1) a) Compressive Stress

\[ \frac{dF_1}{dA_1}, \quad \frac{dF_2}{dA_2}, \quad \frac{dF_3}{dA_3} \]

\[ A_1 \text{ is normal to the force, } F_1. \]

\[ \text{Compressive Stress is a Dilatational Stress (Changes Volume)} \]

Tensile Stress

\[ \frac{dF_1}{dA_1} \]

Bending Stress

\[ \text{Bending Stress is a complex Stress composed of four simple Stresses: Shear Stress } \frac{dF_1}{dA_2} \text{ parallel to the Load} \]

\[ \text{Shear Stress } \frac{dF_2}{dA_2} \text{ perpendicular to the Load} \]

\[ \text{Compressive Stress in the upper region } \frac{dF_1}{dA_1}, \frac{dF_2}{dA_2}, \frac{dF_3}{dA_3} \]

\[ \text{Tensile Stress in the lower region } \frac{dF_2}{dA_2} \]
Shear Stresses: This is like a deck of cards.

Hydrostatic Stresses:
A form of compressive stress where
\[
\frac{dF_1}{dA_1} = \frac{dF_2}{dA_2} = \frac{dF_3}{dA_3}
\]

(b) Bi-axial Stress:
\[
\frac{dF_1}{dA_1} = 0
\]
Lateral tensile stresses have values\[
\frac{dF_1}{dA_1} = 0
\]
This occurs when you

(c) Compressive strain is composed of 3 components:
\[
\frac{du_1}{dx_1}, \frac{du_1}{dx_2}, \frac{du_1}{dx_3}
\]
\(u_1\) is the displacement in the direction 1.

Tensile strain:
\[
\frac{du_1}{dx_1}
\]

Bending strain: similar to bending shears.

Has 9 components: Shear 11 & 22: Compressive Tensile.
**Shear Strain**

\[
\frac{\partial u_2}{\partial x_1} = \frac{\partial u_2}{\partial x_2} = \frac{\partial u_3}{\partial x_1}
\]

**Hydrostatic Strain**

Volume Strain

\[
\frac{\partial u_1}{\partial x_1} = \frac{\partial u_2}{\partial x_2} = \frac{\partial u_3}{\partial x_3}
\]

d) **Tensile Modulus** \( E \)

\[
\sigma_{ii} = \frac{dF_i}{dA_i} = E \frac{\partial u_i}{\partial x_i} = E \epsilon_{ii}
\]

**Shear Modulus** \( G \)

\[
\sigma_{12} = \frac{dF_i}{dA_2} = G \frac{\partial u_i}{\partial x_2} = G \epsilon_{12}
\]

**Compressibility**

\[
\beta = -\frac{1}{V} \frac{dV}{dp}
\]

\( V \) is volume

\( \rho \) is the hydrostatic pressure

\( p \) is the hydrostatic pressure
c) Engineering Stress is the ratio of the applied force, \( F \), to the area it is applied to, \( A \),
\[
\sigma = \frac{F}{A}
\]
Engineering Strain is the change in length relative to the original length,
\[
\varepsilon = \frac{\Delta L}{L}
\]
True Stress and Strain are differential ratios,
\[
\sigma = \frac{dF}{dA}, \quad \varepsilon = \frac{dL}{L}
\]
so the denominator changes during stress.

2) a) A viscous material has no modulus; it doesn't hold together. Viscous materials follow Newton's Law for Flow
\[
\sigma_{12} = \eta \dot{\gamma}_{12}, \quad \nu = 0 \text{ in tension}
\]
Any fluid has a finite modulus that is important to its use. It is a viscoelastic.

b) An elastic material follows Hooker's Law
\[
\sigma_{11} = E \varepsilon_{11}, \quad \sigma_{12} = G \varepsilon_{12}
\]
Then if the viscosity is infinite, \( \nu = \infty \), so there is no response to rate differences.
A rubber band is a viscoelastic because it displays dependence on rate of strain. Brittle & Dachile relate to the mechanism of failure for materials. Brittle materials fail with a smooth sharp fracture like glass. Dachile materials fail in a rough surface like play dough. By this definition, Jello is brittle.

Jello is a viscoelastic material. It displays both elastic & viscous properties. It's not plastic because it does not display a permanent deformation after stress.

d) Thermoplastics – Processed in the melt & become solid (gloss or crystalline) on cooling

- Poly styrene
- Polyethylene
- Poly propylene
- PMMA
- Poly carbonate
- PVC

Thermoset – Processed as a liquid then cured to react/polymerize into a solid.

- Epoxy
- Rubber (Bakelite, Fibro sheets, Phenolic Resin)
Elastomer

A crosslinked polymer that would be a liquid at use temperature if it were not crosslinked. This is a viscoelastic solid.

Natural Rubber (polyisoprene)
Polybutadiene
Polydimethylsiloxane (silicone)
Jello
SBR Rubber
EPDM Rubber
Nitrile Rubber

---

e)

Chain Growth

Polymer by Chain Growth

Addition Polymerization

Condensation Polymerization

Step Growth

$O = C \equiv N - \overset{\ddagger}{C} - N = C = O + 14 C H _ 2 C H _ 2 O H \rightarrow \underset{H}{\overset{14}{C} - N - \overset{\ddagger}{C} - O - C - N = C = O - C - O - C - N = C = O}$

diisocyanate
3) a.)

\[ M_n = \frac{\Sigma n_i M_i}{\Sigma n_i} = M_1 \]

\[ M_w = \frac{\Sigma n_i M_i^2}{\Sigma n_i M_i} = \frac{M_2}{M_1} \]

\[ 2 \times \text{Av} \]

\[ M_2 = \frac{\Sigma n_i M_i^3}{\Sigma n_i M_i^2} = \frac{M_2}{M_2} \]

\[ \text{RDI} = \frac{M_{w0}}{M_n} = \frac{M_2}{M_1} \]

\[ \sigma^2 = \frac{\Sigma n_i (M_i - M_1)^2}{\Sigma n_i} = \frac{\Sigma n_i M_i^2}{\Sigma n_i} - 2 \frac{M_1 \Sigma n_i M_i}{\Sigma n_i} + M_1^2 \]

\[ = M_2 - M_1^2 = M_1^2 (\text{RDI} - 1) = M_2 (1 - \frac{1}{\text{RDI}}) \]

b.)

Diads are tactic or meso

(mixed) (same)

A random distribution correspond to

50% + 50% m

Atactic = Random Tacticity

Triads are

isotactic mm
heterotactic mr or rm
syndiotactic rr

Atactic: 25%

atactic 25%

atactic 50%
pentads are

\[ \text{mmmm} \]

\[ \text{rrrr} \]

\[ \text{ee} \]

\[ \text{mmrr} \]

\[ \text{trmm} \]

\[ \text{rrrr} \]

\[ \text{trtm} \]

\[ \text{mmrm} \]

\[ \text{rmmr} \]

c) Chemical Crosslinks

Vulcanization with sulfur in polyisoprene

\[ \text{mmmm} \rightarrow \text{X}_{n} \]

Glassy nature, SBR rubber,
d) Polyethylene
   Polypropylene
   Nylon
   polyethylene oxide
   polyvinyl alcohol

   crystals have the
   a good ratio of
   asked for

   e) Time-temperature superposition
2) Glass, Leather, Rubber, Flow

\[ E \]

\[ T \]
\[ (T_m^2) \]

\[ \text{crosslinked} \]

\[ E \]

\[ w_g \text{ of } T_g \]

\[ \text{time (t)} \]

Low temperature + high energy made material glassy.