PHYS-E0422 Soft Condensed Matter Physics, exam 4.4.2016 (5 problems, 2 pages)
No auxiliary written material is allowed (tables, notes etc.)
A standard calculator accepted in the Finnish matriculation examinations (yo-kirjoitukset) is allowed.

Problem 1. (8 p)
Consider the polymers in a plastic film equilibrated well above the glass transition temperature. The initial film thickness is $h = 100R$, were R is the end-to-end distance of the polymer.

a) Qualitatively describe how the material will respond if the film is pulled from two opposing sides i) very slowly and ii) very quickly with a constant speed. What happens with the polymers in the bulk of the material?

b) The film thickness is decreased to $h < R$. Briefly describe (illustrate if possible) how the polymer chains will be arranged within the film. Remember that the density within the film needs to be conserved. How will the ratio of self (within polymer) and non-self (between different polymers) interactions change as the film becomes thinner? What consequences does this have for the mechanical properties of the film, that is, what happens when you now pull on it with different speeds?

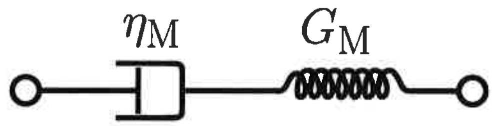
Problem 2. (12 p)
Provide a brief but comprehensive explanation for the following concepts/terms. Use illustrations if possible.
a) Ideal solution
b) Shear thinning and thickening
c) Nylon
d) Laplace's theorem
e) Wenzel state
f) Critical micelle concentration

Problem 3. (6 p)
The surface tension can be measured by dipping a rigid spherical ring horizontally into a liquid and by measuring the force needed to detach the ring from the surface. The ring is made out of platinum. Derive an expression for the force needed for the detachment, and give an estimate for the force for pure water (γ = 72.8 mN/m). Ring radius is 10 mm and wire diameter 200 μm.

Problem 4. (7 p)
Let us consider a viscoelastic material whose response to an applied shear is given by a purely elastic element (shear modulus G_M) and a purely viscous damper (viscosity η_M) in series [see the figure below].
a) What are the relations between the total shear stress, total strain, and the strain and stress related to the elastic and viscous elements?
b) Is this material a viscoelastic solid or liquid? Provide a direct justification for your answer by considering the relaxation of this material after an applied step stress of magniture σ_{init} is removed.
c) Determine the storage and loss moduli of this material. Recall the definition of the complex modulus

$$G^*(\omega) = \frac{\sigma_0}{\gamma_0} e^{i\delta} = G'(\omega) + iG''(\omega),$$

where σ_0 and γ_0 are the amplitudes of the oscillating stress and strain, respectively, and δ is the phase difference between the stress and strain.



PROBLEM 5 ON THE OTHER SIDE

Problem 5. (7 p)
The Flory-Huggins theory gives the following expression for the free-energy of mixing of polymers:

$$\frac{\Delta G}{k_B T} = \chi x_A x_B + \left(\frac{x_A}{N_A}\right) \ln x_A + \left(\frac{x_B}{N_B}\right) \ln x_B, \tag{1}$$

where x_i are the molar fractions of the monomers, N_i are the number of monomers in the polymer, and χ is the Flory-Huggins interaction parameter.

Based on the Flory-Huggins theory, compare the mixing in the three following cases: i) monomers of A and B, ii) polymer of A ($N_A = 500$) with monomers of B ($N_B = 1$), and iii) polymers of A ($N_A = 500$) and B ($N_B = 500$).

(a) What happens in each of the cases when $\chi = 0.5$?

(b) What if $\chi < 0$? What does this mean from the perspective of interactions?

(c) What is the relative significance of the entropic and enthalpic effects in the systems i, ii, and iii?