



Your Roll No. \_\_\_\_\_

**B.Sc. Hons.– (Physics)\_NEP: UGCF-2022****PHYSICS - UPC - 2224002003****(GE ; Biological Physics)****Time : 3 Hours****Maximum Marks : 90**

(Write your Roll No. on the top immediately on receipt of this question paper.)

**Attempt 5 Questions in all. Question Number 1 is compulsory.**

Non-Programmable Scientific Calculators are allowed.

Each question carries 18 marks

- 1) Attempt any six of the following: (6 x3=18)
- What is self-replication? What is its significance for cell division, growth of organisms and inheritance of properties from one generation to the next?
  - The concentration of ATP in E Coli cytoplasm is found to be about 10 mM (milli moles per liter). If an E Coli cell has a volume of about  $1 \mu\text{m}^3$ , what is the number of ATP molecules in it?
  - State Kleiber's law for the rate of energy consumption per unit mass. What is the prediction of this law for the rate of physiological reactions in a mouse (10 g) in comparison to a human (70 kg)?
  - What are the run and tumble modes of motion of bacteria under chemotaxis.
  - A reaction pathway has two reactions  $r_1: A + B \rightarrow 2C$  and  $r_2: C + 2D \rightarrow A$ . Write the stoichiometric matrix for these reactions.
  - Give an example of positive feedback in an ecosystem and briefly explain its consequences.
  - Distinguish the roles of mRNA, tRNA and rRNA in transcription and translation of the genetic code for making proteins.
  - What are different kinds of point mutations in DNA. What effect do these have on protein synthesis?
- 2) a) What is the role of cell membrane in sustaining a living cell? Explain how cell membranes keep an electric potential difference between the inside and outside of a cell. (6)
- b) Why is energy required to make a bacterial cell? Explain with the help of laws of physics. List the main energy consuming processes during the rapid growth phase of a cell. An E Coli cell consumes 6.5 million ATP molecules per second in its exponential growth phase. If the

hydrolysis of ATP releases 57 kJ/mol, what is the minimum power required in this phase of the cell growth. (8)

c) What are the two tenets of the cell theory of life? How do these relate to the problem of origin of life? (4)

- 3) a) Derive the relationship between the mean root square displacement and time for a one-dimensional random walk. Explain how the diffusion in cells can be understood as a random walk. The diffusion coefficient of small metabolites in water is  $D \approx 10^{-9} m^2 s^{-1}$ . Estimate the time it would take a metabolite to diffuse into the volume of a mammalian cell of radius  $10 \mu m$ . Can diffusion be an adequate mechanism to distribute metabolites in a cell? (12)
- b) Distinguish between the primary, secondary, tertiary and quaternary structures of a protein. Describe the bonds which sustain different structures of a protein. (6)
- 4) a) Describe the structure and movement of Myosin and Kinesin based molecular motors in cells. What is the 'sliding model' of muscle contraction? (12)
- b) Describe different processes that translate the same gene into different proteins (6)
- 5) a) Discuss the argument for the implausibility of life based on a simplified probability estimate, and explain how this leads to the origin of life problem. What considerations show that unlike assumptions of a simplified probability estimate, emergence of life was a complex and not a fully random process. (10)
- b) Describe an intracellular biochemical network (e.g., a signaling network). Explain the difference between a one-component system and a two-component system in cellular signaling. (8)
- 6) a) What are food chains? What is the concept of energy pyramid and why do food chains rarely have more than 6 trophic levels? (6)
- b) Define conserved moieties with respect to dynamics of metabolic networks. Explain their significance with the help of an example. (6)
- c) What are different types of cells in human body, and give their percentages in terms of total number of cells? Why is this percentage very small for muscle cells and neurons even though their contribution to the mass of a human body is significant? (6)
- 7) a) State tenets of the neo-Darwinian theory of evolution. Discuss how chromosomal recombination and horizontal gene transfer contribute to genetic variability. (8)
- b) Write a simplified mathematical model that describes the dynamics of transcription and translation. Clearly define the variables and parameters used. Find steady state values of the protein and mRNA concentrations. (10)