

# Planetary Deformation I – Rheology

## Reference Sheet

Lecture 4, 10/19/2004

### Basic Definitions

Rheology – How materials respond to an applied stress.

Stress ( $\sigma$ ) – Force per unit area exerted on a rock surface

Strain ( $\epsilon$ ) – Measure of deformation; ratio of change in dimension to original dimension

Strain rate ( $\partial\epsilon/\partial t$ ) – Change in strain with time

Viscosity ( $\eta$ ) – Resistance to deformation under shear stress

Rigidity ( $\mu$ ) – Resistance to elastic stress (\*\* see additional class notes)

### Other Variables:

E: Young's modulus; used for elasticity

$Q = E_a + PV$ : activation energy;  $E_a$  is thermal and P is pressure and V is volume

A: Pre-exponential factor; experimentally-determined constant for viscous flow equation

### Types of Deformation

- Brittle
  - Loses strength as it deforms; deformation is unrecoverable (breakage)
  - Short time scale
  - Example: a quick pull on two ends of silly putty causes it to break into two
- Elastic
  - Follows Hooke's Law (linear relationship between stress and strain):  $F = -kx$
  - Recoverable deformation
  - Example: stretching a spring and then releasing it, it returns to its original length
  - Example: bouncing a ball of Silly Putty very briefly deforms one side (and mostly recovers)
- Plastic
  - Retains strength as it deforms; deformation is unrecoverable
  - Deformation begins above a particular yield stress and continues until failure
  - Example: overstretch a spring and it does not return to its previous length
  - Example: slowly stretch Silly Putty and it becomes long and stringy
- Viscous
  - Deformation is unrecoverable and begins as soon as stress is applied
  - Linear or nonlinear relationship between stress and strain rate
  - Example: a mound of Silly Putty will flow downwards and outwards with time

### Important Relationships

Elastic:  $\sigma = E \epsilon$

Viscous:  $\sigma \approx 2 \eta \partial\epsilon/\partial t$

Viscous relaxation time:  $\tau_r \approx 4\pi \eta / (\rho g \lambda)$

Maxwell relaxation time:  $\tau_R \approx 2 \eta / \mu$

### Recommended References

*Dynamic Earth* (G.F. Davies)

*Geodynamics* (D. Turcotte & G. Schubert)