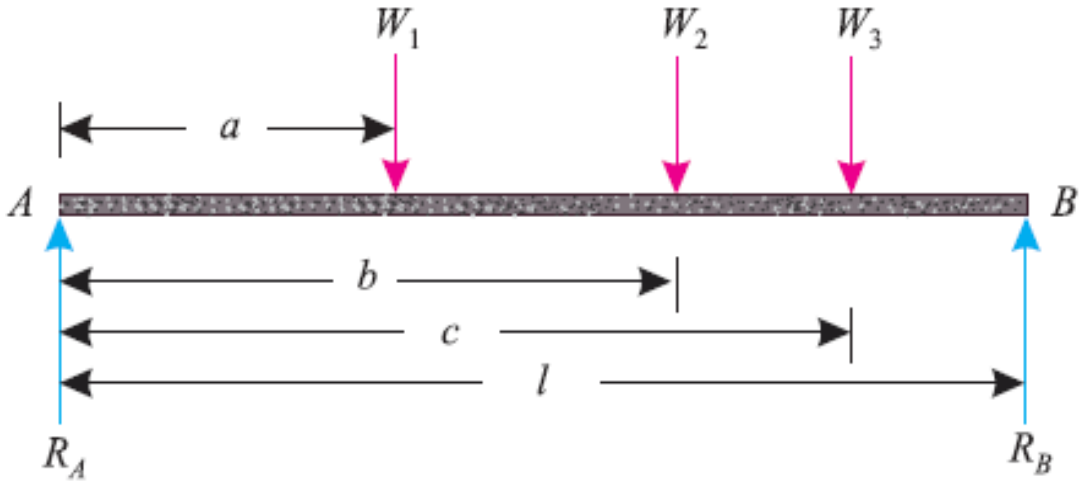
or $$R_B = \frac{W_1a + W_2b + W_3c}{l} \quad ..(iii)$$

ANALYTICAL METHOD FOR THE REACTIONS OF A BEAM

- Since the beam is in equilibrium, therefore

$$R_A + RB = W_1 + W_2 + W_3 \quad \text{...(As, } \Sigma V = 0\text{)}$$

and $R_A = (W_1 + W_2 + W_3) - RB$



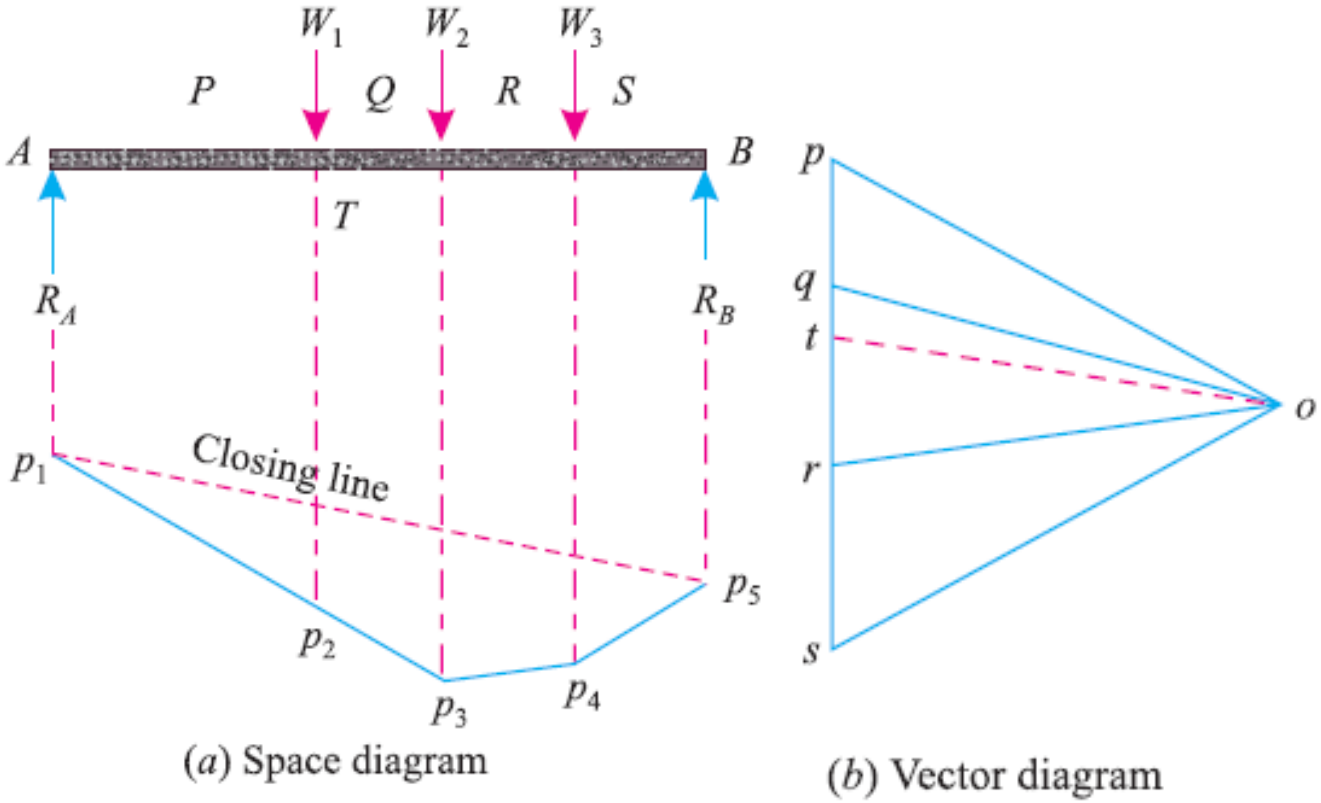
GRAPHICAL METHOD FOR THE REACTIONS OF A BEAM

- It is a systematic, but long method, for finding out reactions of a beam which is done using:

1. **Construction of space diagram.**
   - ❑ It means to construct diagram of the beam to a suitable scale.
   - ❑ It also includes loads, carried by the beam along with the lines of action of reactions.
   - ❑ Name different loads (or forces) including two reactions according to Bow's notations.
2. **Construction of vector diagram.**
   - ❑ The purpose of this step is to draw and construct the vector diagram

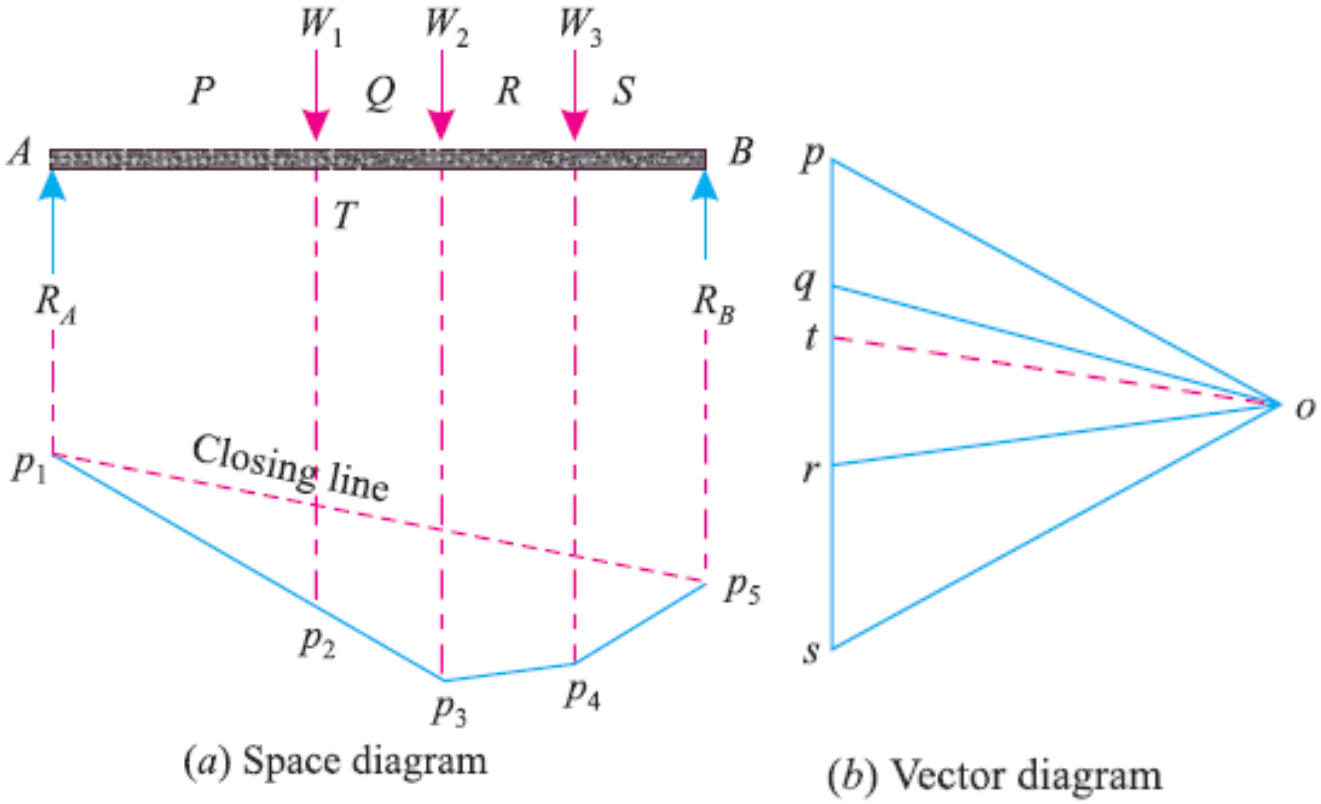
CONSTRUCTION OF VECTOR DIAGRAM

1. Select some suitable point p, near space diagram and draw pq parallel and equal to load PQ (*i*.e.,W_1) to some scale.
2. Similarly, through q and r, draw qr and rs parallel and equal to loads QR and RS (*i*.e., W_2 and W_3) to scale.
3. Select any suitable point o and join op, oq, or and os as shown.
4. Now extend lines of action of loads and two reactions in space diagram.
5. Select some suitable point p_1 on lines of action of reaction R_A. Through p_1 draw $p_1 p_2$ parallel to op intersecting line of action of load W_1 at p_2.



CONSTRUCTION OF VECTOR DIAGRAM

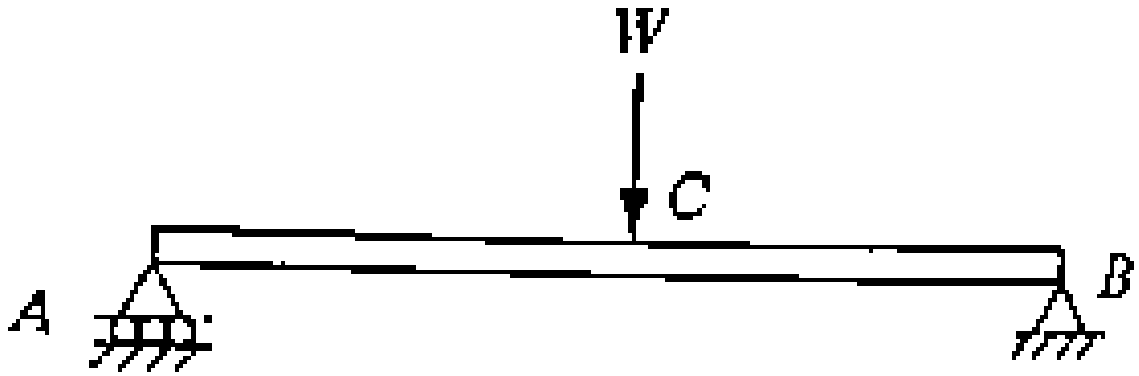
6. Similarly, draw $p_2\ p_3$, $p_3\ p_4$ and $p_4\ p_5$ parallel to *oq*, *or* and *os* respectively.
7. Join *p*1 with *p*5 and through *o* draw a line *ot* parallel to this line.
8. Now lengths *tp* and *st*, in the vector diagram, give the magnitude of the reactions R_A and R_B respectively to the scale as shown in Figure.



(*a*) Space diagram (*b*) Vector diagram

TYPES OF LOADS

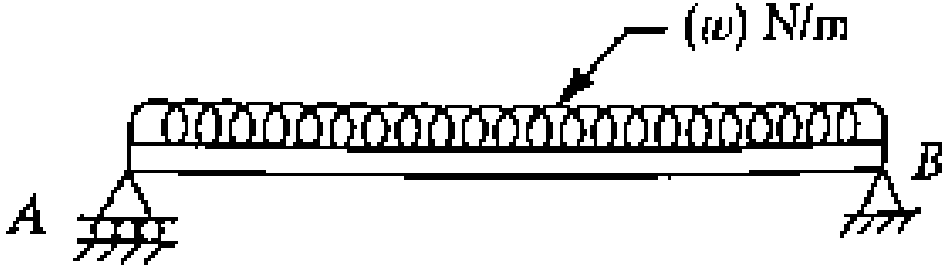
1. **Concentrated load.** A concentrated load is one which is assumed to act at a point.

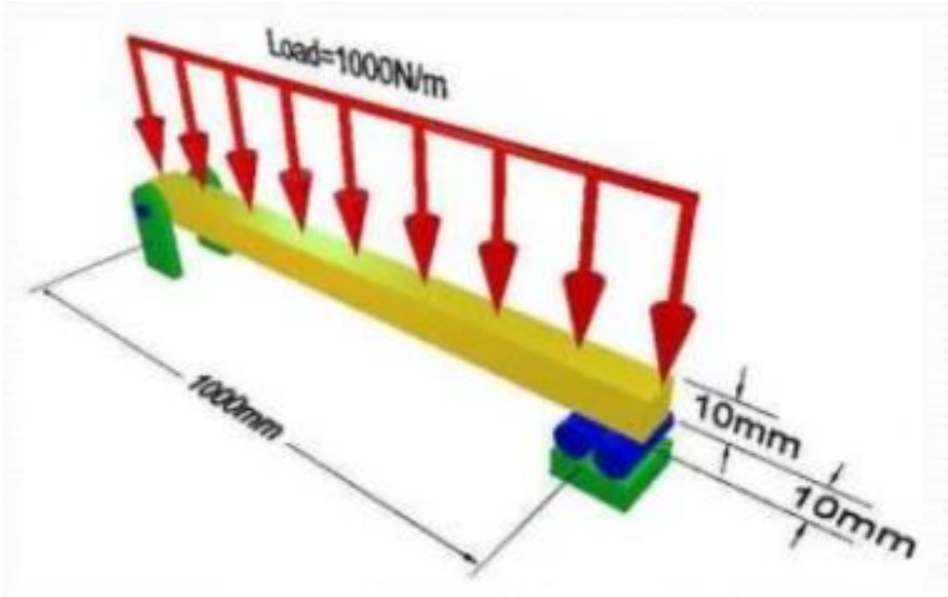


TYPES OF LOADS

2. **Uniformly distributed load.** It is uniformly or evenly distributed over a part or over entire length of beam.

- Rate of loading is expressed in N/m.
- For solving numerical problems, total uniformly distributed load is converted into equivalent point load acting at centre of gravity of uniformly distributed load.





TYPES OF LOADS

3. **Uniformly varying load.** A load whose intensity of loading varies linearly or at constant rate along the length. In triangular load for example it increases from zero at one end to some value at other and at a constant rate.
4. **A combination of above loading.** A trapezoidal loading is a combination of uniform and triangular loading.