ELASTICITY

BY AP Sir, Sakaar Classes

Formula Name / Topic	Formula	Condition / Context / Use Case
Normal Stress (σ)	$\sigma = \frac{F_\perp}{A}$	Restoring force ($F_\perp$) acting per unit area perpendicular to the cross-section.
Tangential / Shear Stress (σ_t)	$\sigma_t = \frac{F_\parallel}{A}$	Force ($F_\parallel$) acting parallel to the surface area. Causes shape change without volume change.
Longitudinal Strain (ε_l)	$\varepsilon_l = \frac{\Delta L}{L}$	Change in length per unit original length (Tensile or Compressive).
Shearing Strain (ϕ)	$\phi \approx \tan\phi = \frac{x}{L}$	Relative displacement (x) between parallel layers separated by distance L.
Volumetric Strain (ε_v)	$\varepsilon_v = -\frac{\Delta V}{V}$	Change in volume per unit original volume. Negative sign indicates decrease in volume with pressure increase.
Hooke's Law	$\text{Stress} \propto \text{Strain}$ $\text{Stress} = E \times \text{Strain}$	Valid only within the **Proportional Limit**. E is the Modulus of Elasticity.
Young's Modulus (Y)	$Y = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}}$ $Y = \frac{FL}{A\Delta l} = \frac{mgL}{\pi r^2 \Delta l}$	Used for solids (wires, rods) undergoing length change. Specific for a material.
Bulk Modulus (B or K)	$B = \frac{-P}{\Delta V/V} = -V\frac{\Delta P}{\Delta V}$	Relates volume change to pressure change. Applicable to solids, liquids, and gases.
Compressibility (K)	$K = \frac{1}{B}$	Reciprocal of Bulk Modulus.

Modulus of Rigidity / Shear Modulus (η or G)	$\eta = \frac{\text{Shear Stress}}{\text{Shear Strain}} = \frac{F}{A\phi}$	Resistance to change in shape. Only for solids.
Poisson's Ratio (σ)	$\sigma = -\frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$	Theoretical limits: -1 to 0.5.
	$\sigma = \frac{\Delta D/D}{\Delta L/L}$	Practical limits: 0 to 0.5.
Work Done in Stretching (Strain Energy U)	$U = \frac{1}{2} \times F \times \Delta l$	Total potential energy stored in a stretched wire.
	$U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{Volume}$	
Energy Density (u)	$u = \frac{1}{2} \times \text{stress} \times \text{strain}$	Energy stored per unit volume.
	$u = \frac{1}{2} Y (\text{strain})^2 = \frac{(\text{stress})^2}{2Y}$	
Elongation due to Self Weight	$\Delta l = \frac{MgL}{2AY} = \frac{\rho g L^2}{2Y}$	Extension of a hanging rod/wire due to its own gravity. M=mass, ρ=density. Note the factor **2** in denominator (acts at Center of Mass).
Thermal Stress	$\sigma_{\text{thermal}} = Y\alpha\Delta T$	Rod fixed between rigid supports.
	Force $F = YA\alpha\Delta T$	α = coeff. of linear expansion, ΔT = temp change.
Analogy with Spring Constant (k)	$k = \frac{YA}{L}$	Treating a wire as a spring ($F = kx$). Useful for series/parallel combination of wires.
Wires in Series	$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$	Composite wire with same Force/Tension acting on both segments.
	$\Delta l_{net} = \Delta l_1 + \Delta l_2$	

Wires in Parallel	$k_{eq} = k_1 + k_2$ $F_{net} = F_1 + F_2$	Composite wire where extensions are forced to be equal ($\Delta l_1 = \Delta l_2$).
Interatomic Force Constant (k_a)	$k_a = Y \times r_0$	r_0 is the equilibrium interatomic distance.
Depression of a Beam (Cantilever)	$\delta = \frac{WL^3}{3YI_g}$	Beam fixed at one end, loaded (W) at the other. I_g is Geometrical Moment of Inertia.
Depression of Beam (Supported at ends)	$\delta = \frac{WL^3}{48YI_g}$	Beam supported at both ends, load W in the center.
Torsion of a Cylinder	$C = \frac{\pi\eta r^4}{2L}$	Restoring couple per unit twist (Torsional rigidity).
Breaking Stress	$\text{Breaking Force} = \text{Breaking Stress} \times A$	Breaking stress depends on material, not dimensions. Breaking Force depends on area.
Relation: Y, B, σ	$Y = 3B(1 - 2\sigma)$	Relates Young's, Bulk Modulus and Poisson's ratio.
Relation: Y, η, σ	$Y = 2\eta(1 + \sigma)$	Relates Young's, Rigidity Modulus and Poisson's ratio.
Relation: Y, B, η	$\frac{9}{Y} = \frac{1}{B} + \frac{3}{\eta}$	Useful when σ is not given.
Relation: σ in terms of B, η	$\sigma = \frac{3B-2\eta}{6B+2\eta}$	Calculation of Poisson's ratio from moduli.

Quick Tips for Numerical Questions (NEET/JEE)

1. **Wire Cut into n parts:** If a wire of Young's Modulus Y is cut into n equal parts, the Young's Modulus of each part remains Y (Material property), but the spring constant becomes nk.
2. **% Change questions:** If strain is small ($< 5\%$), use $\frac{\Delta R}{R} \times 100$. For volume of wire $V = A \times L$ (constant), $\frac{\Delta A}{A} = -\frac{\Delta L}{L}$ (ignoring σ effects for simple resistance type q's) or use conservation of volume $A_1 L_1 = A_2 L_2$.
3. **Adiabatic vs Isothermal Modulus:**