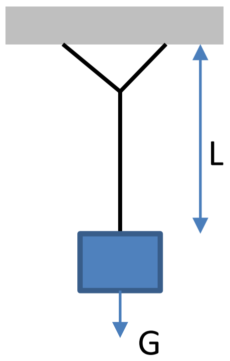
Exercises 7: Viscoelasticity

7.1: A mass G is suspended to a plastic fiber. The fiber consists of an incompressible, viscoelastic material. In its unloaded state, the fiber has a cross section A_0 and a length L_0.



The viscoelastic equation of state of the true fiber tension

$\sigma = G/A(\varepsilon)$ with $A(\varepsilon)$ the instantaneous cross section and the extension $\varepsilon = (L - L_0)/L_0$, L as instantaneous fiber length

is described by the Kelvin-Voigt Model with a spring constant E and a viscosity η .

For which mass G is the strain rate constant? What is then the resulting dL/dt?

7.2: Use the Maxwell model analysis of stress relaxation to estimate the longest relaxation time for the highest molecular weight sample in the plot of the stress realxation modulus G(t) versus time t on page 3 of the lecture notes [G = 3 x 10^6 dyn/cm^2 (plateau value) M = 4.6 x 10^5 g/mol, η= 5.5 X 10^{11} P (= g/cm s)]

7.3: Use the BSM to estimate the longest relaxation time for polystyrene with M = 10^6 g/mol in cyclohexane at the theta temperature (35°C). The values of D_t and [η] are given as a function of M for this system in Figure 1 and Figure 2 respectively. (viscosity of cyclohexane is 0.8 cP).

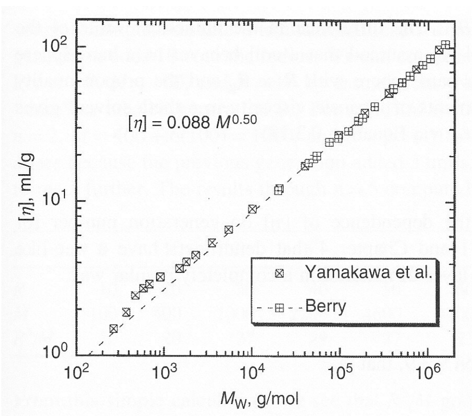


Figure 1: for M = 106 use [η] = 84 mL/g

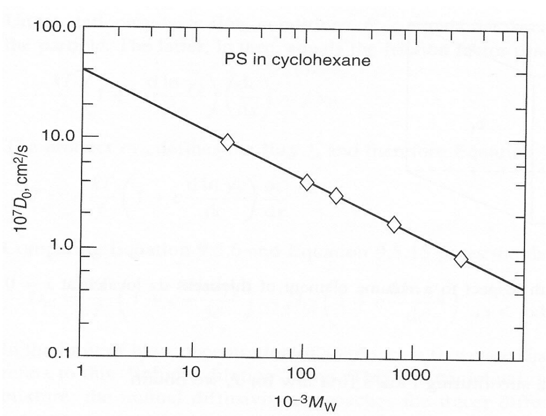


Figure 2: for M = 10^6 is $D_t \approx 10^{-7}$ cm^2/s

7.4: You are an engineer in charge of a polystyrene drinking cup manufacturing plant. Normally, you process the material at 160ºC, where the viscosity of the polymer melt is 1.5 x10^3 poises when Z_w = 800 (Note that $Z_{c,w}$ for polystyrene is 730). Today, your polystyrene has Z_w = 950. What change in processing temperature will bring down the viscosity to the initial value of 1.5 x10^3 poises? T_g for polystyrene is 100ºC. (Note: Use the universal constants for the Williams-Landel-Ferry equation C_1 = 17.44, C_2 = 51.6)

The following relationship exists between the melt viscosity of the polymer and its length:

$$\eta = K_H (Z_w)^{3.4} .$$

With Z the number of atoms along the polymer chain's backbone.
With $Z_{c,w}$ as critical entanglement chain length: weight average number of chain atoms in the polymer molecules