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A course on **Mechanics of Materials BME301**

INTRODUCTION

by

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Introduction

Course Overview

Subject Name	Mechanics of Materials
Subject Code	BME301
CIE Marks	50
SEE Marks	50
Credits	03

Course Learning Objectives:

- ❖ To provide the basic concepts and principles of strength of materials.
- ❖ To give an ability to calculate stresses and deformations of objects under external loadings.
- ❖ To give an ability to apply the knowledge of strength of materials on engineering applications and design problems.

Course Outcomes: At the end of the course, the student will be able to:

- ❖ CO1: Understand the concepts of stress and strain in simple and compound bars.
- ❖ CO2: Explain the importance of principal stresses and principal planes & Analyse cylindrical pressure vessels under various loadings
- ❖ CO3: Apply the knowledge to understand the load transferring mechanism in beams and stress distribution due to shearing force and bending moment.
- ❖ CO4: Evaluate stresses induced in different cross-sectional members subjected to shear loads.
- ❖ CO5: Apply basic equation of simple torsion in designing of circular shafts & Columns

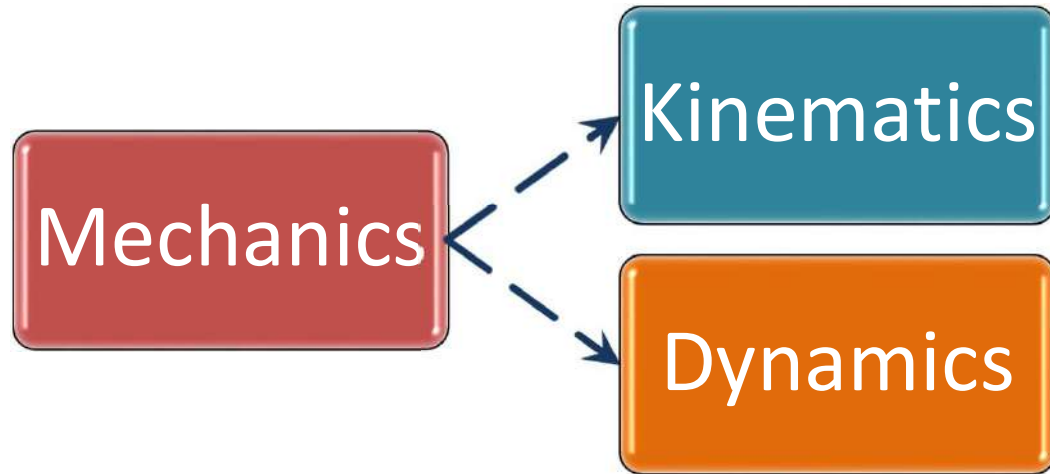
Introduction

Course Syllabus Overview

Module-1	✓ Simple stress and strain
Module-2	✓ Bi-axial Stress system ✓ Thick and Thin cylinders
Module-3	✓ Bending moment and Shear forces in beams
Module-4	✓ Theory of simple bending
Module-5	✓ Torsion of circular shafts ✓ Theory of columns

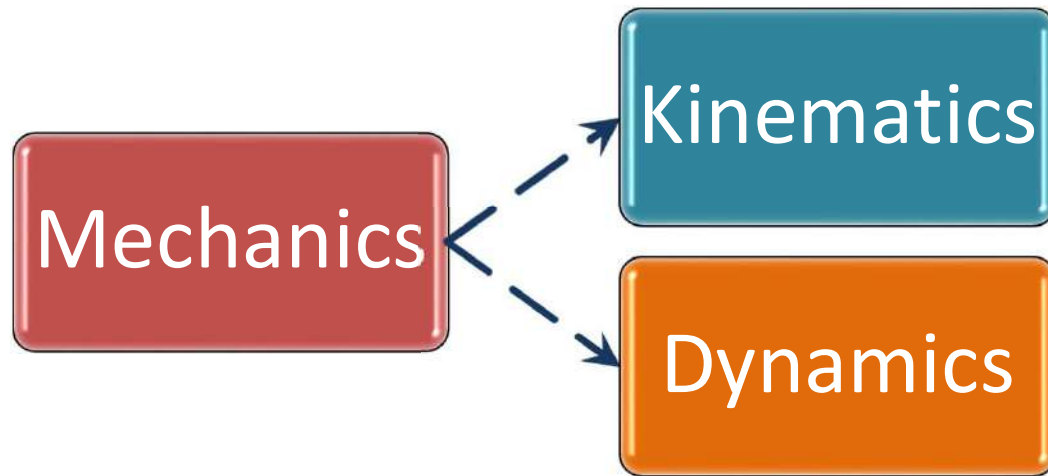
Sl. No.	Title of Book	Author	Publisher	Edition / Year
1.	Mechanics of Materials	K.V. Rao G. C. Raju	Subhash Stores	2007
2.	Strength of Materials	R.K. Bansal	Laxmi Publications	2010

Introduction What is **MECHANICS**?



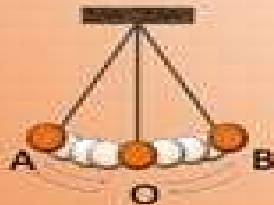
Introduction

What is **MECHANICS**?



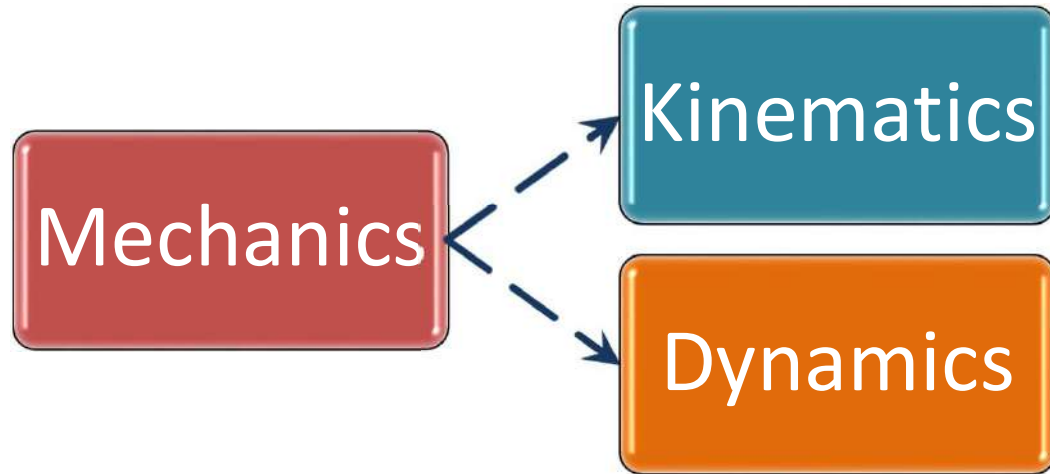
Kinematics, is concerned with the geometrically possible motion of a body or system of bodies without consideration of the forces involved.

TYPES OF MOTION WITH EXAMPLES



Introduction

What is **MECHANICS**?



Dynamics, is concerned with the geometrically possible motion of a body or system of bodies with consideration of the forces involved.

Introduction

What is MECHANICS?

Types of Force



Friction Force



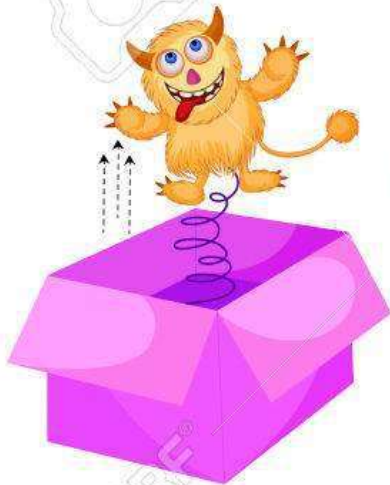
Gravity Force



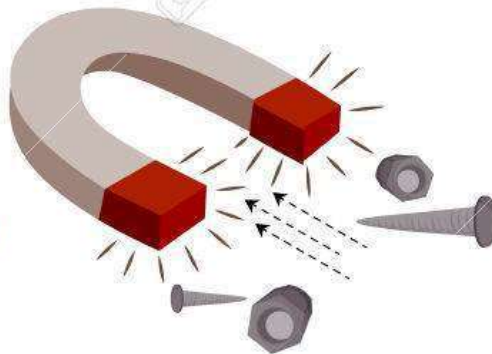
Applied Force



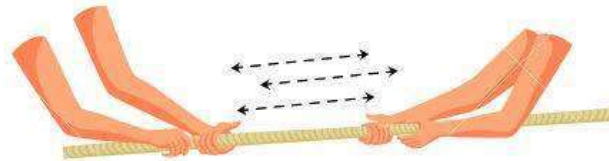
Drag Force



Spring Force



Magnetic Force



Tension Force



Buoyant Force

Introduction What is **MECHANICS** of **MATERIALS**?

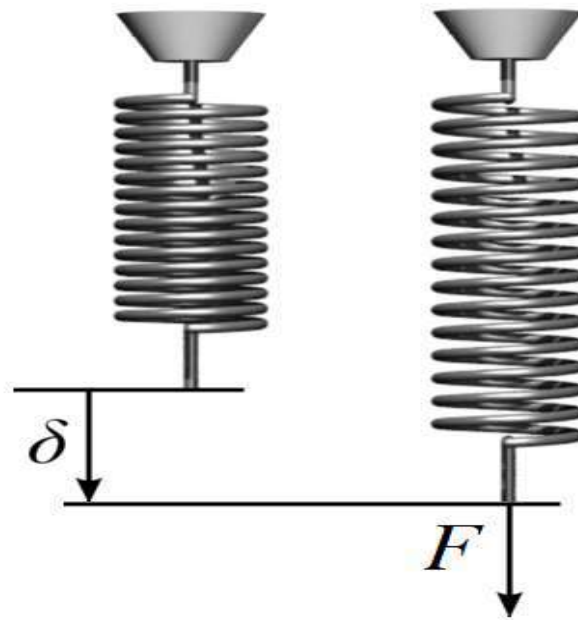
Mechanics of materials, deals with the behaviour of solid objects subject to stresses and strains.

Stress is defined as internal resisting force per unit area.

$$\sigma = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \text{ N/mm}^2$$

Strain is defined as the ratio of change in length to original length.

$$\varepsilon = \frac{\text{Change in Length}}{\text{Original Length}} = \frac{\Delta L}{L}$$



Introduction

Behaviour of Objects to Forces



The Golden Gate Bridge, San Francisco Bay, during Sunday morning's bridge walk, May 24, 1987. An estimated 350,000 people turned out for the bridge walk, for the Golden Gate Bridge 50th anniversary celebration. The unprecedented weight caused the middle of the bridge to sag 7 feet.

Introduction

Behaviour of Objects to Forces



The Tacoma Narrows Bridge (USA) main span collapsed into the Tacoma Narrows as a result of aeroelastic flutter caused by a 42 mph (68 km/h) wind. The bridge collapse event is presented as an example of elementary forced resonance, even though the real cause of the bridge's failure was aeroelastic flutter, not resonance. A contributing factor was its solid sides, not allowing wind to pass through the bridge's deck. Thus, its design allowed the bridge to catch the wind and sway, which ultimately took it down.

Introduction

Behaviour of Objects to Forces



Introduction

Conclusions

- ✓ All objects are made of some material, shape and size based on the application.
- ✓ Different materials have different mechanical properties. Example hardness, stiffness, brittleness, ductility etc.
- ✓ Forces bring change in the shape and size of an object.
- ✓ Some changes are temporary and some are permanent.
- ✓ Forces very large in magnitude cause breakage of the object.

TASK TO DO

- List ten different objects you use.
- Note the forces being applied on these objects.
- Note the behavior of these objects to the applied forces.
- Categorize the changes in the object into temporary and permanent.



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PROPERTIES OF MATERIALS

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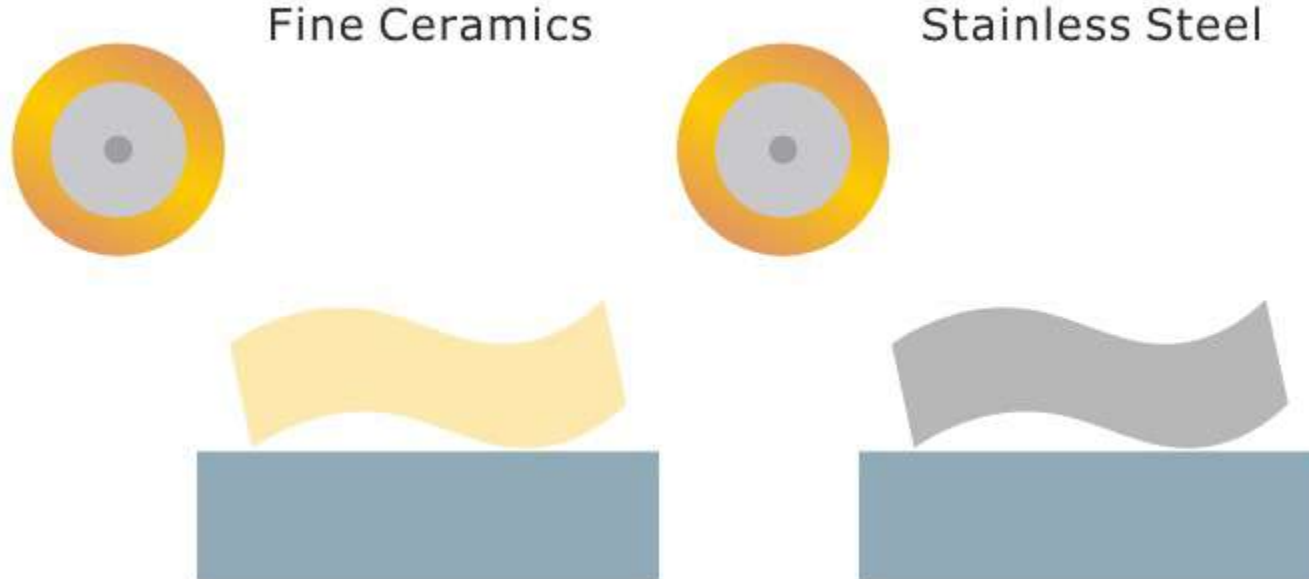
Bearys Institute of Technology, Mangalore

Introduction Properties of Engineering Materials

Strength	The ability of a member to resist load without failure due to excessive stress is known as strength.
❖	Elastic strength is represented by elastic limit or yield point.
❖	Fracture strength is represented by ultimate stress.
❖	Impact strength is represented as energy required to cause failure.
Stiffness	The ability of a material to resist deformation induced by loads is known as stiffness.
❖	Stiffness or rigidity is measured by modulus of elasticity in axially loaded members.
❖	Stiffer material undergoes small deformations.
Hardness	It is a measure of resistance to surface penetration and abrasion.
❖	It is expressed as a number (Ex: 75BHN)
Resilience	The ability of a material to absorb energy when deformed elastically and to return it when unloaded is known as resilience.
❖	It is expressed as area under the elastic region in the stress-strain diagram.
Toughness	The ability of a material to absorb energy in the plastic region is known as toughness.
❖	The area under the stress-strain diagram represents toughness per unit volume of the material.

Introduction Properties of Engineering Materials

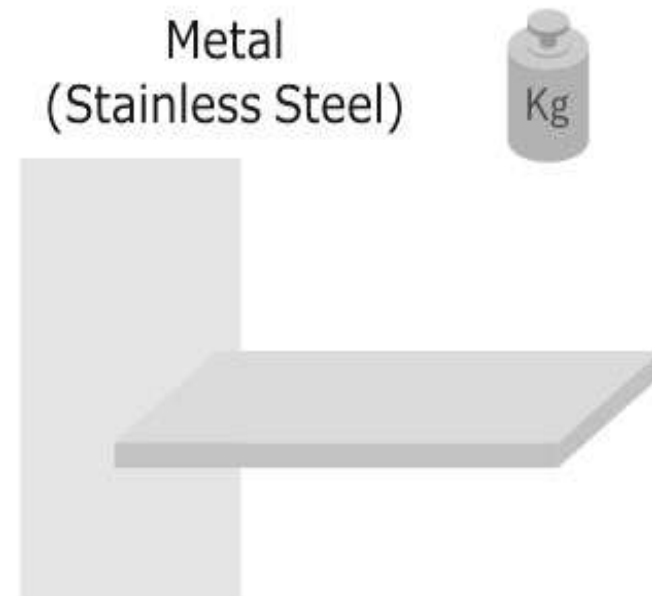
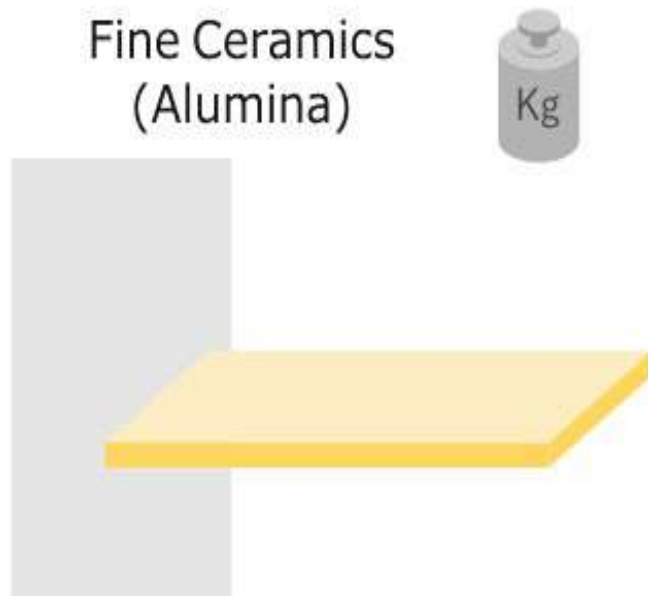
STRENGTH: The ability of a member to resist load without failure due to excessive stress is known as strength.



Introduction Properties of Engineering Materials

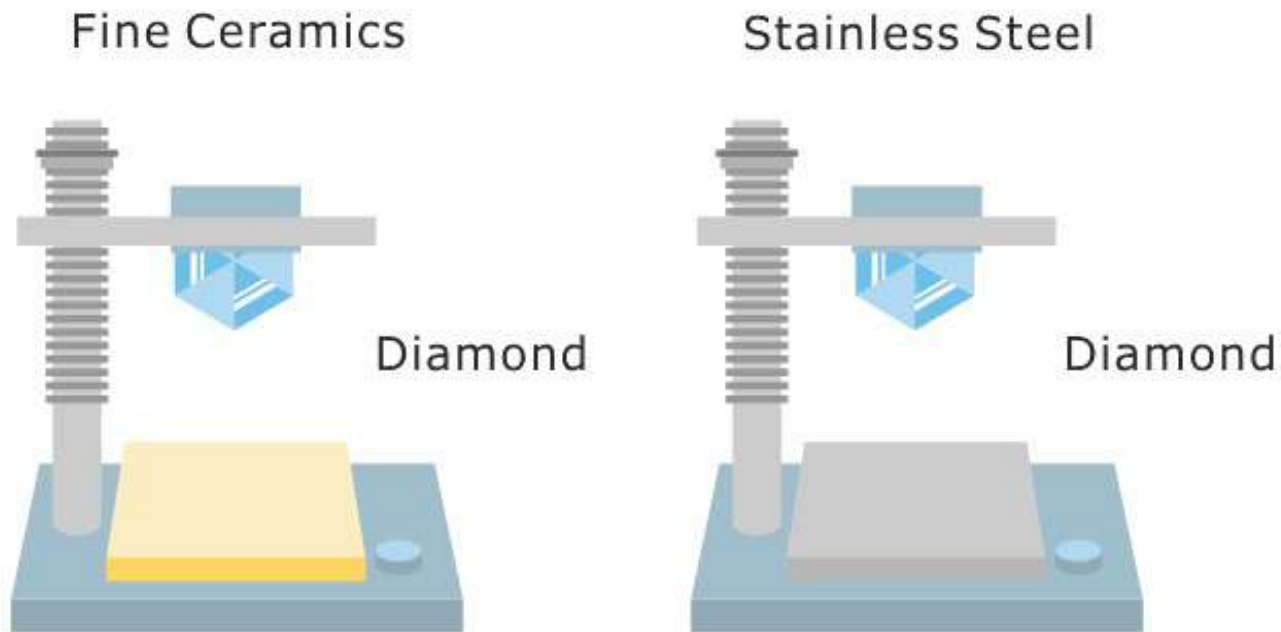
RIGIDITY or STIFFNESS:

The ability of a material to resist deformation induced by loads is known as stiffness.



Introduction Properties of Engineering Materials

HARDNESS: It is a measure of resistance to surface penetration and abrasion.



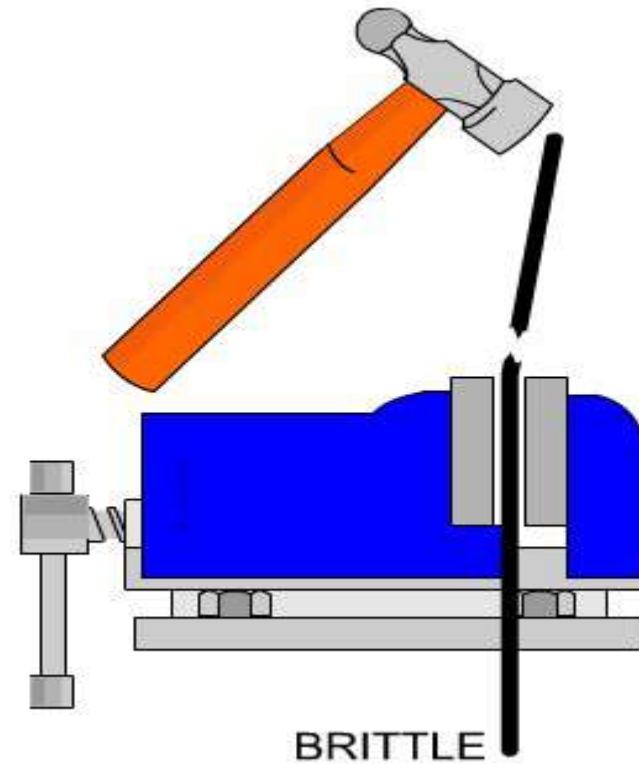
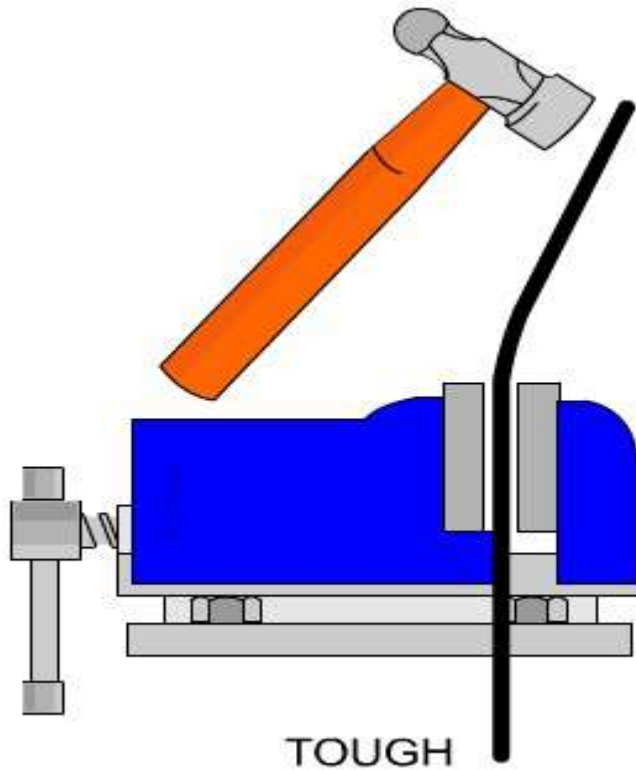
Introduction Properties of Engineering Materials

Resilience: The ability of a material to absorb energy when deformed elastically and to return it when unloaded is known as resilience.



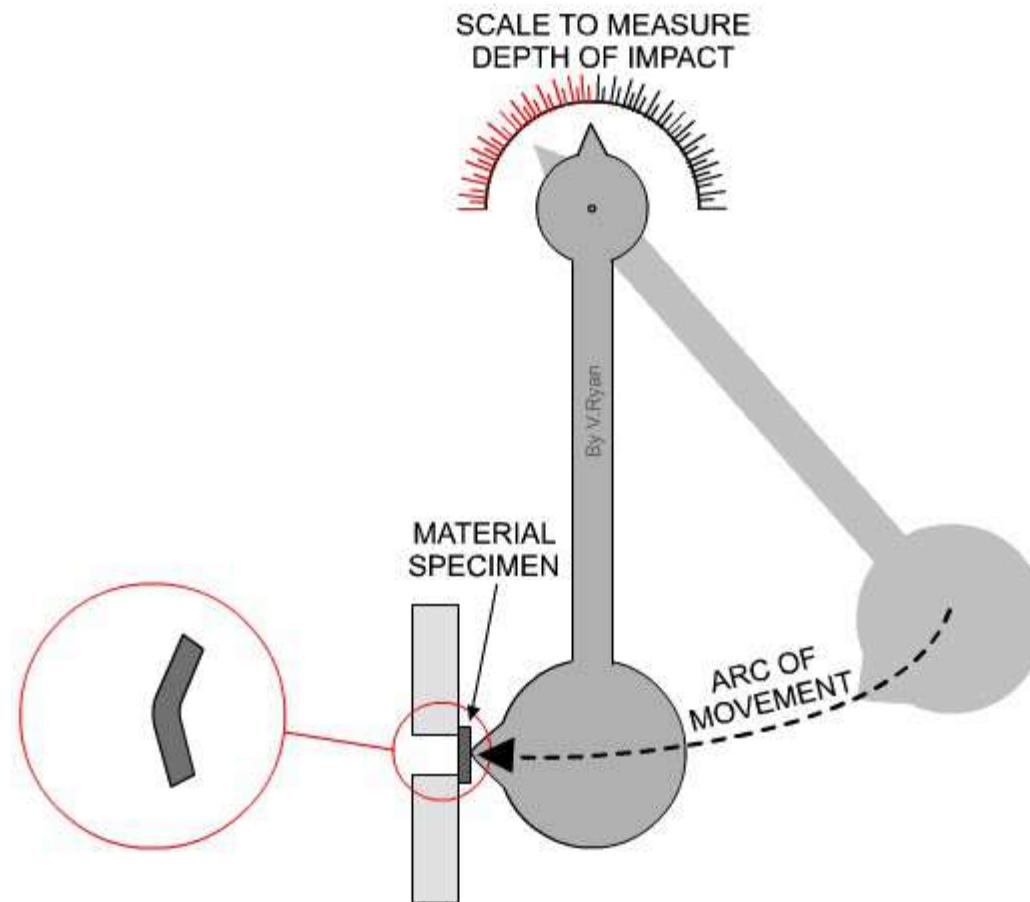
Introduction Properties of Engineering Materials

TOUGHNESS: The ability of a material to absorb energy in the plastic region is known as toughness.



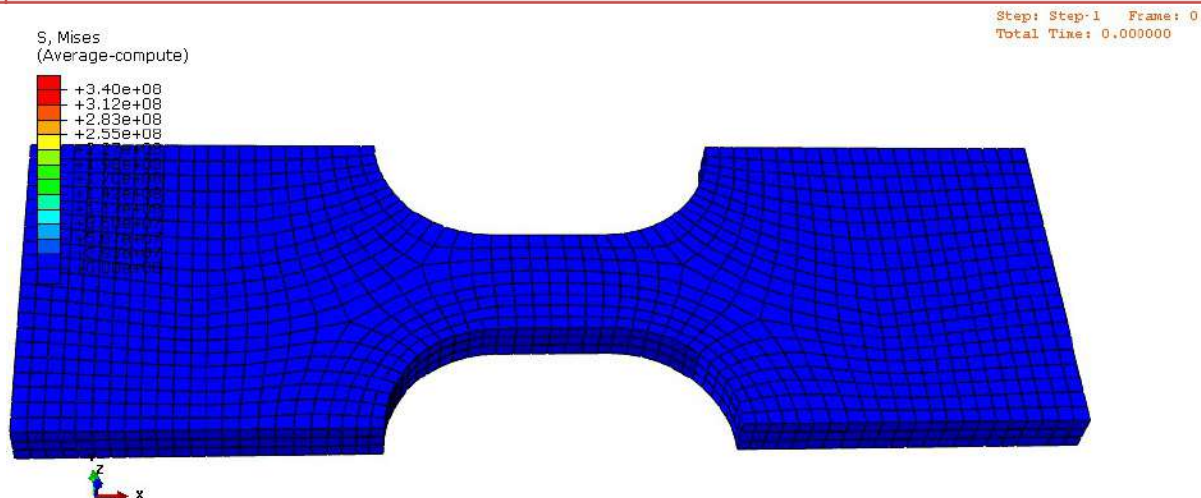
Introduction Properties of Engineering Materials

TOUGHNESS: The ability of a material to absorb energy in the plastic region is known as toughness.



Introduction Properties of Engineering Materials

DUCTILITY	It is the ability of a material to undergo significant plastic deformation before fracture.
❖	Ductile materials are good in tension.
❖	Ductile materials can be drawn into thin sheets.
❖	Ductile materials fail undergo necking.
❖	Example: Low carbon steels, aluminium.
❖	It is represented as a measure of percentage elongation or percentage reduction in area $\% \text{ increase in length} = \frac{(\text{Final length}) - (\text{Initial length})}{(\text{Initial length})} \times 100$ $\% \text{ decrease in area} = \frac{(\text{Initial area}) - (\text{Final area})}{(\text{Initial area})} \times 100$



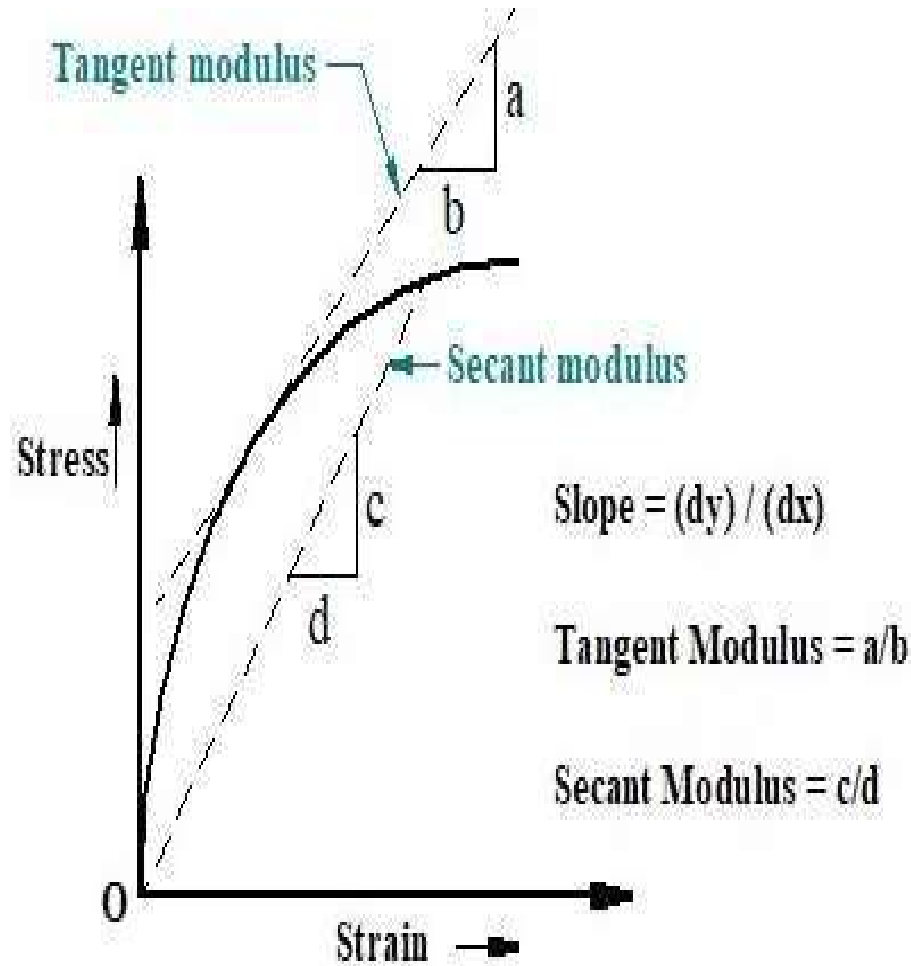
Introduction Properties of Engineering Materials

BRITTLENESS	Brittle materials undergo very less plastic deformation. They exhibit no necking.
❖	Brittle materials are good in compression.
❖	Brittle materials do not undergo yielding.
❖	Brittle materials do not exhibit necking.
❖	Example: High carbon steels, Cast Iron and glass.



Introduction Stress-Strain Diagram for Engineering Materials

Stress-strain diagram for brittle material



❖ Brittle materials when subjected to tensile force undergo very less elongation i.e., the plastic phase is very small for brittle materials.

❖ There is no yielding and no necking. Hence at ultimate load brittle materials break.

❖ The modulus of elasticity in brittle materials is determined by

✓ **Tangent modulus:** The slope of line tangent to the curve at any point.

$$\text{Tangent modulus} = \frac{dy}{dx} = \frac{a}{b}$$

✓ **Secant modulus:** The slope of line joining the origin to any point on the curve.

$$\text{Secant modulus} = \frac{dy}{dx} = \frac{c}{d}$$

Introduction Elastic Constants of Engineering Materials

Modulus of Elasticity (E)	<p>The ratio of stress to strain within elastic limit is called modulus of elasticity. It is a measure of stiffness or rigidity of a structure.</p> <p><i>Young's modulus of elasticity, $E = \frac{\sigma}{\epsilon} \text{ N/mm}^2$</i></p>
❖	Modulus of elasticity is a constant of a material.
❖	Modulus of elasticity does not change with the carbon content.
Modulus of Rigidity (G)	<p>The ratio of shear stress to shear strain within elastic limit is called as modulus of rigidity or shear modulus of elasticity.</p> <p><i>Modulus of rigidity, $G = \frac{\tau}{\gamma} \text{ N/mm}^2$</i></p>
❖	Larger the modulus of rigidity, lesser is the distortion, in a body subjected to shear stress.
Volumetric Strain (ϵ_v)	<p>The ratio between change in volume to original volume of a body is called volumetric strain.</p> <p>$\epsilon_v = \frac{dV}{V}$</p>
Bulk Modulus (K)	<p>The ratio between spherical stress to volumetric strain is known as bulk modulus of elasticity.</p> <p>$K = \frac{\sigma_v}{\epsilon_v}$</p>

Introduction Elastic Constants of Engineering Materials

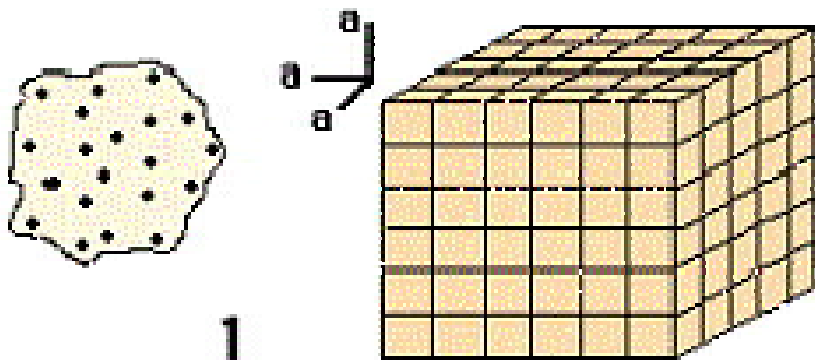
Isotropic body

- A body having same properties in all the directions at a point.

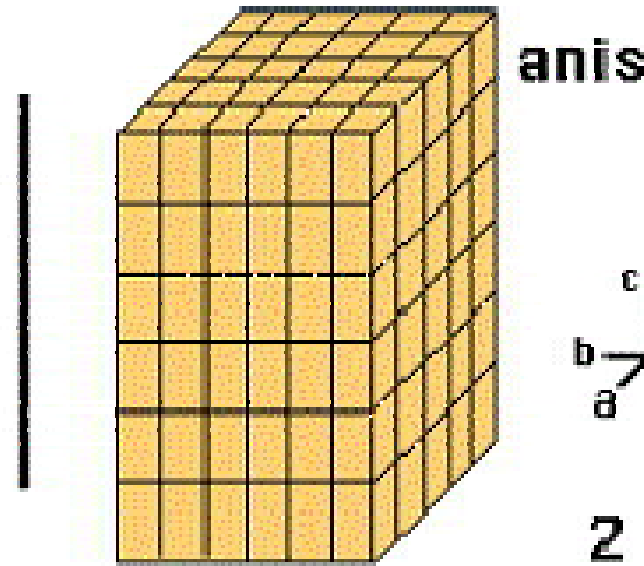
Anisotropic body

- A body having different properties in all the directions at a point.

isotropics



anisotropics



Introduction Elastic Constants of Engineering Materials

Isotropic body

- A body having same properties in all the directions at a point.

Anisotropic body

- A body having different properties in all the directions at a point.

Orthotropic body

- A body having different properties in three mutually perpendicular directions at a point.

Homogeneous body

- A body having uniform properties throughout. The properties are not a function of position of a point in the body



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STRESS-STRAIN DIAGRAM

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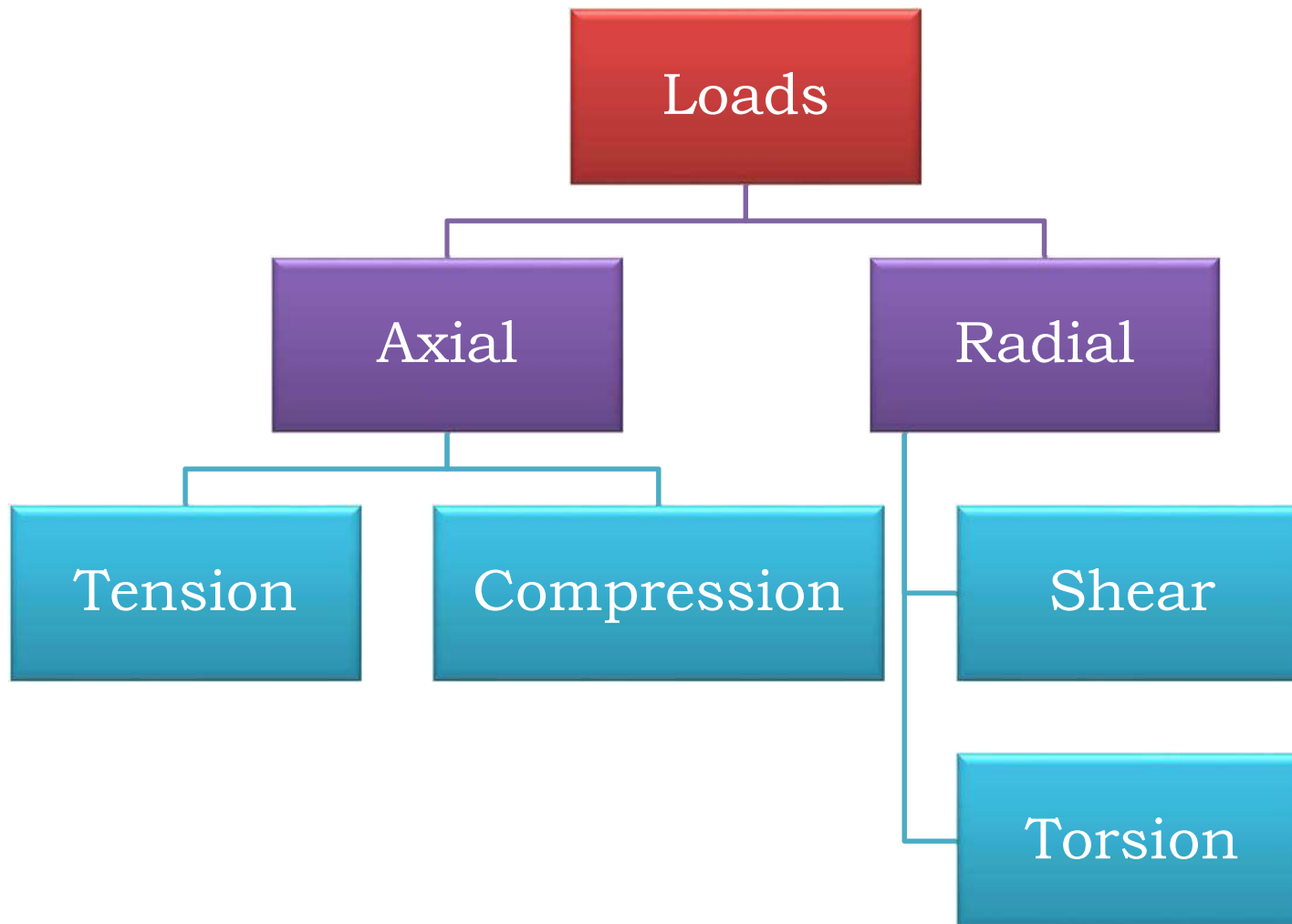
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Introduction

Types of Load Applied

Loads applied on a body can be broadly described as follows:



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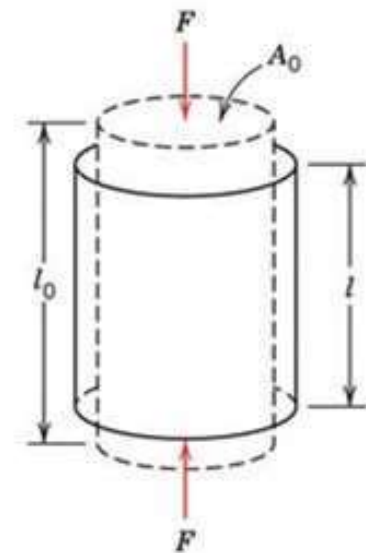
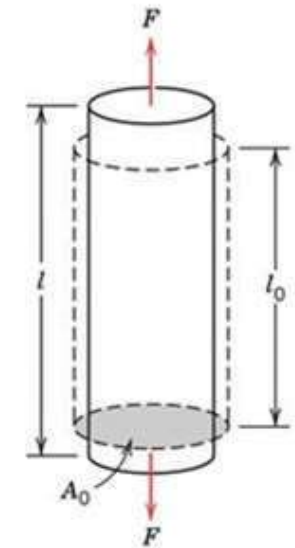
AXIAL LOAD: The load is applied along the axis of the member.

TENSILE LOAD

- ❖ The load is directed away from the member i.e., it is PULLING type in nature.
- ❖ The length of the member increases.
- ❖ The cross-section area of the member decreases

COMPRESSION LOAD

- ❖ The load is directed towards the member i.e., it is COMPRESSIVE type in nature.
- ❖ The length of the member decreases.
- ❖ The cross-section area of the member increases.
- ❖ In case of slender member it causes BUCKLING



Introduction

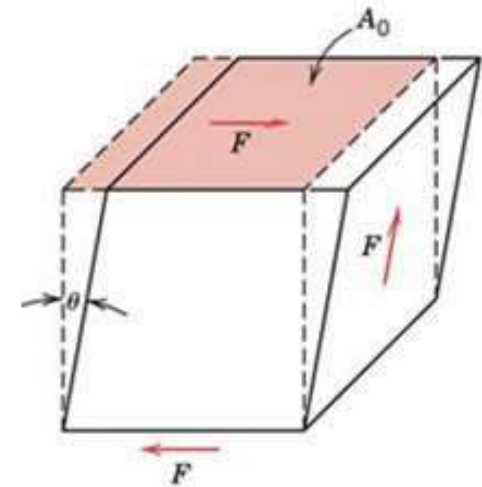
Types of Load Applied

Loads applied on a body can be broadly described as follows:

RADIAL LOAD: The load is applied perpendicular (normal) to the axis and along (parallel) to the cross-section of the member.

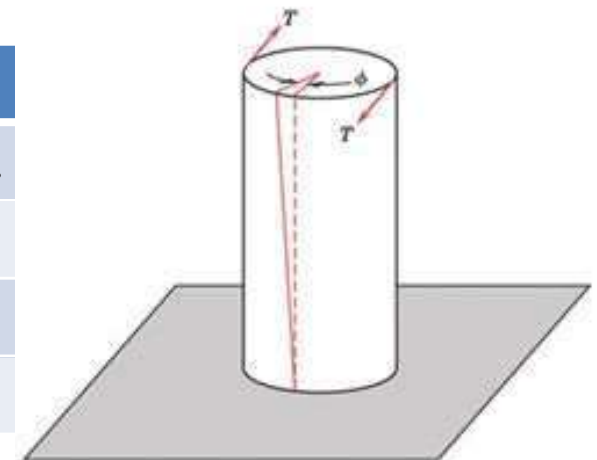
SHEAR LOAD

- ❖ The load is applied along the opposite surfaces of the member.
- ❖ The load is directed in opposite to the other.
- ❖ The perpendicular surfaces of the member are rotated.
- ❖ The load produces BENDING in the member.



TORSION

- ❖ The load is applied tangential to the surface of the member.
- ❖ The load applied is equal and opposite in nature.
- ❖ The load rotates the longitudinal planes of the member.
- ❖ The load produces TORQUE in the member



Introduction

Types of Stresses and Strains

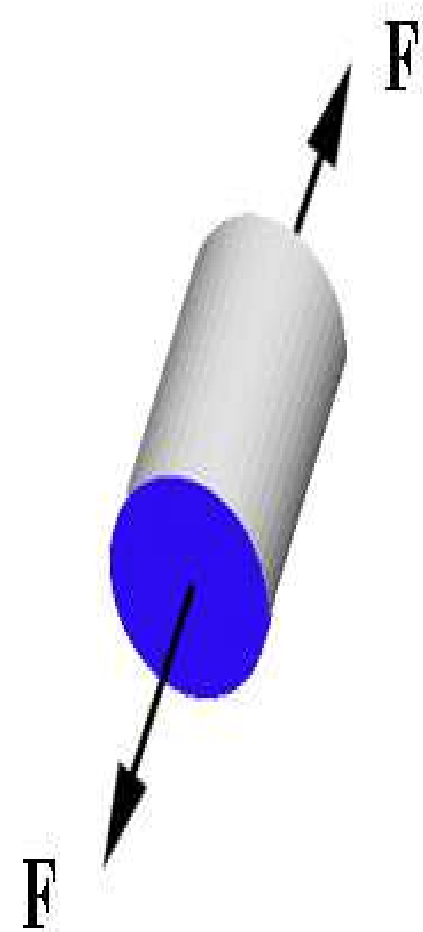
The stresses and strains produced depend on the type of load applied.

NORMAL STRESS: The stress induced normal to a plane (i.e., perpendicular to a plane) is known as normal stress.

$$\sigma = \frac{F}{A} \text{ N/mm}^2$$

TENSILE STRESS: The stress induced by tensile load is known as tensile stress.

$$\sigma_t = \frac{F_t}{A} \text{ N/mm}^2$$



Introduction

Types of Stresses and Strains

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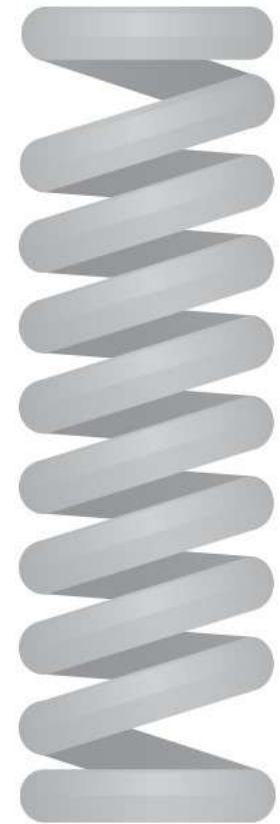
$$\sigma = \frac{F}{A} \text{ N/mm}^2$$

TENSILE STRESS: The stress induced by tensile load is known as tensile stress.

$$\sigma_t = \frac{F_t}{A} \text{ N/mm}^2$$

COMPRESSIVE STRESS: The stress induced by compressive load is known as compressive stress.

$$\sigma_c = \frac{F_c}{A} \text{ N/mm}^2$$



Introduction Types of Stresses and Strains

The stresses and strains produced depend on the type of load applied.

NORMAL STRESS: The stress induced normal to a plane (i.e., perpendicular to a plane) is known as normal stress.

$$\sigma = \frac{F}{A} \text{ N/mm}^2$$

TENSILE STRESS: The stress induced by tensile load is known as tensile stress.

$$\sigma_t = \frac{F_t}{A} \text{ N/mm}^2$$

COMPRESSIVE STRESS: The stress induced by compressive load is known as compressive stress.

$$\sigma_c = \frac{F_c}{A} \text{ N/mm}^2$$

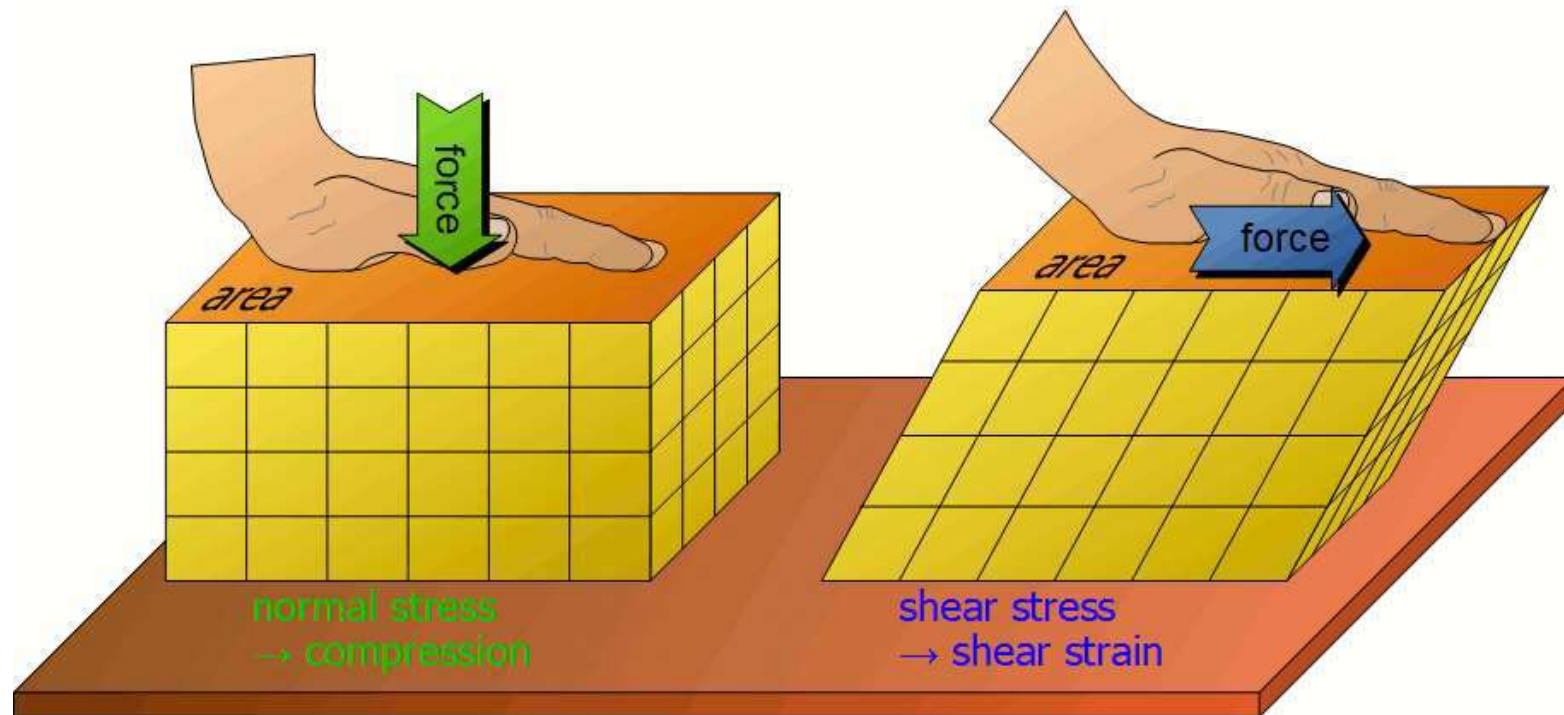
NOTE: The strains corresponding to axial stresses are referred as **AXIAL STRAINS**.

Introduction Types of Stresses and Strains

The stresses and strains produced depend on the type of load applied.

SHEAR STRESS: The shear forces are equal and opposite and act tangentially along a plane. The stress induced by shear force is known as shear stress.

$$\tau = \frac{F}{A} \text{ N/mm}^2$$



NOTE:

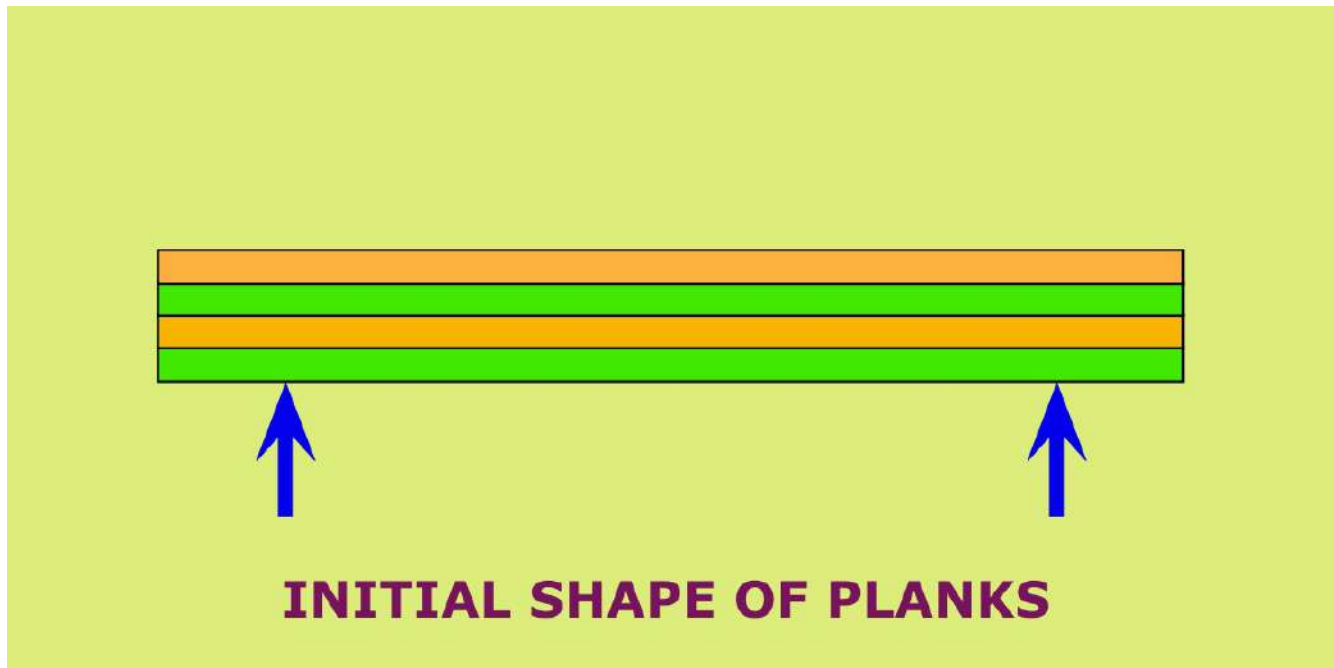
The strains corresponding to shear stresses are referred as SHEAR STRAINS.

Introduction Types of Stresses and Strains

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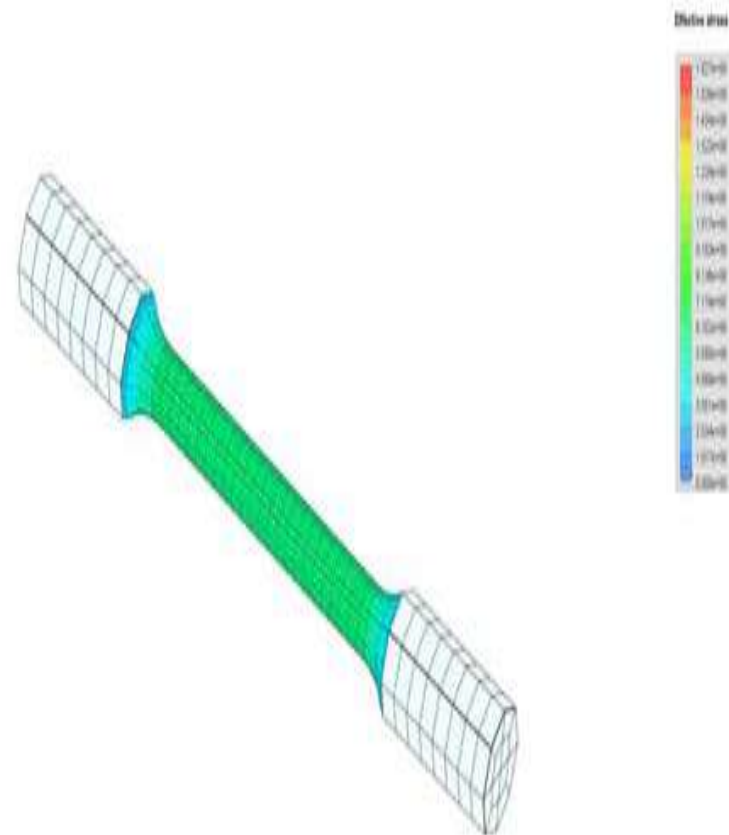
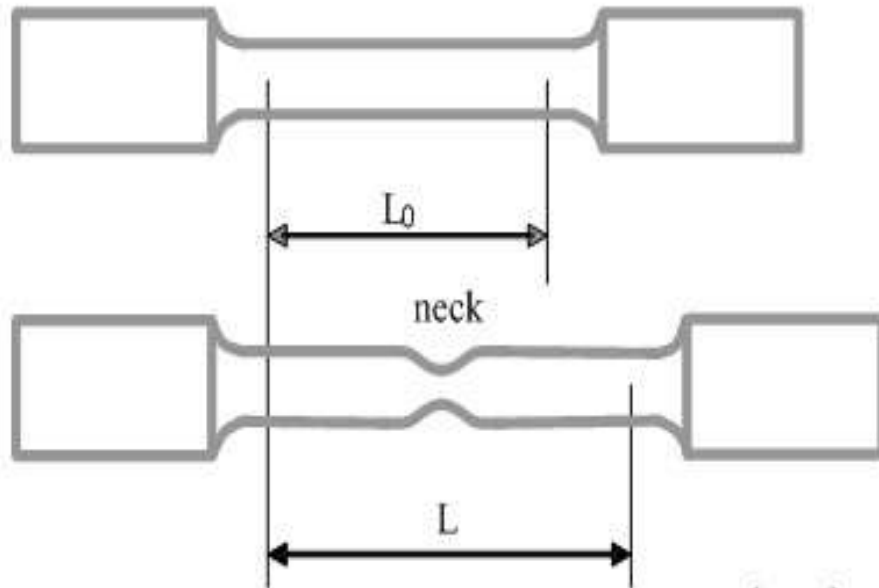
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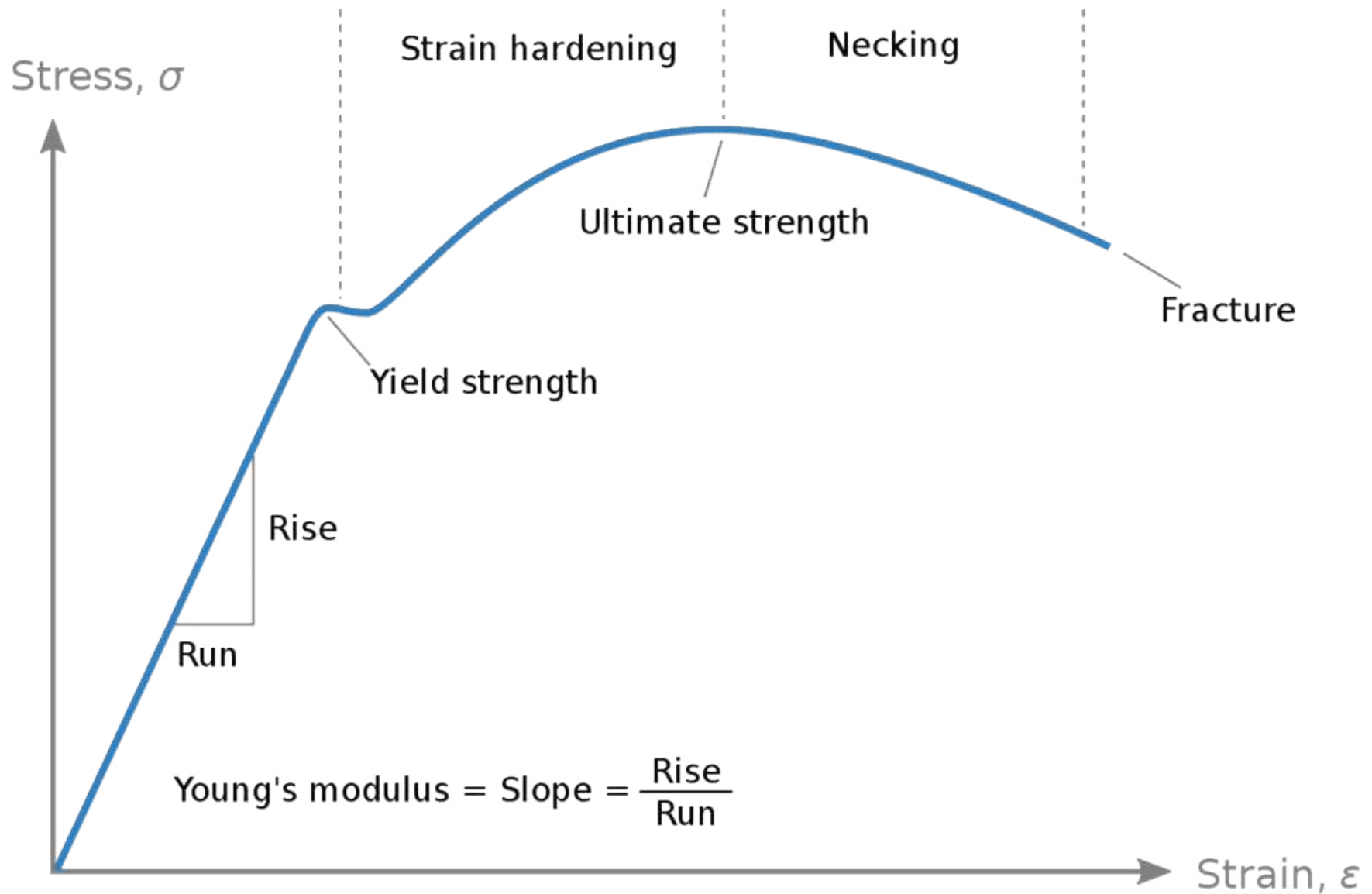


Introduction Types of Stress-Strain Diagram

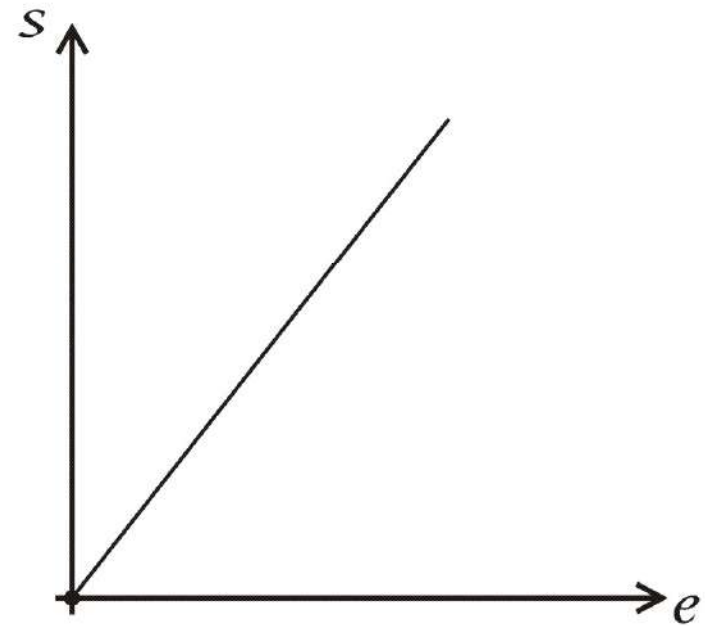
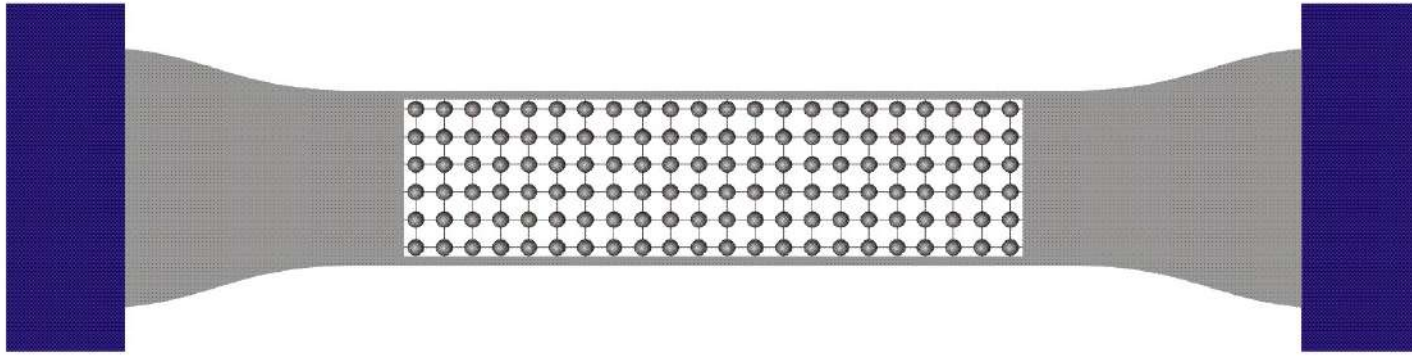
Standard tensile test specimen



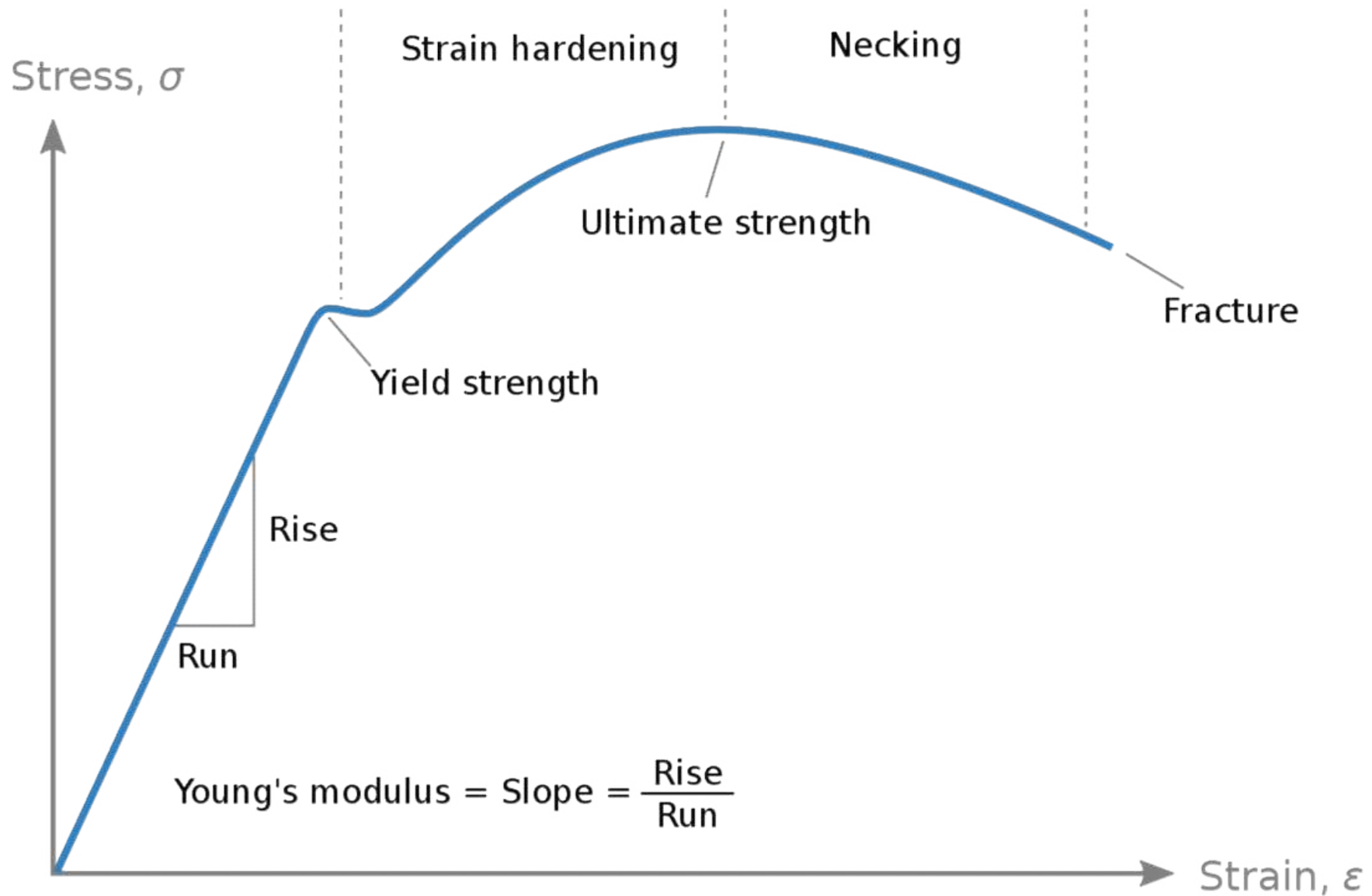
Introduction Types of Stress-Strain Diagram

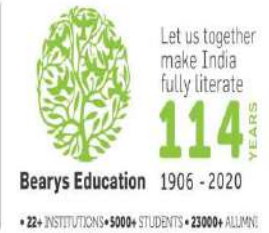


Introduction Types of Stress-Strain Diagram



Introduction Types of Stress-Strain Diagram





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TRUE STRESS-TRUE STRAIN

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Introduction

Stress-Strain Relation

Engineering Stress

- Conventional Stress
- “The internally resisting force developed per unit area”.
- σ (*SIGMA*) .
- $\sigma = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \text{ N/mm}^2$

Engineering Strain

- Conventional Strain
- “The ratio of change in length to original length”.
- ϵ (*EPSILON*).
- $\epsilon = \frac{\text{Change in length}}{\text{Original Length}} = \frac{\Delta L}{L}$

True Stress

- “The internally resisting force developed per unit instantaneous area”.
- $\sigma = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \text{ N/mm}^2$

True Strain

- “The ratio of change in length to original length”.
- $\epsilon = \frac{\text{Change in length}}{\text{Original Length}} = \frac{\Delta L}{L}$

Introduction

Factor of Safety (FOS)

Factor of Safety

- ❖ The material must be loaded within elastic limit to keep it safe and prevent plastic deformation.
- ❖ If the load on the material slightly increases beyond the elastic limit, then yielding starts.
- ❖ Thus the stress in working conditions must be less than the maximum stress that can be taken by the material.

Brittle Material

❖ “The ratio of ultimate stress to working stress”.

$$\text{Factor of safety (FOS)} = \frac{\text{Ultimate stress}}{\text{Working stress}}$$

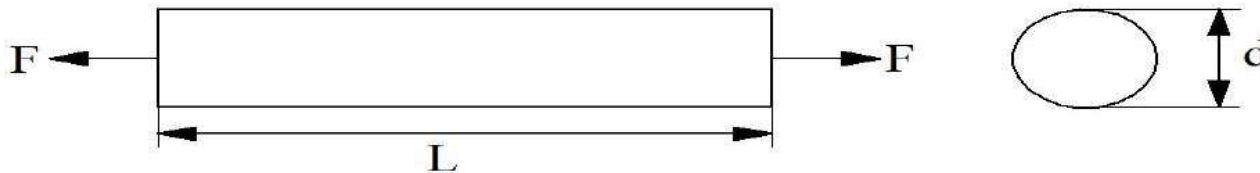
Ductile Material

❖ “The ratio of yield stress to working stress”.

$$\text{Factor of safety (FOS)} = \frac{\text{Yield stress}}{\text{Working stress}}$$

Introduction Elongation (Deformation) in BARS

Elongation in a bar of uniform cross-section



Consider a bar of uniform cross-section subjected to an axial tensile force, “F”.

Let, L = length of the bar

d = diameter of the bar

E = Young’s modulus of elasticity (material constant)

According to Hooke’s Law, stress is proportional to strain

$$\sigma \propto \varepsilon$$

$$\sigma = E\varepsilon$$

$$\frac{F}{A} = E \left(\frac{\Delta L}{L} \right)$$

Therefore change in length,

$$\Delta L = \frac{F \times L}{A \times E}$$

Where, A = Area of cross section

For circular cross-section, $A = \frac{\pi d^2}{4}$, d = diameter of the circular section

For rectangular cross-section, $A = b \times t$

b = width and t = thickness