Properties of Engg. Materials

- Matter state
- Classification of Engineering Materials
- Mechanical properties of engineering materials

What is Matter?

- Matter is everything around you. On Earth, matter is usually found in one of three states, or phases. The three main states of matter are solid, liquid, and gas.



Three Main States of Matter



Gases



Liquids



Solids

Liquids

Liquids are free-flowing & assume the shape of the container that holds them. Liquids, however, do have a fixed volume. Particles in liquid move around fast enough to overcome attractive forces. While the liquid particles do move freely, they still stick together. The speed at which a liquid flows depends on its viscosity. Viscosity is the resistance to flow.

What is attractive force?



Picture of Liquids







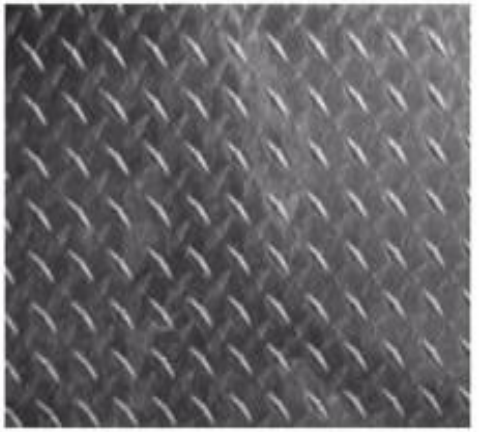


Solids

A solid, like ice, wood, or metal, is matter that has a defined shape & volume. The particles in matter are packed closely together, & they don´t move around freely, which is why a solid has a defined shape & volume. Still, particles in a solid vibrate back & forth, but not enough to overcome the attractive force between particles.





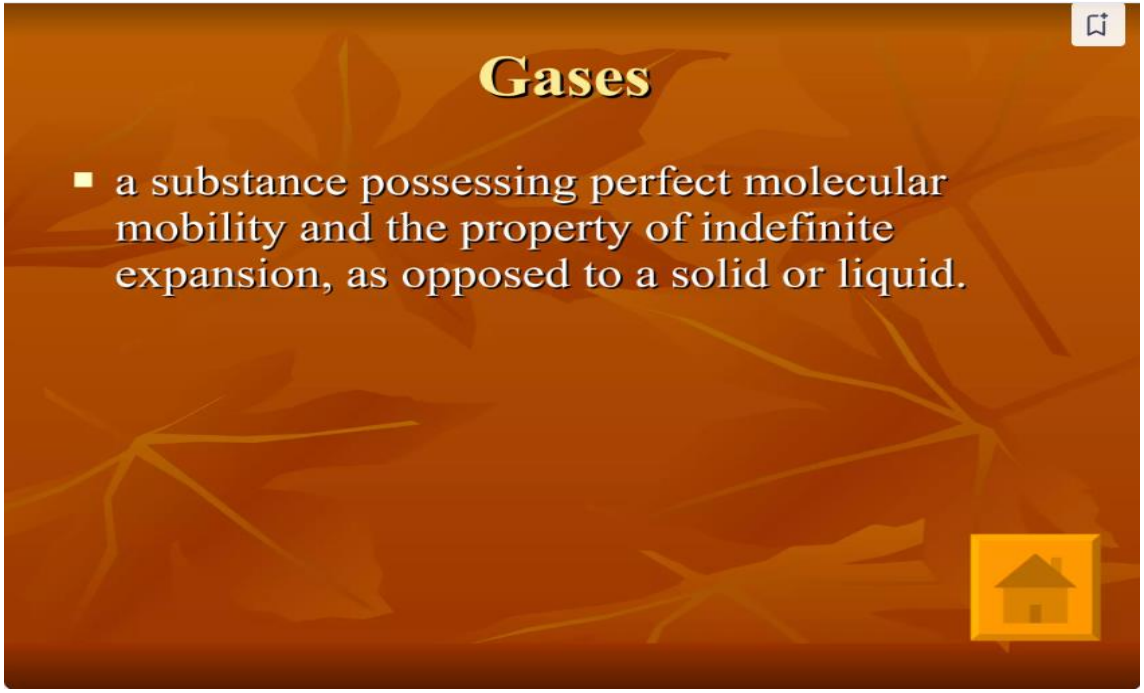


Pictures Of Solids









a substance or matter in a state in which it will expand freely to fill the whole of a container, having no fixed shape (unlike a solid) and no fixed volume (unlike a liquid).

Pictures of Gases







Comparisons

- Gas Particles

  * Gas are well separated with no regular arrangement.

  * Gas vibrate and move freely at high speeds.





Comparisons

- Liquid Particles

  * Liquid are close together with no regular arrangement.

  * Liquid vibrate, move about, and slide past each other.

Comparisons

- Solid Particles

  * Solid are tightly packed, usually in a regular pattern.

  * Solid vibrate (jiggle) but generally do not move from place to place.

Physical Changes

- **Physical changes** occur when objects undergo a change that does not change their chemical nature. A physical change involves a change in physical properties. Physical properties can be observed without changing the type of matter. Examples of physical properties include: texture, shape, size, color, odor, volume, mass, weight, and density.





Physical Changes

- Elements move from one phase to another when physical forces are present
  - * Examples: solid to a liquid
    liquid to gas

Physical Changes

- Increased temperature/Increased Pressure
- Decreased temperature/Decreased Pressure



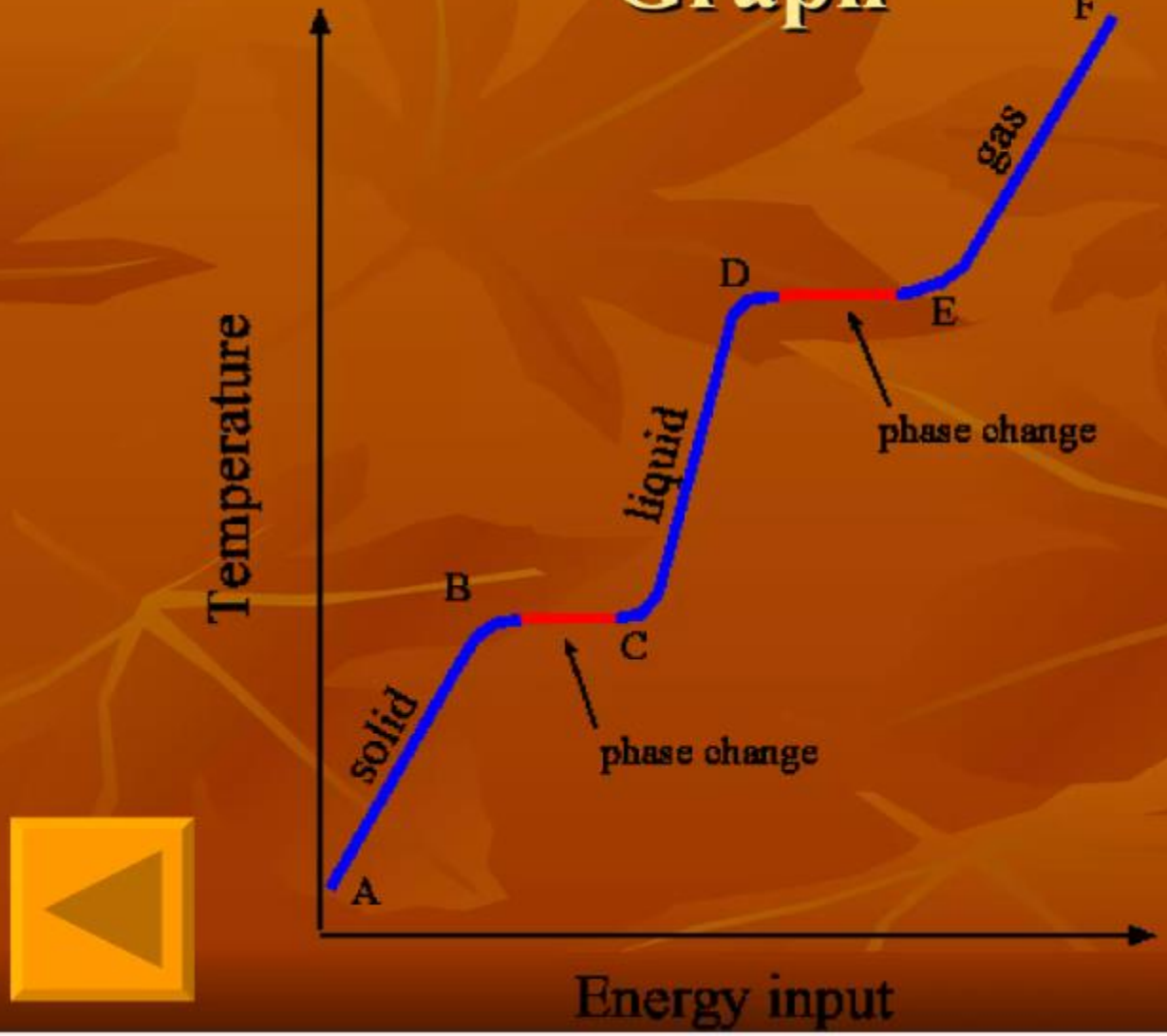


Temperature

- Temperature changes materials from one state of matter to another. Heated solids melt into liquids. Heated liquids evaporate into gases.

- Cooled gases condense into liquids. Cooled liquids freeze into solids.

Graph


Temperature
Energy input
A
B
C
D
E
F
solid
liquid
gas
phase change
phase change

Phase Changes

A state isn´t permanent. Changes in pressure & temperature alter matter - these are described as phase changes.

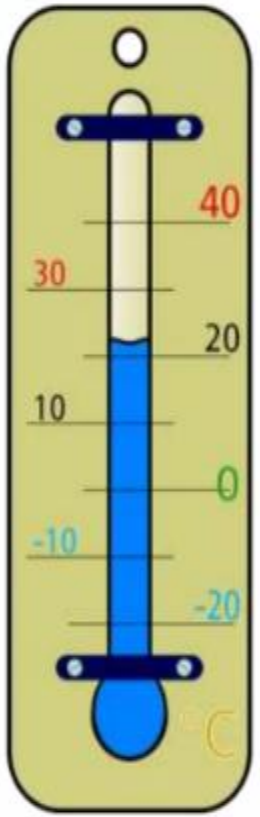
State	Features	Movement of Particles
Solid	Fixed shape & volume	Vibrate, but have fixed positions
Liquid	Shape can change, volume is fixed. Can flow.	Free-moving; no fixed positions
Gas	Shape & volume not fixed & depends on container. Can flow.	Particles move quickly & are far apart

Remember!

Above 100 Celsius, water is a vapor.

Between 0 Celsius & 100 Celsius, water is a liquid.

Below 0 Celsius, water is a solid.

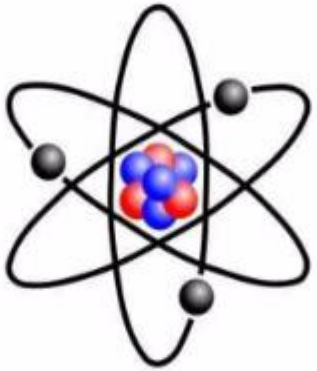


Atoms

atom: the smallest unit of matter

The smallest unit of matter is called an atom. If you chop a piece of metal into a billion pieces, the smallest bit you are left with that still has the properties of the metal is called an atom.

The word *atom* is derived from a Greek word that means ¨cannot be divided¨.



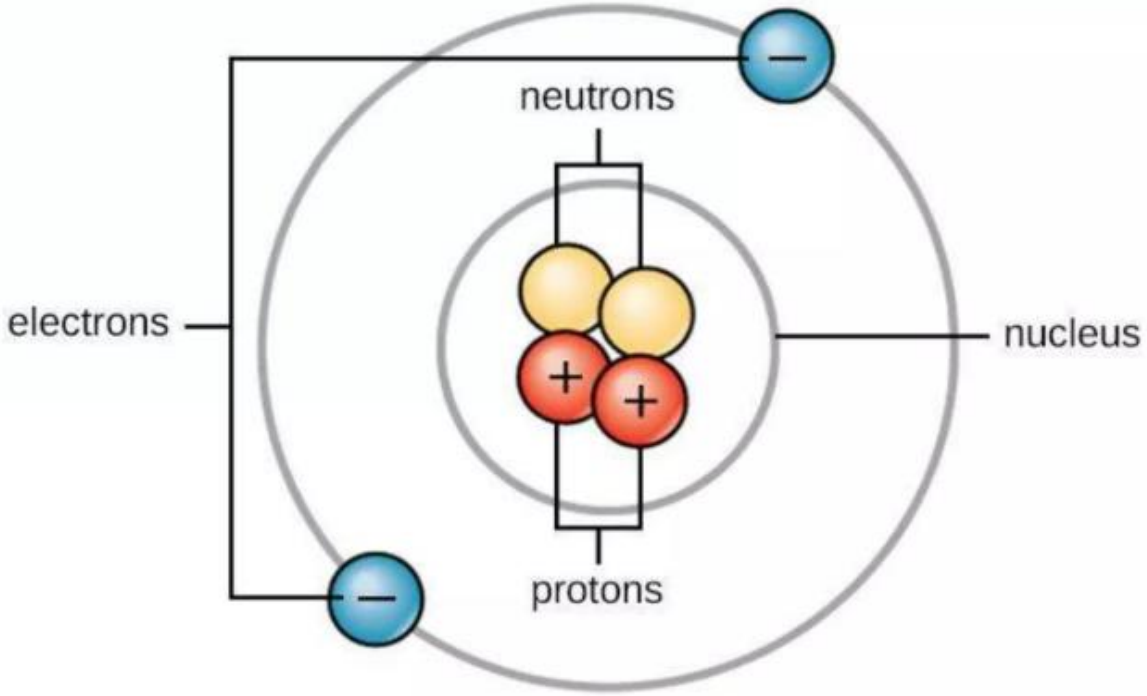
Atomic Models

Atoms are made of smaller particles:

Protons (positively charged particles)

Neutrons (electrically neutral particles, which means they have no change)

Electrons (negatively charged particles with almost no mass)



Conservation of Mass

While things may change appearance or composition during physical & chemical changes, 1 thing remains consistent: the amount of matter present. This concept is called the conservation of mass. So mass doesn´t just dissapear - it still exists, but it may be in a different form, like in the surrounding gases. The atoms have just rearranged to form different substances.

conservation of mass: the amount of mass at the start of a reaction will equal the amount of mass after the reaction

Engineering Materials : Any material which has got application in engineering construction is termed engineering material. Understanding of the fundamental nature of engineering materials is important in all branches of engineering. The subject engineering materials deals with the study of materials in respect of the following:

- Sources, composition and properties
- Manufacturing methods and testing
- Utility in the various fields of engineering and technology
- Modern techniques for handling and using materials to materialize economic and safer design

Classification of Engineering Materials

- **Group A:**
- Civil engineering materials: stones, bricks, cement, concrete, timber, etc.
- Electrical engineering materials: copper, aluminium, silicon, asbestos, iron, cobalt etc.
- Mechanical engineering materials: cast iron, steel, lubricating materials etc.
-
- **Group B:**
- Metals: iron aluminum, copper, zinc etc.
  - Ferrous metals : cast iron, wrought iron, etc
  - Non-ferrous metals: copper, zinc etc.
- Non metals: stones, cement, concrete etc.
-
- **Group C** :
- Metals and alloys: steel, copper, brass, bronze etc.
- Ceramics: silica, soda lime, glass, concrete, ferrites, etc.
- Organic materials : plastics, PVC, synthetic rubber etc,
-

- **Properties of Materials**: some of the important properties of engineering materials are:
- Physical properties
- Mechanical properties
- Chemical properties
- Thermal properties
- Magnetic properties
- Electrical properties

Mechanical Properties

Behavior of material when external forces are applied.

Properties of Solids:

- The molecules are **closely packed in a definite order**.
- The inter-molecular space is **very small**.
- Solids can't be compressed.
- The inter-molecular force in solids are **very strong**.
- Solids have a definite **shape and size**.
- Solids are **crystalline or amorphous.**
- The density of solids is slightly higher than their liquid states.

Properties of Solids:

- Solids are not **perfectly rigid**.
- A rigid body generally means a **hard solid** object having a definite **shape and size**.
- But in reality solid bodies can be **stretched, compressed and bent**.

Elasticity:

- The property of a body by feature of which **it tends to regain its original size and shape,** when the applied force is removed is known as **elasticity** and the deformation caused is known as **elastic deformation.**
- When we apply similar quantities of **stress to steel and rubber** with the same cross-sectional area, we discover that rubber stretches more than steel.
- The strain generated by **rubber is substantially greater than that produced by steel.**
- This indicates that **steel has a higher Young's modulus of elasticity than rubber** and therefore it has more elasticity. Hence, that is why **steel is more elastic than rubber.**

Plasticity:

- The body which has **no tendency to regain its original shape and get permanently deformed** is called plastic body. This property is known as plasticity.

- Eg. **Clay, Wax,** etc..,

- **It is the ability of a material to be deformed permanently without fracture after removal of load.**
- **Plastic deformation will take place only when it exceeds the elastic limit.**
- **This property is desirable for stamping on coins and ornaments.**

Deforming and Restoring Forces:

- ✓A force which changes the **length, shape or volume of a body** is called as a deforming force.
- ✓ When an elastic body is subjected to a deforming force, a restoring force is developed in the body.
- ✓ This restoring force is equal in magnitude but opposite in direction to the applied force.

$$\text{Stress}, \sigma = \frac{Force}{Area}$$

Stress

- The restoring force per unit area is known as stress.
- If **F is the applied force** and **A is the area** of cross-section of the body

Stress = F/A

- The S.I unit of stress is **Nm^{-2} or Pascal (Pa).**

Types of stress

1. **Linear stress** (longitudinal or tensile stress)
2. **Volume stress** (Bulk stress)
3. **Shearing stress** (Tangential stress)

Brief explanation on types of stress

- **Linear stress** is the stress developed, **when the applied force produces** a change in the **length of the body**.

- **Volume stress** is the stress developed in the body, **when the applied force produces a change in the volume of the body.**

- **Shearing stress** is the stress developed in the body, **when the applied force produces, a change in shape of the body.** The effect of these stresses is **to produce distortion or a change in size, volume and shape.**

Strain

- The deforming force applied on a body produces a change in its dimensions and the body is said to be strained.
- Strain is defined as the ratio of change in dimension to the original dimension.

Strain = (Change in dimension) / (Original dimension)

- Strain has no unit and dimension.

$$\text{Strain, } \varepsilon = \frac{L - L_0}{L_0}$$

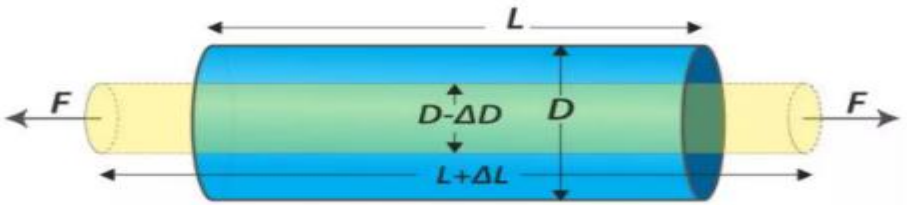
Types of strain

- Longitudinal stress
- Volume strain
- Shearing strain
- Lateral Strain

Longitudinal strain

- If the deforming force produces a change in **length**, the strain produces in the body is called longitudinal strain or tensile strain or linear strain.

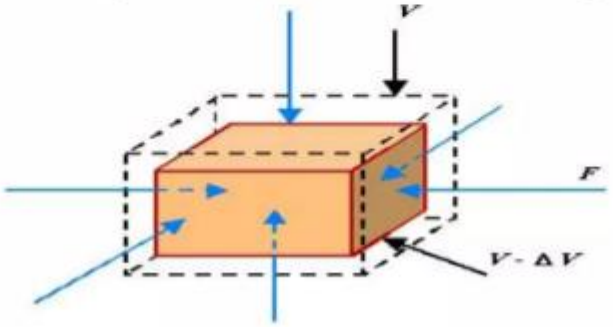
Strain = Change in length / Original length



Volume strain

- If the deforming force produces a change in volume, the strain produced in the body is called volume strain.

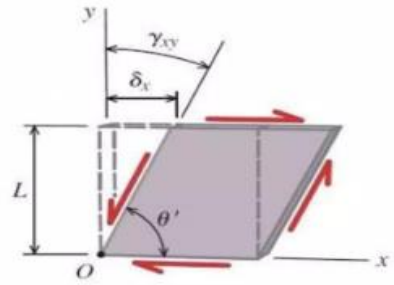
Strain = Change in volume / original volume



Shearing strain

- If the deforming force produces a change in shape of the body without changing volume, the strain produces is called **shearing strain.**

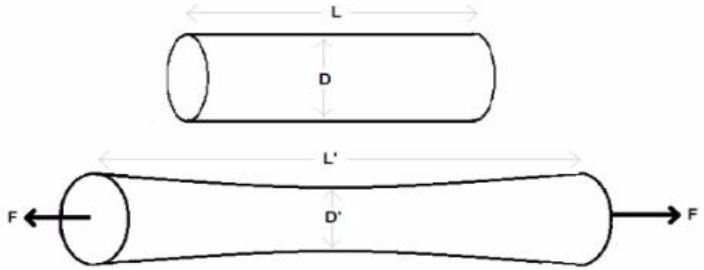
Shearing strain = tan θ = dx / L



Lateral strain

- If the deforming force produces a change in diameter of the body.

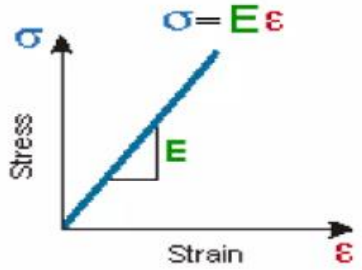
Lateral strain = D' / D



Modulus of Elasticity

- The modulus of a material describes how well it resists deformation. A material with a higher modulus is stiffer and has better resistance to deformation. The modulus is defined as the force per unit area required to produce a deformation or in other words the ratio of stress to strain.

- Modulus of elasticity=Stress/Strain



Hooke's law:

- According to Hooke's law, "within the elastic limits, stress is directly proportional to strain".

Stress = K * Strain

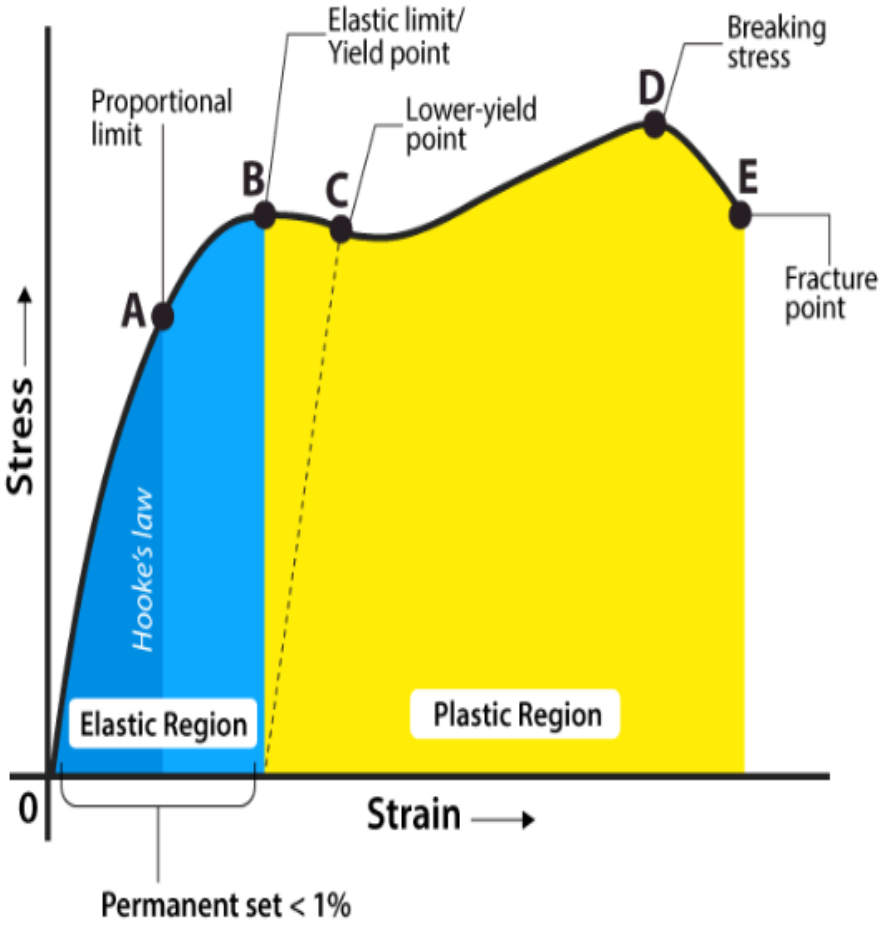
- Where, K is the proportionality constant called the modulus of elasticity.

K = Stress / Strain

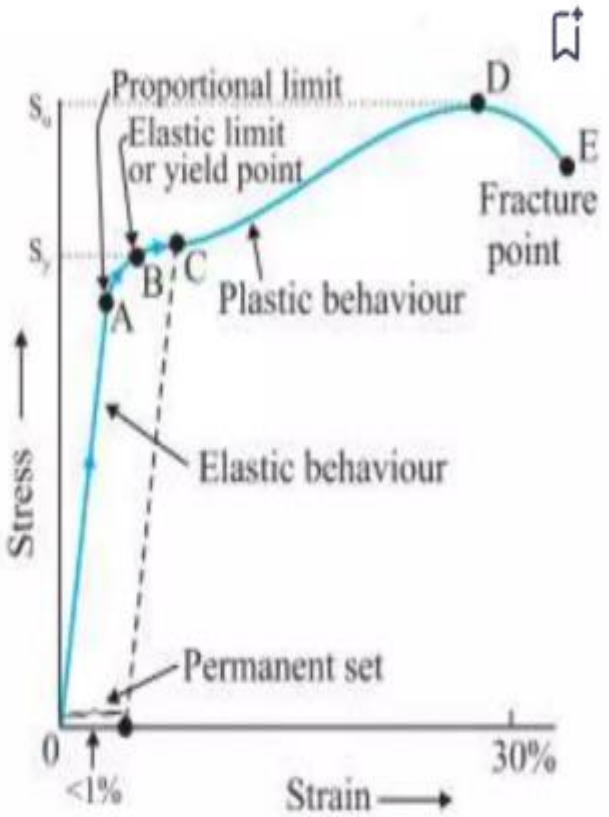
- S.I unit of 'K' is **Nm^{-2}** or Pascal (**Pa**).

Stress-Strain Curve

- In the region between O and A, the **curve is linear**. Hence, Hooke's Law obeys in this region.
- In the region from **A to B**, **stress and strain are not proportional.** However, if we remove the load, the body returns to its original dimension.
- The **point B** in the curve is the **Yield Point or the elastic limit** and the corresponding stress is the Yield Strength (Sy) of the material.
- Once the load is increased further, the **stress starting exceeding the Yield Strength.** This means that the strain increases rapidly even for a small change in the stress.
- This is shown in the region from **B to D** in the curve. If the load is removed at, say a point C between B and D, the body does not regain its original dimension. Hence, **even when the stress is zero, the strain is not zero and the deformation is called plastic deformation.**

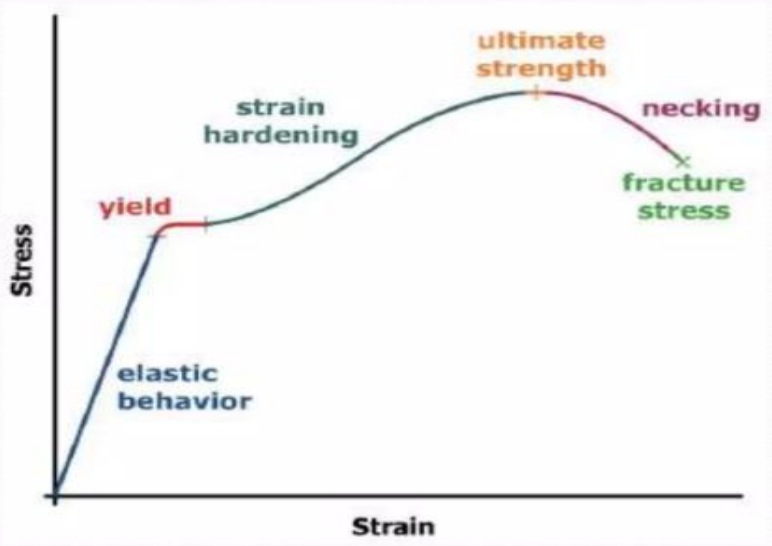


- Further, the point D is the **ultimate tensile strength** (Su) of the material. Hence, if any additional strain is produced beyond this point, a **fracture can occur (point E).**
- If, The ultimate strength and fracture points are close to each other (points D and E), then the material is **brittle**.
- The ultimate strength and fracture points are far apart (points D and E), then the **material is ductile.**



Strain Hardening

- When yielding has ended, a further load can be applied to the specimen, resulting in a cure that rises continuously but becomes flatter until it reaches a maximum stress referred to as **ultimate stress, s_u.**
- The rise in the curve is called **Strain Hardening**



In the plastic region, the true stress increases continuously i.e when a metal is strained beyond the yield point, more and more stress is required to produce additional plastic deformation and the metal seems to have become more stronger and more difficult to deform. This implies that the metal is becoming stronger as the strain increases. Hence, it is called **"Strain Hardening"**.

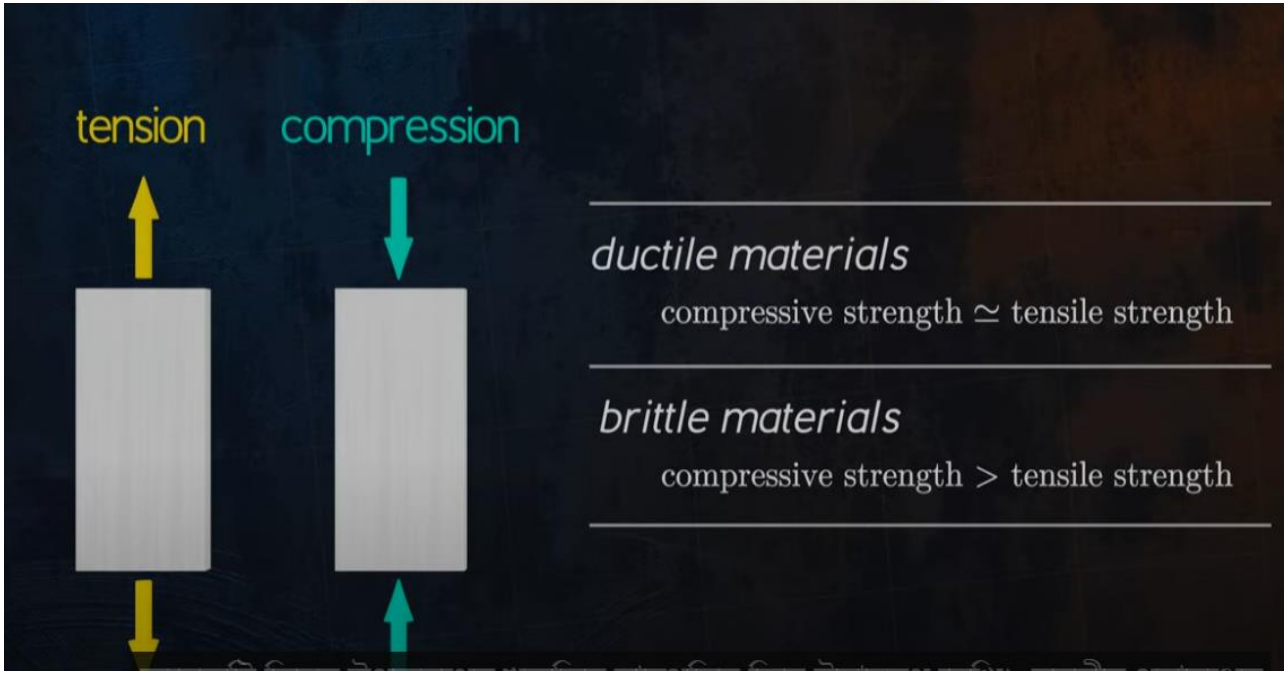
Modulus of Rigidity

- Within the elastic range, shearing stress is proportional to shearing strain. Hence the ratio of shearing stress to shearing strain is expressed by G, the modulus of rigidity.
- $G = \tau / \gamma$

1) Strength

Search as vipulgoti

- It is the ability of a material to resist the external forces without breaking.
- The strength of material depends on type of loading.
- Various types of strength like tensile, compressive, shear etc.



Hardness

- Hardness is the **resistance of material to permanent deformation of the surface**. It is the property of a metal, which gives **it the ability to resist being permanently deformed** (bent, broken or shape change), when a load is applied.
- 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 .

2) Stiffness/ Rigidity

- **It is the ability of a material to resist deformation under the action of external forces.**
- **Stiffness is measured by elasticity.**

Fatigue

- Fatigue is the **initiation and propagation** of cracks in a material due to cyclic loading. Once a fatigue crack has **initiated**, it grows a small amount with each loading cycle, typically producing patterns on some parts of the fracture surface.
- **The crack will continue to grow until it reaches a critical size**, which occurs when the stress intensity factor of the crack exceeds the fracture toughness of the material, producing rapid propagation and typically complete fracture of the structure.
- Fatigue has **traditionally been associated with the failure of metal components** which led to the term metal fatigue.

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
- Impact strength is the **ability of the material to absorb energy during plastic deformation.**
- Brittleness of a material is an **inverse function of its impact strength**.

Factors Affecting Impact Strength

- ✓ If the dimensions of the specimen are increased, the **impact strength also increases.**
- ✓ When the sharpness of the notch increase, the impact strength required causing failure decreases.
- ✓ The temperature of the specimen under test gives an indication about the type of fractures like **ductile, brittle or ductile to brittle transition**.
- ✓ The angle of the notch also improves impact-strength after certain values.
- ✓ The velocity of impact also affects impact strength to some extent.

Search as: vipulgoti

5) Ductility

- It is the property of a material which enables it to be drawn into thin wires under tensile force.
- It is measured by percentage elongation.
- Gold, silver, copper, aluminium, mild steel etc. are ductile materials.

6) Malleability

- It is the property of a material by virtue of which it can be flattened or bent without cracking when hammered.
- Gold, silver, copper, aluminium, lead etc. are malleable materials.
- A malleable material may not be ductile. i.e. lead.
- This property enables a material to be rolled down to very thin sheets.

Brittleness

Lack of ductility and/or malleability is brittleness. When a body breaks easily under shocks or impact, it is said to be brittle. Cast iron is a brittle material.

Search as: vipulgoti

9) Toughness

- It is the property of a material to resist fracture due to high impact loads like hammer blow and to absorb a certain energy.
- It is measured in terms of energy absorbed per unit volume before it fractures.
- Materials having good toughness are cast iron., high carbon steel, ceramics etc.

10) Resilience

- It is the ability of a material to absorb or store energy when it is subjected to impact loads and shocks.
- Material releases the stored energy on removal of load.
- This property is necessary for spring materials.

12) Fatigue

- A material fails at stresses below the yield point when it is subjected to repeated cyclic loads.
- In fatigue failure the maximum stress developed in each cycle is within elastic limit.
- Common examples of parts due to fatigue failure are shafts, connecting rod, gears, springs etc.

Corrosion Resistnce

- Corrosion is the gradual destruction of the metal due to its exposure to moisture, acids and other chemicals.
- Corrosion resistance is the property of the material to resist the corrosion.