PHYS-E0422 Soft Condensed Matter Physics, exam 11.04.2019 (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. (6p)
Experiments with viscoelastic materials.

a) A creep experiment is performed with a silly putty. Make graphs illustrating the applied stress as a function of time and the resulting strain as a function of time. Explain the results.

b) A force relaxation experiment is performed with a biological tissue. Make graphs illustrating the applied strain as a function of time and the resulting stress as a function of time. Explain the results.

c) Which viscoelastic models can be used to describe the experimental results in (a) and (b)?

Problem 2. (12p)
Provide a brief but comprehensive explanation for the following concepts/terms. Use illustrations if possible.

a) Excluded volume
b) Lotus effect
c) Ideal chain
d) 2D lattice model for binary solutions
e) Colloid
f) Capillary length

Problem 3. (7p)
The interaction energy between two surfaces (per unit area) submersed in a liquid is given by DLVO theory as:

$$w(h) = -\frac{A_H}{12\pi h^2} + (64 k_B T R \rho_\infty \gamma^2 / \kappa) e^{-\kappa h}$$

a) What interaction(s) does the first term represent? Draw a scheme of the two plates and discuss briefly how this interaction term can be derived. Is this term of entropic or enthalpic origin?

b) What interaction does the second term represent? Draw a scheme and discuss briefly how this interaction term can be derived. This this term of entropic or enthalpic origin?

c) Which of the two terms is attractive and which one repulsive in typical simple colloidal dispersions?

PROBLEMS 4 AND 5 ON OTHER SIDE

Problem 4. (8p)
Free energy density of mixing of two polymers A and B is given by

$$f(\phi)=\frac{k_B T}{v_c}\left(\frac{\phi}{N_A}\ln\phi+\frac{1-\phi}{N_B}\ln(1-\phi)+\chi\phi(1-\phi)\right)$$

where N_A and N_B denote number of monomers in each respective polymer A and B, χ is the Flory-Huggins interaction parameter, v_c is the volume of each monomer, and ϕ is volume fraction of polymer A.

a) Which terms of the free energy density (given above) are of entropic origin and which ones are of enthalpic origin?

b) Which terms of the free energy density promote mixing? Why?

c) How does the entropic contribution to the free energy density change when lengths of the two polymers increase?

d) What is the physical meaning of the Flory-Huggins interaction parameter? Where does it originate from?

e) So called spinodal line can be obtained from free energy density as $\partial 2f/\partial\phi 2=0$. Derive this line for the free energy density given above. What is the physical interpretation of the spinodal line?

Problem 5. (7p)
a) Describe the physical origin of surface tension. Rank the following liquids from low to high surface tension, and motivate using arguments based on the physical origin of surface tension.

- water at 20°C
- water at 30°C
- liquid nitrogen (N_2)
- mercury
- ethanol

b) Give a mechanical definition of surface tension.

c) What is the effect of curvature of the water surface on the properties of the liquid?

d) Consider two planar surfaces with a water drop in between (see figure). The contact angle with the surface is 0°. The surfaces are separated by a distance H = 10 micrometer, and the radius of the capillary bridge is R = 1 cm. Calculate the force between the two surfaces. Is it attractive or repulsive?