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)
Water is liquid. Meanwhile, water including a reasonable concentration of lipids is not liquid but defined as soft matter instead. Explain the difference: why the latter case is 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) Maple syrup (vaahterasiirappi). Would you consider it as fluid (fluid) or soft matter? Justify your opinion. (1 p).

b) What is 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) Describe what kinds of secondary structures are there in proteins? (1 p)

d) What is the difference between mobility (diffusion) and motility (bacterial motion)? (1 p)

e) Describe the structure of liquid water? (1 p)

f) Radius of gyration. (1 p)

g) Biological systems are often considered as “scaleless” regarding length and time etc. Discuss this topic giving also examples. (2 p)

Assignment 3. (6 p)

a) Assume that the density of your body is 1050 kg/m³, which is a bit less than the density of water, 1000 kg/m³ (here we assume that the amount of air in your lungs is rather small). Compute the effective mass of your body when you are swimming (or 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 175 cm and radius is 15 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 4. (6 p)
The orientational properties of liquid crystal molecules (among others) are described by the order parameter

\[ S = A(\cos^2 \theta) - B. \]

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 either to part (a) or (b).

(a) Dipole-ion interactions. Consider a dipole $u = ql$, where its charge is $q$ and length $l$, and an ion with a charge $Q$. The dipole and the ion are separated by a distance $r$, which describes the distance from the center of mass (middle point) of the dipole to the ion (see the attached figure below). Their relative orientation is fixed and described by a constant angle $\theta$, determined by spherical coordinates. Show that the dipole-ion interaction is given by

$$\mathcal{U}(r, \theta) \propto \frac{Q u \cos \theta}{r^2}.$$  

What happens for the interaction if the dipole is allowed to fluctuate freely? (Justify your view by calculations.)

(b) b1. Electrostatics. Electrostatic interactions come about in a variety of situations and phenomena in soft and biological matter. Discuss what electrostatic interactions mean (use also equations); also describe situations and systems where they emerge in soft and biological matter; finally explain in intuitive terms what the dielectric constant means.

b2. Polymers. Discuss what polymers are, and explain how their structure and dynamics can be characterized. Also consider what biological molecules are polymers, and give examples of polymers that can be used as carriers of drugs.

**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 $1.380662 \times 10^{-23}$ J / K.

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

Snowy regards to everybody!