DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 1: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Biophysics DSE – 1	4	3	0	1	Class XII Pass	NIL

LEARNING OBJECTIVES

This course familiarizes the students with the basic facts and ideas of biology from a quantitative perspective. It shows them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales. The course also gives them a flavour of the interface between biology, chemistry, physics and mathematics.

LEARNING OUTCOMES

After completing this course, students will

- Know basic facts about biological systems, including single cells, multicellular organisms and ecosystems from a quantitative perspective.
- Gain familiarity with various biological processes at different length and time scales, including molecular processes, organism level processes and evolution.
- Be able to apply the principles of physics from areas such as mechanics, electricity and magnetism, thermodynamics, statistical mechanics, and dynamical systems to understand certain living processes.
- Get exposure to complexity of life at i) the level of cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behaviour.
- Perform mathematical and computational modelling of certain aspects of living systems.
- Get exposure to models of evolution.
- Be able to perform experiments demonstrating certain physical processes that occur in living systems.

SYLLABUS OF DSE – 1

THEORY COMPONENT

Unit – I **(4 Hours)**

Overview: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales.

Unit - II **(12 Hours)**

Molecules of life: Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling. Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell. Simplified mathematical models of transcription and translation.

Unit - III **(12 Hours)**

Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Mechanical, entropic and chemical forces: Osmosis, cell assembly, molecular motors, bacterial chemotaxis.

Unit - IV **(12 Hours)**

The complexity of life: At the level of a cell: Intracellular biochemical networks. Dynamics of metabolic networks; the stoichiometric matrix. The implausibility of life based on a simplified probability estimate, and the origin of life problem. At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cellular differentiation and development. Brain structure: neurons and neural networks. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems. Allometric scaling laws.

Unit - V **(5 Hours)**

Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution.

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

List of experiments

1) Demonstration of diffusion, effect of medium, temperature, molecular weight and size on the rate of diffusion.
2) Demonstration of osmosis in a living system.
3) Demonstration of the relationship between viscosity and density.
4) Demonstration of how microscopic particles travel in air through aerosols.
5) Graphic visualization and demonstrations of 3D structure of biomolecules using in-silico visualization tools.
6) Estimation of serum protein using BSA as the standard. (Optional).

References:

Essential Readings:

1) Biological Physics: Energy, Information, Life; Philip Nelson (W. H. Freeman & Co, NY, 2004)
2) Cell Biology by the Numbers; Ron Milo and Rob Phillips (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2016)
3) Physical Biology of the Cell (2^{nd} Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3^{rd} Edition).

Additional Readings:

1) Physics in Molecular Biology; Kim Sneppen and Giovanni Zocchi (Cambridge University Press, Cambridge UK, 2005)
2) Biophysics: Searching for Principles; William Bialek (Princeton University Press, Princeton USA, 2012).

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 2: NUMERICAL ANALYSIS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
NUMERICAL ANALYSIS DSE – 2	**4**	**2**	**0**	**2**	Class 12th Pass	NIL

LEARNING OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis enabling them to solve a wide range of physics problems. The skills developed during the course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Analyse a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as solution of non-linear algebraic and transcendental equations, system of linear equations, interpolation, least square fitting, numerical differentiation, numerical integration, eigen value problems and solution of initial value and boundary value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.
- In the laboratory course, the students will learn to implement these numerical methods in Python/C++/Scilab and develop codes to solve various physics problems and analyze the results.

SYLLABUS OF DSE – 2

THEORY COMPONENT