**Biophysics (LS2103) / Autumn 2018**
**END-SEMESTER EXAMINATION**

**Total marks: 55** **Total Time: 3 hours** 29-11-2018
**Part-I: 16 (8 x 2 marks)**

## PART – I (*maximum* 45 minutes)

**NAME:** **ROLL NO:**

- Do not forget to write your name and roll no.
- Each question has a single correct answer. *Circle it with blue or black pen ONLY.*
- Double markings or scratches will disqualify the answer.
- Do rough work only in answer sheet, not in the question paper.
- *You will get Part - II question paper after submitting Part – I.*

Q1)
i) Appropriate units applicable to the y-axis in the Maxwell-Boltzmann speed distribution is:

a) unitless b) m $s^{-1}$ c) $m^{-1}$ s d) $m^2$ $s^{-1}$

ii) Which of the following is an extensive variable?

a) kinematic viscosity b) molar free energy c) enthalpy d) diffusion coefficient

iii) Consider a protein solution heated from room temperature (~25 °C) to its denaturation temperature (~160 °C). The specific heat capacity of the protein is 40.5 kJ $mol^{-1}$ $K^{-1}$. Which quantities do you need to calculate the total heat required to fully denature the sample?

a) molar concentration b) volume of sample c) protein's molar mass
d) all of the above

iv) The dimensions of viscosity (η) are:
(*Hint.* You may use the Stokes-Einstein relationship to arrive at your results)

a) [M $T^{-1}$] b) [M $L^2$ $T^{-1}$] c) [$M^{-1}$ $L^{-1}$ $T^{-1}$] d) [M $L^{-1}$ $T^{-1}$]

v) The sign of the voltage difference (ΔV) between the intracellular and the extracellular side of a cell membrane will arise from:

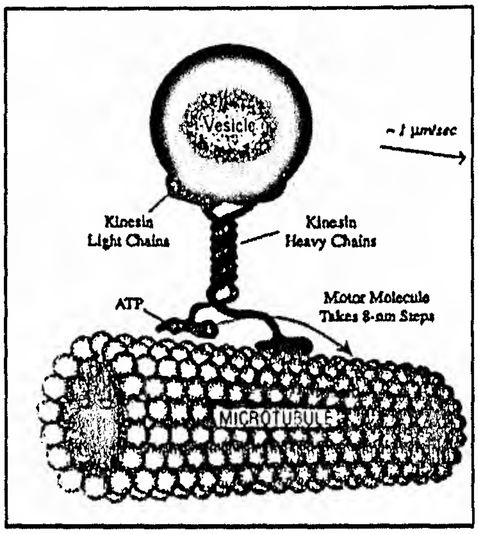
a) temperature b) ion's charge c) concentration ratio of the sides
d) both b) and c)

vi) An ink drop injected within a cylinder of glycerine is stirred by hand and mixed. When reverse stirred by hand, the ink drop appears back. Under what conditions would should the ink drop *not appear back* when reverse stirred?

a) Temperature is raised by a factor of 3 b) Stirring executed with a motor at 8000 rpm
c) Reverse stirred after 15 days d) All of the above

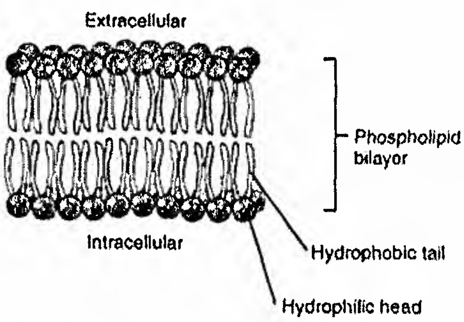
Neelanjana 29.11.18

**vii)** As depicted below, a kinesin carries a vesicle along a microtubule track. Assume that energy required for each stepsize of 8 nm is obtained by the hydrolysis of 1 ATP molecule, producing 30.5 kJ $mol^{-1}$What is the force involved (in picoNewtons) if there is no dissipative loss?




a) 26.1 b) 6.33 c) 1.54 d) 3.17

**viii)** Consider a lipid bilayer 3.5 nanometers thick and with an interior viscosity of 1.5 milliPascal-second (see below). Consider a *square* bilayer leaflet of side 1 micrometer. Estimate the magnitude of the restoring force (in picoNewtons) that arises when one leaflet is sheared over the other leaflet with a speed of 2 micrometer per second.




a) 0.86 b) 6.33 c) 8.57 d) 3.17

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**Total marks: 55** 29-11-2018
**Part-II: 39**

## PART – II

*Read each question carefully. Write answers in your answer booklets.*

**Useful Values:** Boltzmann constant, $k_B = 1.3806 \times 10^{-23}$ Joule $K^{-1}$
Gas constant, $R = 8.3144$ Joule $K^{-1}$ $mol^{-1}$
Density of room temperature water = $10^3$ kg $m^{-3}$
Viscosity of room temperature water = $8.90 \times 10^{-4}$ Pa-s
Atmospheric pressure = 1.013 MPa, equivalent to 760 mm of Hg.

**Q2)** **(3 + 3 + 6 = 12 marks)**

Consider a very dilute sample of protein solution at room temperature (25 °C) and at atmospheric pressure. The protein's molar mass is 4 kDa. A second sample contains a dilute solution of the protein's pentameric form (ie. 5 monomers coalesced) at the same temperature and pressure. Assume both samples obey the ideal gas equation, and the Maxwell-Boltzmann velocity distribution applies.

i) Write down the distributions of one *component* of the velocity, for both samples. Define each variable used. Draw a schematic plot comparing the distributions.

ii) Write down the distributions of the velocity, for both samples. Define any new variable used. Draw a schematic plot comparing the distributions.

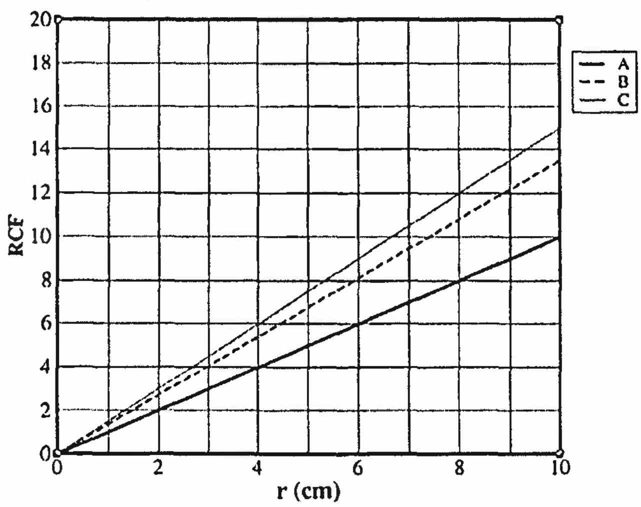
iii) The temperature of the second sample is gently raised to 30 °C. Find root-mean-squared speed ($v_{rms}$) of the proteins in both samples. What is the ratio of the two speeds?

**Q3)** **(3 + 3 + 6 + 6 = 18 marks)**

i) The 'relative centrifugal field' (RCF) is defined as the ratio of the centrifugal force to the gravitational force experienced by a particle in a centrifuge.

a. What are the units of RCF?

b. The plot below provides the RCF as a function of radial distance 'r' for three centrifuges labelled A, B and C. Estimate the ratio of their rotational velocities; specify the units used.




ii) What does the Reynold's number of a body in a fluid characterize? Write down the expression for the Reynold's number. Define and provide the SI units of each variable used.

iii)

a. The critical force ($f_{critical}$) at which laminar flow transitions to turbulent flow depends on fluid viscosity ($\eta$) and mass density ($\rho$) as $\rho^x \eta^y$. There are no constants. Determine $x$ and $y$, and hence write down the relationship between the quantities.

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b. A cellular load is moved along a microtubule track with a force of about 10 pN. Considering the environment to be aqueous, comment on the flow of the surrounding fluid.

iv) Consider a straight artery of length $L$ = 2.5 cm, and of uniform circular cross-section of radius $R$ = 4 mm.
The magnitude of velocity of blood of viscosity $\eta$, flowing along the axis under a pressure $p$, is:

$$v = \frac{pR^2}{4L\eta}$$

The total flow rate is:

$$Q = \frac{\pi p R^4}{8L\eta}$$

a. Show that both equations are dimensionally consistent.

b. If a person's systolic blood pressure is 120 mm of Hg, and the viscosity of blood is 50 milliPoise, calculate magnitude of the velocity and the total flow rate through the artery.

Q4) **(4 + 4 + 1 = 9 marks)**

**i)** The folding of a small, 50-residue protein is considered as a '2-state problem', wherein the unfolded state (named '*U*') has an energy ($\Delta E$) 6 kcal mol$^{-1}$ greater than the energy of the folded state (named '*F*').

a. Derive an expression the ratio of the equilibrium probabilities of the two states. Name the postulate you have used. Specify all variables used in your expression.

b. Find the ratio of the equilibrium probabilities at a temperature of 37 °C. Show how the ratio changes if the temperature is increased by an *additional* 30 °C.

c. The *U* and the *F* states are separated by a *barrier* of height 2 kcal mol$^{-1}$. Draw a schematic energy diagram depicting the states and the barrier.

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