
FYS-7.100 Johdatus pehmeän aineen fysiikkaan / TTY

Exam 23.02.2009 (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 each of these three types of matter (solid, liquid, soft).

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) Colloid. (1 p)
- b) Radius of gyration. (1 p)
- c) Nucleic acid. (1 p)
- d) Free energy. (1 p)
- e) Protein folding. (1 p)
- f) If you were alone on an isolated island in the middle of nowhere, surrounded by the sea in all directions, how would you make soap? (1 p)
- g) Langevin equation. (1 p)
- h) Describe the main different phases, and illustrate a typical phase diagram. (2 p)

Assignment 3. (6 p)

Consider two particles interacting in such a manner that their interparticle interaction has the following form:

$$U(r) = -\frac{A}{r^n} + \frac{B}{r^m},$$

where $A > 0$, $B > 0$, and $m > n$. Also, the parameters m and n are positive integers. Here, you may assume that $n = 6$ and $m = 12$,

- Sketch how this interparticle potential behaves, that is, how the potential changes as a function of distance r .
- Discuss briefly the physical origin of the two terms in the potential.
- Calculate the force $F = -\frac{d}{dr}U(r)$ and sketch its behavior, too.
- Compute the distances at which $U(r) = 0$.
- Compute the point(s) where $F(r) = 0$.

Assignment 4. (6 p)

One way to describe single-particle diffusion is to use the Green-Kubo relation:

$$D = \frac{1}{d} \int_0^{\infty} dt \langle \vec{v}(t) \cdot \vec{v}(0) \rangle,$$

where $\vec{v}(t)$ is the velocity of the particle's center of mass at time t . Here, $\phi(t) = \langle \vec{v}(t) \cdot \vec{v}(0) \rangle$ is the velocity-velocity autocorrelation function.

Now you know that $\phi(t) = \phi(0) \exp(-t/\tau)$. Calculate D .

You know that the mass of the diffusing colloidal particle is 10 000 amu, and that the temperature of the system is 310 K. Also, you know that the diffusion coefficient has a value of $D = 1 \times 10^{-9} \text{ m}^2/\text{s}$. Compute the value of τ .

Generally speaking, what does τ describe?

Assignment 5. (6 p)

Answer either to part (a) or (b).

- (a) Random walk. Let us assume that we have a random walker at position $x = 0$ at time $t = 0$. The walker carries out a one-dimensional random walk with steps of unit length, $\ell = 1$, and the steps are made at fixed discrete time intervals ($\Delta t, 2\Delta t, 3\Delta t, \dots$). At every moment, steps to the left and to the right are equally probable ($p_{\text{left}} = p_{\text{right}} = 1/2$). Calculate the probability that the random walker will be found at x after N steps. When the number of steps is very large, show that the distribution is given by the Gaussian probability distribution function. (Hint: using the binomial distribution might help.)
- (b) b1. **Hydrogen bond.** Discuss the hydrogen bond and its significance in biological systems.
- b2. **Bacteria.** Discuss the main structural and dynamical aspects of bacteria. Especially describe motility; where does it arise from, and how that takes place.
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