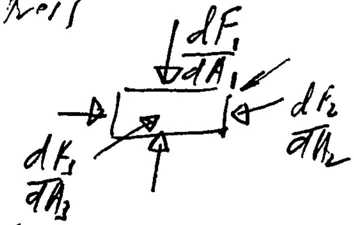
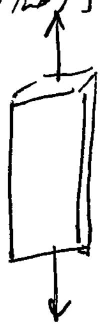
Polymer Homework

1) a) Compressive Stress



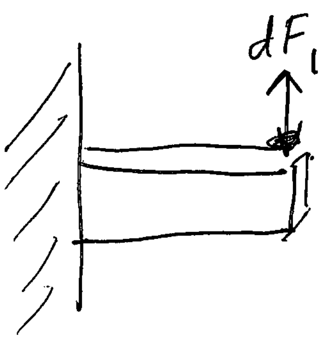
A_1 is normal to the force, F_1.
Compressive Stress is a Dilitational Stress (Changes Volume)

Tensile Stress



Bending Stress

Bending Stress is a complex stress composed of ~~three~~ four simple stresses; Shear stress $\frac{dF_1}{dA_2}$ parallel to the Load

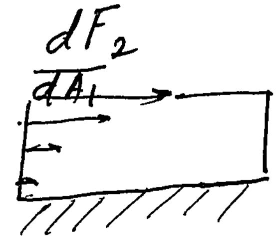


Shear stress $\frac{dF_2}{dA_1}$ ~~parallel~~ perpendicular to the Load

Compressive Stress in the upper region
$\frac{dF_1}{dA_1}$; $\frac{dF_2}{dA_2}$; $\frac{dF_3}{dA_3}$

Tensile Stress in the lower region
$\frac{dF_2}{dA_2}$

Shear Stress This is like a deck of cards

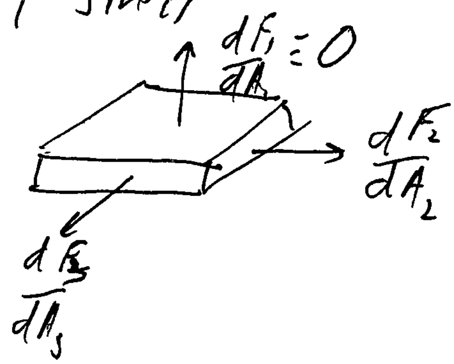


Hydrostatic Stress

A form of Compressive stress where

$$\frac{dF_1}{dA_1} = \frac{dF_2}{dA_2} = \frac{dF_3}{dA_3}$$

b) Biaxial Stress



Lateral Tensile stress have values

$$\frac{dF_1}{dA_1} = 0$$

This occurs when you chew gum

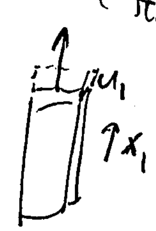
c) compressive strain is composed of 3 components

$$\frac{du_1}{dx_1} ; \frac{du_2}{dx_2} ; \frac{du_3}{dx_3}$$

u_1 is the displacement in the direction 1 (for cartesian coordinates 1, 2, 3)

tensile strain

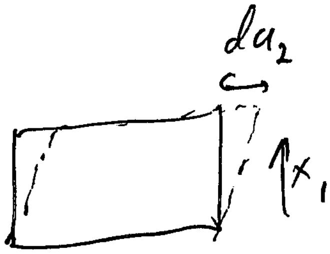
$$\frac{du_1}{dx_1}$$



bending strain similar to bending stress

Has 4 component Shear $\parallel$ & $\perp$; Compressive & Tensile

Shear Strain



$$\frac{du_2}{dx_1}$$

Hydrostatic Strain

Volumetric Strain

$$\frac{du_1}{dx_1} = \frac{du_2}{dx_2} = \frac{du_3}{dx_3}$$

d) Tensile Modulus E

$$\sigma_{11} = \frac{dF_1}{dA_1} = E\,\frac{du_1}{dx_1} = E\,\varepsilon_{11}$$

Shear Modulus G

$$\sigma_{12} = \frac{dF_1}{dA_2} = G\,\frac{du_1}{dx_2} = G\,\varepsilon_{12}$$

Compressibility

$$\beta = -\frac{1}{V}\frac{\partial V}{\partial p}$$

V is volume

p is the hydrostatic pressure $= \frac{dF_1}{dA_1}$ under hydrostatic stress

c) Engineering Stress is the ratio of the applied force, F, to the surface area it is applied to, A,

$$\sigma_{eng} = \frac{F}{A}$$

Engineering Strain is the change in length relative to the original length

$$\varepsilon_{eng} = \frac{\Delta l}{l}$$

True stress & strain are differential ratios

$$\sigma = \frac{dF}{dA} \qquad \varepsilon = \frac{du}{dx}$$

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

$$\sigma_{12} = \eta \dot{\gamma}_{12} \quad \& \quad E = 0 \text{ in tension}$$

Airplane glue has a finite modulus that is important to its use. It is a viscoelastic.

b) An elastic material follows Hooke's Law

$$\sigma_{11} = E \gamma_{11} \quad \& \quad \sigma_{12} = G \gamma_{12}$$

There ~~is no~~ viscosity is infinite $\eta = \infty$ so there's no response to rate differences

A rubber band is a viscoelastic because it displays dependence on rate of strain.

c) Brittle & Ductile refer to the mechanism of failure for materials. Brittle materials fail with a smooth sharp surface like glass. Ductile 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 is not plastic because it does not display a permanent deformation after stress.

d) Thermoplastics - Processed in the melt & become solid (glass or crystalline) on cooling

Polystyrene
Polyethylene
Polypropylene
PMMA
Polycarbonate
PVC

Thermoset - Processed as a liquid then cured to react/polymerize into a solid.
Epoxy, Rubber, Bakelite, Fiberglass; Polyimides; Polyurethane

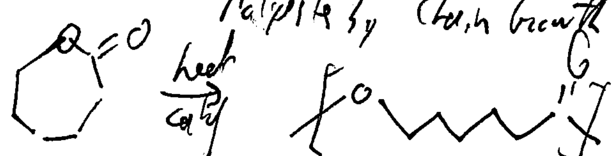
Elastomer

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
Polydimethyl siloxane (Silicone)
Jello
SBR Rubber
EPDM Rubber
Nitrile Rubber

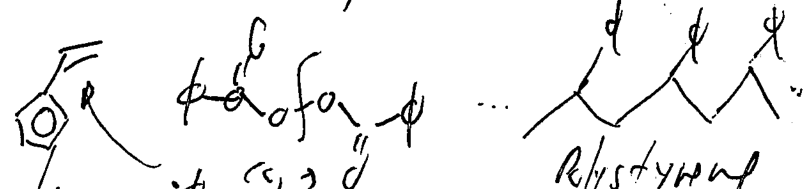
e) **Chain Growth**

Polyester by Chain Growth



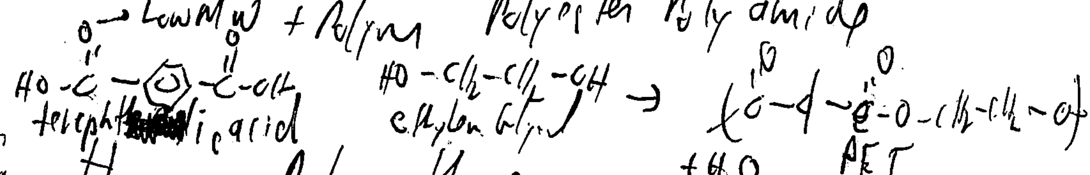
initiation; propagation; termination

Addition Polymerization → Polymer

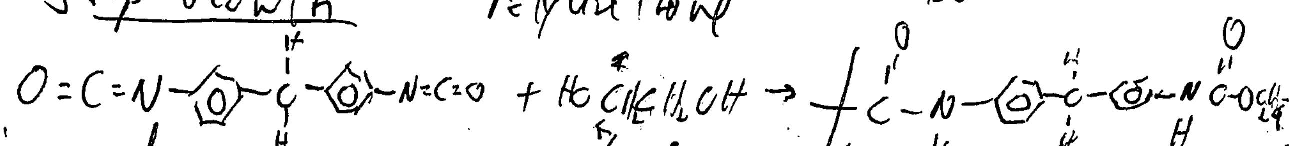


Polystyrene

Condensation Polymerization → Low MW + Polymer Polyester Polyamide



Step Growth Polyurethane



3) a.)

Number Average

$$M_n = \frac{\sum n_i M_i}{\sum n_i} = M_1$$

Weight Average

$$M_w = \frac{\sum n_i M_i^2}{\sum n_i M_i} = \frac{M_2}{M_1}$$

Z-Average

$$M_z = \frac{\sum n_i M_i^3}{\sum n_i M_i^2} = \frac{M_3}{M_2}$$

$$PDI = \frac{M_w}{M_n} = \frac{M_2}{M_1^2}$$

$$\sigma^2 = \frac{\sum n_i (M_i - M_1)^2}{\sum n_i} = \frac{\sum n_i M_i^2}{\sum n_i} - 2\frac{M_1 \sum n_i M_i}{\sum n_i} + M_1^2$$

$$= M_2 - M_1^2 = M_1^2 (PDI - 1) = M_2 \left(1 - \frac{1}{PDI}\right)$$

b.) Diads are racemic or meso
(mixed) (same)

A random distribution corresponds to
50% r 50% m

Atactic = Random Tacticity

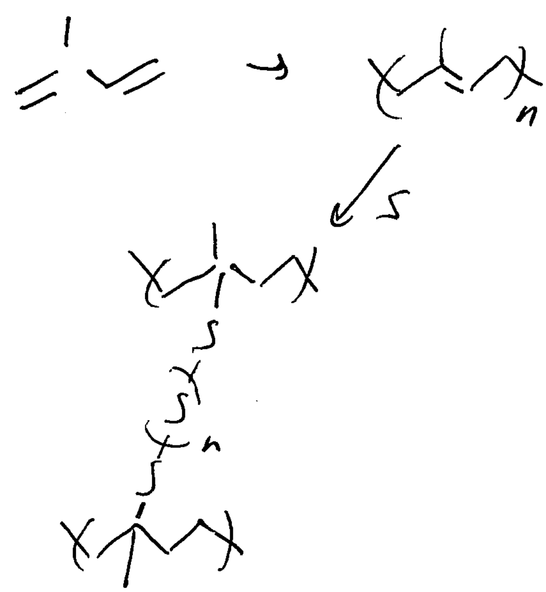
Triads are			Atactic
	isotactic	mm	25%
	heterotactic	mr or rm	50%
	syndiotactic	rr	25%

pentads are

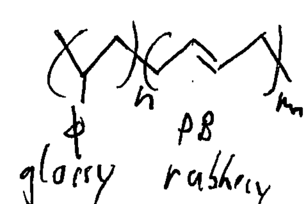
mmmm
rrrr
etc
(mmrr
rrmm)
(mrrr
rrrm)
mrrm
rmmr

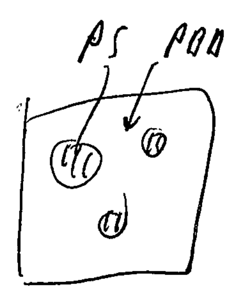
c) Chemical Crosslinks

Vulcanization with Sulfur in polyisoprene



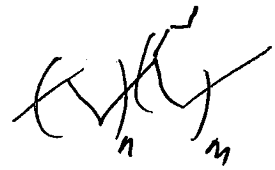
Glassy Phase SBR rubber





Metallocene Polyethylene

Rubber w/ crystalline crosslinks



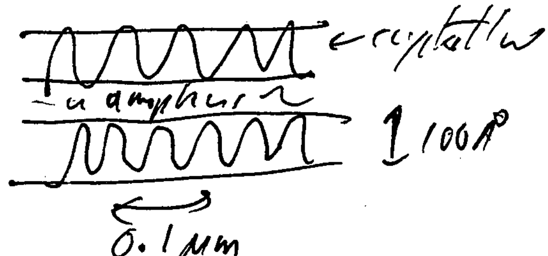
d) Polyethylene

Polypropylene

Nylon

polyethylene oxide

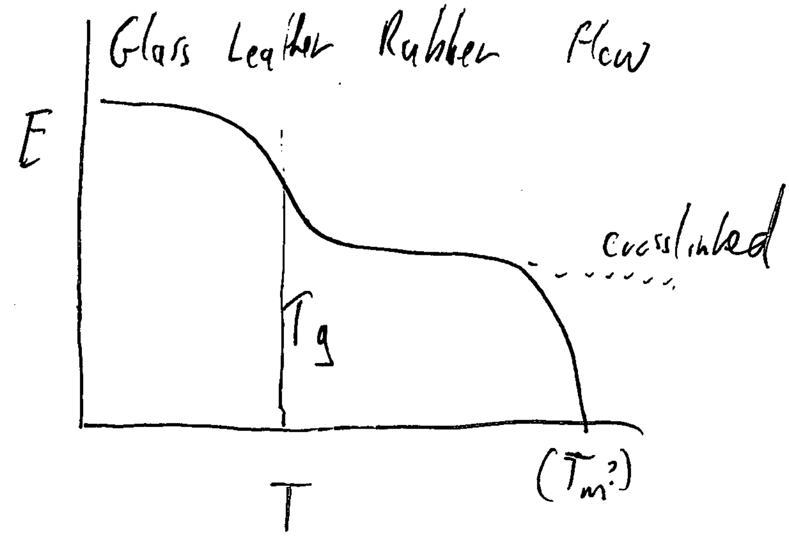
polyvinyl alcohol

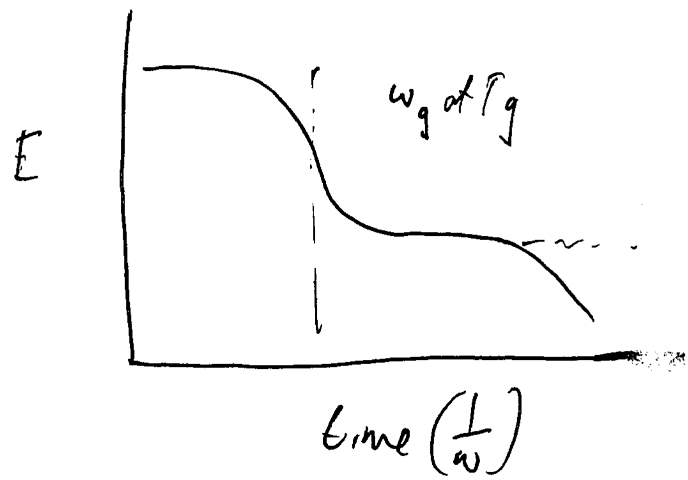


crystals have the aspect ratio of a sheet of paper

e) Time-temperature superposition

e)





Low temperature + high frequency made material glassy
(low time)