FYS–7.100 Johdatus pehmeän aineen fysiikkaan

Exam 15.02.2010 (5 assignments / 2 pages)

Since there may be English speaking students in the exam, the questions below are in English—just like in all previous exercises. Though, answers can be given in Finnish, of course.

Assignment 1. (3 p)
Soft matter. Discuss what types of molecules may give rise to formation of soft matter, and what are the typical interactions in soft matter systems.

Assignment 2. (9 p)
Explain the following concepts, terms and phenomena. Use drawings and/or essay-like descriptions to clarify the issue, when needed.

a) Discuss the structure and functions of RNA. (2 p)
b) If RNA would be considered as a linear chain-like molecule, which it is, how would you construct a simple polymer model to study its structural properties? (1 p)
c) What is a colloid and what types of colloids can you have in a diet? (1 p)
d) Describe the hydrogen bond. (1 p)
e) What happens if a cell is taken from a water solvent to a cell culture dish where the solvent is oil (instead of water)? (1 p)
f) Computational modeling of soft matter – what is it good for and how it can complement experimental sciences? (2 p)
g) What types of different phases there are in liquid crystals? (1 p)

Assignment 3. (6 p)
In the 19th century, Benjamin Franklin carried out an experiment where he was standing by the lake with a teaspoon of oil (volume about 5 cm^3). He allowed that quantity of oil to spread on water. He found that this amount of oil covered an area of 2000 m^2. Estimate the thickness of the oil layer floating on top of water. What is your conclusion for the structure of the layer?

Second, use the above value together with the assumptions that (i) the density of oil is 1000 kg/m^3 and (ii) the mass of an individual oil molecule is 700 amu. Estimate the value of Avogadro's number.

Assignment 4. (6 p)
The orientational properties of liquid crystal molecules (among others) are described by the order parameter

$$S = A\langle\cos^2\theta\rangle - B.$$

In three dimensions, the parameters associated with the above equation are $A = 3/2$ and $B = 1/2$.

Assume that a liquid crystal molecule is confined to a two-dimensional plane such that the molecule is completely planar. Under these circumstances, one needs to describe the orientational order of the molecule in two dimensions (instead of three), and the above equation has to be rewritten in two dimensions as well. Derive the parameters A ja B in this situation.

Assignment 5. (6 p)
Answer <u>either</u> to part (a) <u>or</u> (b).

(a) A bacterium moves in water at a velocity $\vec{v}(t)$ as a function of time t. The mass of the particle is m and it moves in a liquid whose viscosity is $\eta = 10^{-2}$ g/(cm · s), and density is $\rho = 10^3$ kg/m^3. Let us assume that the density of the bacterium is identical to that of the surrounding liquid. Let us also assume that the particle is approximately spherical (with a radius of $R = 1\,\mu$m).

The bacterium first moves at a steady speed $v_0 = 1\,\mu\text{m}/\text{s}$, but then stops "swimming" at the time $t = 0$. There are no external forces exerted on the bacterium, thus its speed starts to slows down. Calculate the velocity of the bacterium as a function of time t.

Next, also calculate the distance the bacterium will move before it eventually stops.

(b) b1. **Protein folding.** Discuss the different structural levels in proteins and the related protein folding problem. Why understanding of the folding process is so important?

b2. **Random walk.** Discuss the random walk by providing a proper "definition" and explain what the random walk means. Using the concept of the random walk, provide a definition for a (single-particle) diffusion coefficient D. What does D describe in practice? Finally give every-day examples of random walks.

These might be useful:
$\sin 2x = 2\sin x \cos x$
$\sin 3x = 3\sin x - 4\sin^3 x$
$\cos 2x = 1 - 2\sin^2 x$
$\cos 3x = 4\cos^3 x - 3\cos x$

Taylor expansion $(1+x)^{-1/2} \approx 1 - \frac{1}{2}x + \frac{3}{8}x^2 + \mathcal{O}(x^3)$ for $|x| < 1$.

Boltzmann constant $1.380662 \cdot 10^{-23}$ J / K.

1 amu = 1.66×10^{-27} kg. (atomic mass unit)

Snowy regards to everybody!