Biophysics (LS2103) / Autumn 2018
MID-SEMESTER EXAMINATION

Total marks: 25 17-09-2018 (1 hour)

Please read the questions *very carefully* before answering

Useful Values: Boltzmann constant, $k_B = 1.3806 \times 10^{-23}$ Joule K^{-1}
Gas constant, $R = 8.3144$ Joule K^{-1} mol^{-1}

Q1) **(4 x 2 marks)**

i) A cell's metabolism (say '*B*') is its total energy usage per unit time. '*B*' is found to roughly scale linearly with the cell's volume. Accordingly, construct a scaling law, and determine the SI units of any constant used.

ii) The 'complexity' of a cell (say '*C*') may also be considered to scale linearly with cell volume; assume any proportionality constant to be dimensionless. Define a cell's evolutionary advantage (say '*A*') for a given cell type as a product of *B* (above) and *C*. Depict with a schematic graph how '*A*' should depend on diameter ('*d*') of a nearly spherical cell. (Neglect any relationship between mass and volume).

Q2) **(3 x 3 marks)**

Consider 1 mL of a very dilute protein solution in equilibrium at a temperature '*T*', and a pressure slightly higher than atmospheric pressure. The protein has a molar mass '*M*', at a temperature '*T*'.

i) Write down and depict schematically the probability distribution function of the molecular speeds of the protein units.

ii) Is the distribution function discrete or continuous? What are the *SI units* of the distribution function?

ii) Chemical perturbations to the solutions were found to induce the formation of protein tetramers (an assembly of four units) in the solution. The solution was allowed to achieve equilibrium again at the same temperature. Compare the old and the new velocity distributions.

Q3) **(4 x 2 marks)**

Consider the diffusion of a fluid along the direction '*z*'. The concentration ('*c*') of the fluid is given as number of particles per unit volume. The *flux* of the fluid ('*j*') is defined as the number of fluid particles crossing per unit area per unit time. The flux is proportional to the diffusion coefficient ('*D*'), and the gradient of the concentration.

i) Construct an equation describing how *j* should depend on the other specified parameters. Include and justify the signs used in your equation. (You may use a schematic diagram if you wish).

ii) Use dimensional analysis to show that your equation is justified.