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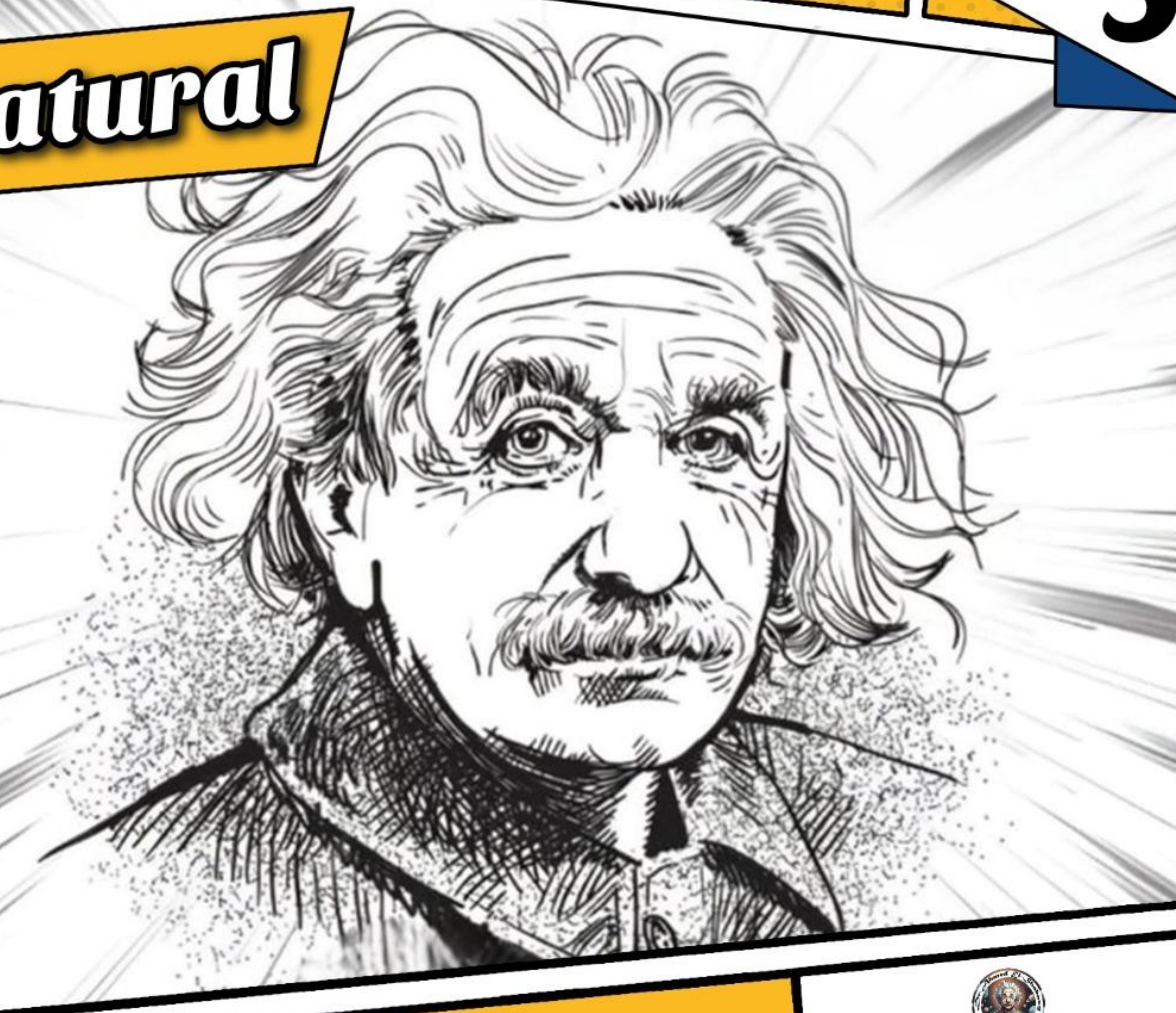
physics

2025

NO 5

Natural



Properties of Matter (Chapter 4 Elasticity)

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Elasticity

deformation

- Elastic
- Plastic

Elastic deformation

- Deformation in which a material changes shape when a stress is applied to it but goes back to its original state when the stress is removed.

Plastic

Bodies which do not show any tendency to recover their original condition.

stress

Is the force per unit area of the object that force is applied

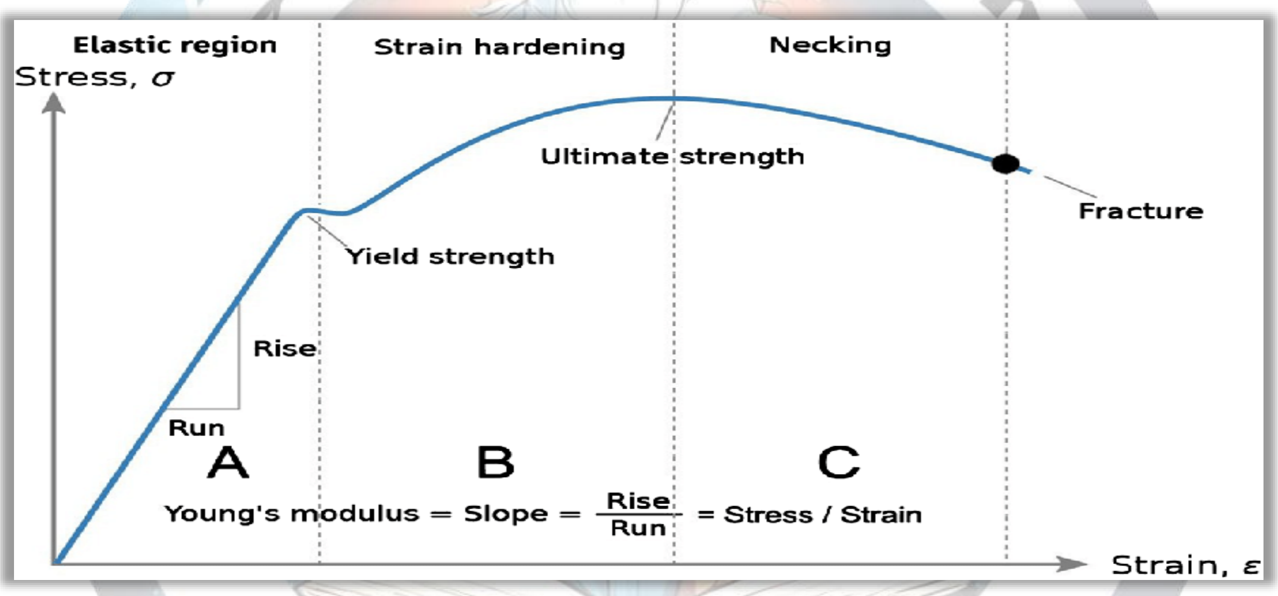
$$\boldsymbol{stress} = \frac{F}{A}$$

$$\frac{N}{m^2}\ or\ Pa\ (\ pascal\ )$$

Strain

- The change produced in the dimensions of a body under a system of forces in equilibrium.
- The strain is a dimensionless quantity

Stress & Strain Curve



Explanation of Stress -Strain Curve

1. Region A

- For small strain, the stress-strain curve is straight line, and the object will return to its original

2. Region B

- If the applied force is increased, the strain increases rapidly

- The object will not return to its original
- It retains a permanent deformation
- The highest point is called ***ultimate tension***

3. Region C

- The additional strain is produced even by a reduced force, fracture is occurring.

$$\boxed{\text{Elastic modulus} = \frac{\text{Stress}}{\text{strain}}}$$

Young's Modulus (Y)

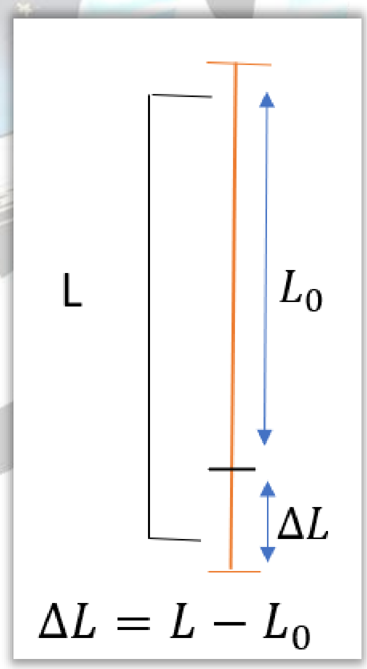
This measures the resistance of a solid to a change in its length

☞ stress

$$\frac{F}{A}$$

☞ strain

$$\boxed{S = \frac{\Delta L}{L_0}}$$



Where:

- L: new length
- L_0: original length
- ΔL: change in length

☞ Young modulus

$$Y = \frac{Stress}{Strain}$$

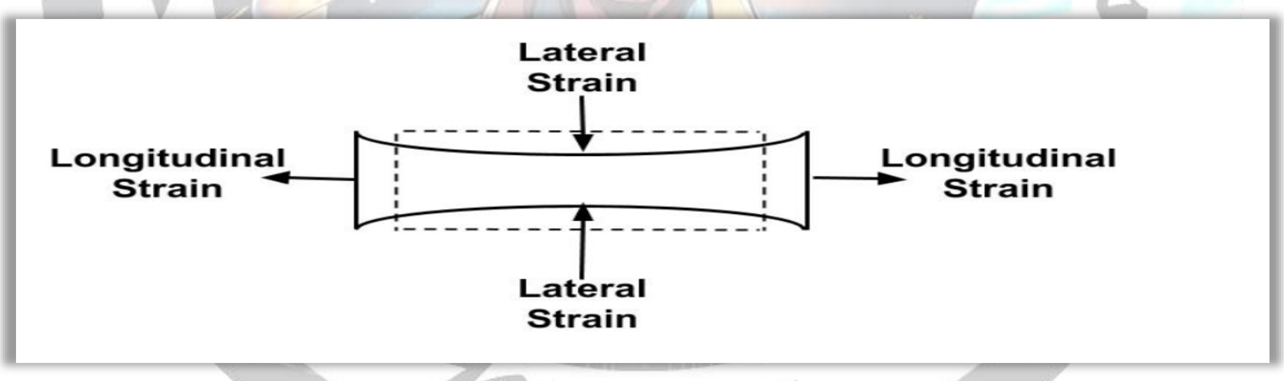
$$Y = \frac{F/A}{\Delta L/L_0}$$

$$Y = \frac{F.L_o}{A.\Delta L}$$

☞ Dimensions

$$Y = \frac{MLT^{-2}L}{L^2.L} = ML^{-1}T^{-2}$$

Poisson's Ratio



- When a wire is stretched, its length increases but its diameter decreases
- This means that the lateral strain is proportional to the longitudinal strain so long as it is small
- The ratio of lateral strain / longitudinal strain is known as ***Poisson's ratio***

$$\sigma = -\frac{\Delta D/D}{\Delta L/L}$$

$$\sigma = -\frac{L}{D} \times \frac{\Delta D}{\Delta L}$$

Where:

- σ is Poisson's ratio
- L is the length of a wire
- r is the radius of that wire
- ΔL is the increase in length
- Δr is the corresponding decrease in radius

☞ The negative sign indicates that if the length increase, the radius decreases

$$Poisson's\ Ratio = \frac{Lateral\ Strain}{Longitudinal\ Strain}$$

Example

A steel wire with a cross-sectional area of $1.5mm^2$ is subjected to a tensile force of $500\ N$. If the wire increases in length by 1%, calculate the original length of the wire, given that the Young's modulus of steel is $2 \times 10^{11} N/m^2$

Answer

Example

A rubber band is stretched, causing its length to increase by 5% and its diameter to decrease by 2%. Calculate the Poisson's ratio of the rubber band.

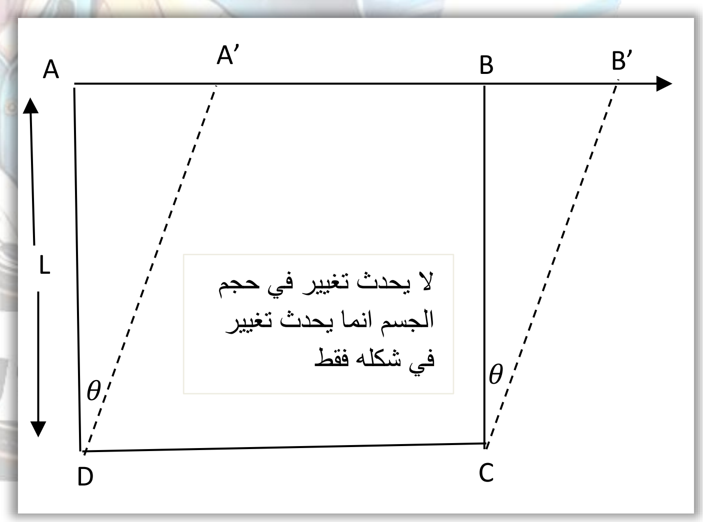
Answer

$$\sigma = -\frac{\epsilon_T}{\epsilon_L}$$

$$\sigma = -\frac{-0.0^{2}}{0.05} = 0.4$$

Shear modulus S (Modulus of Rigidity)

- This measures the resistance to motion of the planes of a solid sliding past each other



☞ **stress**

$$\frac{F}{A}$$

☞ **strain**

$$\theta = \frac{x_o}{L}$$

$$s = \frac{F}{A.\theta} = \frac{F.L}{A.x_o}$$

$$\frac{N}{m^2} or \frac{dyn}{cm^2}$$

$$S = \frac{MLT^{-2}L}{L^2.L} = ML^{-1}T^{-2}$$

Example

A steel beam with a length of $6m$ and a rectangular cross-section of $0.1m \times 0.2m$ is subjected to a shear force of $8000N$. If the shear strain is measured to be 0.003, calculate the shear modulus of the steel.

Answer

1. **Calculate the cross-sectional area (A):**

$$A = 0.1 \times 0.2 = 0.02m^2$$

2. **Calculate the shear stress (t):**

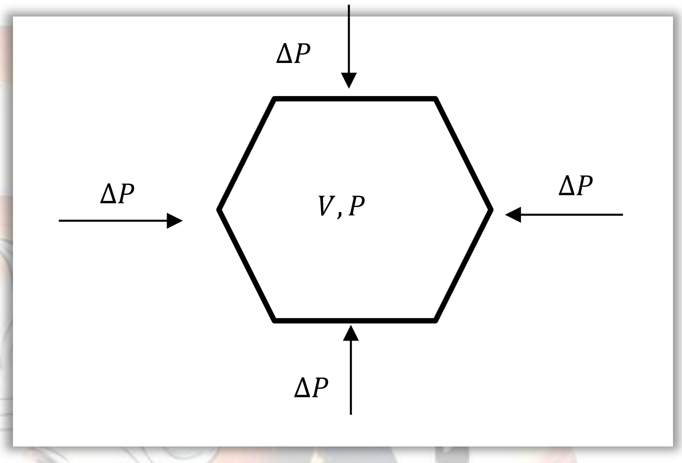
$$\tau = \frac{F}{A} = \frac{8000}{0.02} = 400.000N/m^2$$

3. **Calculate the shear modulus (G):**

$$G = \frac{\tau}{shear\ strain} = \frac{400.000}{0.003} \approx 133.333.333.33N/m^2 \approx 1.33 \times 10^8 N/m^2$$

The bulk modulus

- This measures the resistance that solids or liquids offer to changes in their volume



☞ The volume stress (Bulk)

$$\Delta P = \frac{F}{A}$$

☞ Volume strain

$$Volume\ strain = \frac{\Delta V}{V}$$

☞ The bulk modulus

$$B = \frac{Bulk\ stress}{Bulk\ strain}$$

$$B = -\frac{\Delta F/A}{\Delta V/V_i}$$

$$\boxed{B = -\Delta P.\frac{V}{\Delta V}}$$

The minus sign indicates that an increase in pressure causes a decrease in volume.

Compressibility

- Is equal to $1/B$, where B is its bulk modulus
- Compressibility represents strain per unit stress

Example

A sample of gas is placed in a container with an initial volume of $1m^3$. The pressure is increased from $1 \times 10^5 N/m^2$ to $2 \times 10^5 N/m^2$, and the volume decreases to $0.9m^3$. Calculate the bulk modulus of the gas.

Answer

1. **Calculate the change in pressure (ΔP):**

$$\Delta P = 2 \times 10^5 - 1 \times 10^5 = 1 \times 10^5 N/m^2$$

2. **Calculate the relative change in volume:**

$$\frac{\Delta V}{V_0} = \frac{1 - 0.9}{1} = 0.1$$

3. **Use the bulk modulus formula:**

$$B = \frac{\Delta P}{\frac{\Delta V}{V_0}} = -\frac{1 \times 10^5}{0.1} = 1 \times 10^6 N/m^2$$

Example

A bubble volume is doubled during moving up inside a lake of water of density $1g/cm^3$. If the air compressibility is 0.00005 Pa^{-1}. Determine the lake depth.

Answer

$\rho = 1g/cm^3$, $K = \frac{1}{B} = 0.00005Pa^{-1}$, h

$\because V_2 = 2V_1 \qquad \therefore \Delta V = V_2 - V_1 = 2V_1 - V_1 = V_1$

$\because \Delta P = B\frac{\Delta V}{V} \qquad \therefore \Delta P = \rho gh$

$\therefore \rho gh = \frac{1}{0\cdot 00005} * \frac{V_1}{V_1} \qquad \therefore h = \frac{1}{0\cdot.0005*1000*9.8}$

$\therefore h = 2.04m$