

1. The behavior of a polymer is described by a Maxwell model consisting of a spring element of modulus  $10^{10}$  Pa in series with a dashpot of viscosity  $10^{12}$  Pa s. Calculate the stress in the solid 50 s after the sudden application of a fixed strain of 1%.
  
2. Draw the creep and creep recovery curves for the three-element model consisting of a **Kelvin-Voigt element** and a **spring** in series.
  
3. The molar mass of an entanglement strand in a PDMS (polydimethylsiloxane) melt at 25 °C is  $M_e = 12000$  g/mol. Estimate the plateau modulus  $G_N$  if the density of the PDMS melt at 25 °C is  $\rho = 0.97$  g/cm<sup>3</sup>.
  
4. **Lodge, Problem 11.2** on p. 462.
  
5. **Lodge, Problem 11.5** on p.462.  
 Normally, data are plotted on log scales,  $\log J(t)$  vs  $\log t$ , because there is such a large range of time and  $J$  values. However, here you will likely find it easier to plot  $J(t)$  on linear scales. (Note that log refers to base 10, not base e.)  
 Find values for both the **reptation time**  $\tau_{rep}$  and the **segmental relaxation time**  $\tau_{seg}$  and note how different they are. It takes *much, much longer* to relax the entire chain compared to a group of local segments.
  
6. Consider a polymer chain represented by  $N = 20$  beads connected by springs of root-mean-square size  $b = 5$  Å diffusing in a melt of similar chains with bead friction coefficient  $\zeta = 3 \times 10^{-10}$  g/s at 22 °C.
  - i) What is the root-mean-square end-to-end distance  $R_{EE}$  of this chain?
  - ii) Are hydrodynamic interactions important or screened?
  - iii) What is the best model describing the dynamics of this polymer chain in a melt? Does this represent an unentangled or entangled polymer melt?
  - iv) What is the friction coefficient of the chain? Is the friction coefficient of the polymer proportional to the chain size  $R$  or the number of monomers/beads in the chain  $N$ ?
  - v) Estimate the longest relaxation time  $\tau$  of the chain.

7. **Lodge, Problem 10.12** on p. 417. *Note that the data is from our own Prof. Laura Finzi!*

i) The Gaussian expression we derived in class for the force of a single chain was

$$f = (3kT / Nb^2) h,$$

giving that the force  $f$  is a linear function of the extension  $h$ . This was based on the probability distribution  $P(N,h)$  for a Gaussian chain, Eq (6.7.10), derived in Chap 6.

ii) A better approximation for the probability distribution  $P(N,h)$  of an extended chain is based on the inverse Langevin function and is approximated in Eq (10.6.4) as an expanded power series in  $(h/Nb)$ . This results in an expression for the force of single chain of  $f = (3kT / Nb^2) [ h + 3/5 h^3 / (Nb)^2 + 99/175 h^5 / (Nb)^4 + \dots ]$

iii) However, Carlos Bustamante's group found that the worm-like chain model fit the data best giving the expression for  $f(h)$  shown in the question with fitting parameters for the persistence length  $l_p$  and contour length  $L$  of the DNA chain. (The worm-like chain model is what Prof. Finzi's group currently uses to analyze their data.)

Fit the data given in the question to the three different models and comment on the success or failure of the various expressions, and determine values for the persistence length  $l_p$  and contour length  $L$  of the  $\lambda$ -DNA chain.