Lecture 7

Mechanical Properties

Learning objectives

1. Understand the properties associated with various classes of materials

2. Know why these properties exist

3. Be able to measure important properties of materials and how those properties will impact performance

4. Evaluate the economic considerations that ultimately govern most material issues

5. Consider the long-term effects of using a material on the environment

.

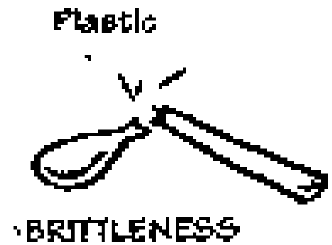
6. Discuss the mechanical properties and other test related to the development of mechanics of materials

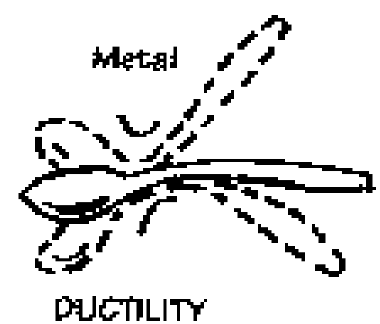
Introduction

Importance of Mechanical Properties

Properties are the way the material responds to the environment and external forces.
Mechanical properties – response to mechanical forces, strength, etc.

- **Its importance:** To know and understand the workability of the materials such as:
  - **malleability** – can be flattened
  - **ductility** – can be drawn into wire (stretched), bent, or extruded



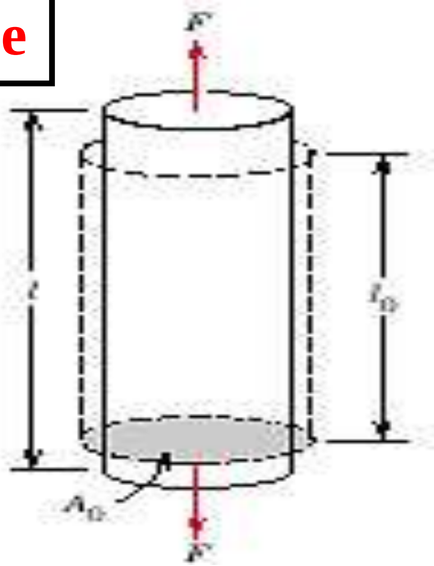


How do materials respond to external loads?

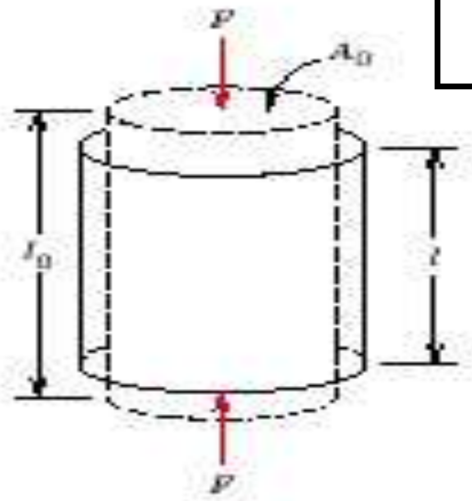
- Stress and Strain
- Elastic deformation
- Plastic Deformation
- Yield Strength
- Tensile Strength
- Toughness
- Hardness

Types of Loading

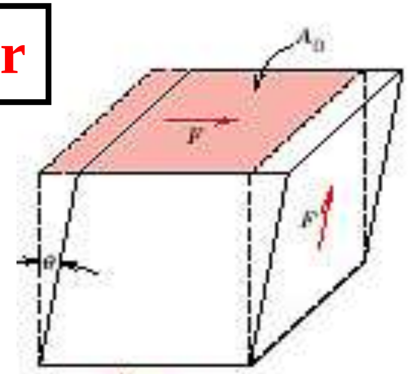
Tensile

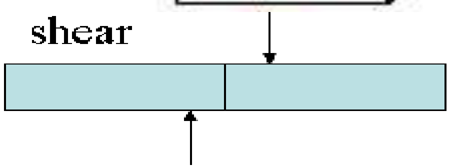


Compressive

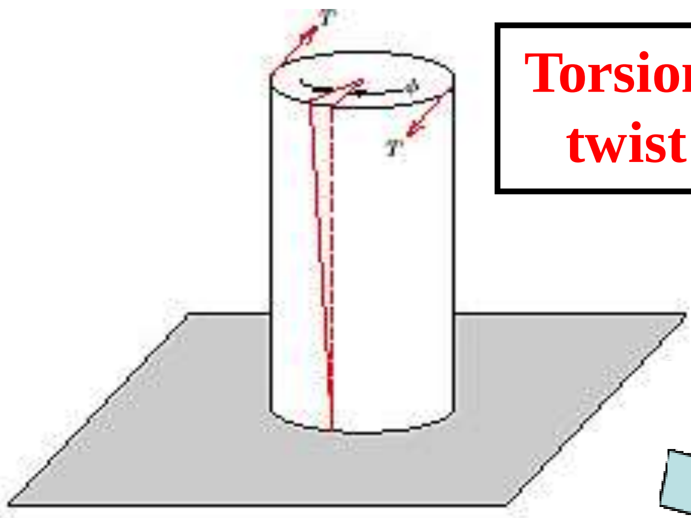


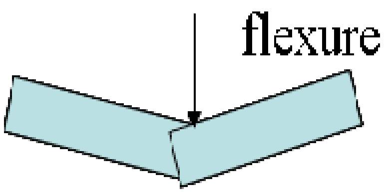
Shear





Torsion, twist





Stress

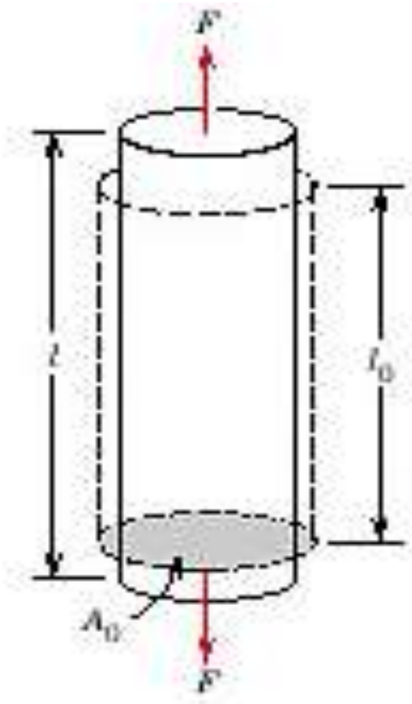
Stress = **σ**= Force/original area

Stress: $\sigma = F / A_o$

F: is load

A_0: cross-sectional area

A_0 perpendicular to F before application of the load.



Force -units? Newton
σ= F/A0 □units =N/m2= Pascal
MPa = 106Pa
GPa= 109Pa

Strain

Strain Physical change in the dimensions of a specimen that results from applying a load to the test specimen(the measure of deformation).

Strain = ε= change in length divided by original length

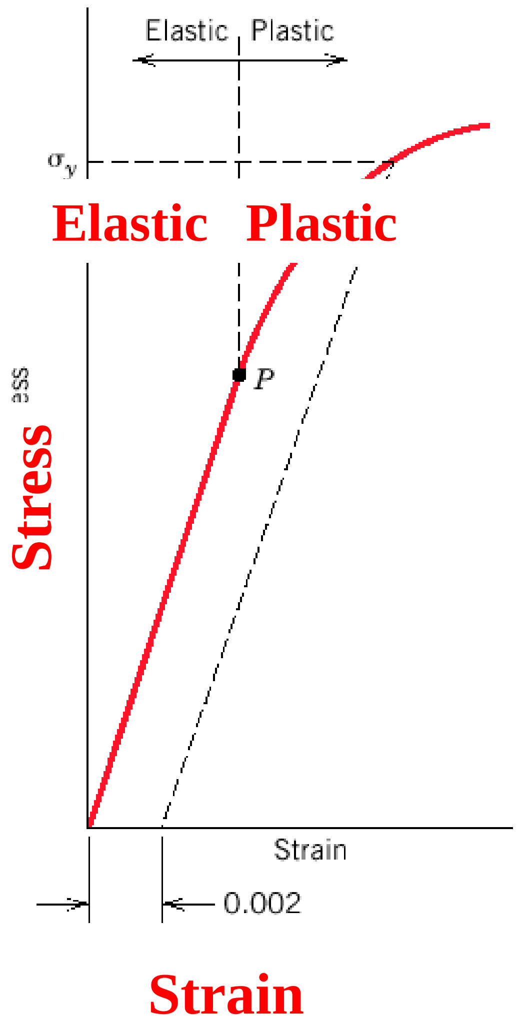
Strain: $\varepsilon = \Delta l / l_o \quad (\times 100\ \%)$

Δl: **change in length**

l_o: **original length.**

Stress / strain = σ / ε

Stress-Strain Behavior



Elastic deformation

Reversible:

(For small strains)

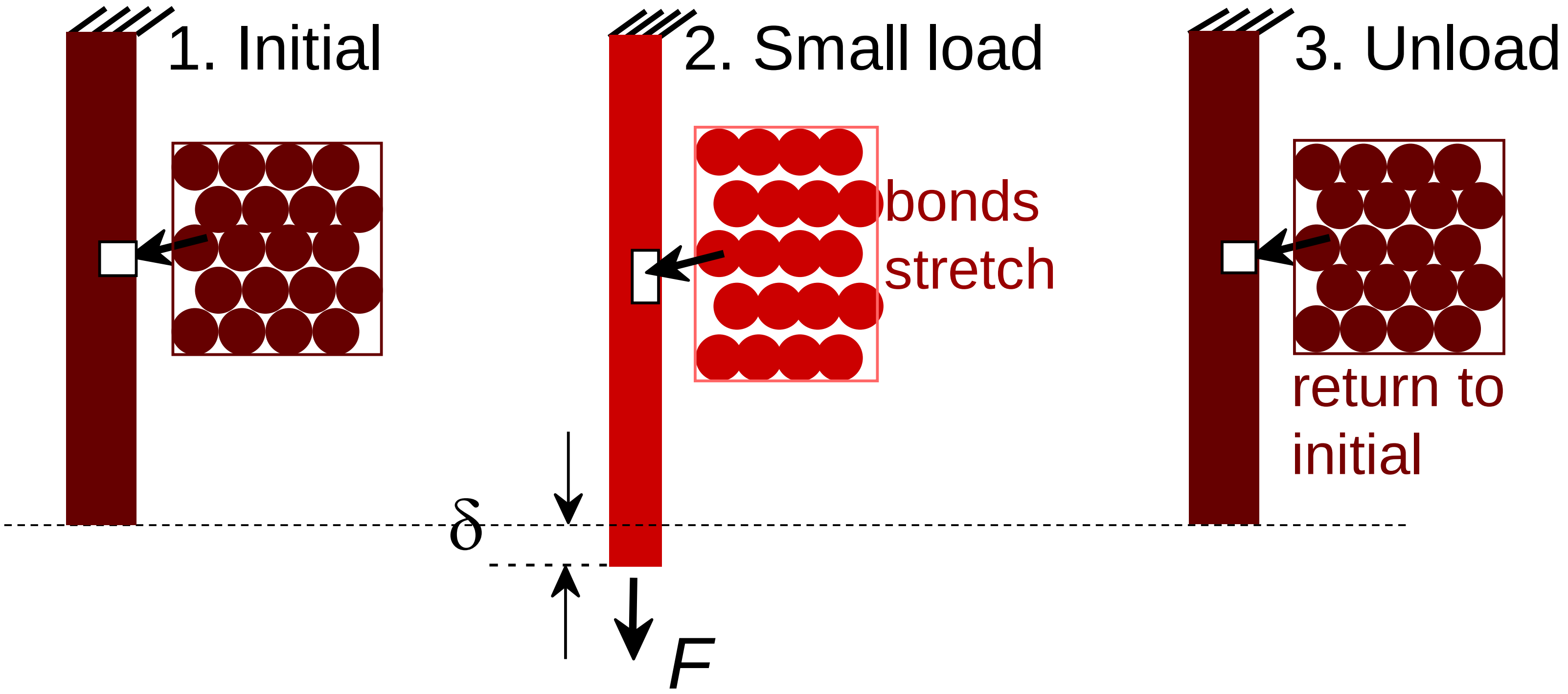
Stress removed → material returns to original size

Plastic deformation

Irreversible:

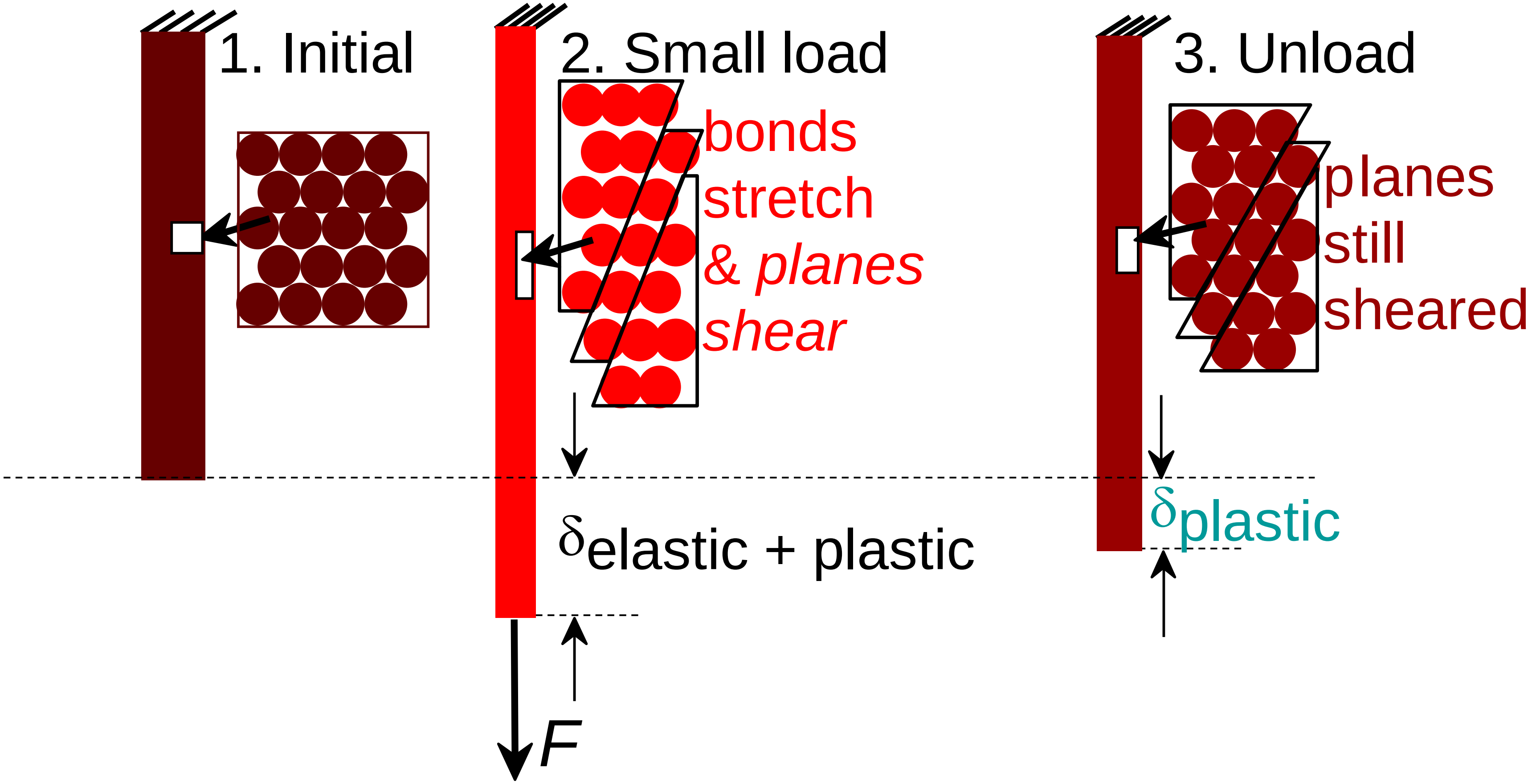
Stress removed → material does not return to original dimensions.

Elastic Deformation



Elastic means reversible!

Plastic Deformation (Metals)



Plastic means permanent!

Fundamental Mechanical Properties

- (i)Tensile strength
- (ii)Stiffness
- (iii) Hardness
- (IV) Impact strength

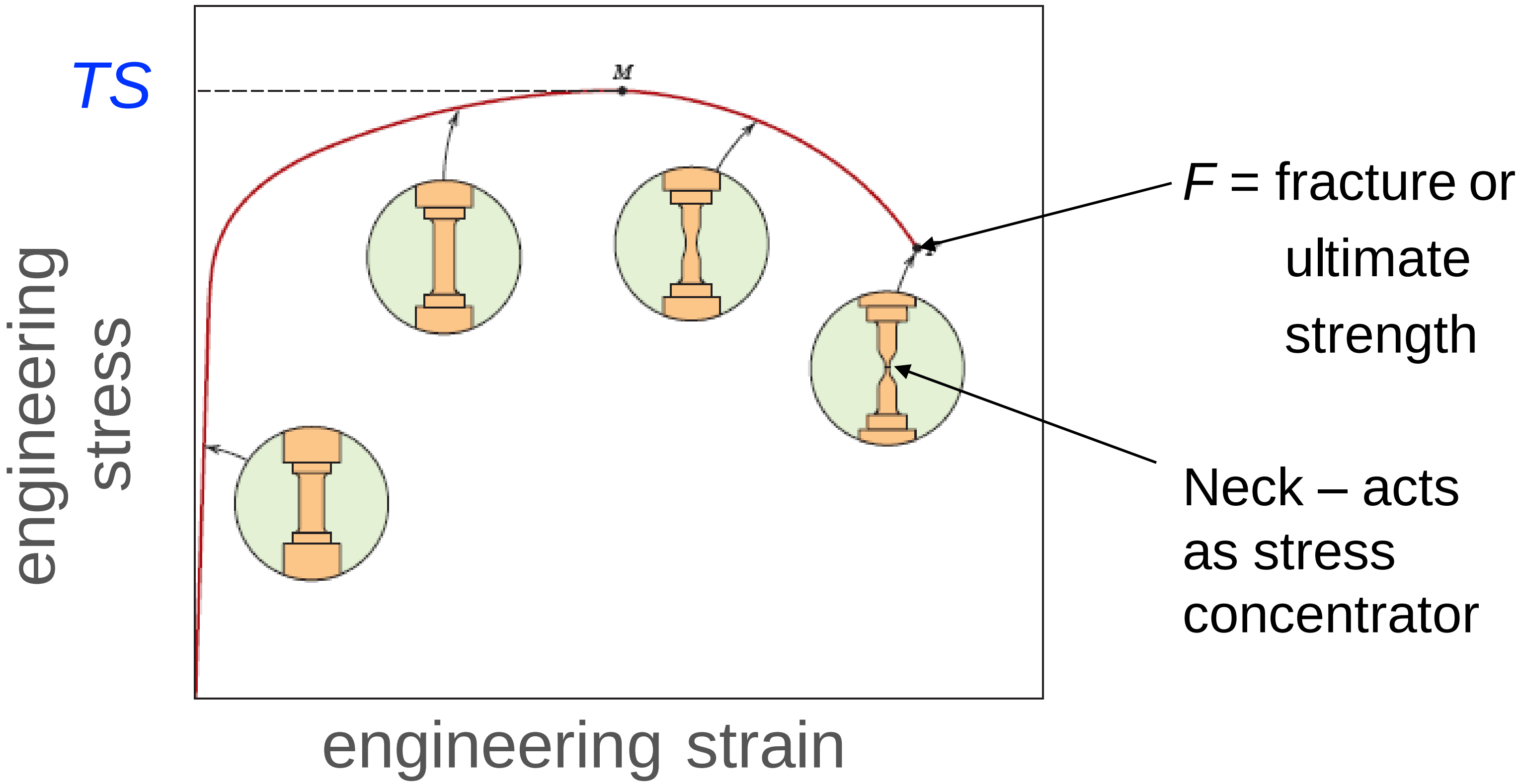
Tensile Strength

- There are three typical definitions of tensile strength.
- **Yield strength**
- The stress at which material strain changes from **elastic deformation to plastic deformation**, causing it to deform permanently is known as **yield strength**.
- **Ultimate strength**
- The maximum stress a material can withstand (before PD) is known as **ultimate strength**.
- **Breaking strength**
- The strength co-ordinate on the stress-strain curve at the point of rupture is known as **breaking strength**.

Tensile Test Specimens

Tensile Strength, TS

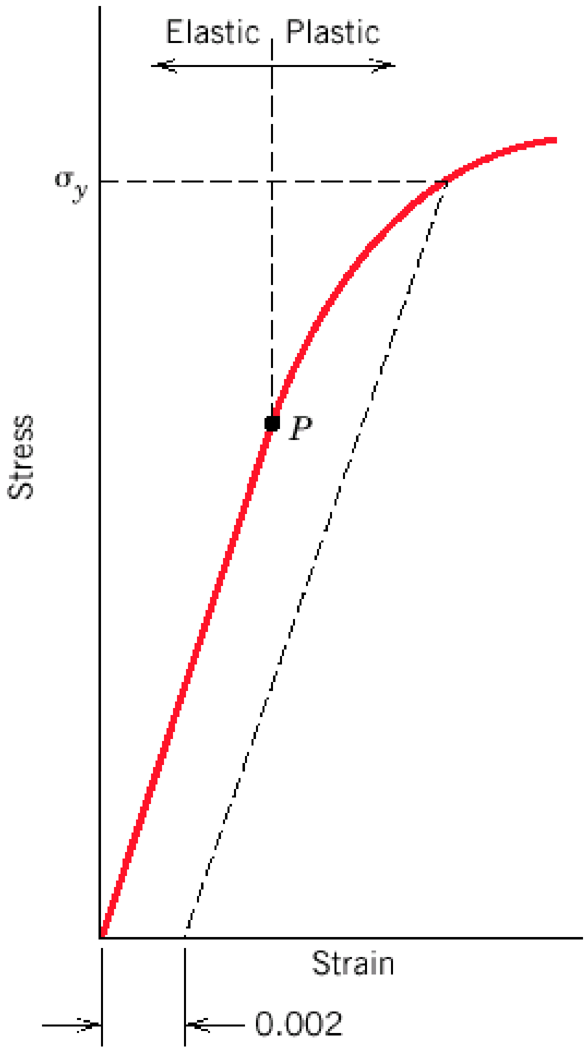
- TS is Maximum stress on **engineering** stress-strain curve.



- **Metals**: occurs when noticeable necking starts.
- **Polymers**: occurs when polymer backbone chains are aligned and about to break.

Adapted from Fig. 6.11, *Callister 7e.*

Tensile properties: Yielding



A measure of resistance to plastic deformation

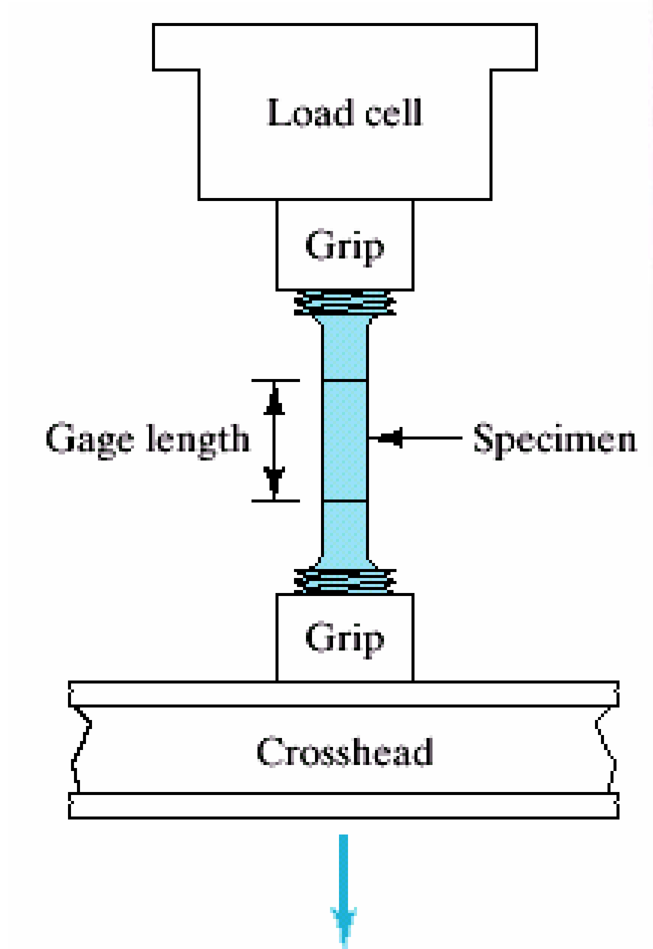
Yield point: P

Yield strength: σ_y

Tensile Strength

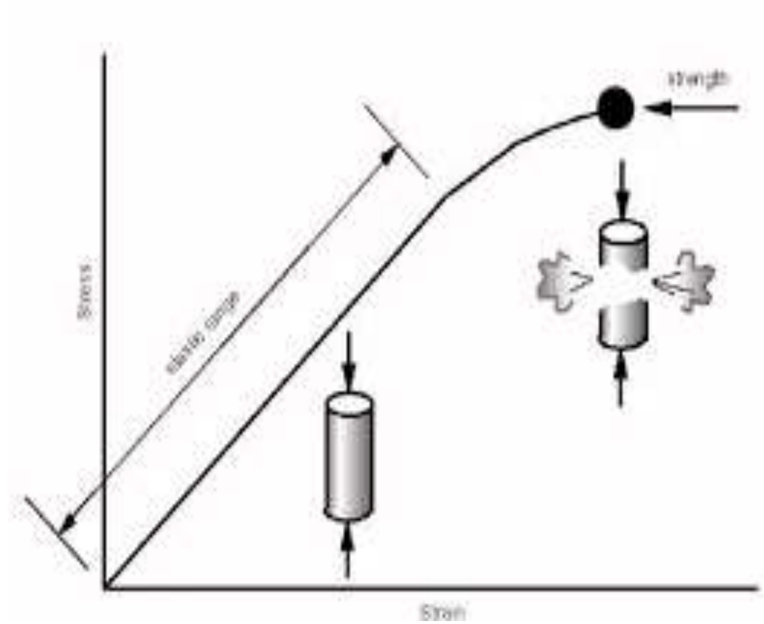
Material	Tensile Strength kg/mm^2
Alloy steel	60 -70
Mild Steel	42
Grey CI	19
White CI	47
Aluminum alloy	47

Universal Testing Machine, UTM



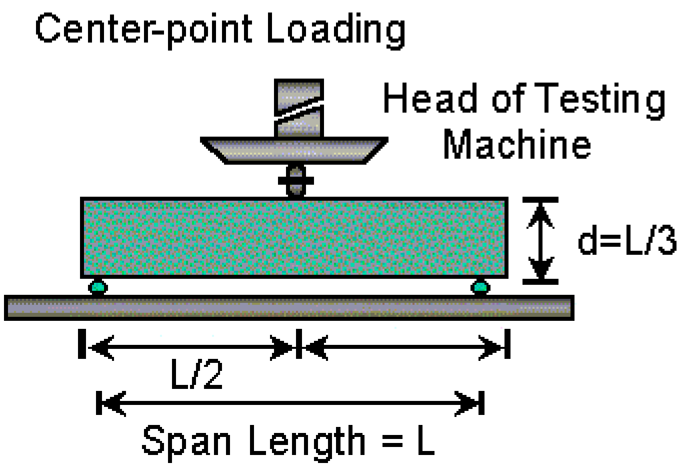
Modulus of Elasticity and Modulus of Rupture

- The ratio of stress to strain within the linear (elastic) region of the stress-strain curve
- A measure of the "stiffness" of a material
- Also known as the **Young's Modulus**
- Units are the same as the units of stress (F/A)



$E = \sigma/\varepsilon$

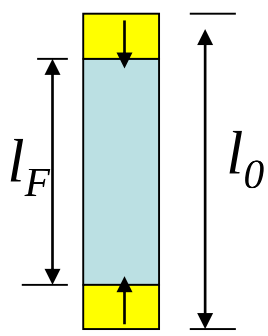
Modulus of Rupture (flexural strength)



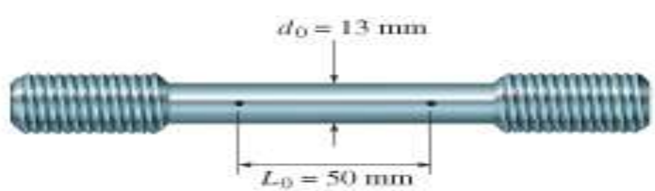
Compression Testing

- Principles
  - Compression results from forces that push toward each other.
  - Specimens are short and large diameter.
  - Circular cross section is recommended.
  - Length to diameter ratio is important consideration
- Stress
  - Force per unit area. Applied force divided by the cross sectional area of the specimen.

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

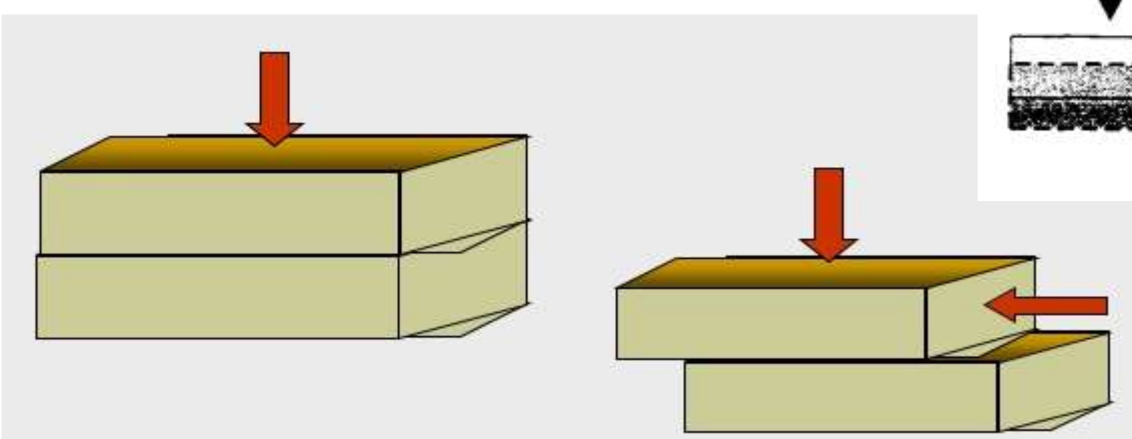


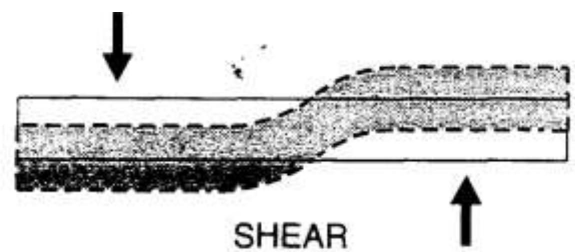
- Strain calculated by the ratio of the change in length and the original length. (Deformation).

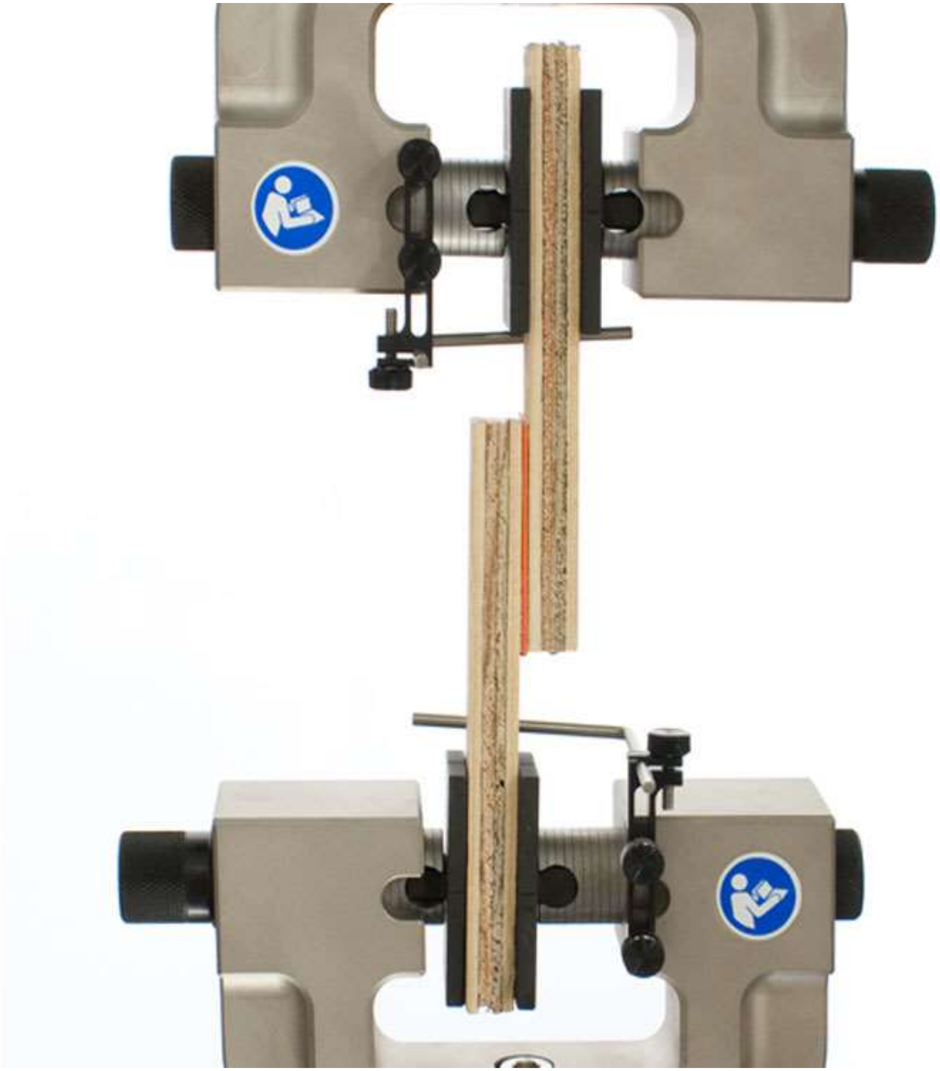


Shear Testing

- Principles
  - Direct shear occurs when parallel forces are applied in the opposite direction. **Twisting motion**
  - Single shear occurs on a single plane.
  - Double shear occurs on two planes simultaneously.
- Torsional forces developed in a material are the result of an applied torque.
- Torque is Forces x distance

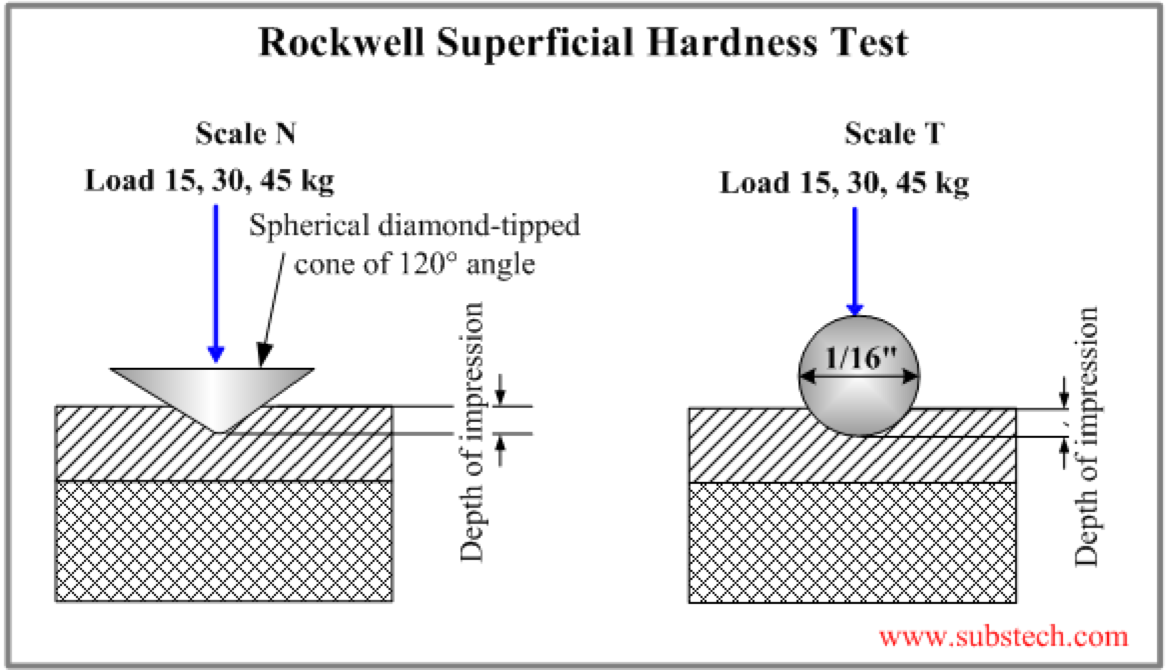






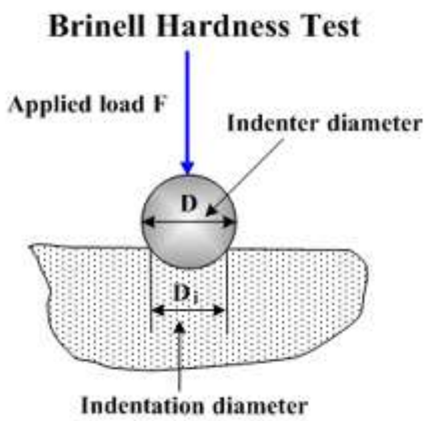
Hardness

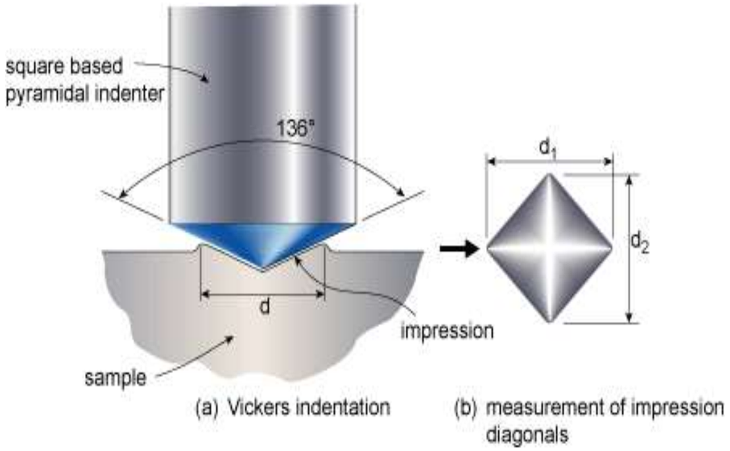
- Hardness is the resistance of material to permanent deformation of the **surface**. It is the property of a material, which gives it the ability to resist being permanently deformed (bent, broken or shape change), when a load is applied.
- It determine the wear resistance of the material involved, as well as the approximate values of its ductility,
- The hardness of a surface of the material is, a direct result of inter atomic forces acting on the surface of the material.
- Hardness is not a fundamental property of a material, but a combined effect of compressive, elastic and plastic properties relative to the mode of penetration, shape of penetration etc.
- The main usefulness of hardness is, it has a constant relationship to the tensile strength of a given material and so can be used as a practical non-destructive test .


Rockwell Superficial Hardness Test
Scale N
Load 15, 30, 45 kg
Spherical diamond-tipped cone of 120° angle
Depth of impression
Scale T
Load 15, 30, 45 kg
1/16"
Depth of impression
www.substech.com

Hardness Measurement Methods

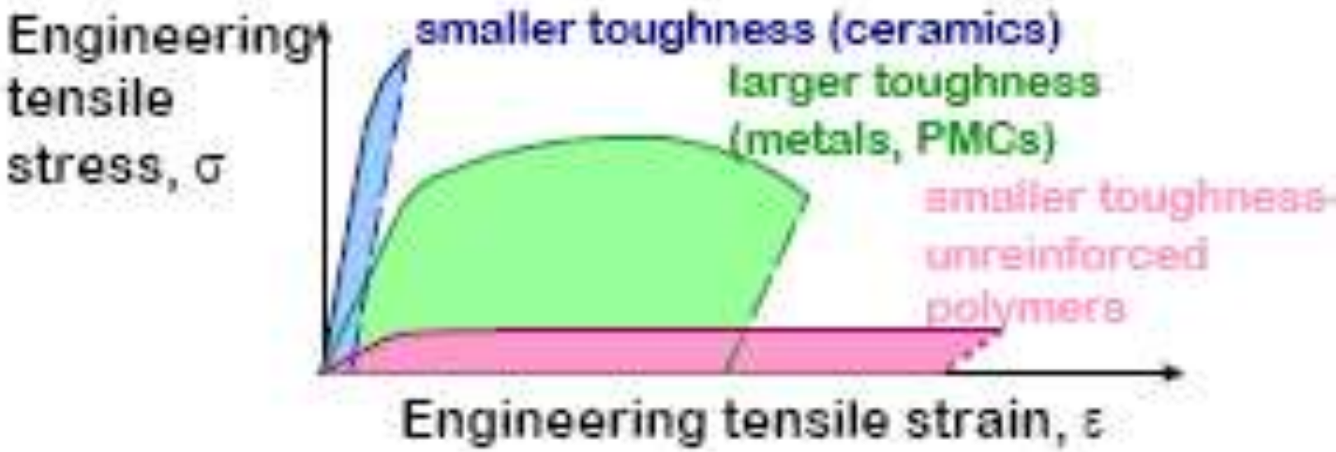
- The following are the hardness test methods:
- **Rockwell hardness test** (ball or cone)
- **Brinell hardness** (Uses ball shaped indentor)
- **Vickers** (Uses square shaped pyramid indentor)





TOUGHNESS

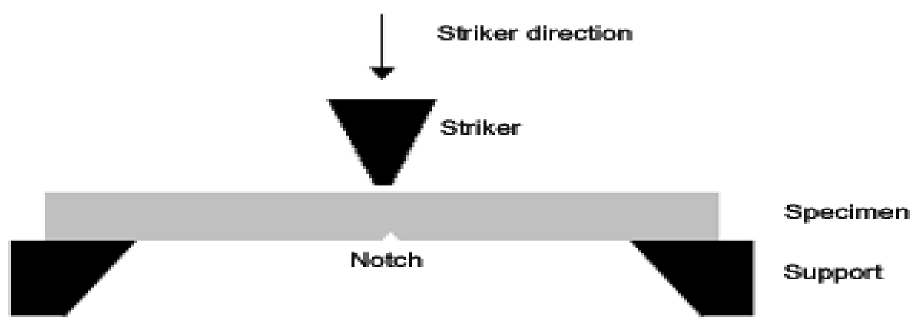
- Energy needed to break a unit volume of material
- Area under stress-strain curve



Impact Strength

- Impact strength is the resistance of a material to fracture under dynamic load.
- It is a complex characteristic which takes into account both the toughness and strength of a material.
- In S.I. units the impact strength is expressed in Mega Newton per m2 (MN/m2).
- It is defined as the specific work required to fracture a test specimen with a stress concentrator in the mid when broken by a single blow of striker in pendulum type impact testing machine.


Start Position
of Pendulum
Scale to read energy
absorbed in breaking
the specimen
Pendulum
Test Specimen
Held Vertically


Striker direction
Striker
Specimen
Notch
Support

Factors affecting Impact strength

- Impact is a very important phenomenon in governing the life of a structure. For example, in the case of an aircraft, impact can take place by a bird hitting a plane while it is cruising, or during take off and landing the aircraft may be struck by debris that is present on the runway, and as well as other causes
- Impact strength is affected by the rate of loading, temperature and presence of stress raisers in the materials.
- It is also affected by variation in heat treatment, alloy content, sulphur and phosphorus content of the material.
- The velocity of impact also affects impact strength to some extent.
- This further helps to study the effect of stress concentration and high velocity load application.

Summary

Properties are the way the material responds to the environment and external forces.
Mechanical properties – response to mechanical forces, strength, etc.

Hardness--resistance to scratching and denting.
Malleability--ability to deform under rolling or hammering without fracture.
Toughness--ability to absorb energy, e.g., a blow from a hammer. Area under stress-strain curve is a measure of toughness.
Ductility--ability to deform under tensile load without rupture; high percentage elongation and percent reduction of area indicate ductility
Brittleness--material breaks instead of deforming when stress is applied
Elasticity--ability to return to original shape and size when unloaded
Plasticity--ability to deform non-elastically without rupture
Stiffness--ability to resist deformation; proportional to Young's Modulus E (psi) E = stress/strain (slope of linear portion of stress/strain curve).
Definition of impact strength, MOE and MOR