

Category II

Physical Science Courses with Physics discipline as one of the Core Disciplines

(B. Sc. Physical Science with Physics as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 3: HEAT AND THERMODYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
HEAT AND THERMODYNAMICS PHYSICS DSC – 3	4	2	0	2	Passed 12 th Class	NIL

LEARNING OBJECTIVES

This course will review the basic concepts of thermodynamics, kinetic theory of gases with a brief introduction to statistical mechanics. The primary goal is to make the student understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms and molecule through a brief knowledge of statistical mechanics. The lab course deals with providing the knowledge of the concepts of thermodynamics along with Planck's law and Stefan Boltzmann laws related to black body radiation.

LEARNING OUTCOMES

At the end of this course, students will be able to,

- gain an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations along with Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzmann distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- gain the basic knowledge about quantum statistics: the Bose-Einstein statistics and the Fermi-Dirac statistics.
- In the laboratory course, the students are expected to: Measure of Planck's constant using black body radiation, determine Stefan's Constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of

resistance, study variation of thermo-e.m.f. across two junctions of a thermocouple with temperature etc.

SYLLABUS OF PHYSICS DSC – 3

THEORY COMPONENT

Unit – I - Laws of Thermodynamics (10 Hours)

Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V , work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements, Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit – II - Thermodynamic Potentials and Maxwell's Relations (5 Hours)

Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of $C_P - C_V$, TdS Equations, Energy equations for ideal gases, evaluation of C_P/C_V

Unit – III - Kinetic Theory of Gases and Molecular Collisions (6 Hours)

Maxwell-Boltzmann Law of Distribution of Velocities in an ideal gas and its experimental verification, Mean, Root Mean Square and Most Probable Speeds, Mean Free Path (Zeroth order), Transport Phenomena in ideal gases: Viscosity, Thermal Conductivity and Diffusion (for vertical case)

Unit – IV - Theory of Radiation (5 Hours)

Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law

Unit – V - Statistical Mechanics (4 Hours)

Macrostate and Microstate, phase space, Entropy and thermodynamic probability, Maxwell-Boltzmann law, qualitative description of Quantum statistics – Bose Einstein and Fermi Dirac, comparison of three statistics.

References:

Essential Readings:

- 1) Heat and Thermodynamics: M. W. Zemansky and R. Dittman, Tata McGraw-Hill, 1981
- 2) Thermal Physics: S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, Tata McGraw-Hill.
- 3) Thermodynamics, Kinetic Theory and Statistical Thermodynamics: Sears and Salinger, Narosa, 1988
- 4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, Oxford University Press, 2009
- 5) Thermal Physics, A. Kumar and S. P. Taneja, R. Chand Publications, 2014
- 6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, S. Chand, 1981

Additional Readings:

- 1) An Introduction to Thermal Physics: D. Schroeder, Oxford University Press (earlier published by Pearsons), 2021
- 2) Thermal Physics: C. Kittel and H. Kroemer, 2nd Edition, W. H. Freeman, 1980
- 3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company

PRACTICAL COMPONENT**(15 Weeks with 4 hours of laboratory session per week)**

At least six experiments to be done from the following:

- 1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
- 2) To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
- 3) To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method using steam or electrical heating.
- 4) Measurement of Planck's constant using black body radiation.
- 5) To determine the temperature coefficient of resistance by Platinum Resistance Thermometer using Carey Foster's bridge.
- 6) To study the variation of thermo-e.m.f. across two junctions of a thermocouple with temperature.
- 7) To determine Stefan's Constant.
- 8) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge

References for laboratory work:

- 1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, Asia Publishing House, 1971
- 2) A Text Book of Practical Physics: Indu Prakash and Ramakrishna, 11th Edition, Kitab Mahal
- 3) Advanced level Practical Physics: Nelkon and Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- 4) An Advanced Course in Practical Physics: D. Chattopadhyay and P. C. Rakshit, 1990, New Central Book Agency.
- 5) Practical Physics: G. L. Squires, Cambridge University Press, 1985
- 6) B.Sc. Practical Physics: Harnam Singh, P. S. Hemne, revised edition 2011, S. Chand and Co.
- 7) B. Sc. Practical Physics: C. L. Arora, S. Chand and Co.
- 8) B. Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 13a: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Biophysics PHYSICS DSE 13a	4	3	0	1	Passed 12 th Class	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 PHYSICS DSE – 13a

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 (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
- 4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd 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 – PHYSICS DSE 13b: MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
MATHEMATICAL PHYSICS I PHYSICS DSE – 13b	4	3	1	0	Passed 12 th Class	NIL

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The mathematical tools might be building blocks to understand the fundamental computational physics skills and hence enable them to solve a wide range of physics problems. Overall, to help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers

LEARNING OUTCOMES

After completing this course, student will be able to,

- Learn the functions more than one variable using the concepts of calculus.
- Solve first order differential equations and apply it to physical problems.
- Represent a periodic function by a sum of harmonics using Fourier series.
- Obtain power series solution of differential equation of 2nd order with variable coefficients using Frobenius method.
- Learn beta and gamma functions

SYLLABUS OF PHYSICS DSE 13b

THEORY COMPONENT

Unit – I

(18 Hours)

Calculus of functions of more than one variable: Partial derivatives, chain rule for partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions. Application to Summing of Infinite Series.

Unit – II

(12 Hours)

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre Differential Equations and its solution. Properties of Legendre Polynomials: Rodrigues Formula, Orthogonality. Simple recurrence relations.

Unit – III

(15 Hours)

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions.

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular geometry. Solution of 1D wave equation.

References:

Essential Readings:

- 1) An introduction to ordinary differential equations, E.A. Coddington, PHI learning, 2009
- 2) Differential Equations, George F. Simmons, McGraw Hill, 2007
- 3) Mathematical methods for Scientists and Engineers, D. A. McQuarrie, Viva Book, 2003
- 4) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5th Edition, Jones and Bartlett Learning, 2012
- 5) Advanced Engineering Mathematics, Erwin Kreyszig, Wiley India, 2008
- 6) Fourier Analysis: With Applications to Boundary Value Problems, Murray Spiegel, McGraw Hill Education, 2017
- 7) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 7th Edition, Elsevier, 2013
- 8) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, Cambridge Univ. Press, 2011

Additional Readings:

- 1) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4th Edition, Cambridge University Press, 2017
- 2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, Narosa Publishing House, 2008
- 3) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5th Edition, Jones and Bartlett Learning, 2012
- 4) Mathematical Tools for Physics, James Nearing, Dover Publications, 2010
- 5) Mathematical Physics, A. K. Ghatak, I. C. Goyal and S. J. Chua, Laxmi Publications Private Limited, 2017