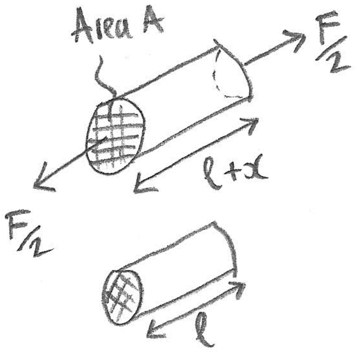
PRE-U REVISION NOTES. MECHANICS

MATERIALS



$\boxed{\text{Stress}}$ $\sigma = \dfrac{\text{force}}{\text{area}}$ ie $\boxed{\sigma = \dfrac{F}{A}}$

$\boxed{\text{Strain}}$ ε is $\dfrac{\text{extension } (x)}{\text{original length } (l)}$ $\boxed{\varepsilon = \dfrac{x}{l}}$

Young's modulus $\boxed{Y = \dfrac{\sigma}{\varepsilon}}$ $\Rightarrow \boxed{\sigma = \varepsilon Y}$

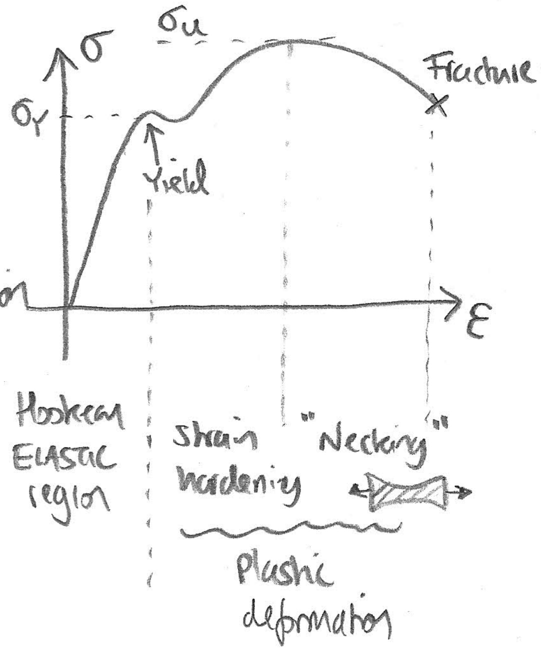
If a material is elastic and obeys $\boxed{\text{Hooks law}}$ $\boxed{F = kx}$

Elastic strain energy $\boxed{E = \frac{1}{2}kx^2}$

Strain energy density $U = \dfrac{E}{Al}$ ← original volume $= \frac{1}{2}\underbrace{\frac{kx}{A}}_{\sigma} \times \underbrace{\frac{x}{l}}_{\varepsilon} = \frac{1}{2}\sigma\varepsilon$

$\therefore \boxed{U = \frac{1}{2}Y\varepsilon^2}$

Most materials follow the $\boxed{\text{stress-strain curve}}$

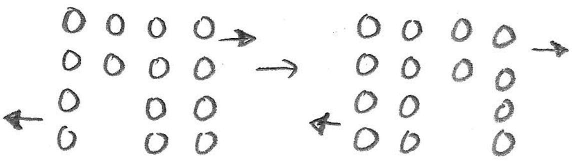


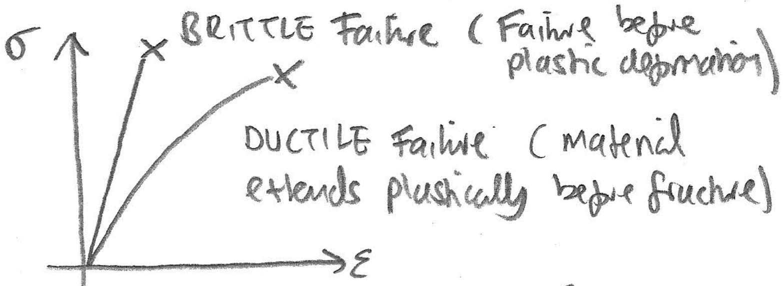
$\boxed{\sigma_Y \text{ Yield stress}}$ – lowest stress for permanent deformation

$\boxed{\sigma_u \text{ Ultimate stress}}$ – stress which leads to DUCTILE or BRITTLE failure

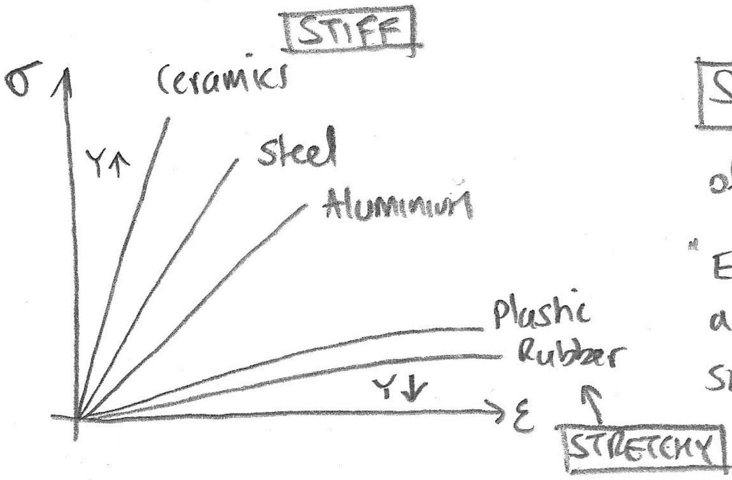
- Y is constant during Hookean region.
- when load is removed in elastic region material returns to original shape
- In plastic deformation region, material is permanently deformed.

$\boxed{\text{FRACTURE}}$ results from the propagation of cracks. The latter originate from $\boxed{\text{DISLOCATIONS}}$ in the atomic structure, ie a <u>slip</u> of one plane of atoms over another





NOT ALL MATERIALS YIELD e.g CERAMIC



$\boxed{\text{Stiff}}$ materials have a high Y often fail in a brittle manner.

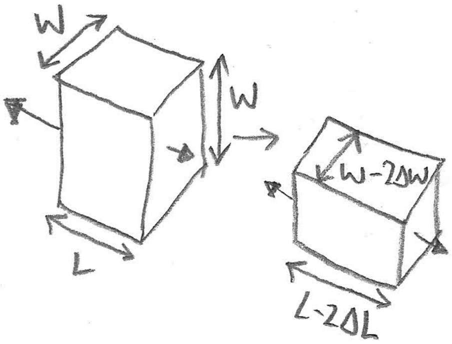
"Elastic" or $\boxed{\text{stretchy}}$ materials have a low Y ie large strain ε for small stresses σ

$\boxed{\text{Strong}}$ materials have a high yield (and ultimate) stress

$\boxed{\text{Tough}}$ materials are somewhat <u>resilient to Brittle fracture</u>. ie <u>metals</u> are often tough, but ceramics are not.

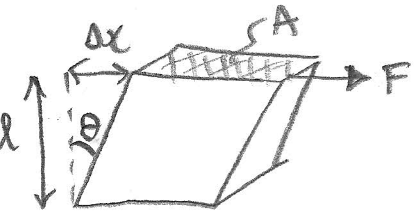
Most materials will shrink transversely as they are stretched. This is a positive $\boxed{\text{POISSON RATIO}}$

$$\boxed{\nu = -\frac{\text{transverse strain change}}{\text{axial strain change}} \approx \frac{\Delta W}{\Delta L}}$$



$\boxed{\text{SHEAR MODULUS}}$

$$\boxed{G = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{Fl}{A\Delta x}}$$

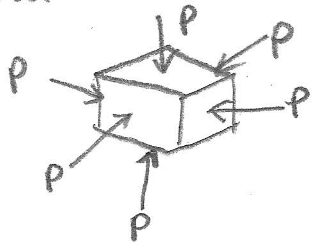


Note fluids and gases will <u>flow</u> rather than shear ie $G=0$

The compressibility of a material is described by the $\boxed{\text{BULK MODULUS}}$

$$\boxed{K = -V\frac{dP}{dV} = \rho\frac{dP}{d\rho}}$$

ρ is density
P is pressure
V is volume



ie ratio of a change in pressure P applied to result in the fractional change of volume V

NOTE FOR $\boxed{\text{ISOTROPIC}}$ MATERIALS (ie equally strong in all directions - i.e. NOT like carbon fibre!)

$$\boxed{K = \frac{Y}{3(1-2\nu)} \qquad Y = 2G(1+\nu)}$$

For isotropic materials, the elastic moduli give the $\boxed{\text{speed of sound}}$

Pressure (P) waves $\quad c_p = \sqrt{\dfrac{K + \frac{4}{3}G}{\rho}}$

Shear (S) waves $\quad c_s = \sqrt{G/\rho}$

Example data: $[\text{GPa} = 10^9\ \text{N/m}^2]$

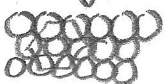
MATERIAL	Y/GPa	ν	G/GPa	K/GPa	ρ/kgm^{-3}	c_p /ms^{-1}
RUBBER	0.01	0.5	0.0006	1	801	1120
STEEL	200	0.3	79.3	160	7800	5840
COPPER	117	0.3	44.7	123	8960	4510
PLASTIC	0.5 → 3	0.3 → 0.5	0.1	2.9	930	1810
CONCRETE	30	0.1 → 0.2	21	14.3	2400	4200
DIAMOND	1050 → 1210	0.07	478	443	3510	17540
WOOD	11	0.2 → 0.7	13	36.7	600 – 900	8490
GLASS	50 → 90	0.18 → 0.3	26.2	35 → 55	2500	5560
	Young's modulus	Poisson ratio	shear modulus	Bulk modulus	Density	Pressure wave speed

Note speed of (P) waves in air $\simeq 340\ \text{ms}^{-1}$

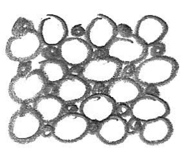
" " " " " water $\simeq 1480\ \text{ms}^{-1}$

$\boxed{\text{Crystal Structure}}$ is the (3D) pattern of ions/atoms/molecules in a material. A crystal usually implies an ordered, repeating, pattern of a distinct 'unit cell'

Different $\boxed{\text{packing}}$ arrangements of atoms of same size/type



eg hexagonal packing



∘ Sodium Na^+ ion

○ chlorine Cl^- ion

↖ Repeating pattern of NaCl (salt)