PHYS-E0422 Soft Condensed Matter Physics, exam 15.4.2021 (5 problems, 2 pages)
You can choose if you write all your responses on paper (option #1), or if you type text in the text box in MyCourses and use paper for equations, drawings, etc. (option #2). Both options are ok. For your responses on paper, take a high-quality scan or photo and upload to MyCourses. Please mark clearly the problem number and add page numbers.

Problem 1. (6p)
A polymer chain is stretched by a few percent of its length and the required force to do so is measured.

a) Sketch the expected force-extension graph from such an experiment and give a brief explanation of the results.

b) The temperature of the system is *increased* and the same experiment is repeated. Draw the expected results in the same graph as (a) and explain the results.

c) The stretching experiment is performed with a *longer* polymer of the same chemical composition. How does this affect the stiffness of the polymer chain?

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

a) Receding contact angle
b) Polydispersity index
c) Ideal chain
d) Block copolymer self-assembly
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)
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].

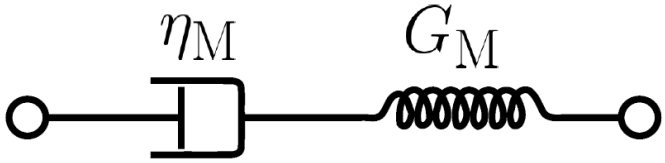
a) What are the relations between the total shear stress, total strain, and the strain and stress related to the elastic and viscous elements?

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 magnitude 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. (7p)
Surface tension

a) Describe how surface tension, energy and forces are related to each other.

b) Describe the molecular origin of surface tension. Rank the following liquids from low to high surface tension, and motivate using arguments.

- water at 20°C
- water at 60°C
- liquid nitrogen (N_2)
- mercury
- ethanol

c) What is the effect of curvature of the water surface? Describe in detail.

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?