FYS–A265 Johdatus pehmeän aineen fysiikkaan

Exam 22.01.2010 (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)
Define *soft matter*. 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.

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) Polymers: essentially all biologically relevant molecules are polymers. What quantities are usually used to characterize their size? (1 p).
b) Discuss Brownian motion. Write the Langevin equation for a Brownian particle and discuss the physical origin and interpretation of the terms appearing in the equation. (2 p)
c) Persistence length. What does the persistence length describe? How would you define that? (1 p)
d) Hydrogen bond. (1 p)
e) Protein folding and protein denaturation. (1 p)
f) Explain the difference between DNA and RNA. What are their roles in the flow of information in cells. (1 p)
g) Describe the main phases of liquid crystals, including drawings to highlight their structures. (2 p)

Assignment 3. (6 p)

a) 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?

b) The orientational properties of liquid crystal molecules (among others) are described by the order parameter
$$S = A\langle \cos^2 \theta \rangle - B.$$
The conditions are that when the molecules are all aligned along the director (the direction of an external field), then $S = 1$, and if all molecules are randomly oriented, then $S = 0$. Compute the values of A and B that satisfy these conditions.

Assignment 4. (6 p)

a) Assume that the density of your body is 1200 kg/m^3, which is a bit more than the density of water, 1000 kg/m^3 (here we assume that you have plenty of muscles, which we know to be true, and there is no air in your lungs). Compute the effective mass of your body when you are diving in a pool such that you are completely below water-level. (Remember to account for buoyancy.) You may consider yourself as a cylinder whose height is 170 cm and radius is 14 cm.

b) Next assume that you are swimming breaststroke such that your head is above water-level all the time (this is no good since it overburdens your neck) while the rest of your body is below water-level. If your head accounts for 7 % of your body weight, compute the effective mass of your whole body while swimming.

c) Using these data, interpret the importance of mass on a cellular level.

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

(a) Assume that you are considering a spherical cell whose radius is $10\,\mu$m. The plasma membrane surrounding the cell is composed of lipids and proteins, which diffuse laterally (in a two-dimensional manner) in the plane of the membrane. The rate of how rapidly the lipids and proteins move along the membrane plane is described by a lateral diffusion coefficient D. You know from experience that the dimensions of D are length squared divided by time. Using this as a basis (the so called dimensional analysis), and remembering the definition of the lateral diffusion coefficient (which actually is not necessarily needed in this exercise), calculate the following.

a1. Assume the lateral diffusion coefficient of lipids to be $D = 1 \times 10^{-7}\,\mathrm{cm}^2/\mathrm{s}$. Then, how long it takes (on average) until the lipid diffuses as a random walker from its present site at time $t = 0$ to the opposite site on the other side of the spherical cell?

a2. Next assume that you are considering the diffusion of a membrane protein along the plane of a plasma membrane. The lateral diffusion coefficient of a protein is $D = 1 \times 10^{-10}\,\mathrm{cm}^2/\mathrm{s}$. Calculate again the time it takes to reach the opposite position on the other side of the cell.

a3. Using these data, interpret how relevant diffusion is as a means to transport particles in a cell.

(b) b1. **Interactions.** Discuss the various interaction mechanisms and bond types found in biomolecular systems. In addition, discuss their relative magnitudes. Provide examples of each type. Please note that this issue is broad and calls for a rather thorough discussion.

b2. **Protein folding.** Discuss the different structural levels in proteins and the related protein folding problem. Why understanding of the folding process is so important?

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)