Mechanical Properties of Solid-Unit 5

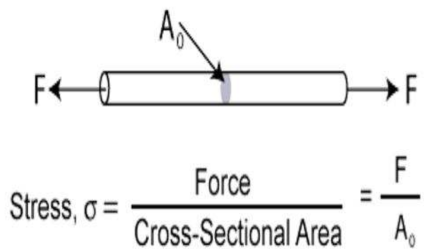
Chemistry (SRM Institute of Science and Technology)

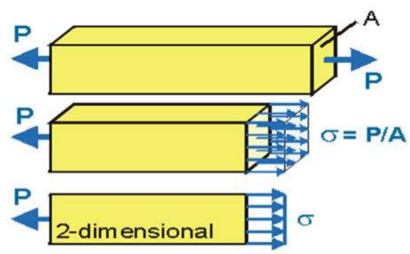
MECHANICAL PROPERTIES OF SOLID

- The properties of material that determine its behaviour under applied forces are known as mechanical properties.
- They are usually related to the elastic and plastic behaviour of the material.
- These properties are expressed as functions of stress-strain,etc.
- A sound knowledge of mechanical properties of materials provides the basis for predicting behaviour of materials under different load conditions and designing the components out of them.

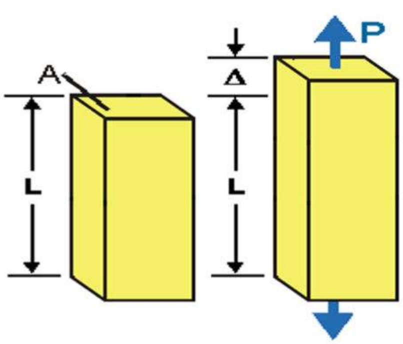
STRESS AND STRAIN

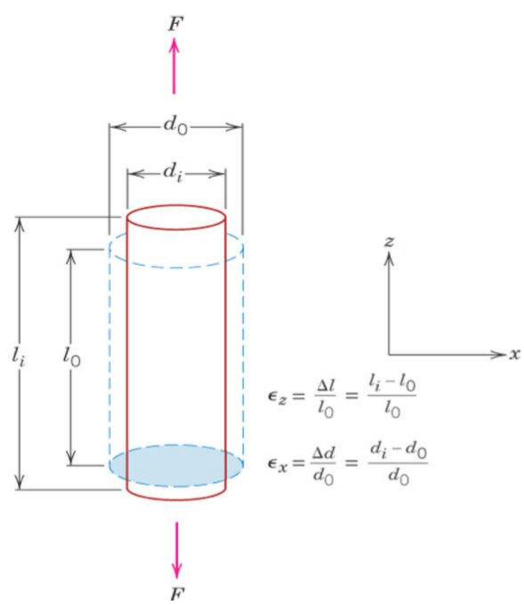
- The sum total of all the elementary interatomic forces or internal resistances which the material is called upon to exert to counteract the applied load is called stress.
- Mathematically, the stress is expressed as force divided by cross-sectional area.



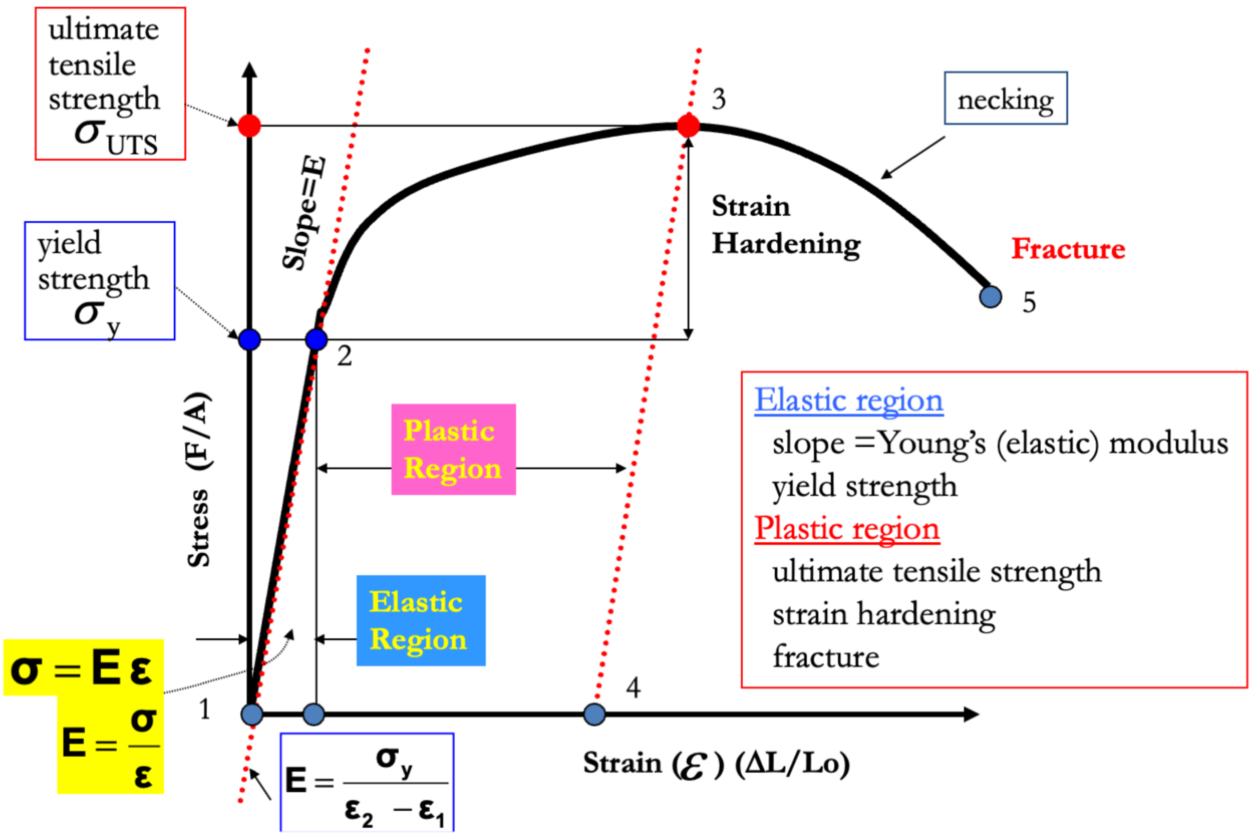


- Strain is the dimensional response given by material against mechanical loading/Deformation produced per unit length. Mathematically Strain is change in length divided by original length.





Stress-Strain Diagram

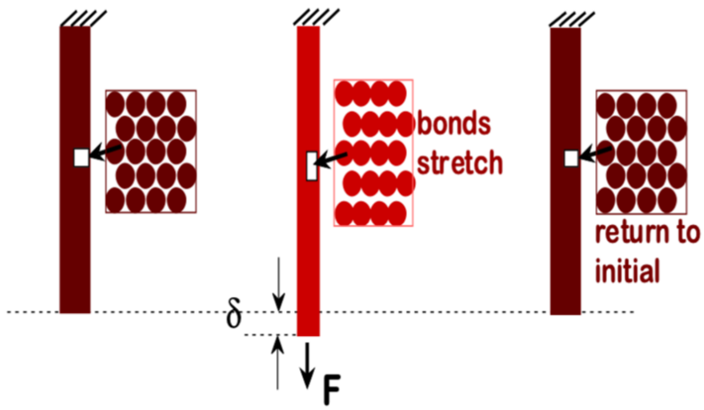


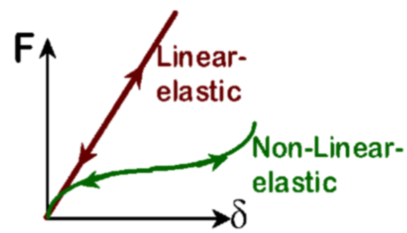
STRENGTH

- The strength of a material is its capacity to withstand destruction under the action of external loads.
- It determines the ability of a material to withstand stress without failure.
- The maximum stress that any material will withstand before destruction is called ultimate strength.
- Ultimate tensile strength (UTS), often shortened to tensile strength (TS) can be defined as the maximum stress that a material can bear before breaking when it is allowed to be stretched or pulled

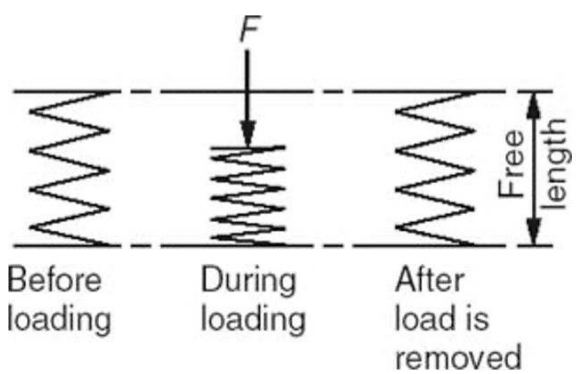
ELASTICITY:

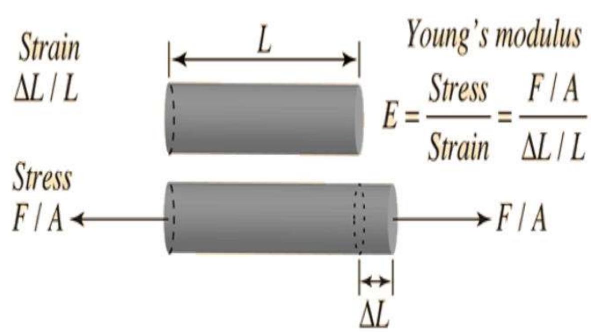
- The property of material by virtue of which deformation caused by applied load disappears upon removal of load.
- Elasticity of a material is the power of coming back to its original position after deformation when the stress or load is removed.





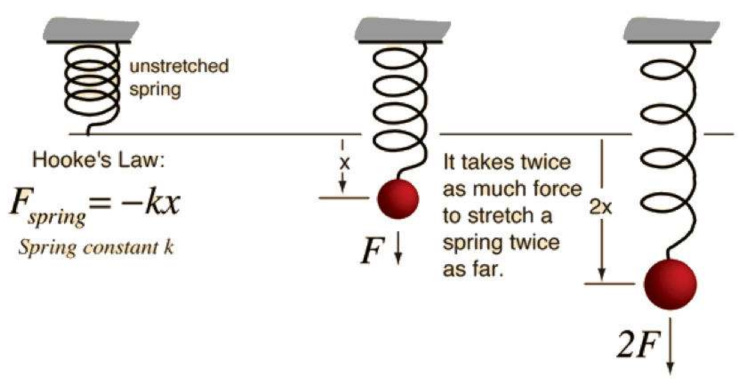
Elastic means reversible.





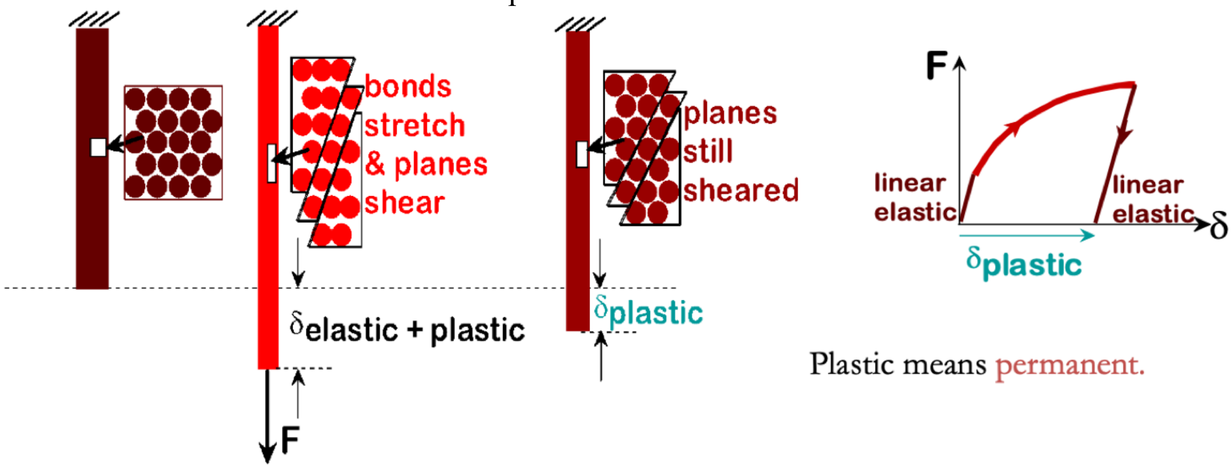
HOOKE'S LAW

One of the properties of elasticity is that it takes about twice as much force to stretch a spring twice as far. That linear dependence of displacement upon stretching force is called Hooke's law.

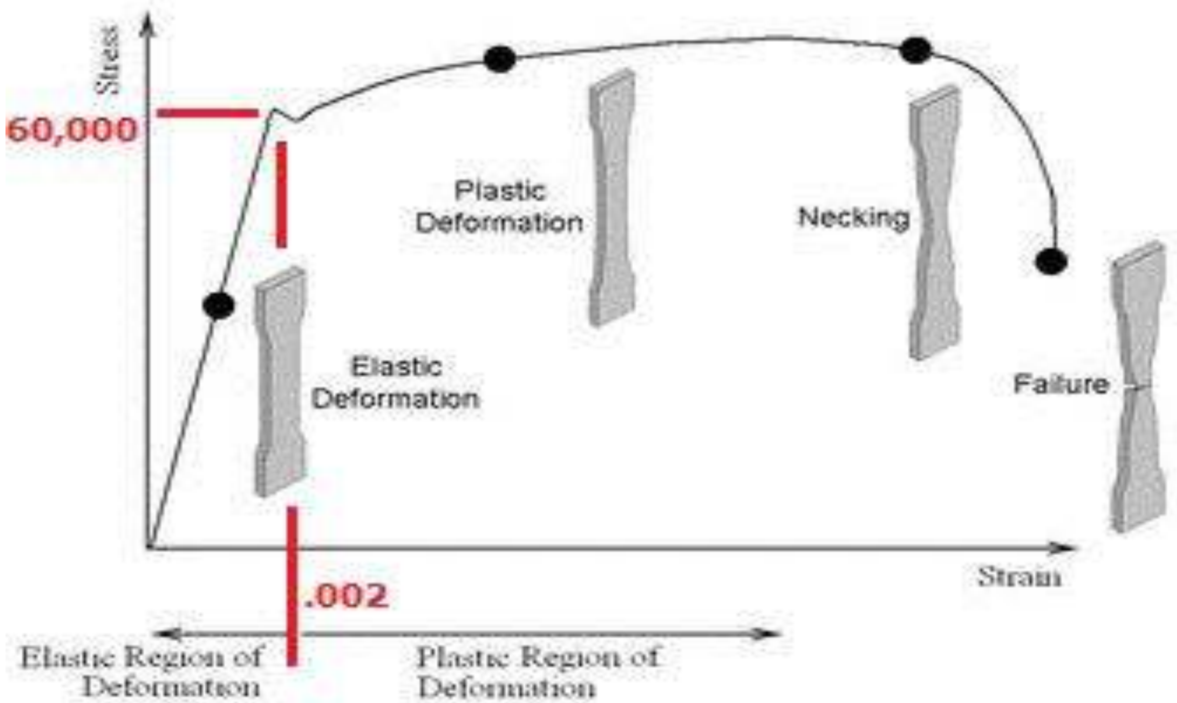


PLASTICITY:

- The plasticity of a material is its ability to undergo some degree of permanent deformation without rupture or failure.
- Plastic deformation will take only after the elastic limit is exceeded.
- It increases with increase in temperature.



STRESS-STRAIN CURVE SHOWS ELASTICITY AND PLASTICITY FOR MATERIALS:



STIFFNESS:

- The resistance of a material to elastic deformation or deflection is called stiffness or rigidity.

- A material which suffers slight deformation under load has a high degree of stiffness or rigidity.
- E.g. Steel beam is more stiffer or more rigid than aluminium beam.

DUCTILITY:

- It is the property of a material which enables it to draw out into thin wires.
- E.g., Mild steel is a ductile material.
- The percent elongation and the reduction in area in tension is often used as emperical measures of ductility.

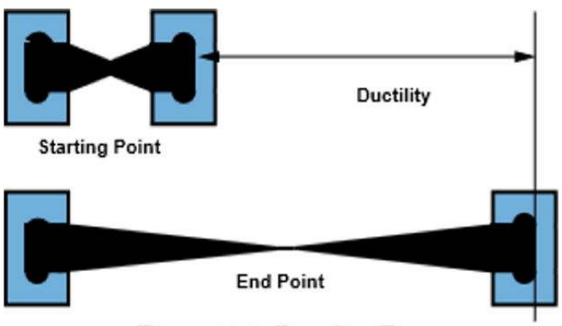
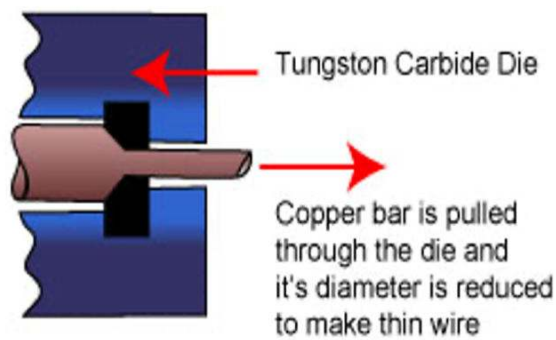
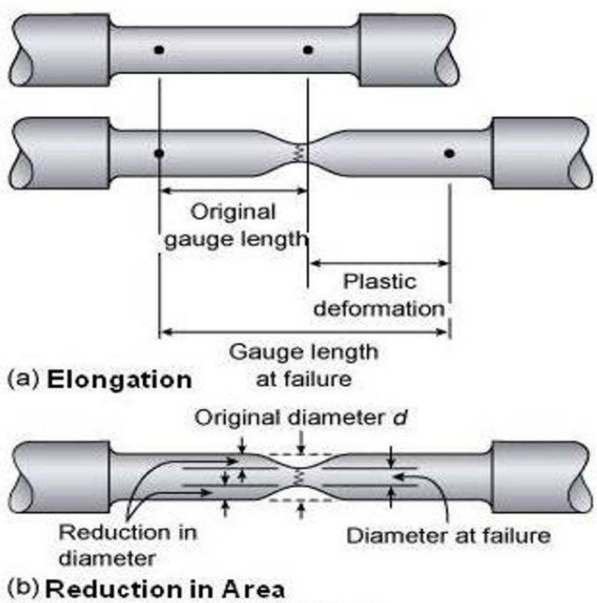
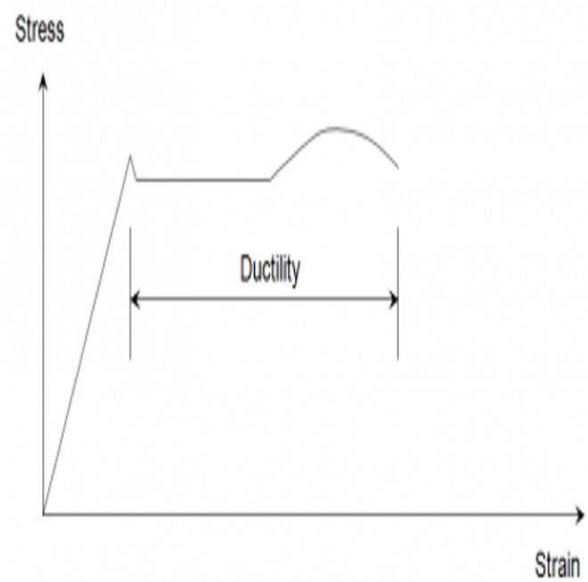


Figure 23:2: Ductility Test





Ductility



POISSON'S RATIO

Poisson's ratio (letter *v*) is a measure of the contraction that happens when an object is stretched. This contraction is perpendicular to the stretching force. It can also expand as the object is compressed in a perpendicular direction.

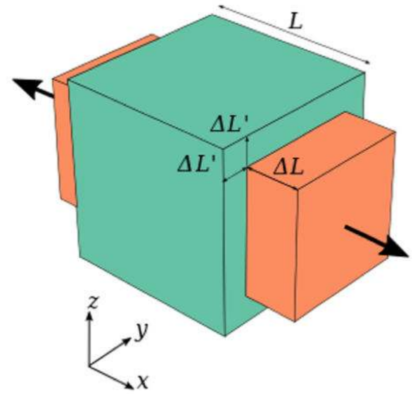
$$\nu = -\frac{d\varepsilon_{\mathrm{trans}}}{d\varepsilon_{\mathrm{axial}}} = -\frac{d\varepsilon_{\mathrm{y}}}{d\varepsilon_{\mathrm{x}}} = -\frac{d\varepsilon_{\mathrm{z}}}{d\varepsilon_{\mathrm{x}}}$$

where

ν is the resulting Poisson's ratio,

$\varepsilon_{\mathrm{trans}}$ is transverse strain (negative for axial tension (stretching), positive for axial compression)

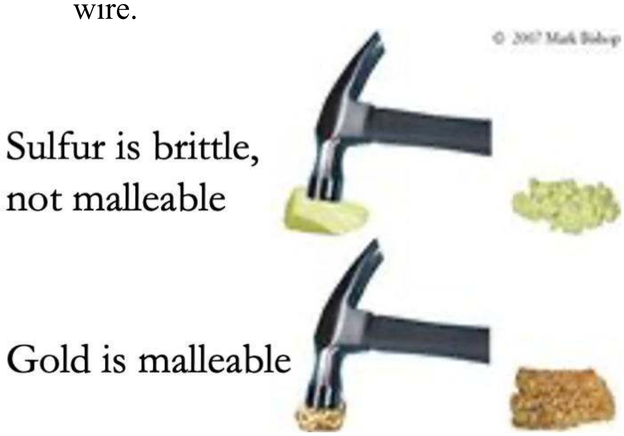
$\varepsilon_{\mathrm{axial}}$ is axial strain (positive for axial tension, negative for axial compression).



Poisson's ratio ranges from 0.0-0.5 for common materials

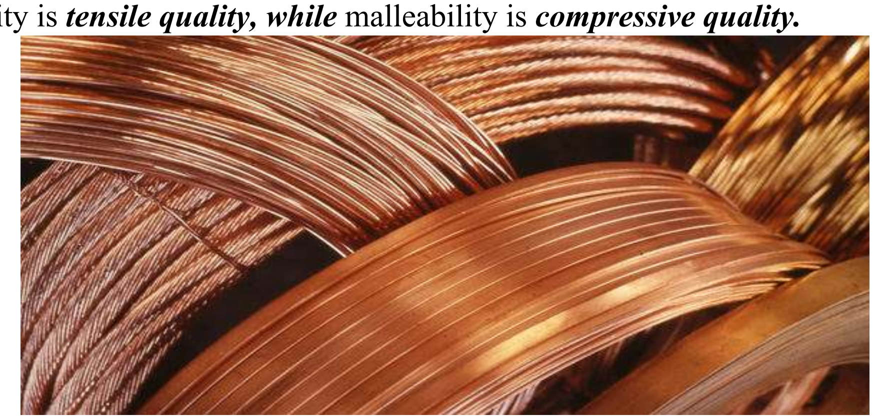
MALLEABILITY:

- Malleability of a material is its ability to be flattened into thin sheets without cracking by hot or cold working.
- E.g Lead can be readily rolled and hammered into thin sheets but cannot be drawn into wire.



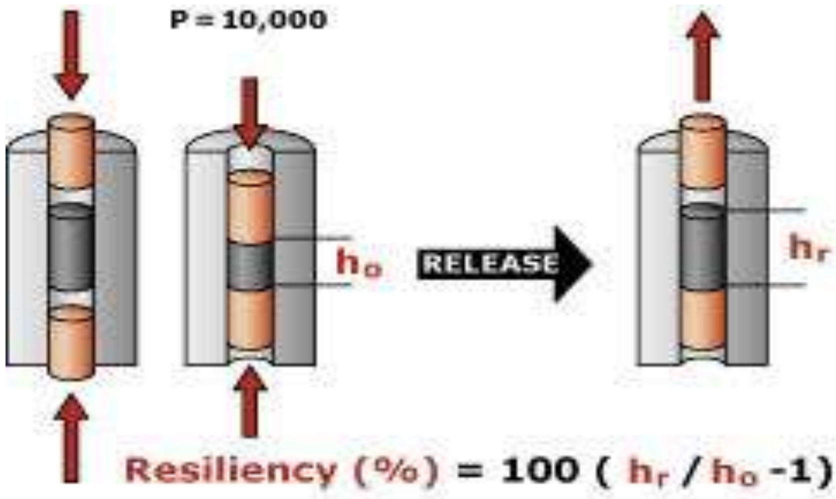
Comparison of ductility and malleability

- Ductility and Malleability are frequently used interchangeably many times.
- Ductility is ***tensile quality, while*** malleability is ***compressive quality.***



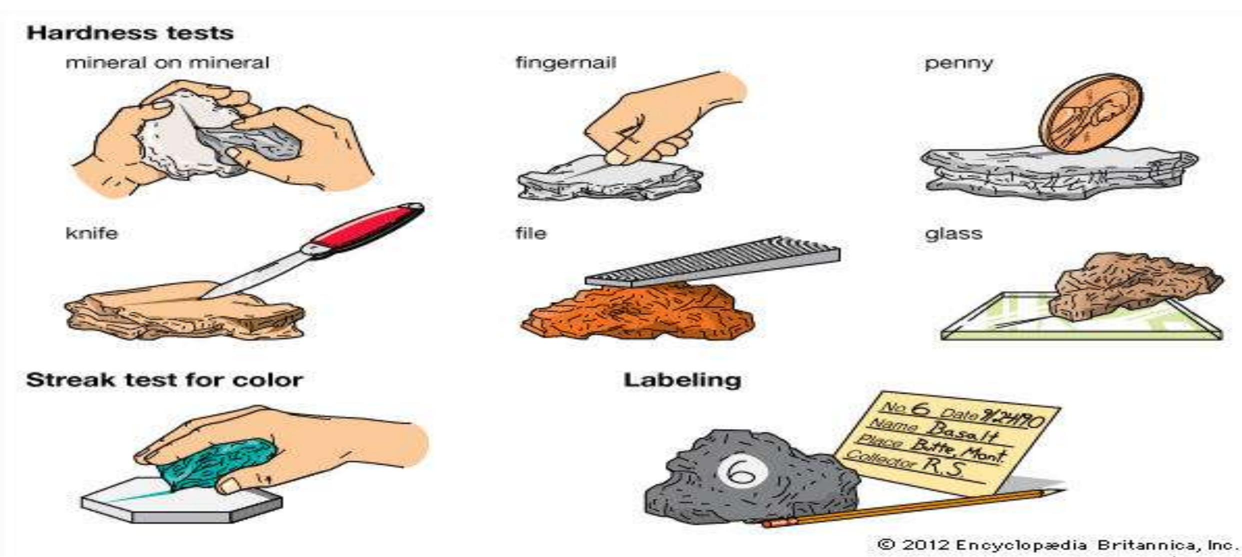
RESILIENCE:

- It is the property of a material to absorb energy elastically and to resist shock and impact loads.
- It is measured by the amount of energy absorbed per unit volume within the elastic limit. This property is essential for spring materials
- The maximum energy which can be stored in a body up to elastic limit is called the ***proof resilience, and*** the proof resilience per unit volume is called ***modulus of resilience***.
- The quantity gives capacity of the material to bear shocks and vibrations.



HARDNESS:

- Hardness is a fundamental property which is closely related to strength.
- Hardness is usually defined in terms of the ability of a material to resist to ***scratching, abrasion, cutting, identation,or penetration.***
- Methods used for determining hardness: Brinel, Rockwell ,Vickers.

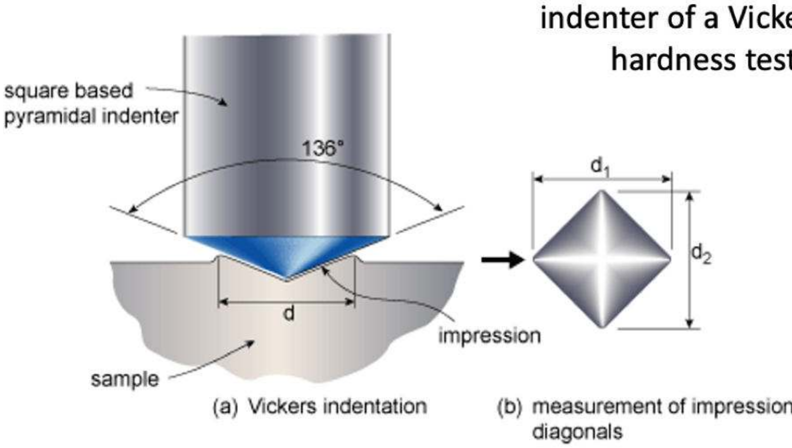


Mohs scale of mineral HARDNESS:

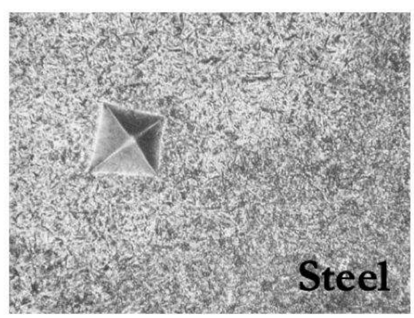
The Mohs scale of mineral hardness is a qualitative ordinal scale characterizing scratch resistance of various minerals through the ability of harder material to scratch softer material

Mohs hardness	**Mineral**	**Chemical formula**
1	Talc	$Mg_3Si_4O_{10}(OH)_2$
2	Gypsum	$CaSO_4{\cdot}2H_2O$
3	Calcite	$CaCO_3$
4	Fluorite	CaF_2
5	Apatite	$Ca_5(PO_4)_3(OH^-,Cl^-,F^-)$
6	Orthoclase feldspar	$KAlSi_3O_8$
7	Quartz	SiO_2
8	Topaz	$Al_2SiO_4(OH^-,F^-)_2$
9	Corundum	Al_2O_3
10	Diamond	C

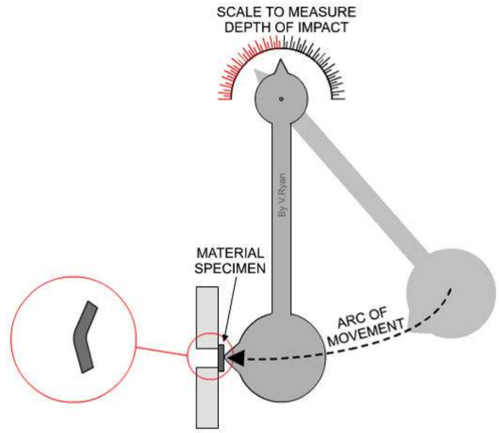
Hardness correlates well with scratch proof ability meaning that harder materials are harder to scratch. It also correlates well with the yield strength (σ_y, that is the value of stress after which is deforms permanently) or the ultimate tensile strength of the material (that is the maximum load it can bear in a tensile test)



Pyramidal diamond indenter of a Vickers hardness tester



TOUGHNESS (Impact strength)



- Toughness is the ability of a material to absorb energy when impacted. It is tested with impact Charpy or Izod testing machines by measuring how much the pendulam (with predetermined weight) will rise after impacting and breaking on the piece under test.
- Materials known to be very tough are stainless steels and titanium alloys. Materials known to be very fragile (the opposite of tough) are ceramics such as glasses or porcelain.
- Toughness usually goes in the opposite direction of hardness, that is if a material is very hard it is usually very fragile. Diamonds are fragile even though they are hard. Aluminum is tough but not hard at all.
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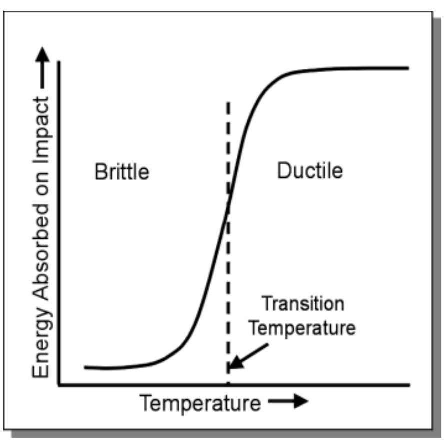
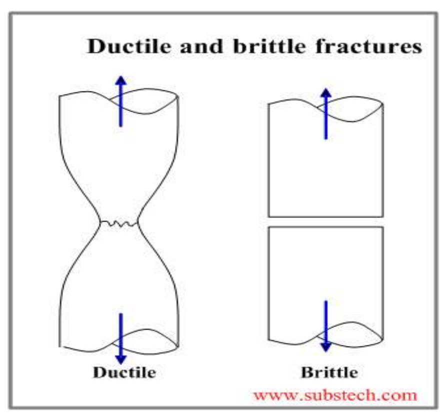
BRITTLENESS:

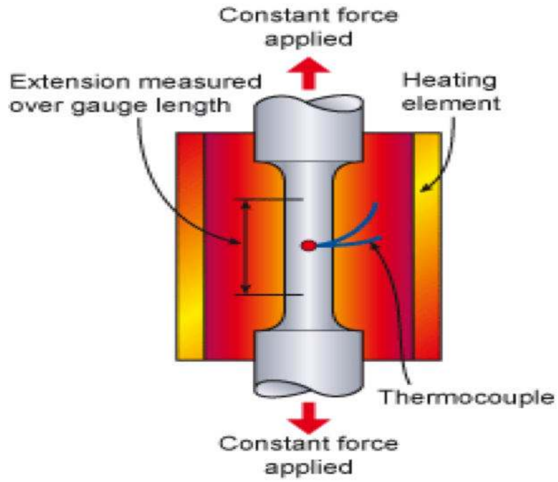
- It is the property of breaking without much permanent distortion.
- Non-Ductile material is considered to be brittle material.
- E.g, Glass, Cast iron,etc.





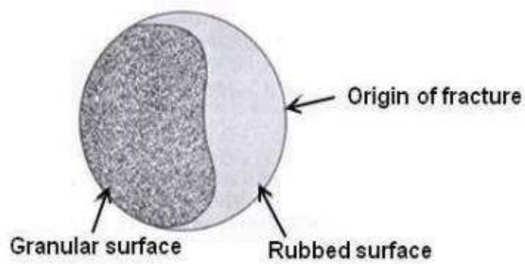
CREEP:

- The slow and progressive deformation of a material with time at constant stress is called creep.
- Depending on temperature, stresses even below the elastic limit can cause some permanent deformation.
- It is most generally defined as time-depandent strain occurring under stress.



FATIGUE:

- This phenomenon leads to fracture under repeated or fluctuating stress.
- Fatigue fractures are progressive beginning as minute cracks and grow under the action of fluctuating stress.
- Many components of high speed aero and turbine engines are of this type.



Surface of a Fatigue Fracture