ChE 531 Polymer Engineering University of Rhode Island
Professor Greenfield Spring 2008

Homework 3
due April 9, 2008

If you find yourself without enough information, make and justify a reasonable approximation.

1. Boltzmann superposition problem. Watch the web page for the problem on this topic. PROBLEM DEFERRED TO HOMEWORK 4.

2. Continue with the polyisobutylene data you shifted in homework 2 (from fig 4.7) by using the multi-element Maxwell model (eq 4.65, but with E instead of G) to fit the $E(t)$ data, as shifted to the reference temperature. Choose whatever number of elements you find appropriate. What are the resulting prefactors and characteristic times? Then use your parameterized model to predict the storage and loss moduli for oscillatory shear (don't forget to convert E to G) as a function of frequency. HINT: You will definitely want to use a computer to help with solving this problem. (I don't have a preference about what program you use.)

3. A set of shear stress/ shear rate data (see class web page) were obtained for a polymer solution of sodium cellulose sulfate / water.

   (a) Plot the viscosity as a function of shear rate.

   (b) Is there a Newtonian regime? A power law regime? If so (for either), what is the Newtonian viscosity and/or what are the power law constants?

   (c) Can the data be fit using an Ellis model (i.e. Cross model with no second Newtonian plateau),

   $$\eta/\eta_0 = \frac{1}{1 + K\dot{\gamma}^{1-n}}$$

   Show your answer graphically.

4. The rheology handout had sets of data (taken from Macosko's book) for the viscosity of an ABS sample at different temperatures and shear rates. Use time-temperature supoerposition to combine these data to a single master curve. Choose the lowest temperature as the reference temperature.
   Hints:

   (a) Look to the course web pages for a file with the data points.

   (b) Remember that both η and $\dot{\gamma}$ need to be shifted for rheology data. Why? Think about if the low-shear rate (Newtonian) viscosity of a fluid varies with temperature.

5. Textbook, chapter five, problem fo ur (yielding and Eyring model).
   Hints: see eqs 5.12-13 and fig 5.5.

   See other side for last problem

6. This problem was on the final exam back in 2002.
With the semester ending soon, you decide to plan for a trip. However, you are concerned that your luggage (10 kg when packed) might not survive the plane flight, so you do some calculations to check.

The thick wheels on this particular bag are made of polystyrene, with mechanical properties as listed in the table, and you suspect they contain crazes of size 1.2 μm. How far can your bag fall without cracking a wheel? Make the following assumptions:

- The bag always falls such that one wheel takes the entire impact, over an area of 1 cm^2.
- the impact force equals $ma = \dfrac{m\sqrt{2gh}}{\delta t}$, with

$$
\begin{aligned}
m &= \text{mass} \\
g &= 9.8 \text{ m/s}^2 \text{ (acceleration due to gravity)} \\
h &= \text{height} \\
\delta t &= \text{time of impact (assume } 10^{-3}\text{s)}
\end{aligned}
$$

- Due to deformation and geometry, the impact leads to tensile stresses near the crazes equivalent to those within a wide plane, and equal in magnitude to the stress at the impact site.

Selected physical properties:

	PS
E	3.4 GPa
G_c	280 J/m^2
ν	0.38
ultimate strength	50 MPa
elongation to break	2%