SIMPLE STRESS AND STRAIN

1. STRESS :

Each material is elastic in nature. Whenever some external force acts on a body, it undergoes some deformation. Due to these facts, it sets up some resistance to deformation. This is called or known as stress. It is expressed as resistance per unit area of deformation.

Stress (σ):

Stress is the applied force or system of forces that tends to deform a body.

Stress...

- $Stress = \frac{External\ deforming\ force}{Area} = \frac{F}{A}$
- Dimensional formula of the stress = $\frac{[MLT^{-2}]}{L^2}$

  $\therefore = [ML^{-1}T^{-2}]$
- The SI unit of stress is $Nm^{-2} = (Pa)scal$

  Same as that of pressure

Types of Stress...

- The stress developed in a body depends upon how the external forces are applied over it. On this basis, there are two types of stress ,

  i. **Normal Stress**

  ii. **Tangential Stress**

Normal Stress

- Is a stress that occurs when the surface of the body is loaded by an axial force.

$$\sigma = \frac{P}{A}$$

σ – Normal Stress

P – Axial Force

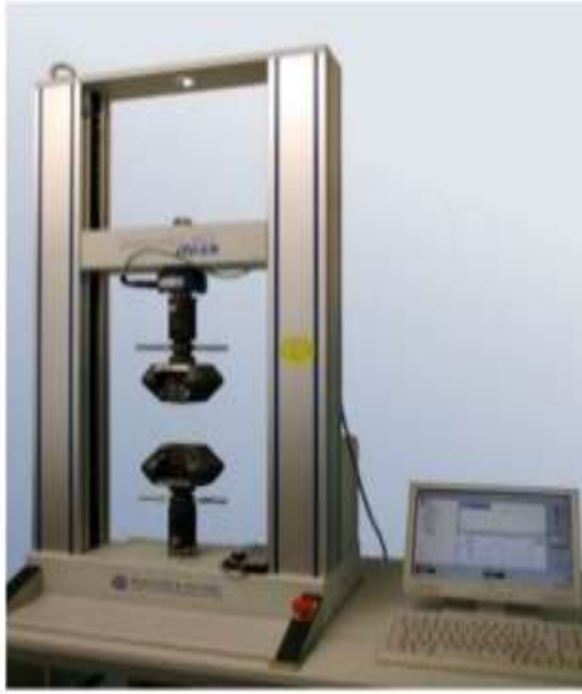
A – Cross Sectional Area

- Normal stress is of two types;
  - i. **Tensile stress**
  - ii. **Compressive stress**

Tensile stress:

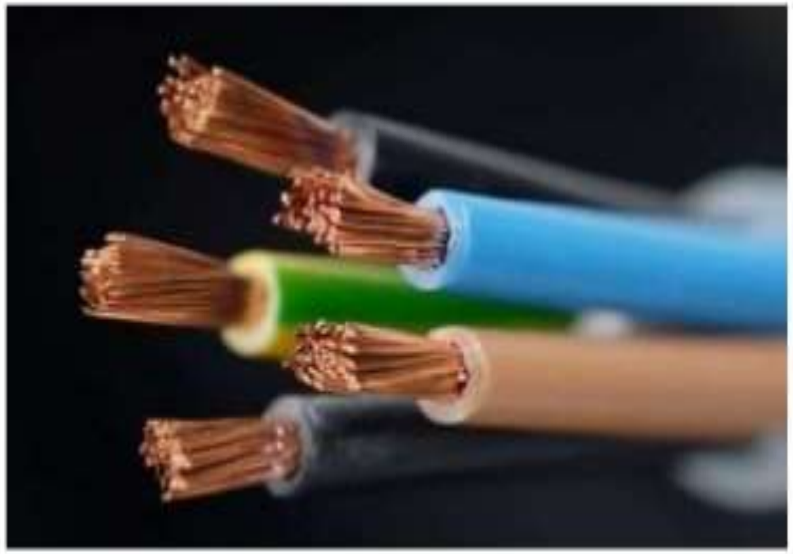
- Is the stress state leading to expansion; that is, the length of a material tends to increase in the tensile direction.

This is an example of tensile stress tester (Universal Testing Machine)



Ductile behavior:

- Ductility is a solid material's ability to deform under tensile stress.



Copper wires

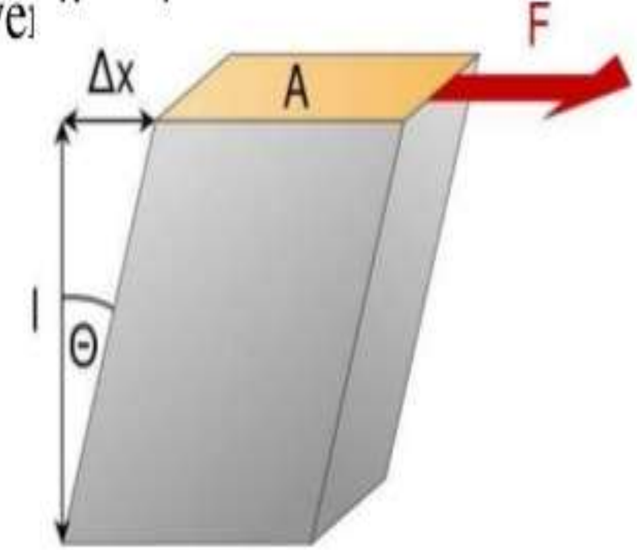
Compressive stress:

- A force that attempts to squeeze or compress a material.

- Here, the Universal Testing Machine (UTM) is testing a concrete block.

Tangential Stress

- A force acting in a generally horizontal direction; *especially* : a force that produces mountain folding and ove



Brittle behavior:

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

STRAIN

Strain (ε)

- Is the change in the size or shape of a body due to the deforming force.Type equation here.
- i.e.

$$Strain, = \frac{Change\ in\ Dimension}{Original\ dimension}$$

- **Strain is Dimensionless hence no unit**

Types of Strain;

- Since the deforming force can produce three of deformations (i.e. Change in length, or volume or shape) in a body, there are three types of strain;

    i. Longitudinal strain

    ii. Volumetric strain

    iii. Shearing strain

Longitudinal Strain

- Is when the deforming force produces change in length.

- $Longitudinal\ Strain = \frac{Change\ in\ Length}{Original\ Length} = \frac{l}{L}$

$$\therefore \varepsilon_{\text{long}} = \frac{l}{L}$$

Volumetric Strain

- Is when the deforming force produces change in the volume.

$$Volumetric\ Strain = \frac{Change\ in\ Volume}{Original\ Volume} = \frac{\Delta V}{V}$$

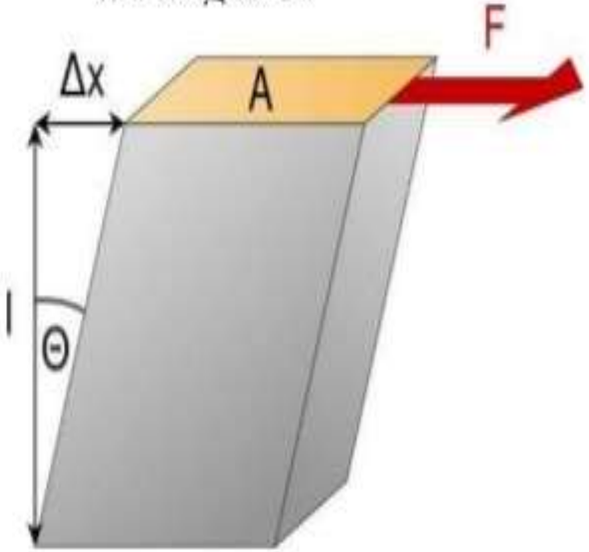
$$\therefore \varepsilon_{\text{vol}} = \frac{\Delta V}{V}$$

Shearing Strain

- Is when the deforming force produces change in the shape of the body.
- It is measured by the angle θ (in radian) through which a line originally perpendicular to the fixed face is turned due to the application of the tangential force.

Shearing Strain ...

- The figure below is said to be sheared through an angle θ.



- Shearing strain = θ

$$= \tan\theta$$

$$= \frac{\Delta x}{l}$$

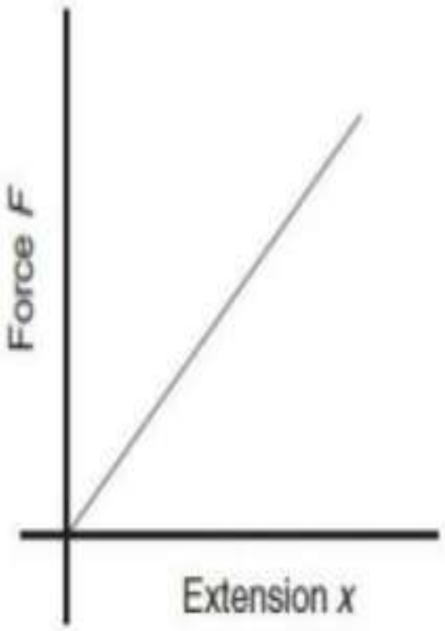
Elasticity

- Elasticity is the tendency of solid materials to return to their original shape after being forces are applied on them.
- When the forces are removed, the object will return to its initial shape and size if the material is elastic.
- In other words, The deformation disappears completely, after removal of external forces.
- Steel cables, rubber bands, springs are the examples of the elastic materials.

Elastic Limit

- Is the maximum stress from which an elastic body will recover its original state after the removal of the deforming force.
- It differs widely for different materials.
- It is very high for a substance like steel and low for a substance like lead.

Limits of proportionality

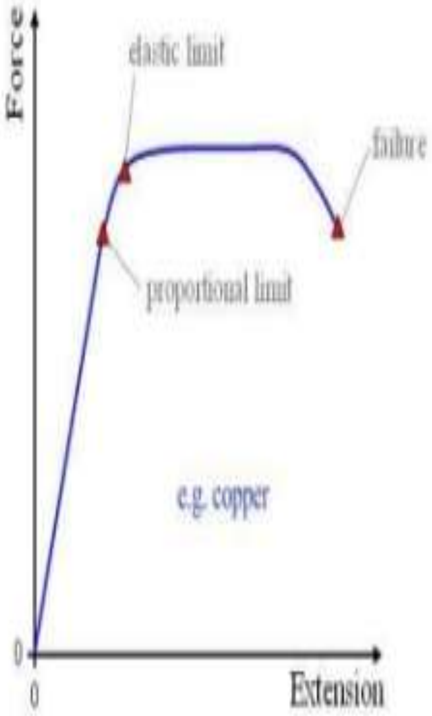


- If a tensile force applied to a uniform bar of mild steel is gradually increased and the corresponding extension of the bar is measured, then provided the applied force is not too large, a graph depicting these results is likely to be as shown in Figure.

- Since the graph is a straight line, **extension is directly proportional to the applied force. (Hooke's Law)**

The point on the graph where extension is no longer proportional to the applied force is known as the limit of proportionality.

Limits of elasticity

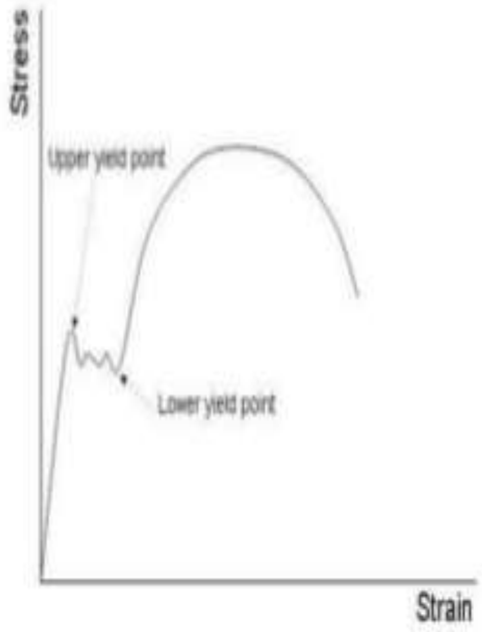


- As mentioned, limits of proportionality … Just beyond this point the material can behave in a non-linear elastic manner, until the elastic limit is reached.

- If the applied force is large, it is found that the material becomes plastic and no longer returns to its original length when the force is removed.

In short, The value of force up to and within which, the deformation entirely disappears on removal of the force is called limit of elasticity

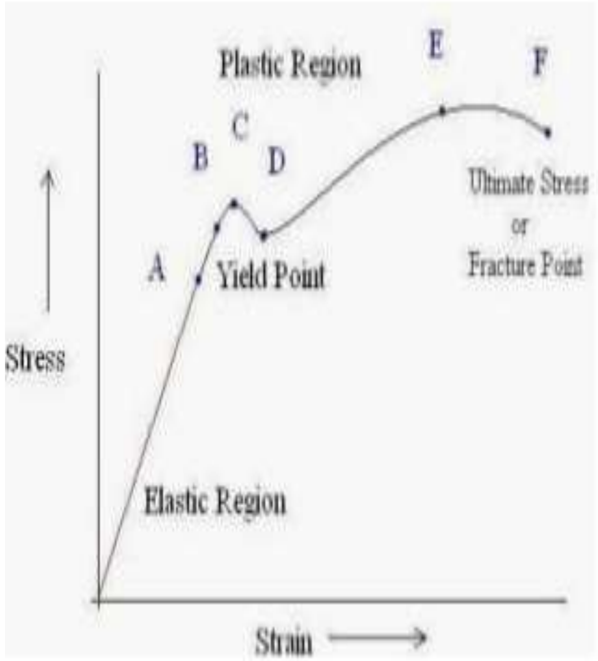
Yield limit



•When specimen is stressed beyond elastic limit, strain increases more rapidly than the stress. Because, sudden elongation of the specimen takes place, without appreciable increase in the stress. This phenomena is known as yielding of material.

- The portion between upper yield point and lower yield point is called yield stage.
- The stress corresponding to point of upper yield point is called yield stress.

Ultimate stress

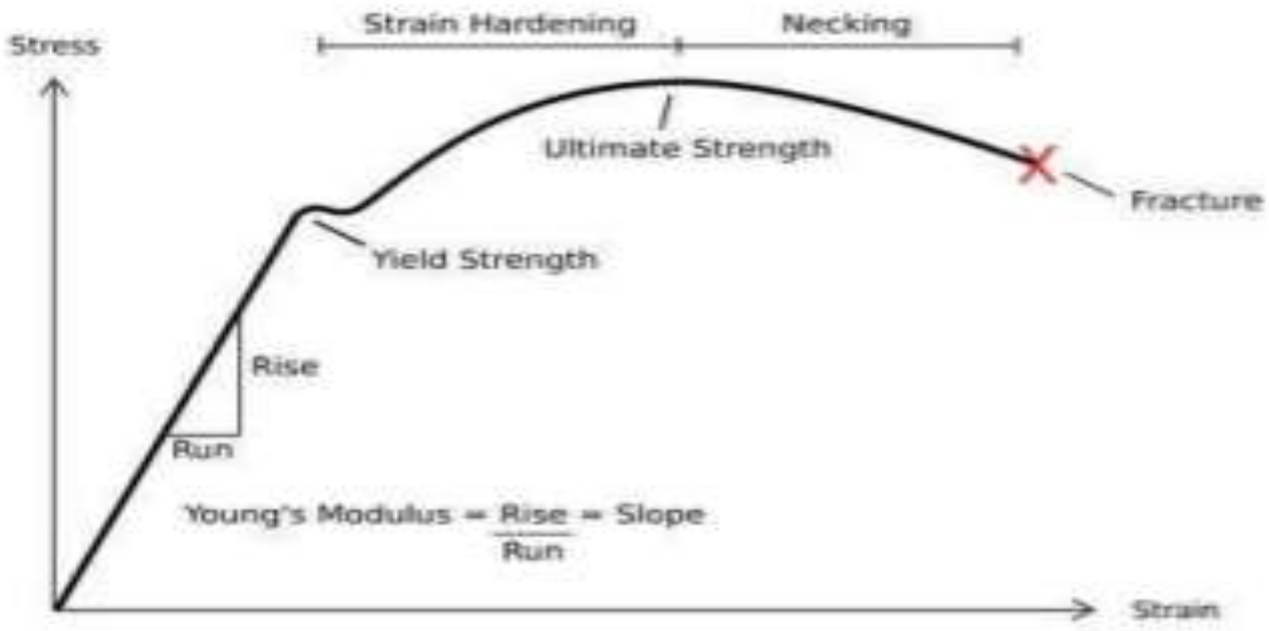


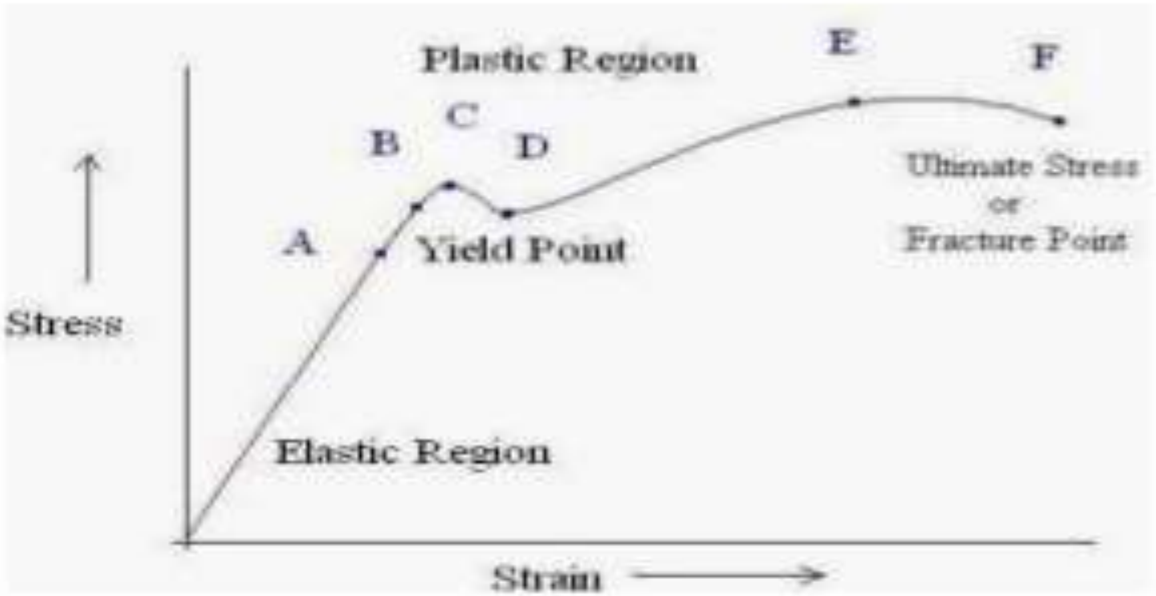
•Because of the plastic deforms, the material strain hardens and further strain beyond lower yield point requires an increase in stress.

•The maximum stress reached at point E is called ultimate stress.

•In other words, Stress corresponding to the maximum load taken by the specimen is called ultimate stress.

Strain hardening





- The phenomenon of increase in stress from D to E is known as strain hardening.
- During strain hardening, the extension of the specimen is quite large. Also if the specimen has mill scale or rust, it will be flaked off.

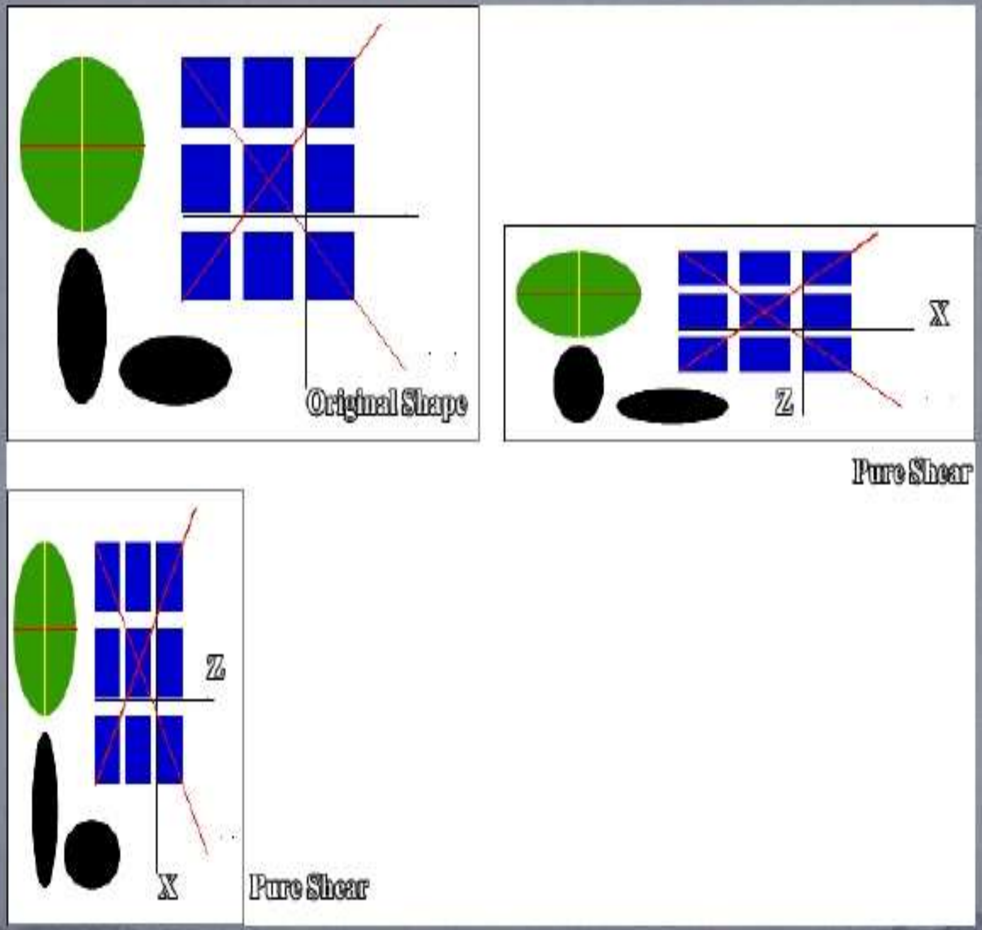
DEFORMATION OF A BODY DUE TO FORCE ACTING ON IT

Consider a body subjected to a tensile stress-

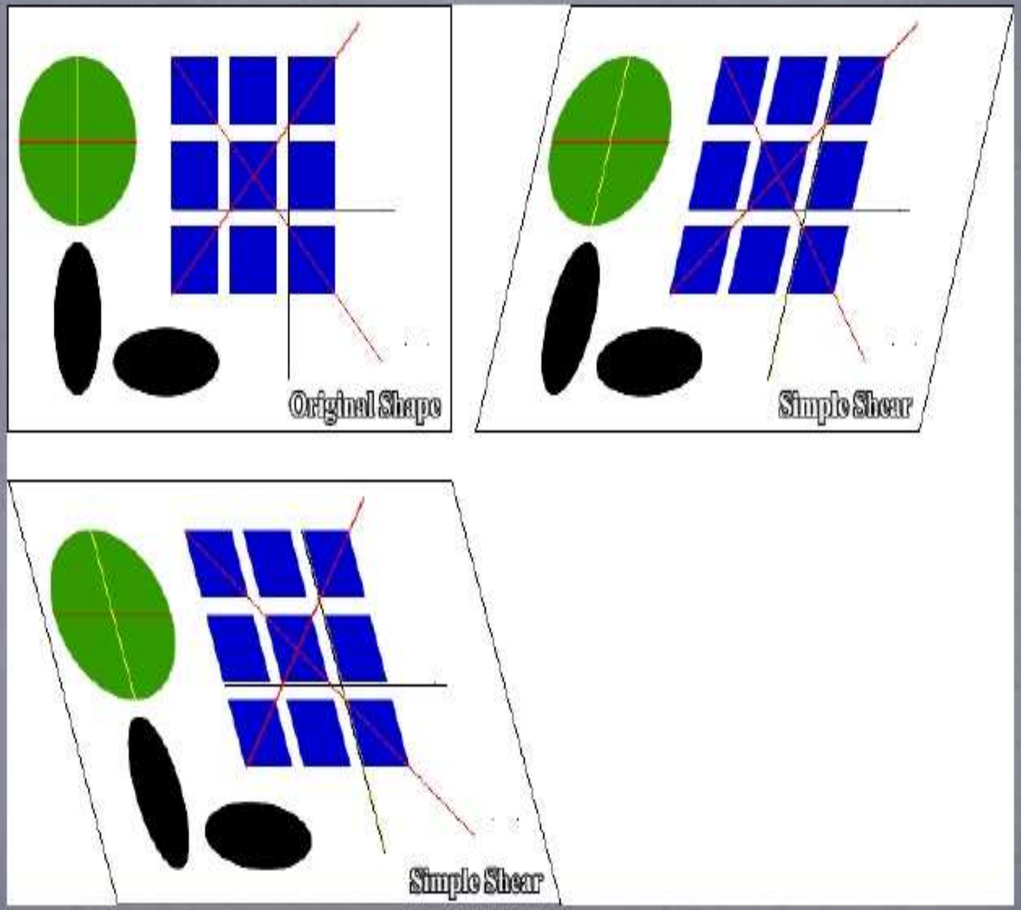
Let, P= Load or force acting on the body, L= Length of the body, A= Cross sectional area of the body, þ= Stress developed in the body, E=Modulus of elasticity or material of the body, e=Strain and l = deformation of the body.

We know that the Stress, þ=$\frac{P}{A}$ and Strain, e= $\frac{þ}{E}$, Hence, $\frac{þ}{E}$=$\frac{P}{AE}$ (as þ=$\frac{P}{A}$) and after deformation, l =e x L = $\frac{PL}{E}$, or l =$\frac{PL}{AE}$ (as þ=$\frac{P}{A}$).

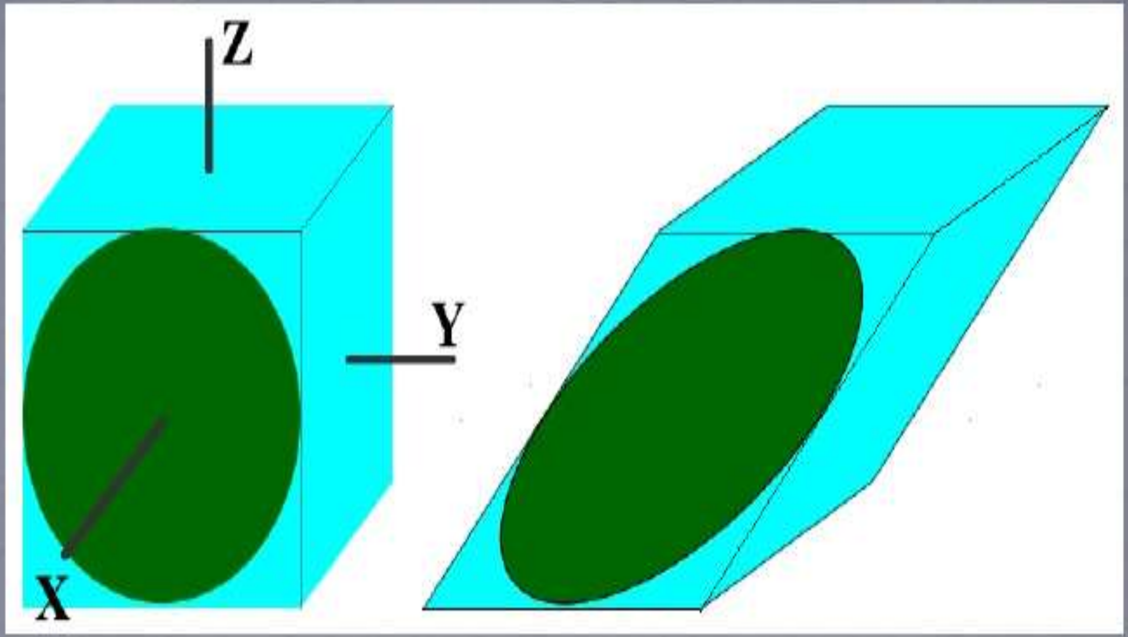
Homogeneous Deformation - Pure Shear



Homogeneous Deformation - Simple Shear



Homogeneous Strain



- Originally straight lines remain straight
- Originally parallel lines remain parallel
- Circles (spheres) become ellipses (ellipsoids)

Heterogeneous strain affects non-rigid bodies in an irregular, non-uniform manner and is sometimes referred to as non-homogeneous or inhomogeneous strain