Quiz 1 Polymer Physics Fall 2000

9/27/00

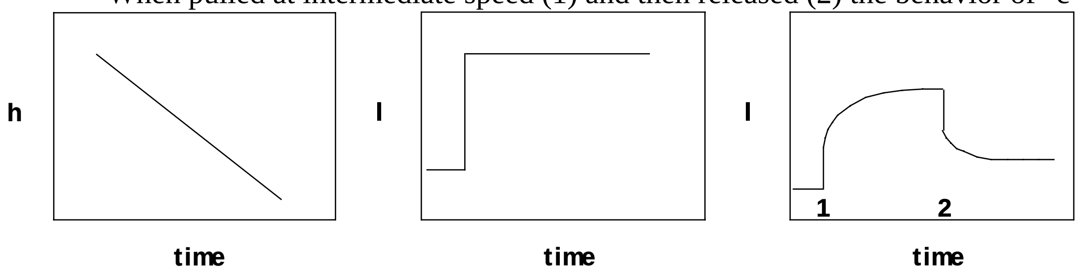
Silly Putty® is a typical viscoelastic material made from polydimethylsiloxane, silica and oils.

a) **Propose 3 functions** for the following behavior of Silly Putty.

-When left on the table for a long period of time the height, h, decays in the manner of figure "a".

-When rapidly pulled and observed over only shot times the length, l, follows "b".

-When pulled at intermediate speed (1) and then released (2) the behavior of "c" results.



(a)   (b)   (c)

b) **-For question "a"** which terms are related to permanent set in the silly putty?

-What relaxation times are involved in your answer to question "a"?

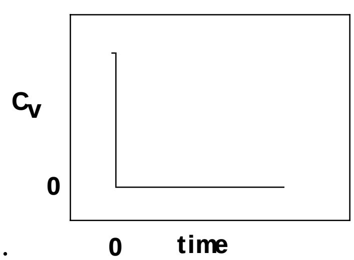
c) If the Silly Putty were subjected to an oscillatory stress following a cosine function,

-**which of terms** in your equations would be related to the in-phase and out-of-phase parts of the dynamic strain?

-**On a plot** of real and imaginary modulus versus frequency, ω, at room temperature, where would you expect to see the behavior of figures "a" and "b"?

-**What do you expect** to be the behavior of creep compliance, $J(t) = \varepsilon(t)/\sigma_0$, at long times for Silly Putty?

d) In addition to the two relaxation times related to Silly Putty, briefly **describe two other** characteristic times discussed in class related to a bell and a grain of pollen subjected to thermal motion. (*In your description of the bell mention the basic features of the delta function.*)



e) If the velocity correlation function, C_v, had the form:

What could you say about τ_v?

What type of particles display such behavior? Why (give relationship)?

Answers Quiz 1 Polymer Physics

a) "a" is typical of Newtonian flow, $\sigma = \eta\ (d\varepsilon/dt)$ so $\varepsilon = \sigma_0\ t/\eta$.

"b" is typical of a Hookean Elastic, $\sigma = E\ \varepsilon$ or $\varepsilon = J\ \sigma$.

"c" is typical of a complex viscoelastic response composed of flow, elasticity and an anelastic response, $\varepsilon = K_1\ t + K_2 + K3\ (1- e^{-t/\tau})$.

b) The flow term (term linear in time) is related to the set of the silly putty seen in figure "c". The viscosity is proportional to a characteristic relaxation time for flow in the material. The anelastic relaxation is also governed by a characteristic time given by tau in the equation.

c) -Flow is related to the imaginary modulus, $\eta/\omega = E''$, the real modulus if related to the Hookean response, $E = E'$.

-The long time, flow behavior would be seen at low frequencies, the short time Hookean behavior would be seen at high frequencies. The loss modulus is related to flow and the real modulus is related to Hookean behavior.

-$J(t) = t/\eta$ at long times where Newtonian behavior dominates.

d) Two other characteristic times.

-Translational velocity relaxation time for center of mass thermal motion of a pollen grain subjected to Brownian motion, $\tau_v = m/\xi$, where ξ is the friction factor given by Stokes law for a sphere, and m is the mass of the pollen grain. $V = V_0\ \exp(t/\tau_v)$, describes random thermal motion dampened by a Stokes friction factor.

-A bell resonates at a frequency ω_0 that is inversely related to a characteristic time, $\tau = 1/\omega_0$. The bell responds to a delta function stress, $\sigma(t) = \sigma_0\ \delta(t_1)$, where $\delta(t_1)$ has a value of 0 at all times except t_1, and has a value of ∞ at t_1. The integral of $\delta(t_1)$ over all time is equal to 1.

e) The translational velocity correlation function shown is similar to that of a polymer coil in that the relaxation time can be assumed to be 0 for all times accessible to experiment. Under the assumption of simple spherical particles in a dilute solution subjected to thermal motion, $\tau_v = m/(6\pi\eta a)$, where m is the mass of the particle, η is the solvent viscosity and a is the radius of the spherical particle. m is typically very small for polymer coils compared to colloidal particles such as pollen grains.