CIHAN UNIVERSITY
SULAIMANI

Chapter 1: Introduction

Strength of Materials

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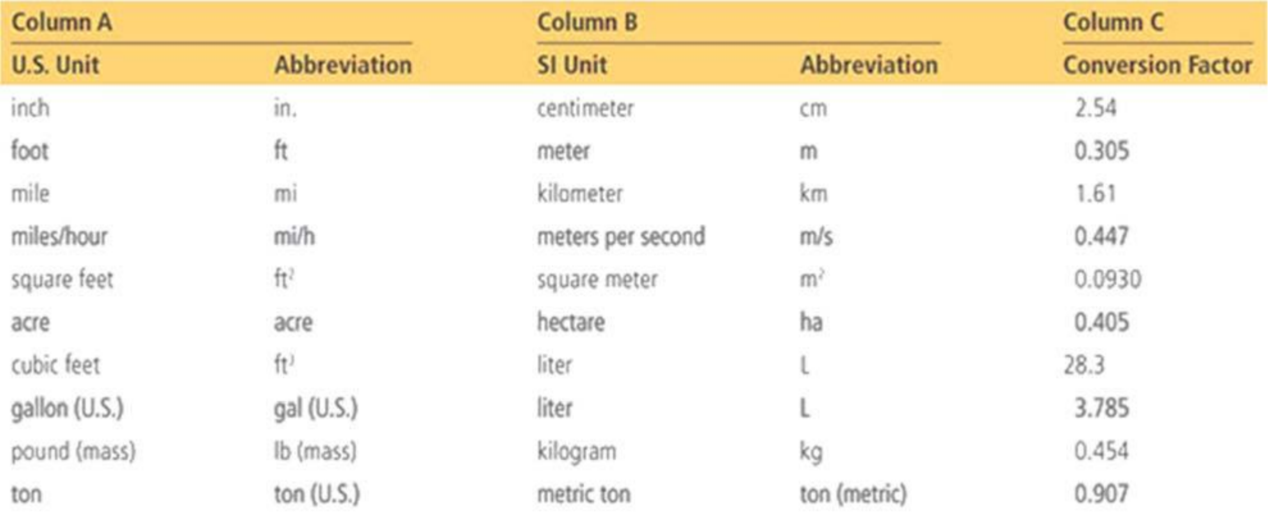
Chapter Outline

- SI and US units
- What is Mechanics of Materials?
- Types of Supports
- Types of Beams
- External Loadings
- Equilibrium for a rigid body
- Equilibrium Examples for a rigid body
- Equilibrium for a deformable body
- Internal forces

U.S. unit and SI Unit

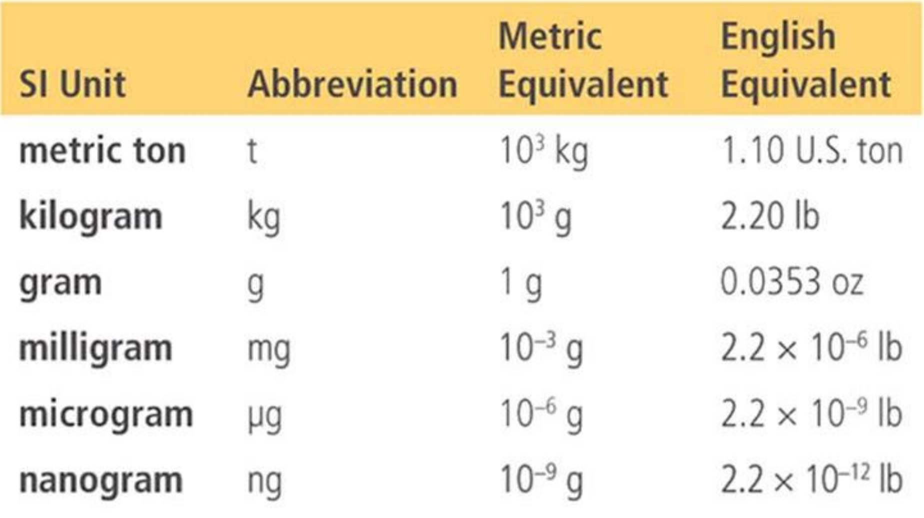
Unit of length



Column A		Column B		Column C
U.S. Unit	Abbreviation	SI Unit	Abbreviation	Conversion Factor
inch	in.	centimeter	cm	2.54
foot	ft	meter	m	0.305
mile	mi	kilometer	km	1.61
miles/hour	mi/h	meters per second	m/s	0.447
square feet	ft^2	square meter	m^2	0.0930
acre	acre	hectare	ha	0.405
cubic feet	ft^3	liter	L	28.3
gallon (U.S.)	gal (U.S.)	liter	L	3.785
pound (mass)	lb (mass)	kilogram	kg	0.454
ton	ton (U.S.)	metric ton	ton (metric)	0.907

U.S. unit and SI Unit

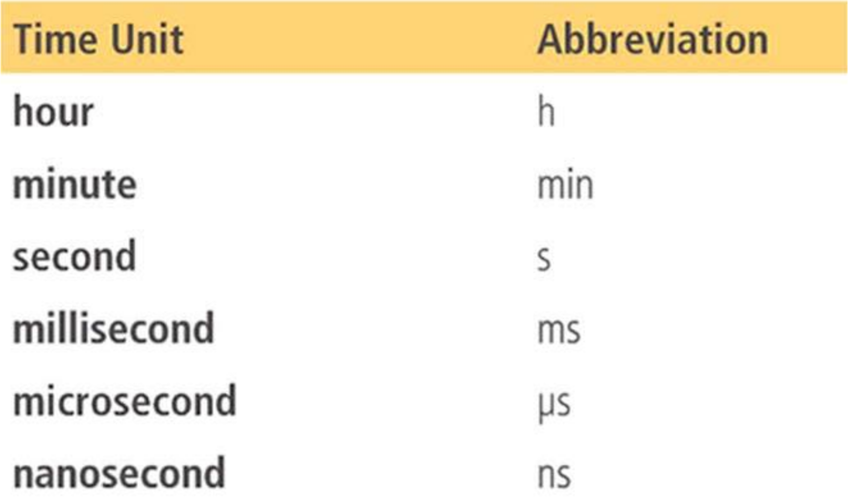
Unit of mass



SI Unit	Abbreviation	Metric Equivalent	English Equivalent
metric ton	t	10^3 kg	1.10 U.S. ton
kilogram	kg	10^3 g	2.20 lb
gram	g	1 g	0.0353 oz
milligram	mg	10^{-3} g	2.2×10^{-6} lb
microgram	µg	10^{-6} g	2.2×10^{-9} lb
nanogram	ng	10^{-9} g	2.2×10^{-12} lb

U.S. unit and SI Unit

Unit of time



Time Unit	Abbreviation
hour	h
minute	min
second	s
millisecond	ms
microsecond	μs
nanosecond	ns

U.S. unit and SI Unit

SI Units (International system of units):

force(N), Moment (N.m), stress(N/m^2)

1 N/m^2= 1 Pascal(Pa)

1 MPa = 1000,000 Pascal(Pa)

1 MPa = 1 N/mm^2

1 Kg = 9.81 N

1 N = 4.45 lb

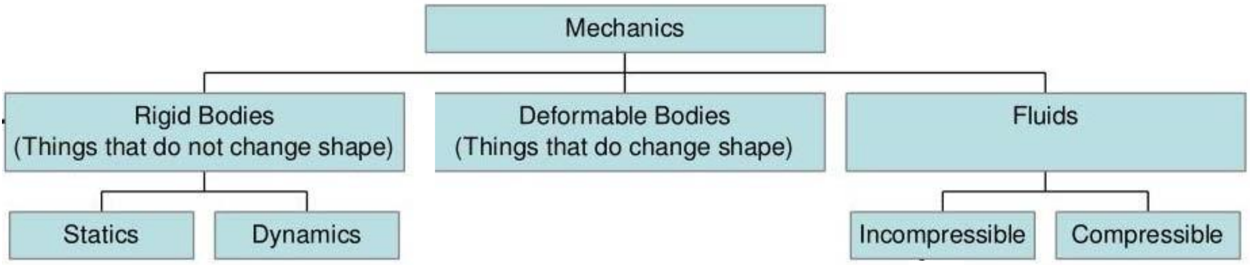
1 kilopound (kip) = 1000 lb.

PREFIXES:

10^9 :Giga (G)	**10^{-9} : nano (η)**
10^6 :Mega (M)	**10^{-6}: micro (μ)**
10^3 :Kilo (K)	**10^{-3}: milli (m)**

What is Mechanics of Materials?

The term **(Strength of Materials)**or **(Mechanics of Materials)** refers to the study of the behavior of **solid bodies** under the action of different forces.



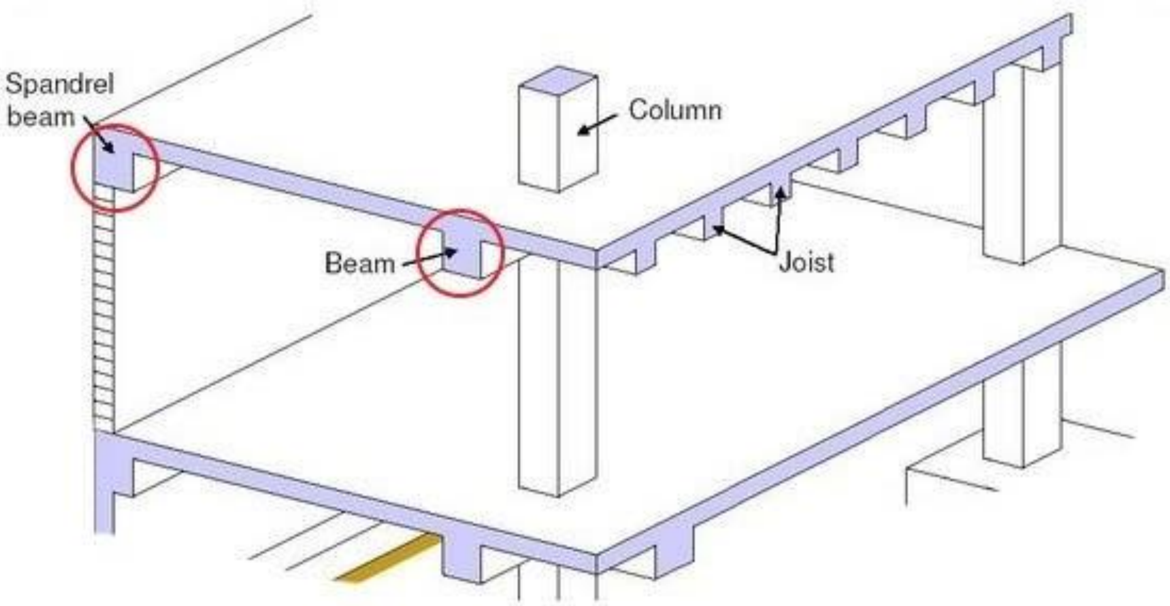
Mechanics

- Rigid Bodies (Things that do not change shape)
  - Statics
  - Dynamics
- Deformable Bodies (Things that do change shape)
- Fluids
  - Incompressible
  - Compressible

What is Mechanics of Materials?

Solid bodies: shafts, bars, beams, columns, plates, shells, as well as structures and machines that are assemblies of these components

What is Mechanics of Materials?

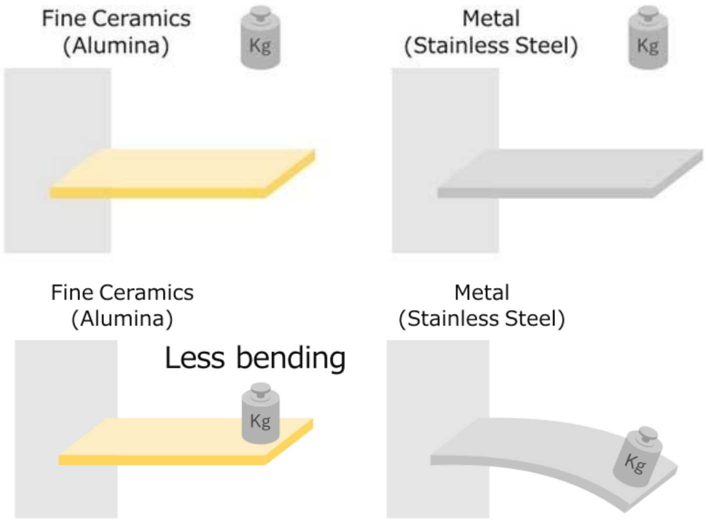


What is Mechanics of Materials?

- **Mechanics of Materials answers TWO questions:**
  1. ***Is the material strong enough?***
  2. ***Is the material stiff enough?***

- Therefore in strength of materials, the principles that govern **STRENGTH** and **RIGIDITY,** should be studied.

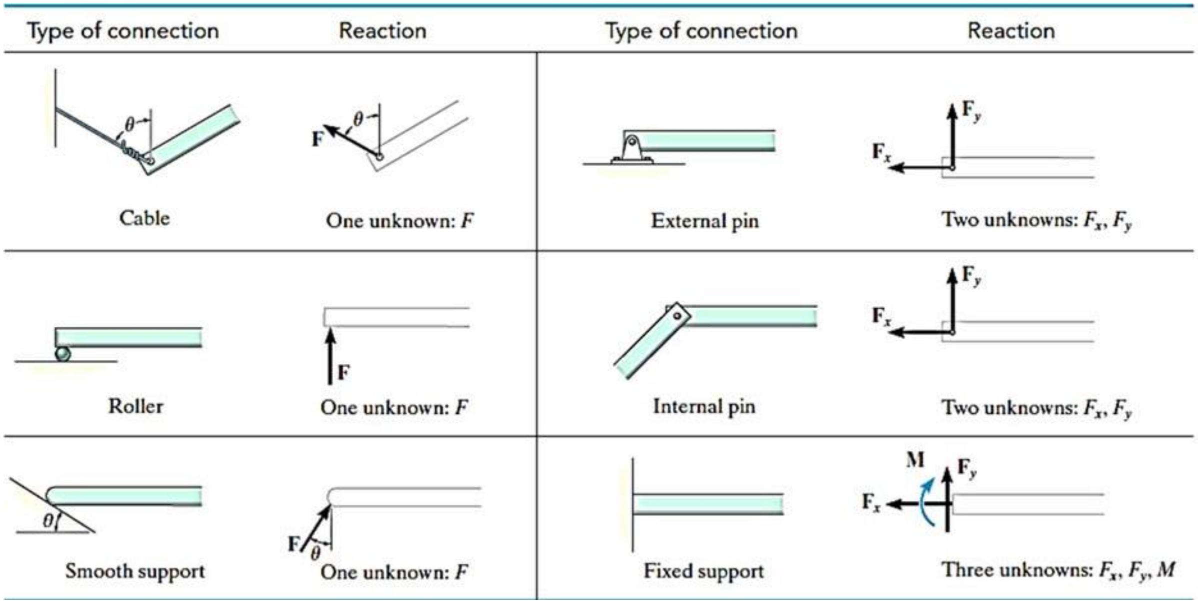
What is Mechanics of Materials?



High rigidity

Less rigidity

Types of Supports



Type of connection	Reaction	Type of connection	Reaction
Cable	One unknown: F	External pin	Two unknowns: F_x, F_y
Roller	One unknown: F	Internal pin	Two unknowns: F_x, F_y
Smooth support	One unknown: F	Fixed support	Three unknowns: F_x, F_y, M

Types of Supports

Roller supports are free to rotate and translate along the surface upon which the roller rests. The surface can be horizontal, vertical, or sloped at any angle. Roller supports are commonly located at one end of long bridges.

Roller supports

simple supports

Types of Supports

Pinned supports (Hinge supports) can resist both vertical and horizontal forces but not a moment. They will allow the structural member to rotate, but not to translate in any direction.

External Pinned support

Internal Pinned support

Types of Supports

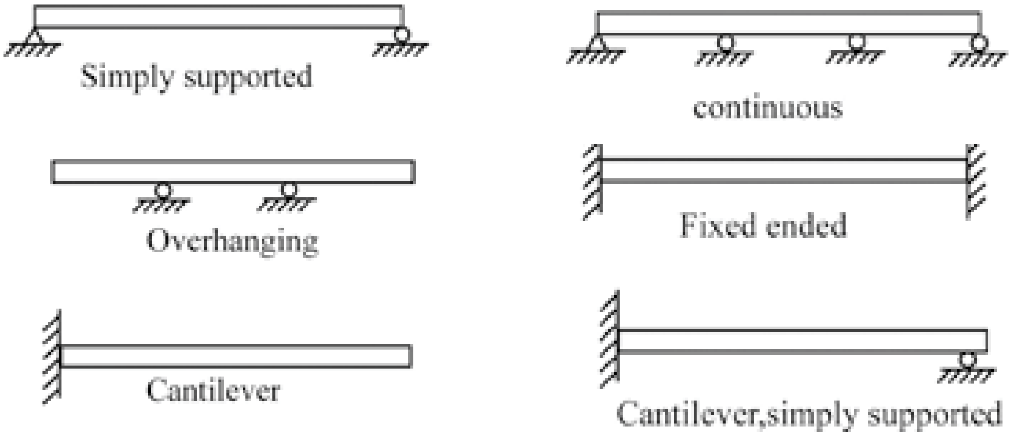
Fixed supports are the most rigid type of support or connection. It constrains the member in all translations and rotations (i.e. it cannot move or rotate in any direction).

Fixed support

Fixed connection

Types of Beams

Types of beams depending on *support conditions*



Statically determinate

Statically indeterminate

Types of Beams

Depending unknown reactions and equilibrium equations

1- STATICALLY DETERMINATE BEAMS

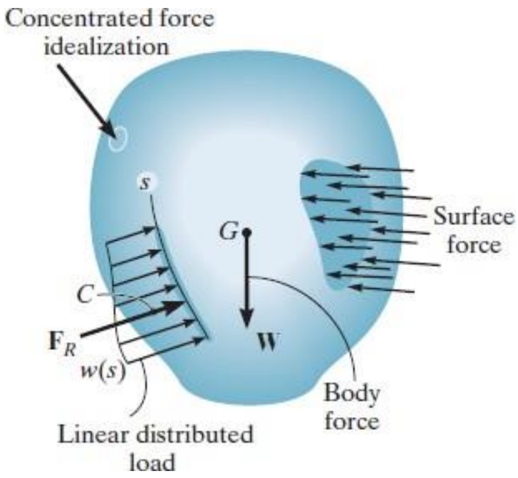
No. of unknowns = No. of static
(Reactions) equilibrium equations

2- STATICALLY INDETERMINATE BEAMS

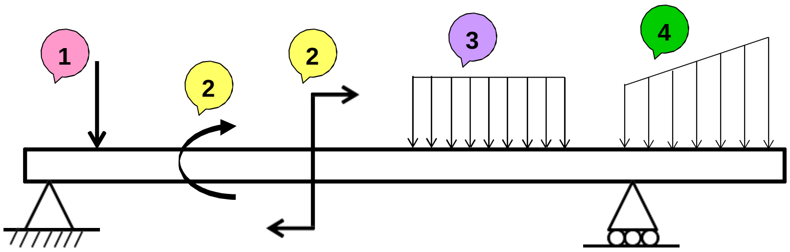
No. of unknowns > No. of eq^{m}. equations

External Loads

- A body is subjected to only two types of external loads; namely, surface forces or *body forces*.
- *Surface forces* are caused by the direct contact area of one body with the surface of another.
- If the contact area is small in comparison with the total surface area of the body, then the surface force can be *idealized* as a single *concentrated force*.
- If the surface loading is applied along a narrow strip of contact area, the loading can be *idealized* as a *linear distributed load*



Types of external loads on beams



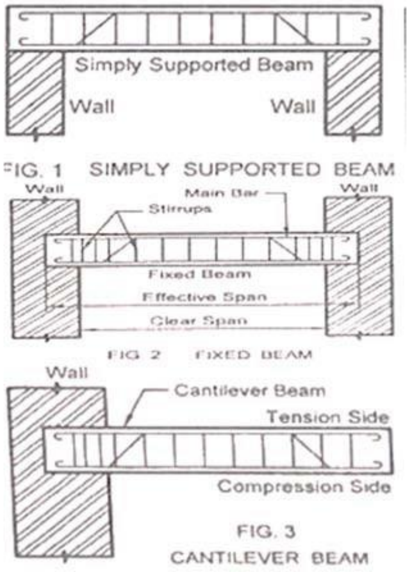
1 **concentrated load**

2 **concentrated moment**

3 **uniformly distributed load**

4 **uniformly Varying load**

Some real examples of beams with support idealization



Some real examples of beams with support idealization

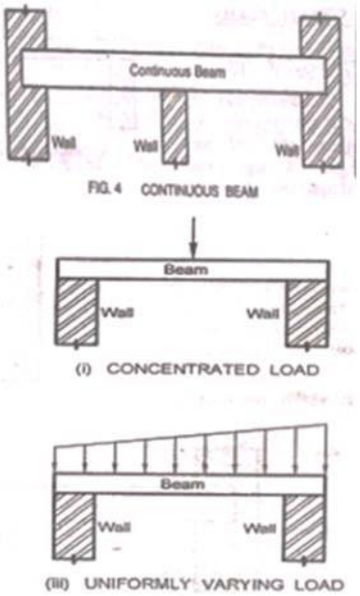


FIG. 4 CONTINUOUS BEAM

(i) CONCENTRATED LOAD

(iii) UNIFORMLY VARYING LOAD

Some real examples of beams with support idealization

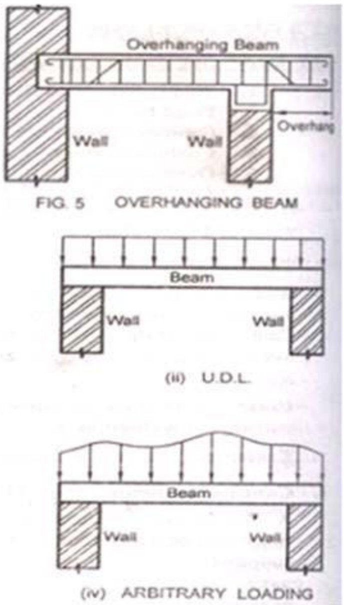


FIG. 5 OVERHANGING BEAM

(ii) U.D.L.

(iv) ARBITRARY LOADING

Equations of Equilibrium for a rigid body

In three dimensions (x-y-z plane)

$$\begin{aligned} \Sigma F_x &= 0 & \Sigma F_y &= 0 & \Sigma F_z &= 0 \\ \Sigma M_x &= 0 & \Sigma M_y &= 0 & \Sigma M_z &= 0 \end{aligned}$$

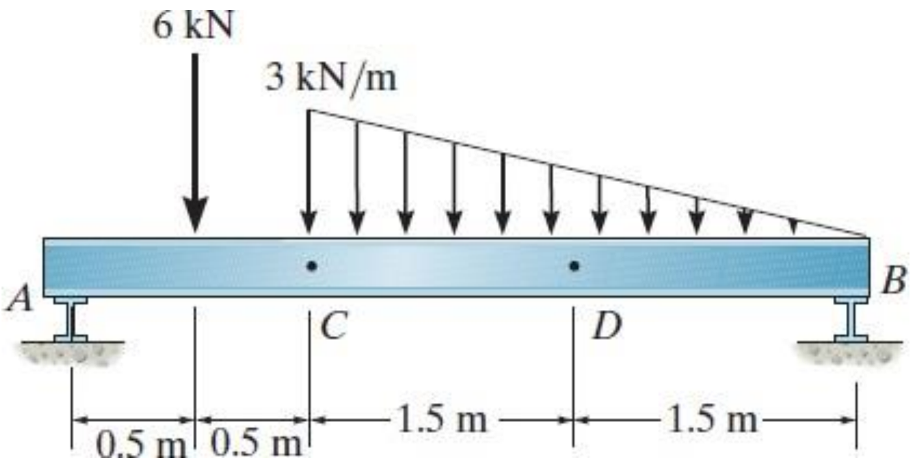
In two dimensions (x-y plane)

$$\begin{aligned} \Sigma F_x &= 0 \\ \Sigma F_y &= 0 \\ \Sigma M_O &= 0 \end{aligned}$$

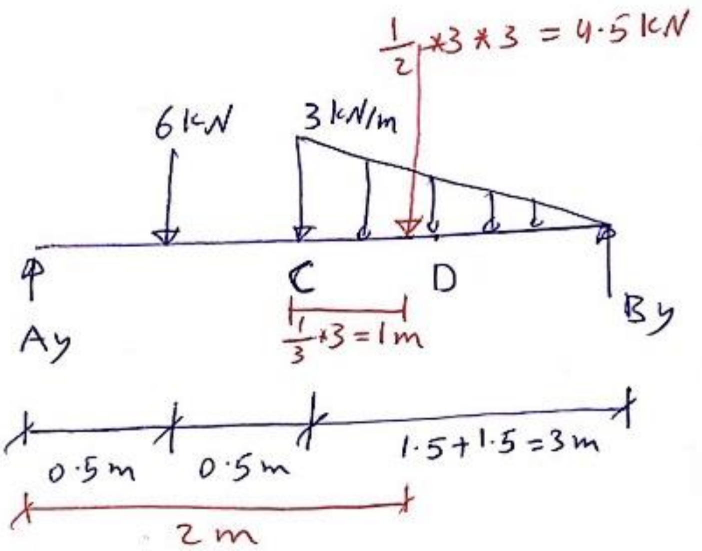
In (x-y plane) all the moments are summed about point *O* and so they will be directed along the *z* axis.

Example

Draw the free body diagram and determine the support reactions.



Example :-



$+\circlearrowleft$

$\Sigma M_A = 0$

$6 * 0.5 + 4.5 * 2 - B_y * 4 = 0$

$B_y = \frac{3+9}{4} = 3$ kN ↑

$+\uparrow \Sigma F_y = 0$

$A_y - 6 - 4.5 + \overset{B_y}{3} = 0$

$A_y = 10.5 - 3 = 7.5$ kN ↑

for check :-

$+\circlearrowleft$

$\Sigma M_B = 0$

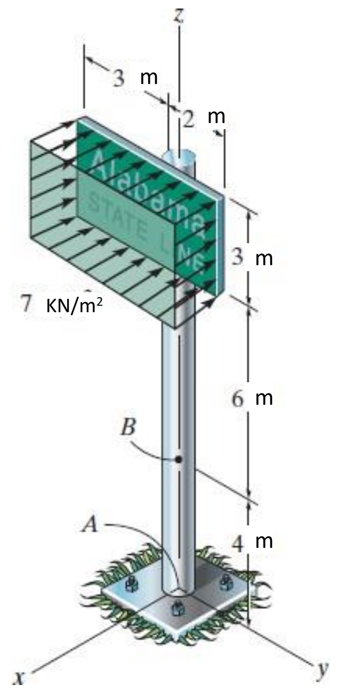
$A_y * 4 - 6 * 3.5 - 4.5 * 2 = 0$

$A_y = \frac{21+9}{4} = \frac{30}{4} = 7.5$ kN ↑ Checked ✓

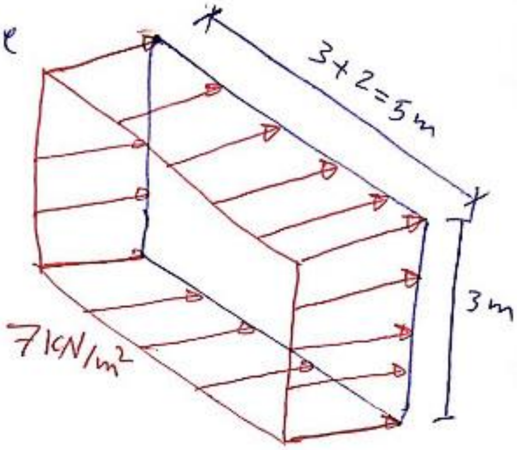
Solution

Example

Draw the free body diagram and determine the support reactions



Example :-



*The force is act on z-y Plane and the direction of the force is in X-direction.

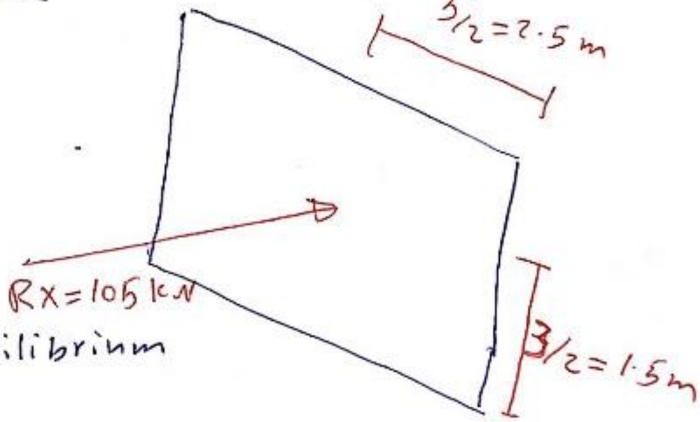
* Resultant of the force = Force * Area under the force

$$\text{Resultant} = \underbrace{7}_{\text{force}} * (\underbrace{5*3}_{\text{Area under the force}})$$

$= 105\ kN \rightarrow$ in X-direction

So, $R_x = 105\ kN \rightarrow$

*Then find the Position of the resultant force which is act at half of length & half of width of the Plane under the force



Now, use the three equilibrium equations

$\overset{+}{\rightarrow}$

$\Sigma F_x = 0$ $\Rightarrow A_x = 105\ kN \leftarrow$

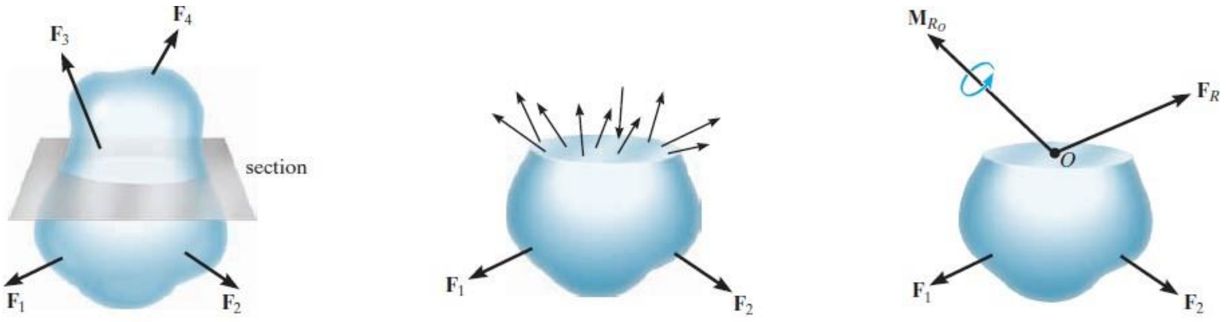
$-A_x + 105 = 0$

$\Sigma F_y = 0 \Rightarrow A_y = 0$ there is no force in y-direction

$\Sigma F_z = 0 \Rightarrow A_z = 0$ there is no force in z-direction

Solution

Equilibrium for a deformable body

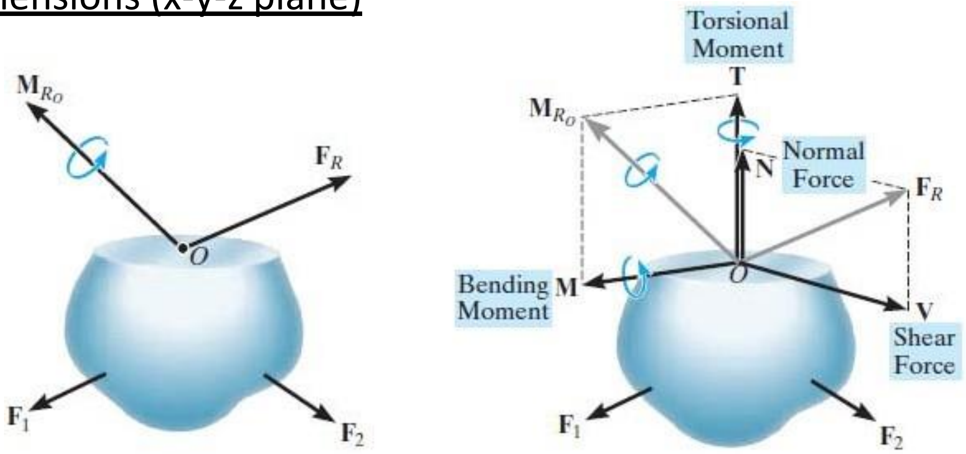


(a) (b) (c)

(a) The body held in equilibrium by the four external forces and imaginary section passed through it
(b) distribution of internal force acting on the “exposed” area of the section.
(c) the distribution’s *resultant force and moment*, and *at any specific point O* on the sectioned area

Equilibrium for a deformable body

In three dimensions (x-y-z plane)



(c)

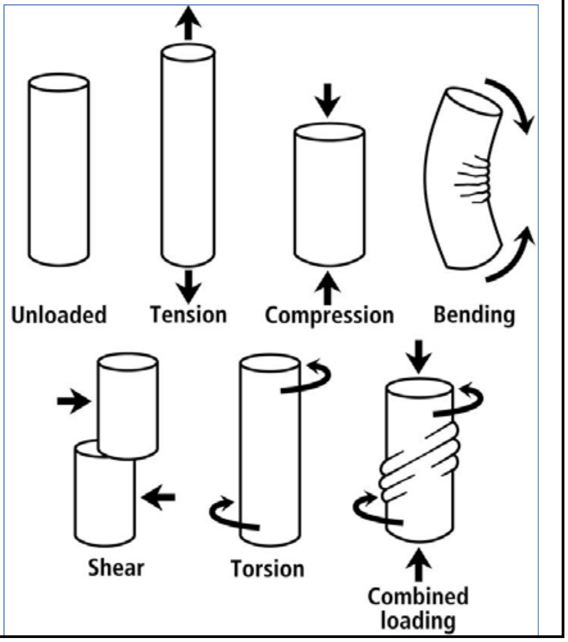
(d)

(d) Resultants of both moment and forces are distributed into the components acting parallel or perpendicular on the sectioned area.

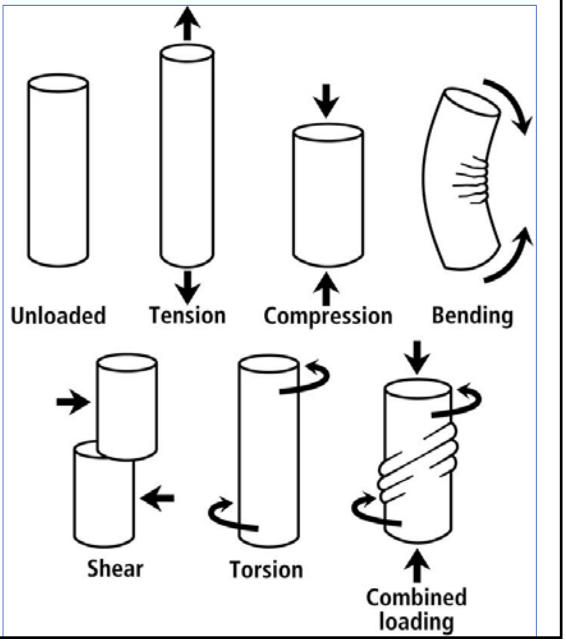
Internal forces

Normal force, N. This force acts perpendicular to the area. It is developed whenever the external loads tend to push or pull on the two segments of the body.

Shear force, V. The shear force lies in the plane of the area and it is developed when the external loads tend to cause the two segments of the body to slide over one another.



Internal forces

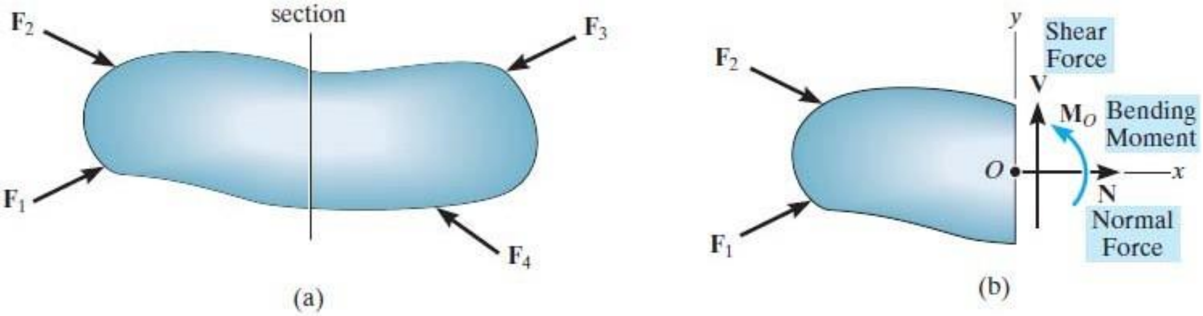


Torsional moment or torque, T. This effect is developed when the external loads tend to twist one segment of the body with respect to the other about an axis perpendicular to the area.

Bending moment, M. The bending moment is caused by the external loads that tend to bend the body about an axis lying within the plane of the area.

Internal forces

In two dimensions (x-y plane)



normal force (N), shear force (V) and bending moment(M)

components will exist at the section