Tfy-0.3252 Soft Matter Physics / Pehmeän aineen fysiikka
Exam 08.01.2009 (5 problems / 2 pages).

Since the language of the course was English, the exam problems are in English as well. You can write your answers either in English or Finnish.

Problem 1. (4 points)
Define *soft matter*: What are the characteristic features of soft matter systems? What distinguishes soft matter from other types of condensed matter, for example crystalline solids and standard liquids? Give three every-day examples of soft matter and explain why your examples classify as soft matter.

Problem 2. (8 points)
Give a short explanation of the following concepts and terms. Use illustrations if possible.
a) Mean field theory (2 p.)
b) Emulsion (2 p.)
c) Free energy (2 p.)
d) Protein (2 p.)

Problem 3. (6 points)
Answer either to part **(a)** or **(b)**.

a) Describe the most typical liquid crystal phases and the general types of molecules forming them. What are the positional and orientational symmetries related to each phase? Describe the general relation between temperature and liquid crystal phases formed at a fixed mesogen concentration.

b) An isolated system with internal energy U, particle number N, temperature T, and entropy S is at thermodynamic equilibrium. Consider then a small subregion of the system with a fixed volume and particle number (V_1 and N_1, respectively), interacting with the rest of the system.

Derive the probability of finding this small subregion in one specific microstate with an internal energy $U_1 = \varepsilon$. (Assume $\varepsilon \ll U$). Further, identify the characteristic energy scale from the expression obtained. Why is this energy scale especially important in the study of soft matter systems?

Problem 4. (6 points)
Define the surfactant packing parameter P and explain its importance. What physical or chemical factors determine the values of the different quantities in P? How could one control the value of P in the case of some given surfactant? Finally, show that surfactants form cylindrical micelle aggregates when $\frac{1}{3} < P \leq \frac{1}{2}$.

Problem 5. (6 points)
Consider an ideal chain model polymer consisting of N bond vectors ($N \gg 1$). The end-to-end distance R_x of such a polymer in one given cartesian direction (here x) follows Gaussian statistics

with a probability density

$$P_{1D}(N, R_x) = \frac{1}{\sqrt{2\pi\langle R_x^2\rangle}} \exp\left(-\frac{R_x^2}{2\langle R_x^2\rangle}\right).$$

As you learned during the course, linear polymer end-to-end distance root-mean-square values $\sqrt{\langle R^2\rangle} \equiv R_{\mathrm{rms}}$ in general follow a scaling law $R_{\mathrm{rms}} \propto N^{\nu}$.

a) Give a short explanation of the term *ideal chain* when it is used in the context of linear polymer models.

b) What is the scaling exponent ν for ideal chain conformations in two dimensions? (For example, polymer chains confined to a 2D flat surface).

c) Let us then also take into account the finite excluded volume taken up by the monomers in the polymer chain. What is now the scaling exponent ν? Use simple arguments, but give sufficient justification to your assumptions and approximations.