Knowledge Institute of Technology, Salem.

Department of Mechanical Engineering

Strength of Materials for Mechanical Engineers

PRESENTED BY
Mr.K.S.Prabhakaran

- Strength is a measure of how well a material can resist being deformed from its original shape.
- the strength of a material is its ability to withstand an applied load without failure
- Strength is measured in units of pressure

INTRODUCTION TO STRENGTH OF MATERIALS

- Strength is the ability to resist deformation.
- The strength of a component is usually considered based on the maximum load that can be borne before failure.

Strength of A Material:

- **Mechanics of materials**, also called **strength of materials**, is a subject which deals with the behavior of solid objects subject to stresses and strains.
- The study of strength of materials often refers to various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts.

Strength Of Materials :

Rigid Body:

- A rigid body is defined as a body on which the distance between two points never changes whatever be the force applied on it.
- Practically, there is no rigid body.

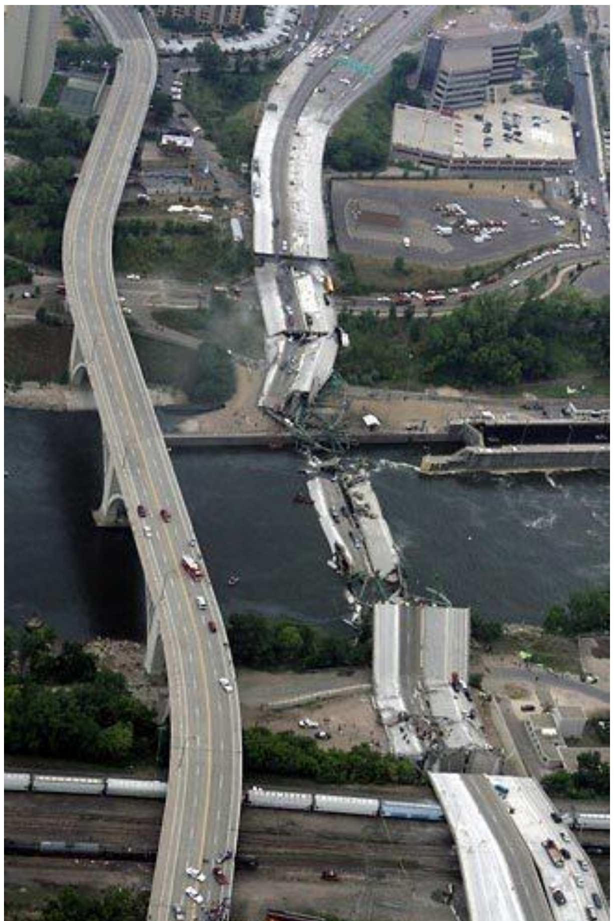
A deformable body is defined as a body on which the distance between two points changes under action of some forces when applied on it.

Deformable body:

- A material is brittle if, when subjected to stress, it breaks without insignificant deformation.
- Glass is a good example.

Brittle

Why do we study STRENGTH of Materials?



Elastic Deformation:

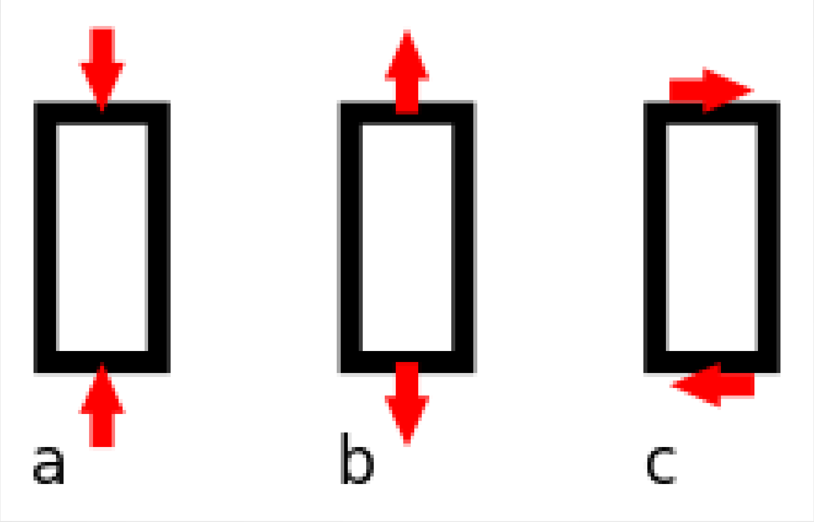
Plastic deformation:

Engineering Mechanics

- Rigid Body Mechanics
  - Statics
  - Dynamics
- Deformable Body Mechanics
  - Strength of Materials
- Fluid Mechanics

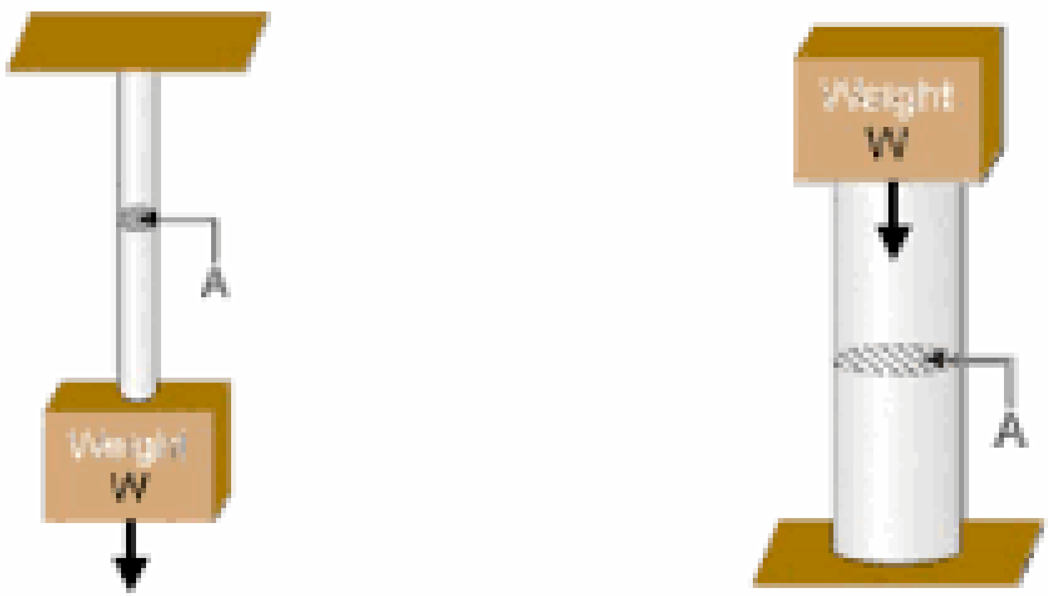
* A material being loaded in

a) compression, b) tension, c) shear.



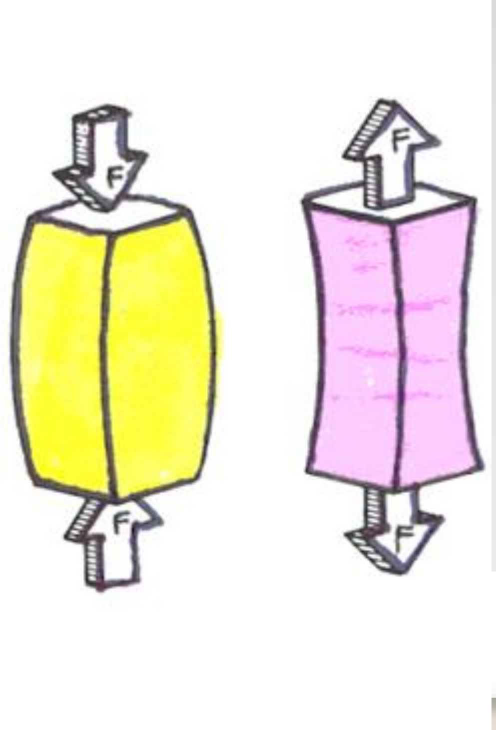
Load

$$\text{Stress} = \frac{\text{Force}}{\text{Cross-Sectional Area}}$$



Tensile Stress **Compressive Stress**

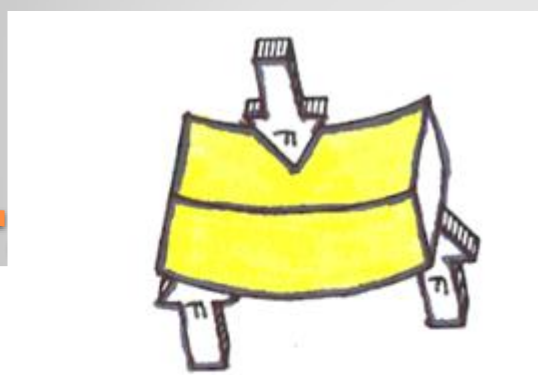
- Axial loading - The applied forces are collinear with the longitudinal axis of the member. The forces cause the member to either stretch or shorten.

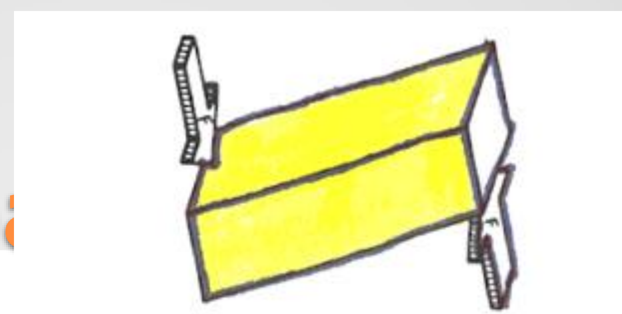


Types of loa

- Forces applied perpendicular to the longitudinal axis of a member. Transverse loading causes the member to bend and deflect from its original position, with internal tensile and compressive strains accompanying the change in curvature of the member

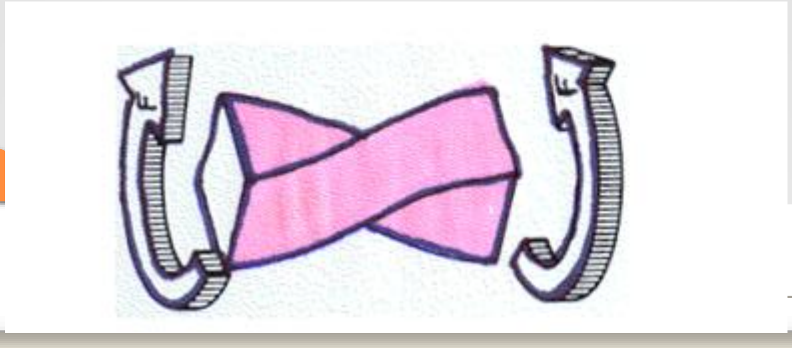
Tr loa



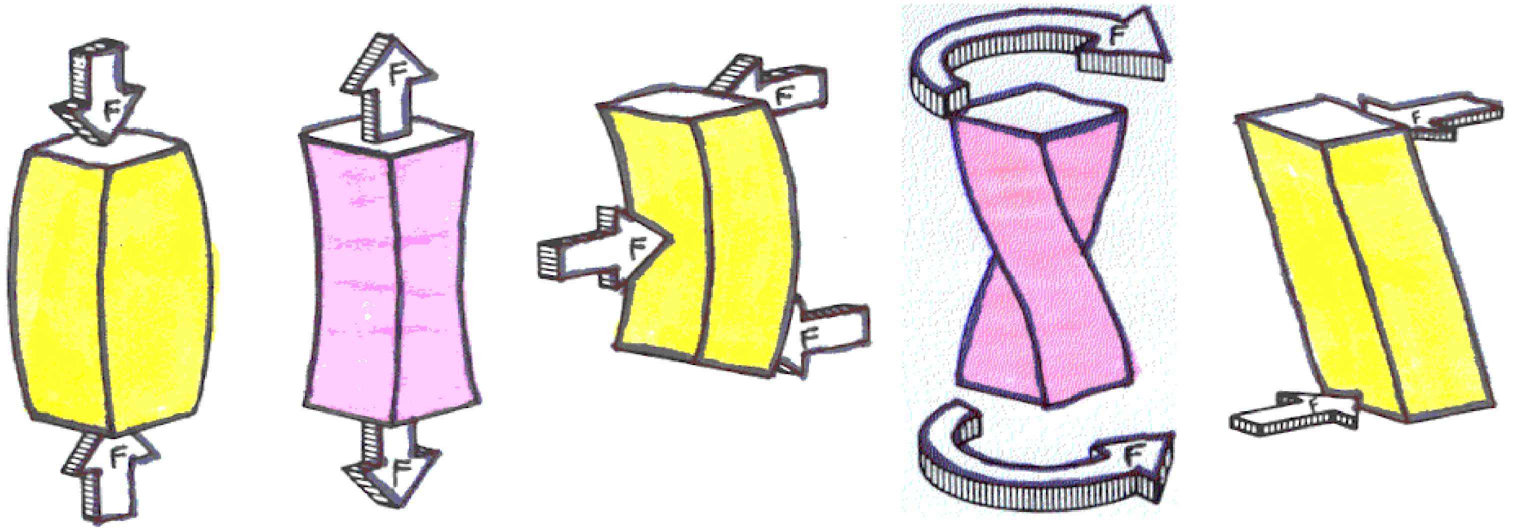


- - Twisting action caused by a pair of externally applied equal and oppositely directed force couples acting on parallel planes or by a single external couple applied to a member that has one end fixed against rotation.

Torsiona



Definition: *STRENGTH of materials* is a branch of applied mechanics that deals with the behaviour of solid bodies subjected to various types of loading



Compression ***Tension (stretched)*** ***Bending*** ***Torsion (twisted)*** ***Shearing***

- A load applied to a mechanical member will induce internal forces within the member called stresses
- cause deformation of the material.
- deformation of the material is called strain
- The applied loads may be axial (tensile or compressive), or shear.

1.1 DIRECT OR NORMAL STRESS

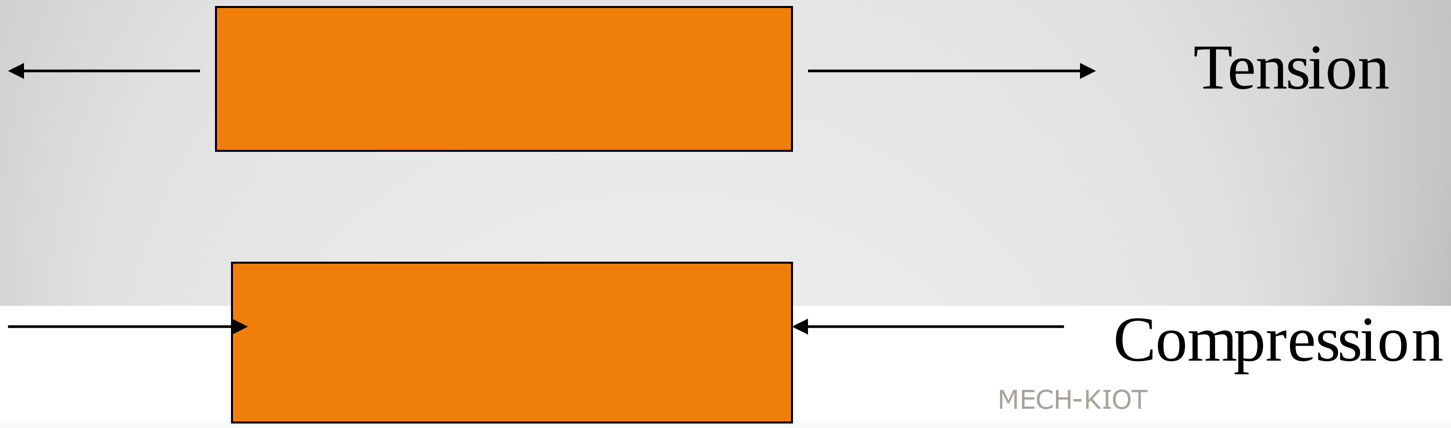
- When a force is transmitted through a body, the body tends to change its shape or deform. The body is said to be strained.

- Direct Stress = $\dfrac{\text{Applied Force (F)}}{\text{Cross Sectional Area (A)}}$

- **Units:** Usually N/m^2 (Pa), N/mm^2, MN/m^2, GN/m^2 or N/cm^2
- **Note:** $1\ N/mm^2 = 1\ MN/m^2 = 1\ MPa$

Direct Stress Contd.

- Direct stress may be tensile, σ_t or compressive, σ_c and result from forces acting perpendicular to the plane of the cross-section



- Axial loading occurs when an object is loaded so that the force is normal to the axis that is fixed.

- force / unit area (internal resistance)
- Type: tensile stress, compressive stress and shear stress

<u>Strain</u>

- change in length to original length ratio.
- Type: tensile strain, compressive strain and shear strain

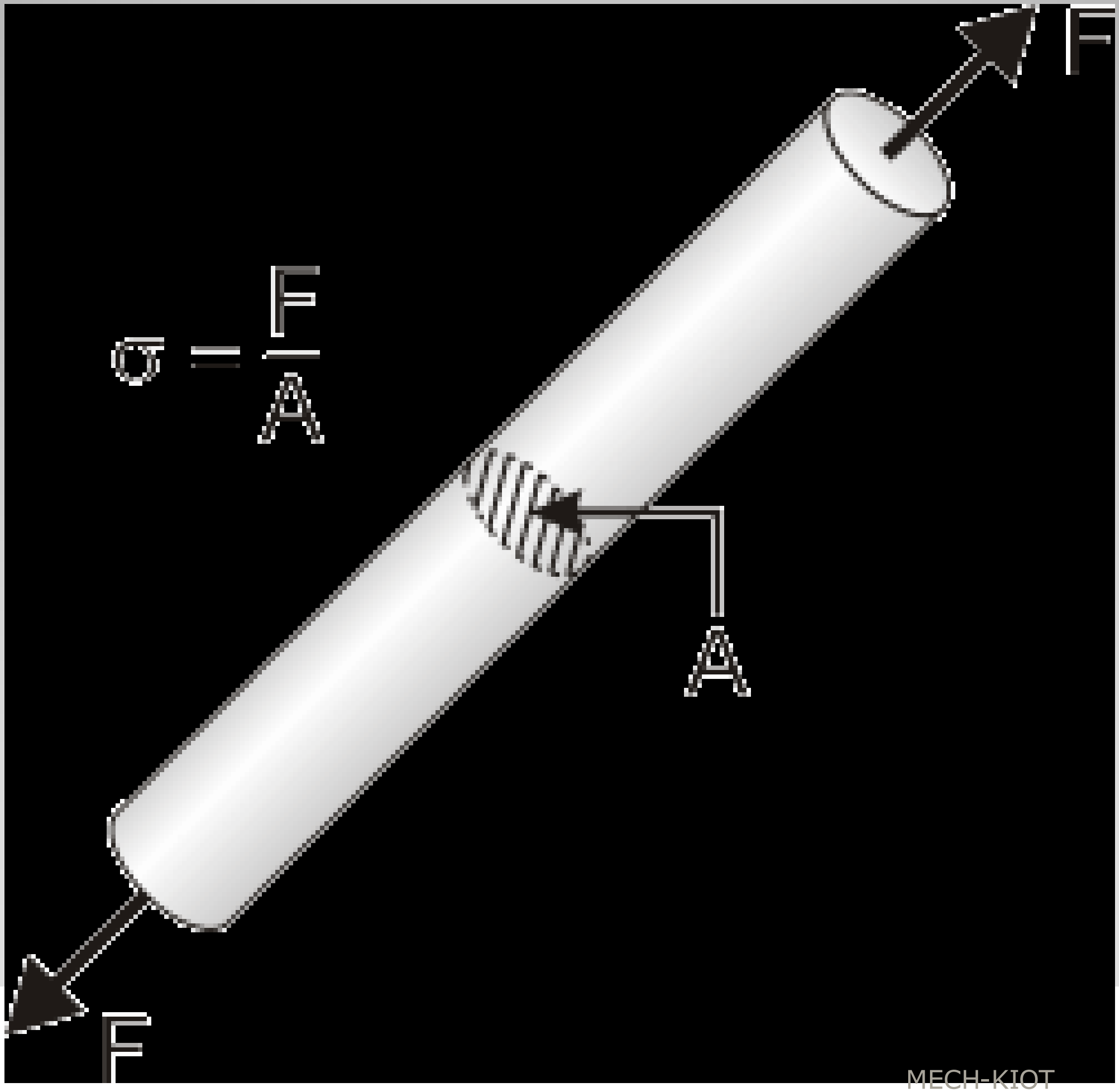
Stress

- Young's modulus, also known as the tensile modulus or elastic modulus, is a measure of the stiffness of an elastic material.
- Ratio of stress to strain
- Its unit is “pa” or N/m^2

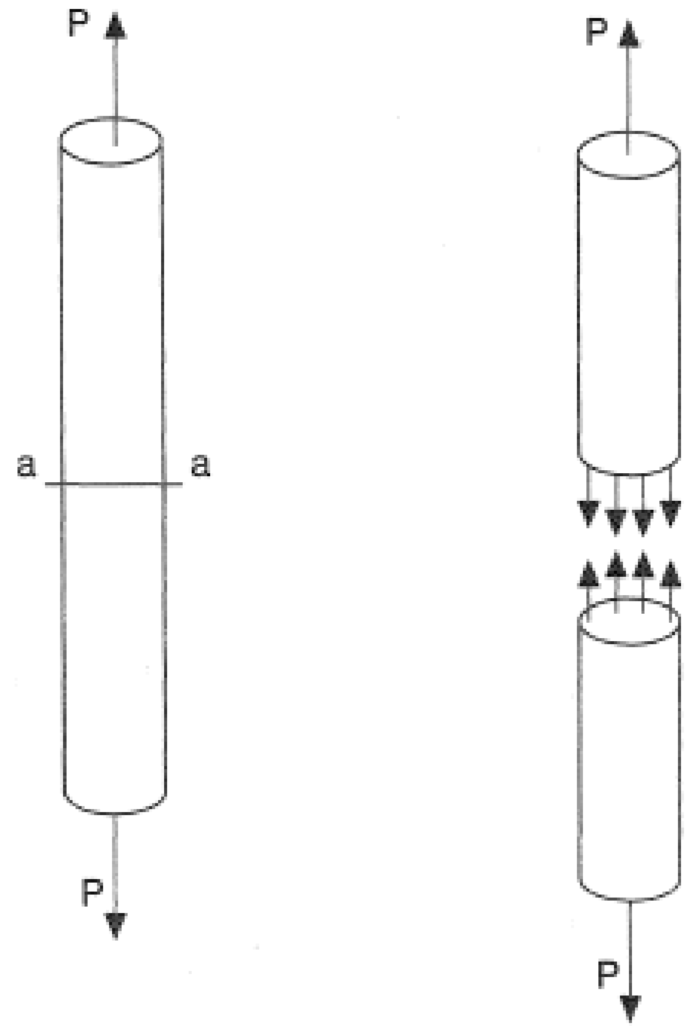
Young’s Modulus:

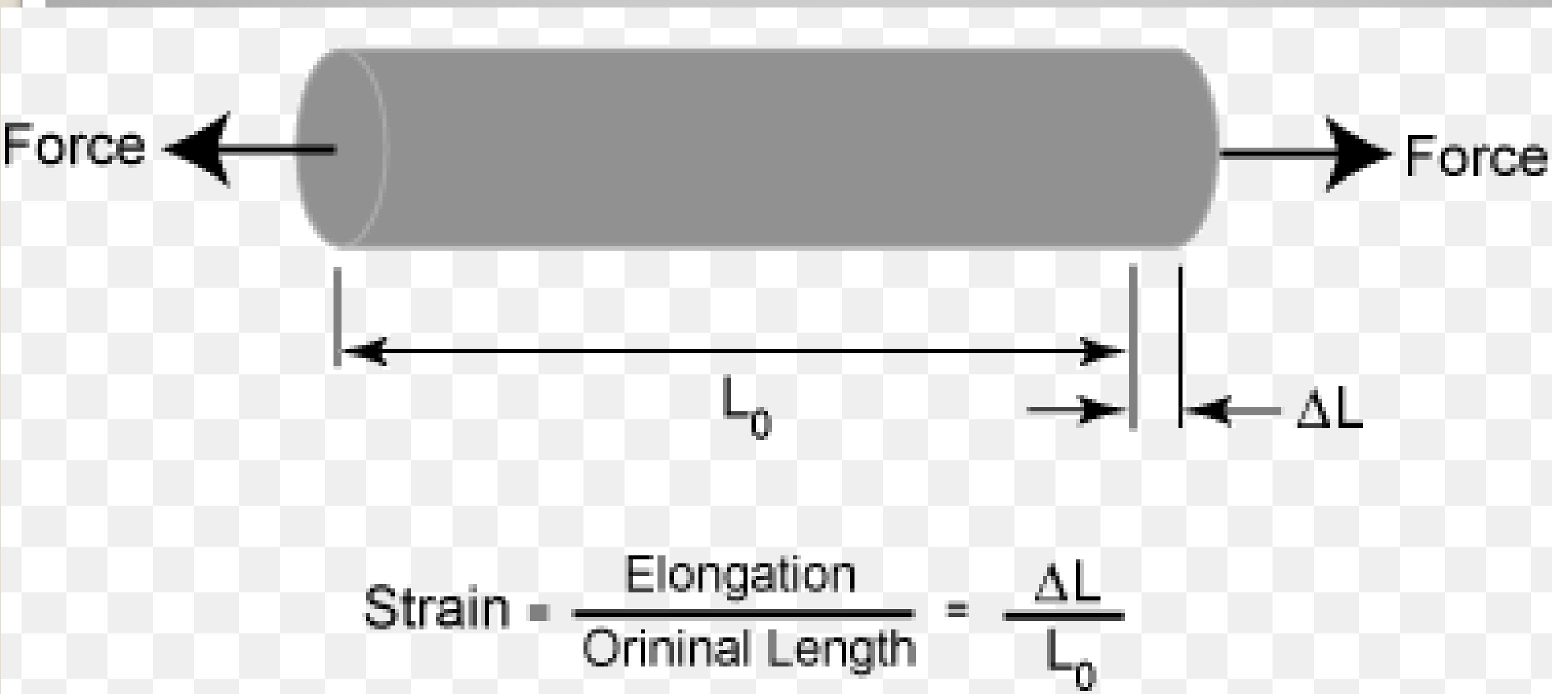
- Poisson’s ratio, named after Simeon Poisson, is the negative ratio of transverse to axial strain.
- When a material is compressed in one direction, it usually tends to expand in the other two directions perpendicular to the direction of compression.
- This phenomenon is called the Poisson Effect.

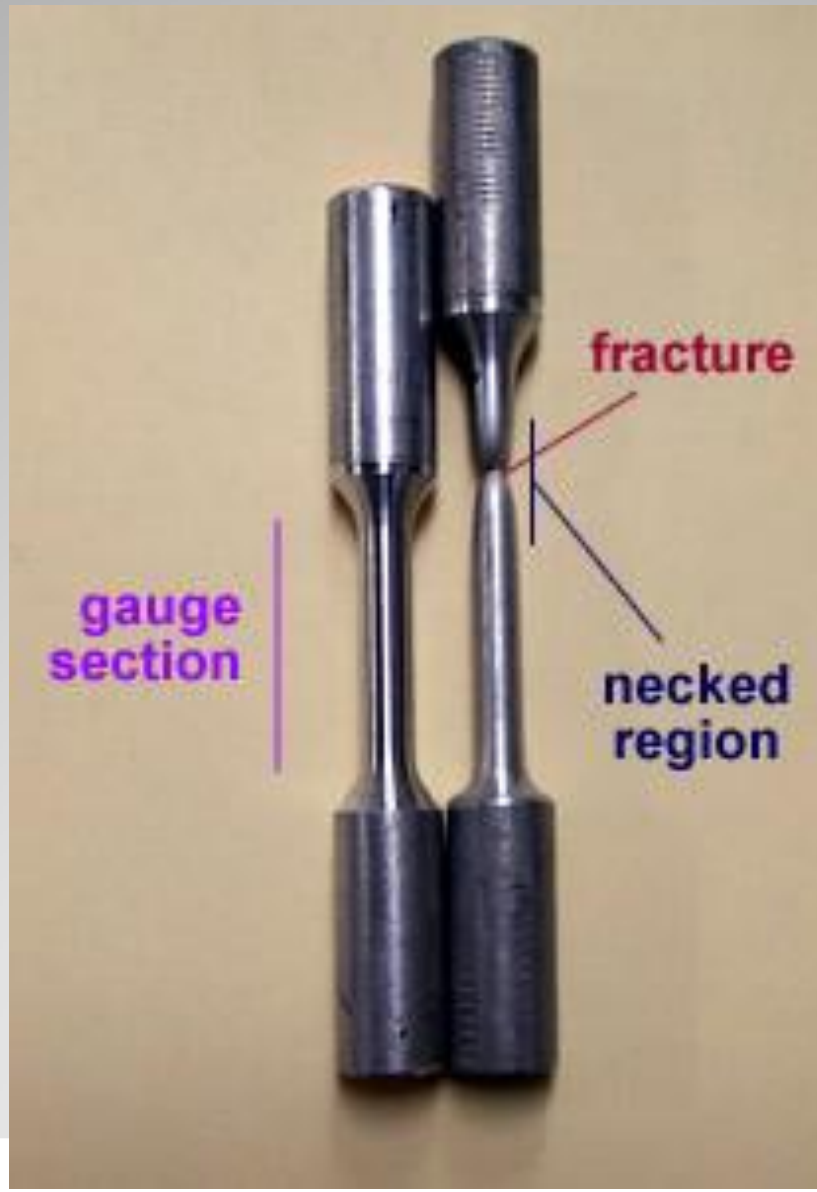
Poisson’s Ratio:



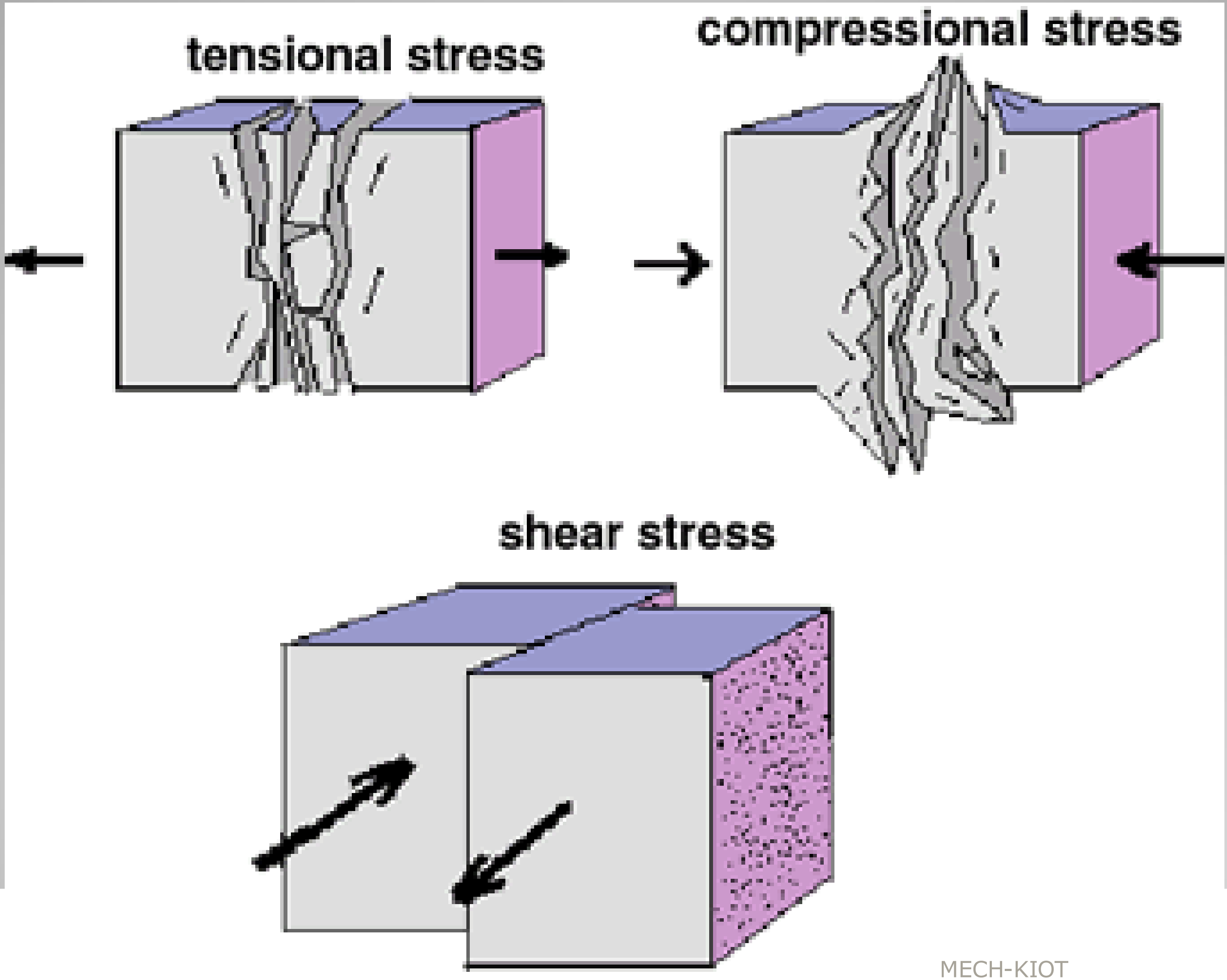
MECH-KIOT

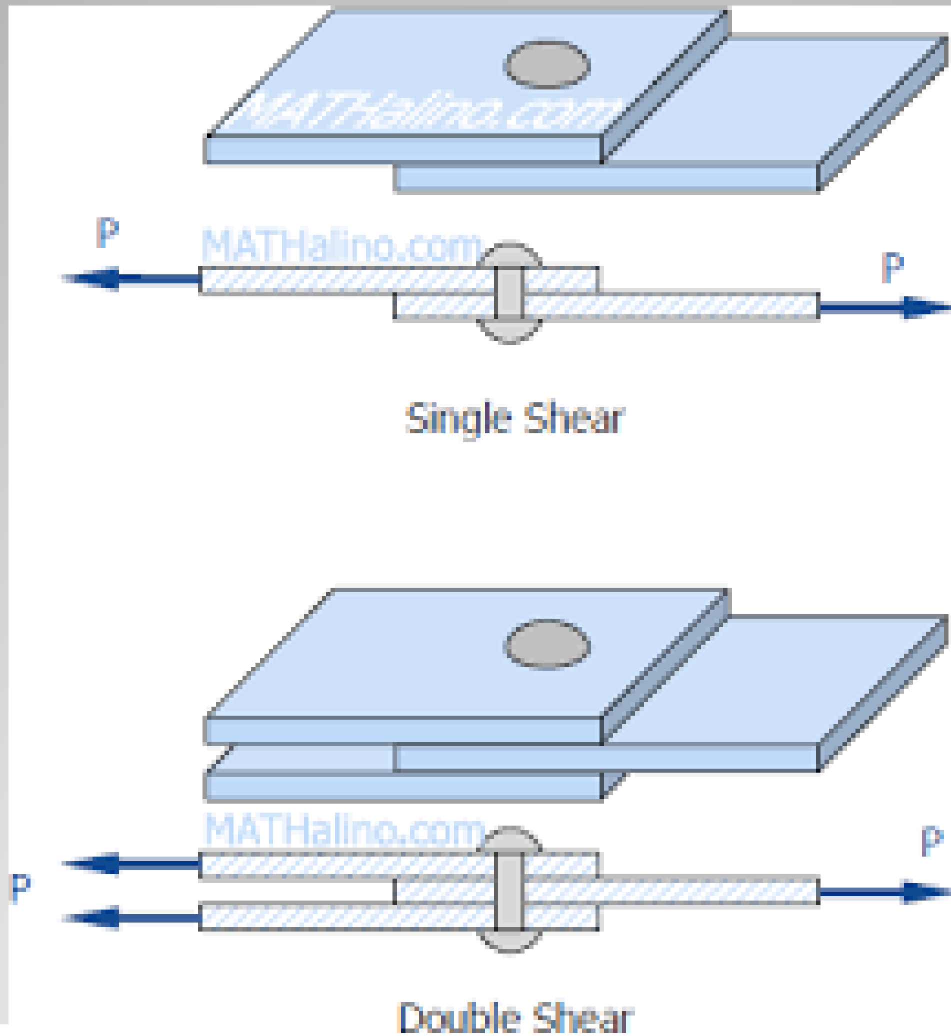

P
a
a
P
P
P


Force
Force
L0
ΔL
Strain = Elongation / Orininal Length = ΔL / L0


fracture
gauge
section
necked
region

- internal forces (stress) requires
    geometry of the member,
    its constraints,
    the loads applied
    and the properties


tensional stress
compressional stress
shear stress


P
P
MATHalino.com
Single Shear
P
P
MATHalino.com
Double Shear

Volumetric Strain

- tensile or compressive stress in all dimensions.
- change in volume of the material.

$$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z$$

(iv) Given ε_D and ε_L as strains on the diameter and length of a cylinder,

Strain on the volume is

$$\varepsilon_v = 2\,\varepsilon_D + \varepsilon_L$$

1.5 Elasticity and Hooke's Law

- All solid materials deform when they are stressed, and as stress is increased, deformation also increases.
- If a material returns to its original size and shape on removal of load causing deformation, it is said to be **elastic**.
- If the stress is steadily increased, a point is reached when, after the removal of load, not all the induced strain is removed.
- This is called the elastic limit.

Hooke's Law

- States that providing the limit of proportionality of a material is not exceeded, the stress is directly proportional to the strain produced.
- If a graph of stress and strain is plotted as load is gradually applied, the first portion of the graph will be a straight line.
- The slope of this line is the constant of proportionality called modulus of Elasticity, E or Young's Modulus.
- It is a measure of the stiffness of a material.

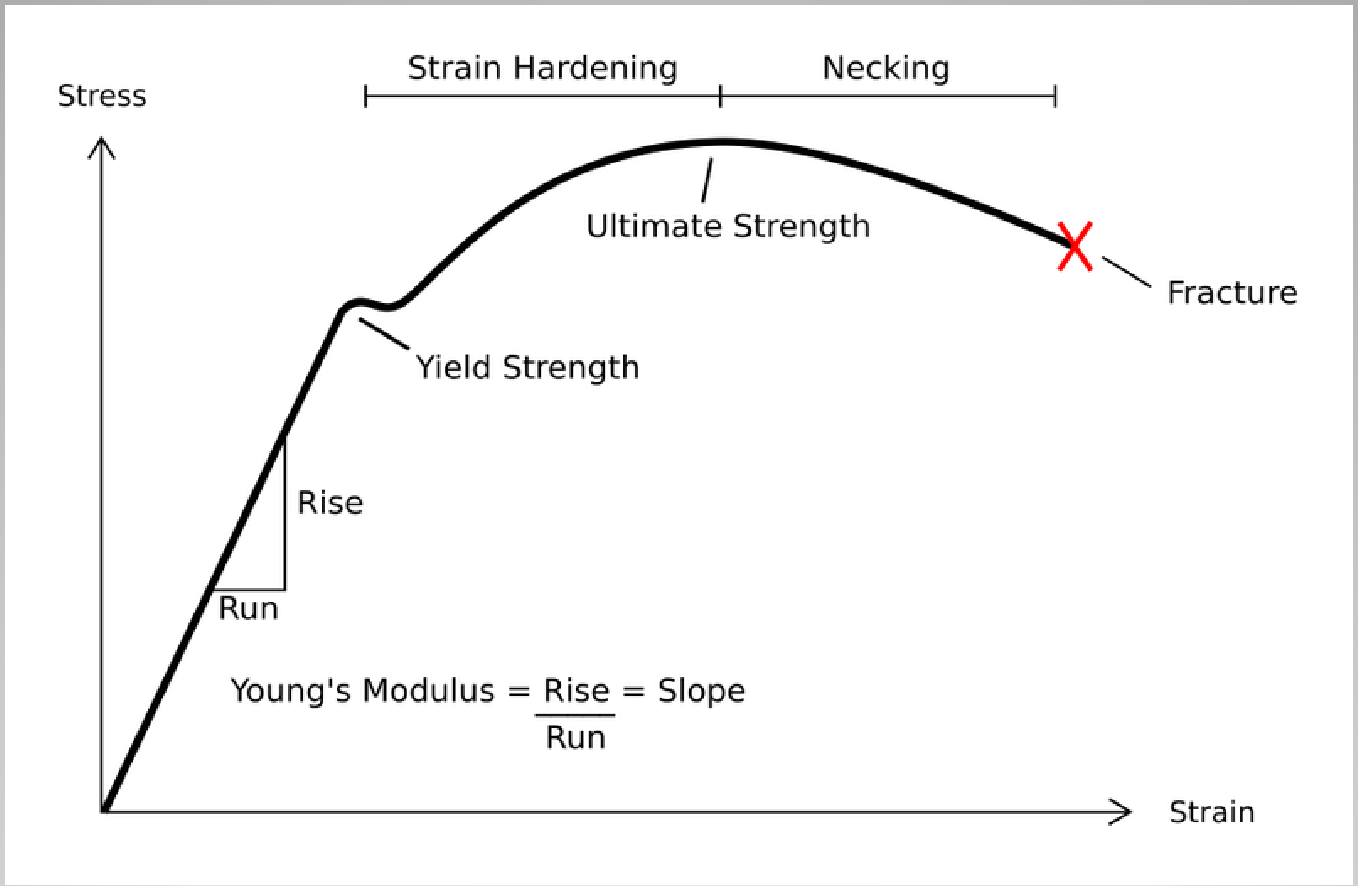
Hooke's Law

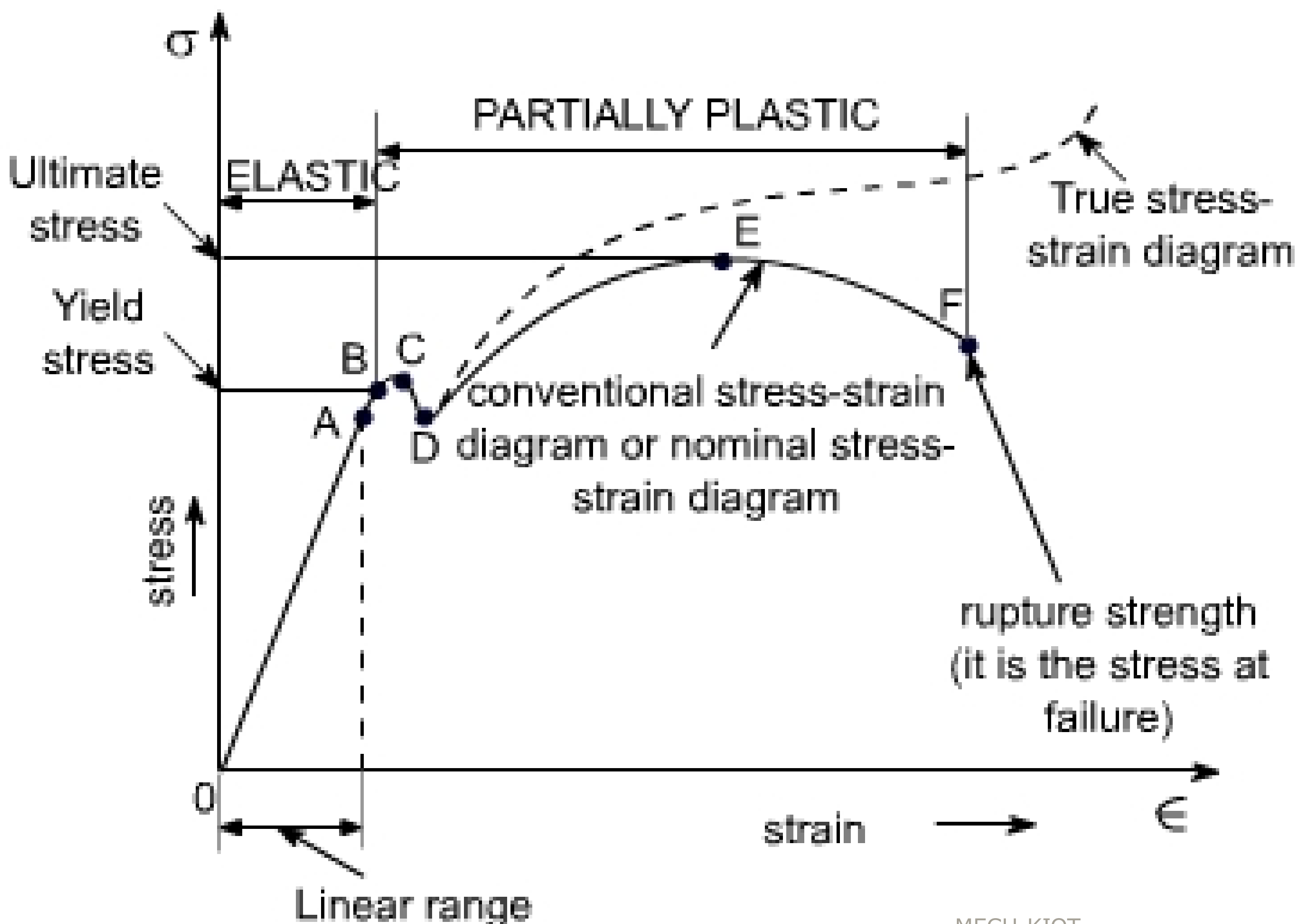
Modulus of Elasticity, E = $\dfrac{Direct\ stress}{Direct\ strain} = \dfrac{\sigma}{\varepsilon}$

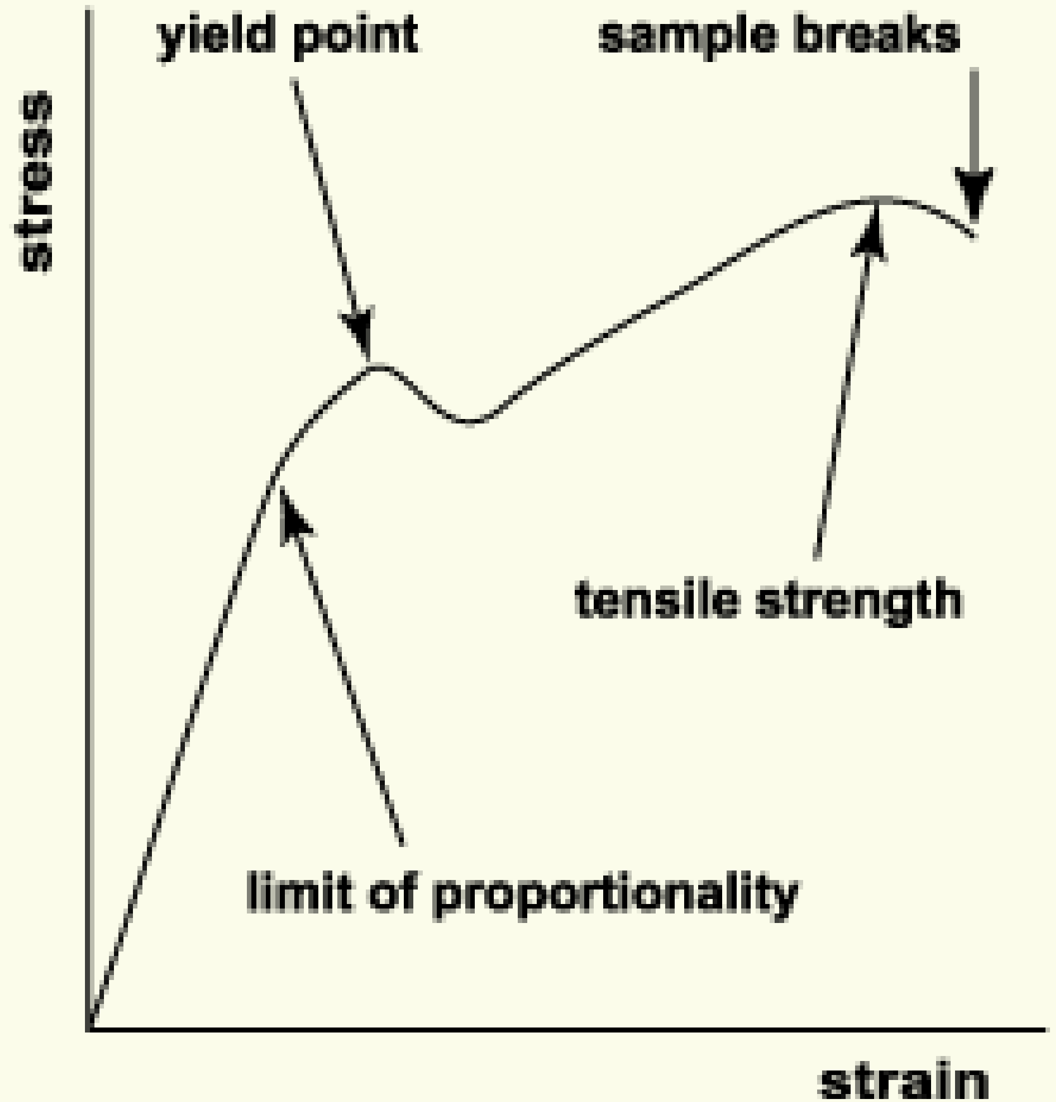
Also: For Shear stress: Modulus of rigidity or shear modulus, G = $\dfrac{Shear\ stress}{Shear\ strain} = \dfrac{\tau}{\gamma}$

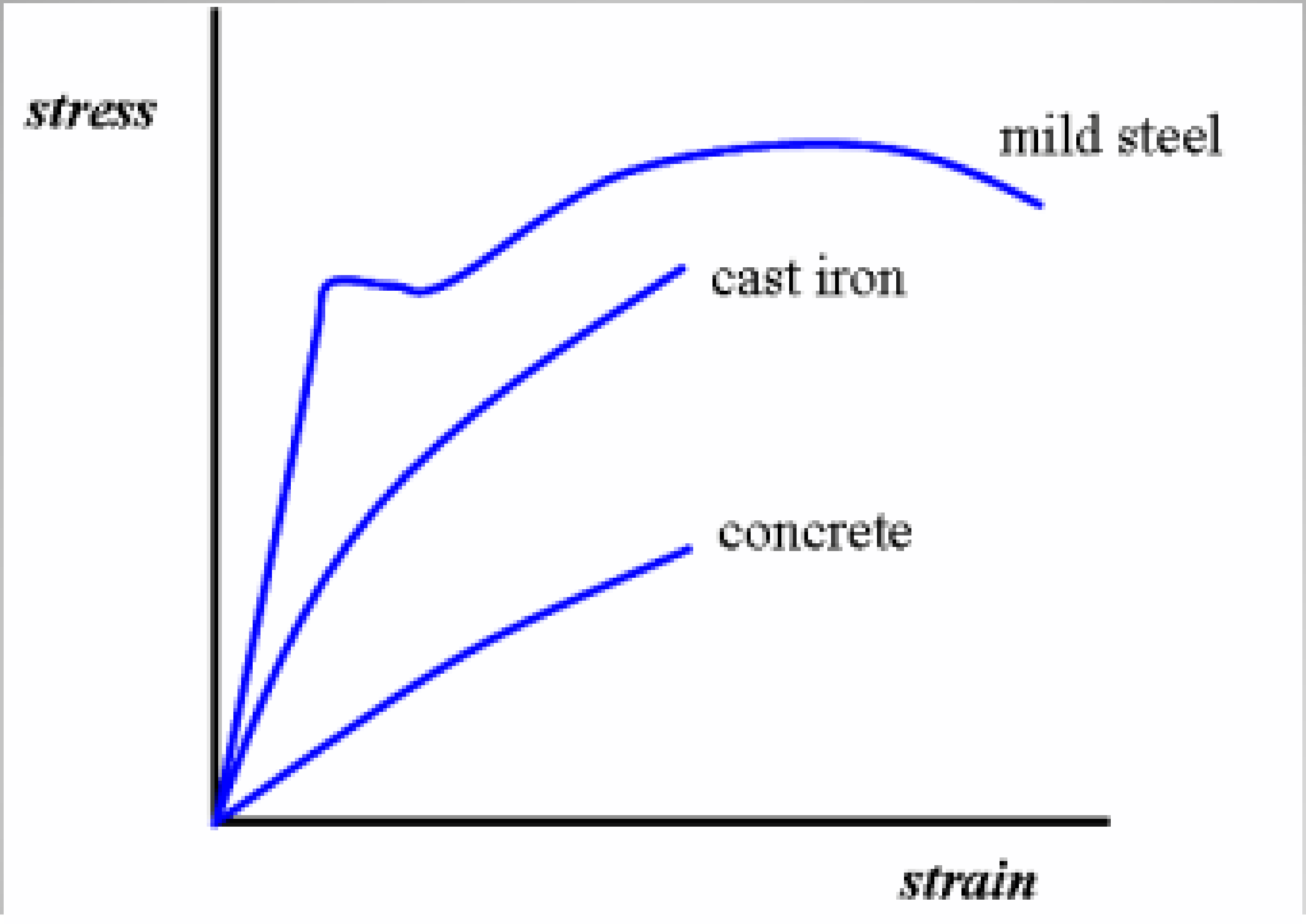
Also: Volumetric strain, ε_v is proportional to hydrostatic stress, σ within the elastic range

i.e. : $\sigma / \varepsilon_v = K$ called **bulk modulus**.


Strain Hardening
Necking
Stress
Ultimate Strength
Fracture
Yield Strength
Rise
Run
Young's Modulus = Rise = Slope
Run
Strain


σ
PARTIALLY PLASTIC
ELASTIC
Ultimate stress
Yield stress
True stress-strain diagram
E
F
B
C
A
D
conventional stress-strain diagram or nominal stress-strain diagram
stress
rupture strength (it is the stress at failure)
0
strain
∈
Linear range


yield point
sample breaks
stress
tensile strength
limit of proportionality
strain


stress
mild steel
cast iron
concrete
strain

Factor of Safety

- The load which any member of a machine carries is called working load, and stress produced by this load is the working stress.
- Obviously, the working stress must be less than the yield stress, tensile strength or the ultimate stress.
- This working stress is also called the permissible stress or the allowable stress or the design stress.

Factor of Safety Contd.

- Some reasons for factor of safety include the inexactness or inaccuracies in the estimation of stresses and the non-uniformity of some materials.

$$\text{Factor of safety} = \frac{\textit{Ultimate or yield stress}}{\textit{Design or working stress}}$$

Note: Ultimate stress is used for materials e.g. concrete which do not have a well-defined yield point, or brittle materials which behave in a linear manner up to failure. Yield stress is used for other materials e.g. steel with well defined yield stress.

Results From a Tensile Test

(a) Modulus of Elasticity, $$E = \frac{Stress\ up\ to\ limit\ of\ proportionality}{Strain}$$

(b) Yield Stress or Proof Stress (See below)

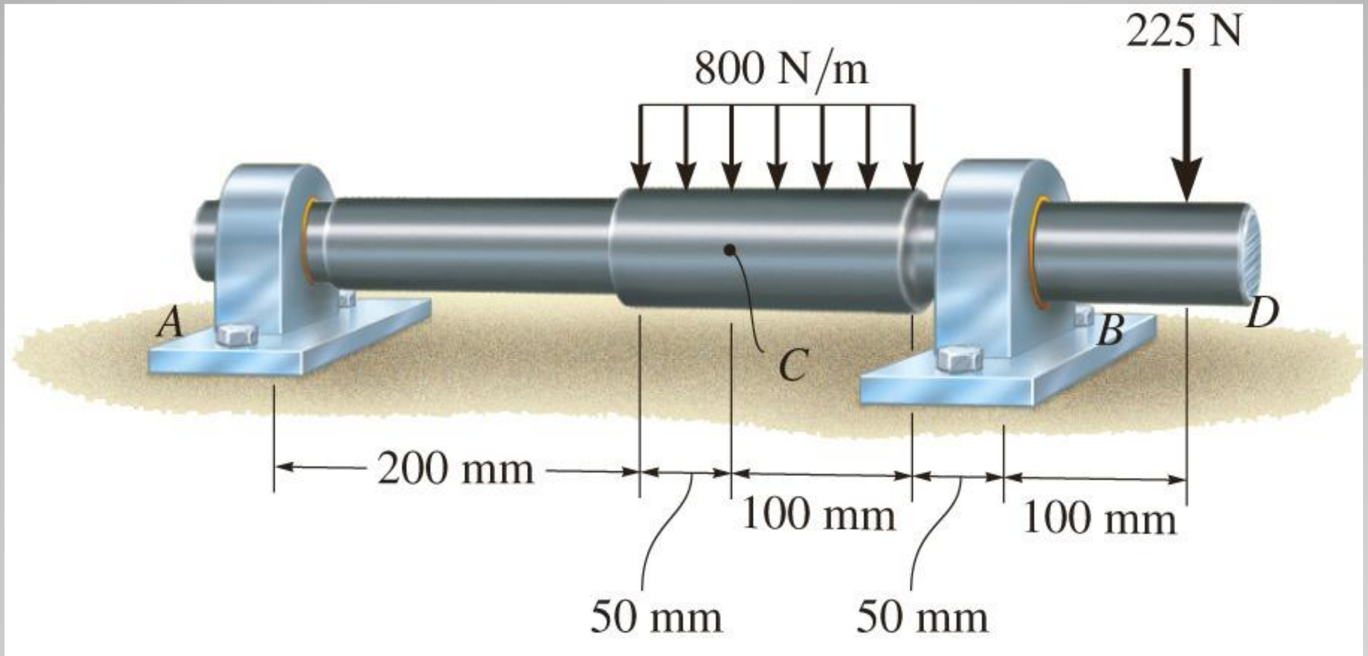
(c) Percentage elongation = $$\frac{Increase\ in\ gauge\ length}{Original\ gauge\ length} x\ 100$$

(d) Percentage reduction in area = $$\frac{Original\ area - area\ at\ fracture}{Original\ area} x\ 100$$

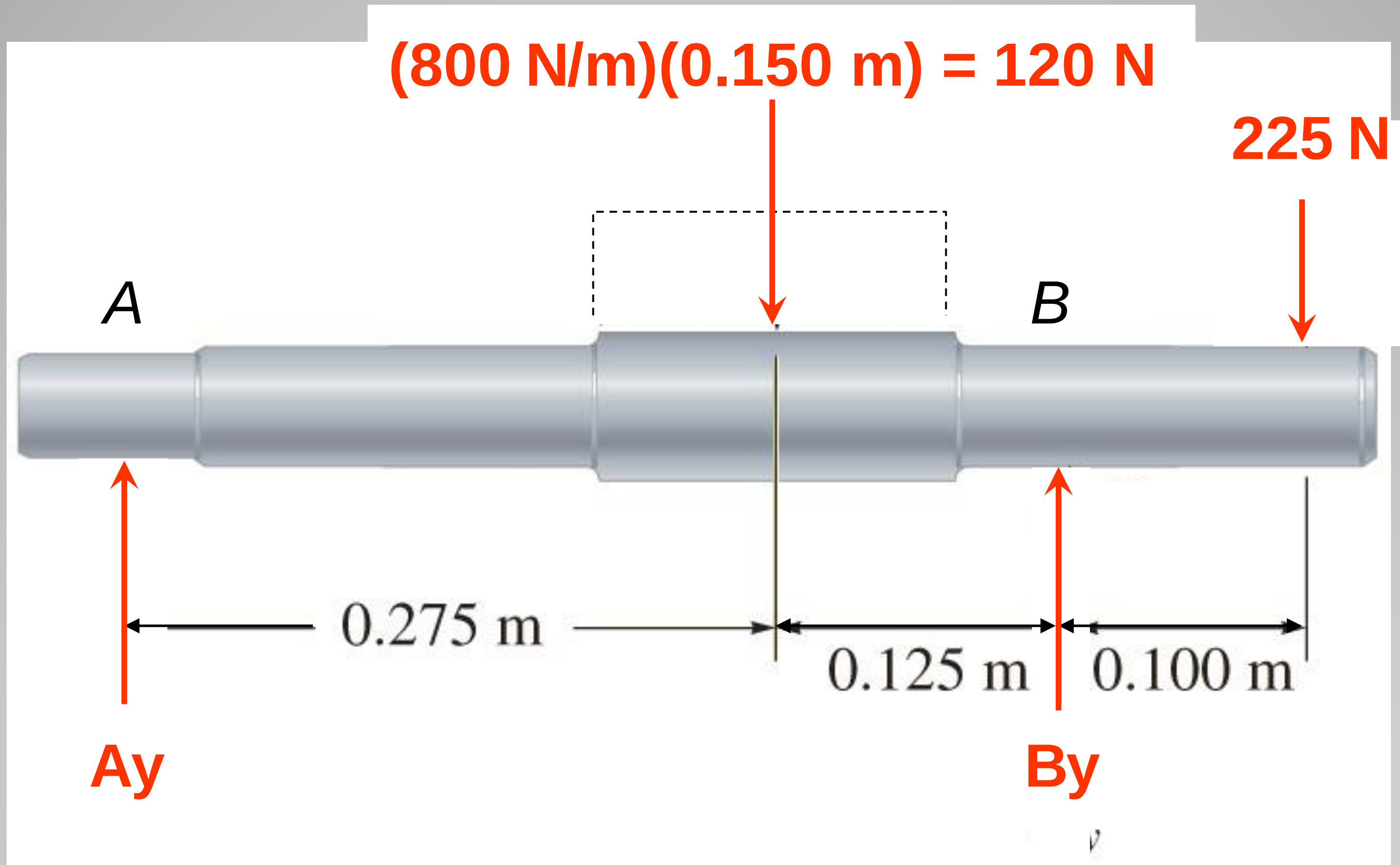
(e) Tensile Strength = $$\frac{Maximum\ load}{Original\ cross\ sectional\ area}$$

The percentage of elongation and percentage reduction in area give an indication of the ductility of the material i.e. its ability to withstand strain without fracture occurring.

Example: Find the vertical reactions at A and B for the shaft shown.



FBD

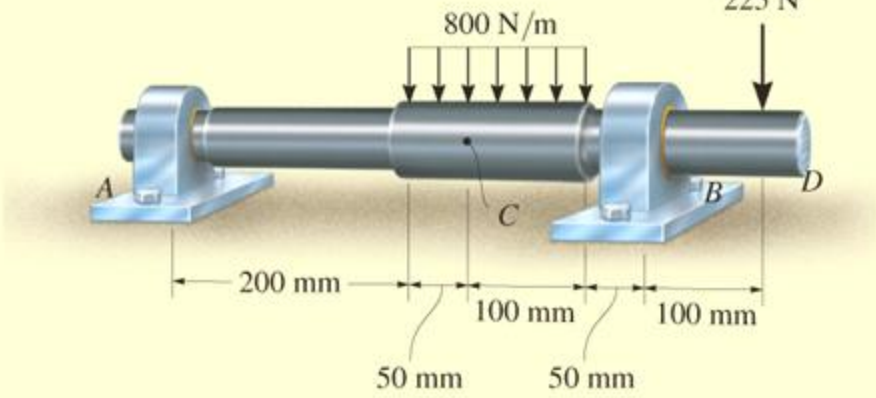


Comment on dashed line around the distributed load.

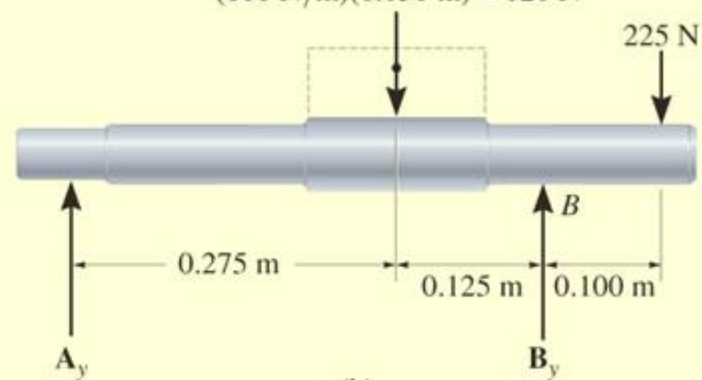
See Page 10, Procedure for Analysis for FBD hints.

EXAMPLE 1.2

Determine the resultant internal loadings acting on the cross section at C of the machine shaft shown in Fig. 1–5a. The shaft is supported by bearings at A and B, which exert only vertical forces on the shaft.



(a)

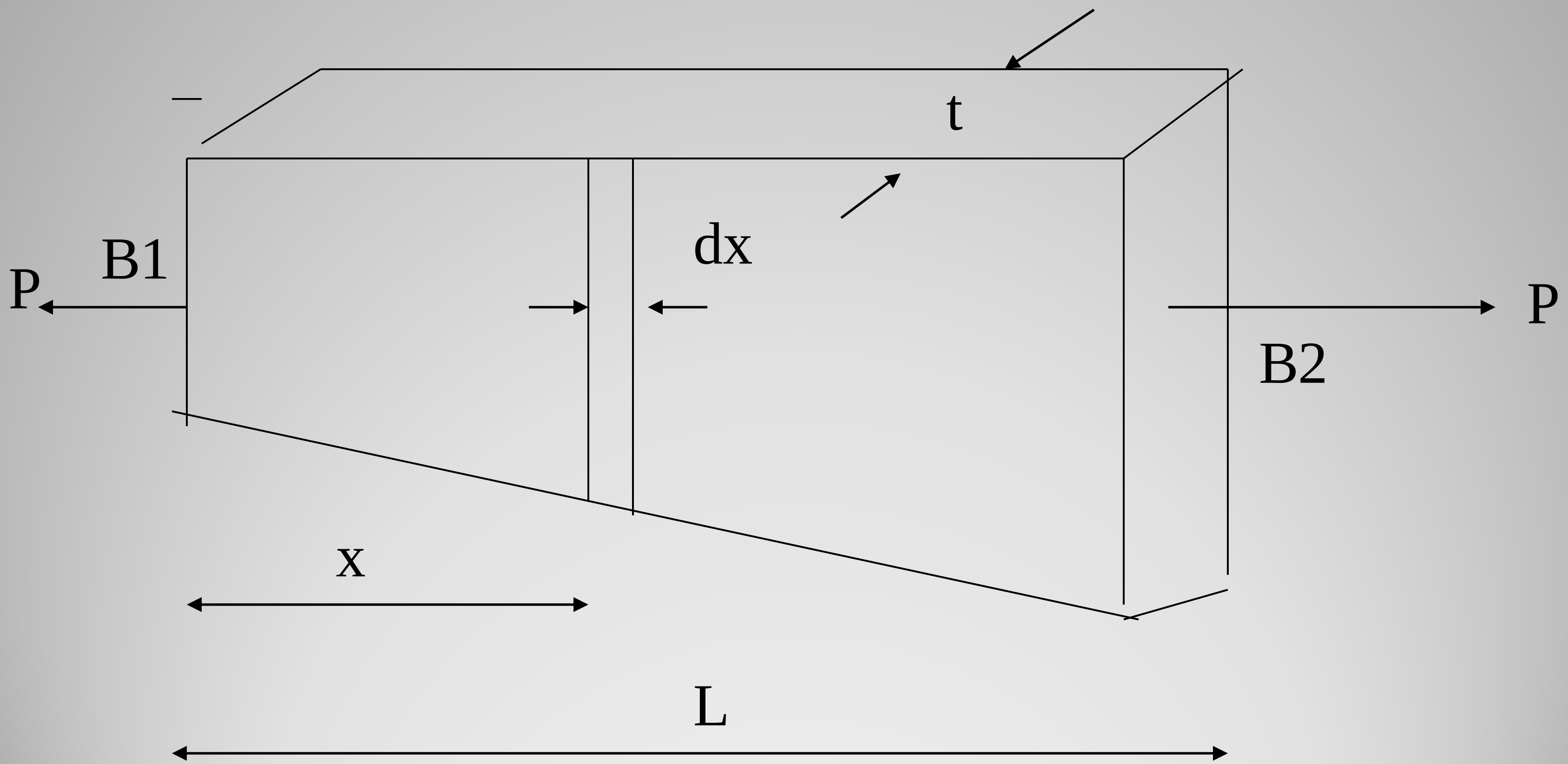


(b)

Fig. 1–5

Fig. 1–5b

Diagram of a Trapezoidal Steel Plate



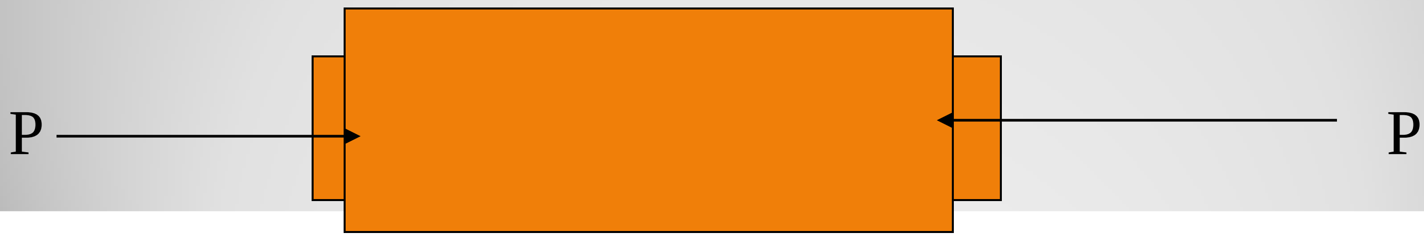
- Under the action of a longitudinal stress, a body will extend in the direction of the stress and contract in the transverse or lateral direction
- (see Fig. below).
- The reverse occurs under a compressive load.

1.9 Lateral Strain and Poisson’s Ratio

-

Stress Effects

Longitudinal Tensile Stress Effect



Longitudinal Compressive Stress Effect

Poisson's Ratio

Lateral strain is proportional to the longitudinal strain,
with the constant of proportionality called 'Poisson's ratio' with symbol, ν .

Mathematically, $$\nu = \frac{\text{Lateral strain}}{\text{Direct or longitudinal strain}}$$

For most metals, the range of ν is 0.28 to 0.33.

Deformation due to self weight:

The bar … n due to

1.11. Principle of Superposition

- It states that the effects of several actions taking place simultaneously can be reproduced exactly by adding the effect of each action separately.
- The principle is general and has wide applications and holds true if:
- (i) The structure is elastic
- (ii) The stress-strain relationship is linear
- (iii) The deformations are small.

1.10 Thermal Strain

Most structural materials expand when heated,

in accordance to the law: $\varepsilon = \alpha T$

where ε is linear strain and

α is the coefficient of linear expansion;

T is the rise in temperature.

That is for a rod of Length, L;

if its temperature increased by t, the extension,

dl = α L T.

Thermal Strain Contd.

As in the case of lateral strains, thermal strains do not induce stresses unless they are constrained. The total strain in a body experiencing thermal stress may be divided into two components:

Strain due to stress, ε_σ and

That due to temperature, ε_T .

Thus: $\varepsilon = \varepsilon_\sigma + \varepsilon_T$

$$\varepsilon = \frac{\sigma}{E} + \alpha T$$

Sagging:

Saggin

o weight of

Hogging:

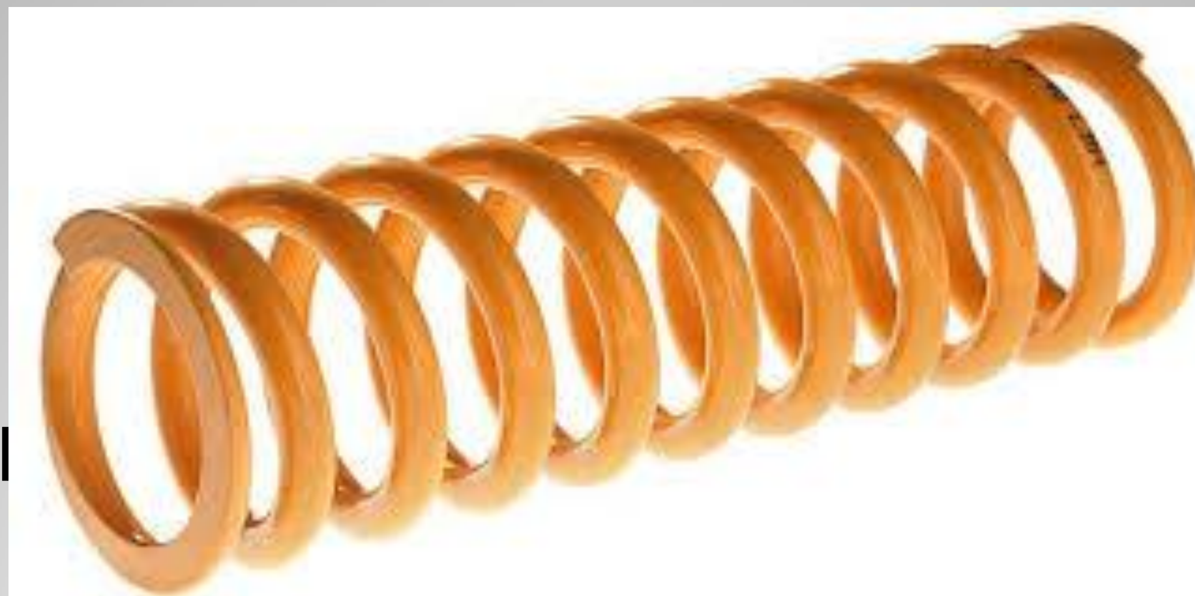
Hoggi

ck due to

The cer… n is a simply … n.

Simply supported Beam:

Continuous beam:



Helical springs:

Cylindrical shells:

Thin shell:

Sphe

Acid and

Spherical Shell: