Part 1  Knowledge questions

1. Describe the following physical effects in Bionano systems:
   a. Brownian motion
   b. Viscous drag
   c. Diffusion
   d. Electrical drift and conductivity

2. What is the equipartition of energy theorem?

3. State the Einstein relation for the diffusion coefficient

4. State Langevin’s equation, clearly describing the meaning of each term

5. What is the Stokes-Einstein relation between RMS displacement, time and the friction factor?

6. State the Stokes expression for the friction factor of a spherical particle, clearly describing each term.

7. Write down an expression for Fick’s first law, clearly describing each term.

8. Why is the hydrodynamic radius of an ion different from the physical radius of an ion in water?

9. Briefly describe the three forces that comprise the Van der Waals forces.

10. What is electrophoresis?
Part 2   Longer questions (derivation, calculation or discussion)

1. Describe the Brownian motion of biological molecules or particles and explain the importance of this in Biology. Compare this with diffusion of molecules and outline the different conditions where you would expect the two mechanisms to dominate. Highlight the expected difference in the effect of each mechanism over time.

2. Derive an expression for the Nernst Potential from Fick’s First Law and Ohm’s Law. Describe the importance of the Nernst potential in Biology?

3. The ionic mobility of two ions are given by: $K^+ = 7.62 \times 10^{-8} \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$ and $Cl^- = 7.91 \times 10^{-8} \text{ m}^2 \text{V}^{-1} \text{s}^{-1}$. Use the Einstein relation to calculate the diffusion coefficient for the ions. Using the Stokes expression, calculate the hydrodynamic radius.

4. Describe conduction in an aqueous solution of salt.

5. Explain with the aid of diagrams, the main features of the Electrical Double Layer. Draw a figure showing the concentration of co- and counter-ions, and the electrical potential from the surface into the bulk solution. Discuss the physical processes responsible for the Electrical Double layer and define the Debye Length.

6. Outline the physical effects involved in the DLVO theory. Use a figure to illustrate the behaviour of molecules under the action of these effects.