LS5203 (Spring 2019)
END-SEMESTER EXAMINATION

Time: 2 hrs 30 mins | 01-05-2019
Total marks: 50 | *Provide clear explanations (marks are assigned for clarity).*

Q1. a) Folic acid (mol. wt. 441.4 g/mol) is commercially available at a concentration of 5 mg/mL. What is the molar concentration of the folic acid sold?

b) It is recommended that 1-year old babies take 8 μg of folic acid *per kg of body weight* every day. The average weight of 1 year-old Indian babies is 9.4 kg, with a standard deviation of 2.3 kg. What is the concentration that a pharma company should prepare so that an average baby can consume a 5 mL daily dose? Clearly explain all the steps for preparation.

c) What is the *range* of dosage that a doctor would prescribe?

(2 + 4 + 2 marks)

Q2. The smallest detectable viral load for HIV is 350,000 virus particles in a human body. A person is infected on *day-1* with 1000 HIV virus particles. The growth rate of the viral particles (y) is found to be:

$$\frac{dy}{dt} = 0.05y$$

where 't' is time in days. Rounded to the closest number, find the number of days after day-1 on which the infection can first be detected.

8 marks

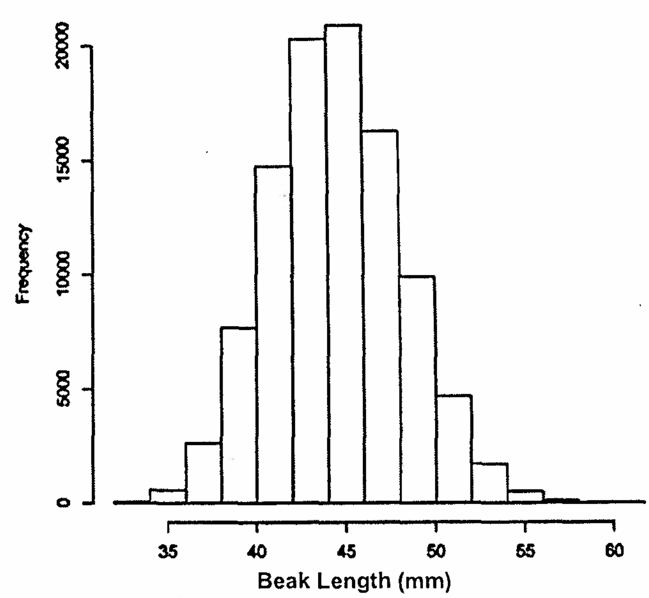
Q3. A colony of bacteria at an initial observation time (t_0) occupies a radius r_0 = 1cm. The surface density of the bacterial colony, at a distance r from the centre, is found to be $(1 - r^2) * 10^6$ bacteria cm^{-2}. The colony expands outward at the rate of 2 mm per hour. Find the *increase* in the number of bacteria 6 hours after t_0. Explain all steps carefully. It may be helpful to draw a schematic diagram.

8 marks

Q4. a) Write down a clear description of the Central Limit Theorem (CLT).

b) A geneticist started by assuming that the beak length of a particular species of bird was determined by 3 genes. Analysis of a very large data set yielded the distribution as shown in the figure below. Explain, with reasons, why the initial hypothesis of the geneticist was either correct or incorrect.

(3 + 5 marks)



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Q5. a) Consider a protein molecule making a random walk on the outer surface of a cell. Its *mean squared displacement* (R^2) depends on the *time span* 't', the *diffusion coefficient* 'D', and a dimensionless constant 'A'. Use dimensional analysis to establish the relationship connecting R^2 with 't', 'D' and 'A'. What would be the SI units of the diffusion coefficient?

b) Assume that the protein is nearly spherical with a radius 'r', and an effective viscosity 'η' encountered on the cell surface. It is found that the *product* of r, D and η is directly proportional to the available thermal energy. Use dimensional analysis to determine the units of the effective viscosity.

(4 + 4 marks)

Q6. In a molecular (computer) simulation, a chemical bond is modelled as a springs of spring constant 'k'. If the bond connects two atoms (particles) of mass m_1 and m_2, then the frequency ('f') of the spring is given by,

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}}$$

where the 'reduced mass' of the system is, $\mu = (m_1 m_2)/(m_1 + m_2)$

a) What are the dimensions, and hence the SI units, of the force constant k?

b) The time period of vibration is the inverse of the frequency. In a simulation setup, the peptide bond, connecting a carbon and a nitrogen atom, is modelled with $k = 370.0\ kCal\ mol^{-1}\ Å^{-2}$. The atomic weights of carbon and nitrogen are 14.007 and 12.011, respectively. Determine the time period of vibration.

c) A student decides to set up a simulation using the above parameters, and with a *time step* of 20 femtoseconds. Explain why the simulation setup is either correct or incorrect.

(3 + 5 + 2 marks)

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Useful Quantities:

1 Calorie = 4.184 Joules
Avogadro constant (N_A) = 6.022×10^{23} mol^{-1}
Boltzmann constant, k_B = 1.3806×10^{-23} Joules K^{-1}
Gas constant, R = 8.314 Joules mol^{-1} K^{-1}