Quiz 2: BB 101-Physical Biology Module

Date: March 21, 2018 **Total Marks:** 10 Marks

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Instructions:

• *You are not allowed to consult other students, any of your notes or any other material during the exam.*

• *All the questions are self-explanatory. Seeking explanation/clarification from the invigilators is discouraged.*

• *Use of scientific calculators is allowed however you are not allowed to use cellphone calculators.*

• *Use* $k_B = 1.38 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$

• *Avogadro's number or Avogadro's constant* $= 6.023 \times 10^{23}$

• *Viscosity of water = 1mPa·s*

1. Consider a globular protein of molecular mass 10 kDa whose radius is 3nm placed inside water whose temperature is 300 K.

(i) Calculate the diffusion constant for this protein.

(ii) Calculate the drag coefficient for this protein.

(iii) Suppose that this protein undergoes one-dimensional diffusion in water. Calculate the distance travelled by this proteins (in mm) by means of diffusion in 6 days.

[1+1+1 Mark]

2. Suppose a biomolecule has four possible states A, B, C and D. Suppose that energy of the biomolecule in state A, State B, State C and State D are 0 pNnm, 0 pNnm, 4.12 pNnm and 4.12 pNnm respectively.

(i) Find out the partition function at temperature T=300 K? **[0.5 Mark]**

(ii) Calculate the partition function in the limit $T \rightarrow 0$ **[0.25 Marks]**

(iii) Calculate the partition function in the limit $T \rightarrow \infty$ **[0.25 Marks]**

(iv) What is the probability of finding the biomolecule in state A in the limit $T \rightarrow 0$? **[0.25 Marks]**

(v) What is the probability of finding the biomolecule in state D in the limit $T \rightarrow 0$? **[0.25 Marks]**

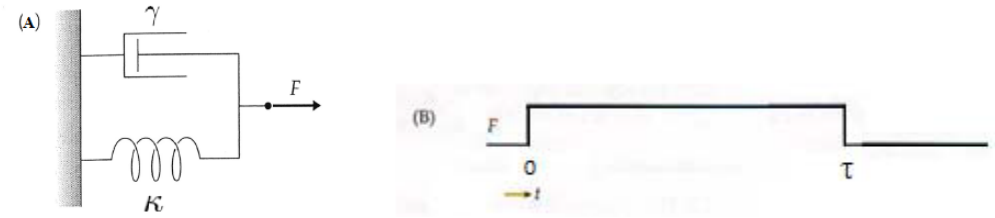
(vi) What is the probability of finding the biomolecule in state A in the limit $T \rightarrow \infty$? **[0.25 Marks]**

(vii) What is the probability of finding the biomolecule in state D in the limit $T \rightarrow \infty$? **[0.25 Marks]**

3. Consider the sedimentation of a spherical bio-molecule of radius 1 nm, initially right below the surface, in an Eppendorf tube of length 5 centimeters filled with water. Suppose that density of this biomolecule is nineteen times that of water and this bio-molecule sediments under the effect of gravity. Further assume that this bio-molecule attains a constant velocity as soon as it starts to descend in the Eppendorf tube. How much time (in seconds) this bio-molecule would take to descend 4 centimeters in the Eppendorf tubule (Density water=1000 Kg m^{-3} and g=10m/s^2)?

[2 Marks]

4. Consider a system consisting of a spring and dashpot in parallel as shown below in (A). The stiffness or spring constant of the spring is k and drag coefficient of dashpot is γ. Initially both spring and dashpot are at rest. Suppose a constant force F is abruptly applied to this system as at t=0 and is maintained for t = τ as shown below in (B), and force is abruptly removed thereafter (i.e. F=0 for t > τ). Find out the expression for displacement x(t) of the biomolecule for t ≤ τ and for t > τ (Note: Zero marks if calculations are not shown and answers are given with unexplained variables).



[1+1 Mark]

5. Figure below shows a cylindrical cell that is initially stationary in the middle of a 100μm long tube filled with water. The concentration of a chemical at the front end of the tube is maintained at 10 μM, and the concentration at the back end is maintained at 0 μM. Assume that a steady-state concentration profile has been reached inside the tube at T = 300 K and the viscosity of water is 1 m Pa s. Compute the diffusive flux of the chemical at x= 50 μm if diffusion constant of the chemical is 1000 $\mu m^2/s$? What is the direction of net diffusive flux i.e. back to front or front to back? **[0.75+0.25 Mark]**