Quiz 5 Polymer Processing 3/1/01

a) In our analysis of the Lodge Liquid we considered a time dependent modulus G(t).
   -Explain how a time dependent modulus could be measured for a viscoelastic material such as a rubber band.
   -Sketch the results, G(t) vs. t, you might expect for a polymer melt from this measurement.
   -Sketch the result for a Newtonian Fluid.
   -Sketch the result for a Hookean Elastic.

b) The time dependent modulus is related to the zero shear rate viscosity.
   -Give an expression that relates the time dependent modulus, G(t), to the zero shear rate viscosity, η_0.
   -Explain why this expression is correct for a Newtonian fluid.
   -Explain why this expression is correct for a Hookean Elastic.

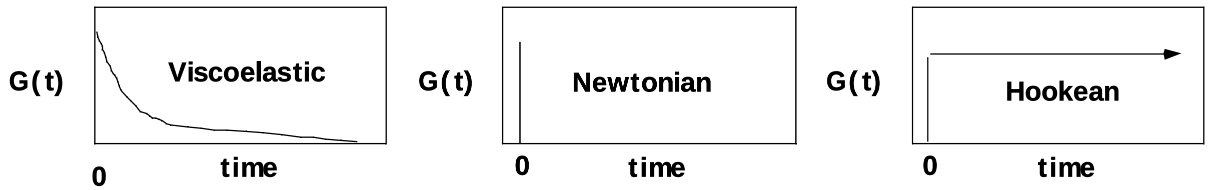
c) -How is the expression of part "b" related to the Generalized Newtonian Fluid (GNF) equations such as the power-law fluid and Carreau Models?

d) In class we discussed three viscometric flows for the determination of viscosity.
   -List these three flows.
   -Explain how each relates to processing flows.

e) -Draw a sketch of the cone-and-plate viscometer.
   -For the cone-and-plate viscometer how is the rate of strain calculated? (refer to your drawing)
   -How is the shear rate calculated? (refer to your drawing)
   -How is the viscosity measured?
   -How is the first normal stress difference calculated?
   -What is the main advantage of the cone-and-plate viscometer?

Answers: Quiz 5 Polymer Processing 3/1/01

a) The time dependent modulus is measured in a stress relaxation experiment where a fixed strain is applied to a sample and the decay in stress is observed, $G(t) = \tau(t)/\gamma_0$.



b) $\eta_0 = \int_{-\infty}^{\infty} G(t)dt$

For a Newtonian fluid G(t) is a delta function who's integral is 1 so a constant viscosity results. For a Hookean elastic the integral is infinity, i.e. it is a solid.

c) Integral expressions for time dependent behavior are the theoretical justification for all GNF equations. The function for G(t) needs to be written with shear rate or process time dependence (process time = $1/(d\gamma/dt)$). Such functions can analytically lead to power-law and Carreau type equations.

d) The three viscometric flows discussed are the capillary viscometer, the Couette viscometer and the cone and plate viscometer.
The cone and plate viscometer does not have a processing analogy.
The Couette viscometer mimics flow between the flights of a screw extruder and the capillary viscometer mimics die flow in an extruder.

e) See notes for a sketch.
The shear rate is calculated from the ratio of the velocity of the cone at a position r from the center, $v(r) = 2\pi r\, \Omega$, and the gap size at position r, Gap = r $\sin\beta$ = r β for small cone angle where β is in radians. Then the shear rate is not dependent on the position in the fluid, $d\gamma/dt = v(r)/Gap(r) = \Omega/\beta$.
The shear stress is the torque force divided by the area of the cone $\tau = 3T/(2\pi R_c^2)$, where R_c is the cone radius.
The viscosity is the ratio of the torque to the shear rate, $h = 3T\beta/(2\pi\, \Omega R_c^2)$.
The first normal force is calculated from the force pushing up on the cone shaft, F_N, and the area of the cone, $\Psi_1 = F_N/2\pi R_c^2$.
The main advantage of the cone-and-plate viscometer is constant shear rate across the gap so that complex viscosity/shear rate functionalities can be determined.