Tfy-0.3252 Soft Matter Physics / Pehmeän aineen fysiikka
Exam 15.12.2008 (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) Surfactant packing parameter (2 p.)
b) Hydrogen bond (2 p.)
c) Dendrimer (2 p.)
d) Critical micelle concentration (2 p.)

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

a) Outline the fundamental molecular interactions that give rise to the hydrophobic effect with small solute particles (linear size $R < 1$ nm). From a thermodynamic point of view, what is the driving force for the hydrophobic effect in this case? How does this differ from the case of a large solute particles ($R \gg 1$ nm)? Finally, give two examples of how the hydrophobic effect manifests in the functioning of biological soft matter systems.

b) Describe different ways to control the stability of colloidal systems. Briefly explain the physics behind each method. Use illustrations if possible. Give an example of a real-life application where the stability of a colloidal system is desired. Conversely, give an example of an application where a colloidal system needs to be made unstable instead.

Problem 4. (6 points)
A full solution of the Langevin equation gives the mean-square displacement of a Brownian particle in one dimension as

$$\langle x^2(t)\rangle = \frac{2k_B T}{\xi}\left[t - \frac{m}{\xi}\left(1 - e^{-(\xi/m)t}\right)\right],$$

where t is time, k_B the Boltzmann constant, T temperature, and ξ and m are the friction factor and mass of the particle, respectively.

a) Identify the related characteristic time τ that divides the motion of the particle into two distinct types.

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b) For these two types of motion, what is the relation between the particle displacement and time?

c) Give a proper physical explanation for these two time dependencies.

Problem 5. (6 points)
Consider a system consisting of rodlike liquid crystal molecules. Each of the molecules has a permanent electric dipole moment $\vec{u}$ that is parallel with the long axis of the molecule.

Initially the system is in the isotropic phase. An external homogeneous electric field $\vec{E}$ is then applied on the system. The electric field is weak enough so that the interaction energy between a molecule and the field, $U = -\vec{u}\cdot\vec{E}$, is small compared to the thermal energy $k_{\mathrm{B}}T$ at all molecule orientations.

a) Derive the probability of finding a given molecule with an angle between its dipole moment $\vec{u}$ and the electric field $\vec{E}$ in the interval θ, $\theta+d\theta$ when the system has reached equilibrium.

b) The orientational polarizability α of the molecules is given by the relation

$$u_{\mathrm{eff}} = \langle u\cos\theta\rangle = \alpha E,$$

where u_{eff} is thus the average component of $\vec{u}$ in the direction of $\vec{E}$. Calculate α.

Remember that it was possible to get 1 exam point by filling in and returning the course feedback form by December 15. This point is *not* a bonus point.