INDEX

DEPARTMENT OF PHYSICS

Semester-III

B. SC. (HONOURS) PHYSICS

DISCIPLINE SPECIFIC CORE COURSE – DSC - 7: MATHEMATICAL PHYSICS III

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Mathematical Physics III DSC – 7	4	3	0	1	Should have studied DSC - 1 and DSC - 4 of this program or its equivalent

LEARNING OBJECTIVES

The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during 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,

- Determine continuity, differentiability and analyticity of a complex function, find the derivative of a function and understand the properties of elementary complex functions.
- Work with multi-valued functions (logarithmic, complex power, inverse trigonometric function) and determine branches of these functions.
- Evaluate a contour integral using parameterization, fundamental theorem of calculus and Cauchy's integral formula.
- Find the Taylor series of a function and determine its radius of convergence.
- Determine the Laurent series expansion of a function in different regions, find the residues and use the residue theory to evaluate a contour integral and real integral.
- Understand the properties of Fourier transforms and use these to solve boundary value problems.
- Solve linear partial differential equations of second order with separation of variable method.
- In the laboratory course, the students will learn to,
    - create, visualize and use complex numbers
    - use Gauss quadrature methods to numerically integrate proper and improper definite integrals
    - Solve the boundary value problems numerically
    - Compute the fast Fourier transform of a given function

SYLLABUS OF DSC – 7

THEORY COMPONENT

Unit - I **(28 Hours)**

Complex Analysis: The field of complex numbers. Graphical, Cartesian and polar representation. Algebra in the complex plane. Triangle inequality. Roots of complex numbers. Regions in the complex plane – idea of open sets, closed sets, connected sets, bounded sets and domain.

(3 Hours)

The complex functions and mappings. Limits of complex functions. Extended complex plane and limits involving the point at infinity. Continuity and differentiability of a complex function, Cauchy-Riemann equations in Cartesian and polar coordinates, sufficient conditions for differentiability, harmonic functions. Analytic functions, singular points. Elementary functions. Multi-functions, branch cuts and branch points.

(10 Hours)

Integration in complex plane: contours and contour integrals, Cauchy-Goursat Theorem (No proof) for simply and multiply connected domains. Cauchy's inequality. Cauchy's integral formula. Taylor's and Laurent's theorems (statements only), types of singularities (removable poles and essential), meromorphic functions, residues and Cauchy's residue theorem, Jordan Lemma (statement only), evaluation of real integrals by contour integration (excluding integrands with branch points)

(15 Hours)

Unit – II **(9 Hours)**

Fourier Transform: Fourier Integral theorem (Statement only), Fourier Transform (FT) and Inverse FT, existence of FT, FT of single pulse, finite sine train, trigonometric, exponential, Gaussian functions, properties of FT, FT of Dirac delta function, sine and cosine function, convolution theorem. Fourier Sine Transform (FST) and Fourier Cosine Transform (FCT)

Unit – III **(8 Hours)**

Partial Differential Equations: Solutions to partial differential equations (2 or 3 independent variables) using separation of variables: Laplace's equation in problems of rectangular geometry. Solution of wave equation for vibrational modes of a stretched string. Solution of 1D heat flow equation (Wave/Heat equation not to be derived)

References:

Essential Readings:

1) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
2) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge Univ. Press.
3) Mathematical Methods for Physicists, G. B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.
4) Complex Variables and Applications, J. W. Brown and R. V. Churchill, 9th Ed. 2021, Tata McGraw-Hill.
5) Complex Variables: Schaum's Outline, McGraw Hill Education (2009).
6) Fourier analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
7) Fourier series and boundary value problems, J. W. Brown and R. V. Churchill, 5th edition,

Tata McGraw-Hill, 1993.
8) Applied Mathematics for Engineers and Physicists, 3rd edition, L. A. Pipes and L. R. Harvill, Dover Publications.

Additional Readings:

1) Mathematical Physics with Applications, Problems and Solutions, V. Balakrishnan, Ane Books (2017).
2) Complex Variables, A. S. Fokas and M. J. Ablowitz, 8th Ed., 2011, Cambridge Univ. Press.
3) Fourier Transform and its Applications, third edition, Ronald New Bold Bracewell, McGraw Hill (2000).
4) A Students Guide to Fourier Transforms: With Applications in Physics and Engineering, 3rd edition, Cambridge University Press (2015).
5) Partial Differential Equations for Scientists and Engineers, S. J. Farlow, Dover Publications (1993).
6) Differential Equations – Theory, Technique and practice, George F. Simmons and Steven G. Krantz, Indian Edition McGraw Hill Education Pvt. Ltd (2014).

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)
The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory.
- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. More programs may be done in the class with physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve it by computational methods.
- At least 6 programs must be attempted (taking at least one from each unit). The implementation can be either in Python/ C++/ Scilab. Inbuilt libraries can be used wherever applicable.

Unit 1
Handling of Complex Numbers: Syntax for creating complex numbers in Python/C++/Scilab, accessing real and imaginary parts, calculating the modulus and conjugate of a complex number, complex number arithmetic, plotting of complex numbers as ordered pairs of real numbers in a plane, conversion from Cartesian to polar representation.
Recommended List of Programs:

a) Determine the nth roots of a complex number and represent it in Cartesian and polar form.
b) Transformation of complex numbers as 2-D vectors e.g. translation, scaling, rotation, reflection.
c) Visualisation of mappings of some elementary complex functions w = f(z) from z-plane to w-plane.

Unit 2
Gauss Quadrature Integration Methods: Gauss quadrature methods for integration: Gauss Legendre, Gauss Lagaurre and Gauss Hermite methods.
Recommended List of Programs:

a) Solving a definite integral by Gauss Legendre quadrature method. Application – representation of a function as a linear combination of Legendre polynomials.
b) Solving improper integrals over entire real axis or the positive real axis using Gauss Lagaurre and Gauss Hermite quadrature method. Comparison of results with the ones obtained by contour integration analytically.
c) Comparison of convergence of improper integral computed by Newton Cotes and Gauss Quadrature Methods.

Unit 3

Fast Fourier Transform: Discrete Fourier transform, Any algorithm for fast Fourier transform.
a) Computation of Discrete Fourier Transform (DFT) using complex numbers.
b) Fast Fourier Transform of given function in tabulated or mathematical form e.g function $\exp(-x^2)$.

Unit 4

Numerical Solutions of Boundary Value Problems: Two-point boundary value problems, types of boundary conditions – (Dirichlet, Neumann and Robin), importance of converting a physics problem to dimensionless form before solving numerically. Finite difference method, Shooting method with bisection/Secant/Newton method for solving non-linear equation and using RK methods for solving IVP (The programs developed in the last semester may be used here).
Algorithm for any one numerical method to solve Partial Differential Equations e.g. Finite Difference method, relaxation methods, Crank-Nicolson method
Recommended List of Programs:
(a) The equilibrium temperature of a bar of length L with insulated horizontal sides and the ends maintained at fixed temperatures.
(b) Solve for the steady state concentration profile y(x) in the reaction-diffusion problem given by $y''(x) - y(x) = 0$ with $y(0) = 1, y'(1) = 0$.
(c) Use any numerical method to solve Laplace equation/ wave equation/ Heat Equation.

References (for Laboratory Work):

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Schaum's Outline of Programming with C++', J. Hubbard, 2000, McGraw-Hill Education.
4) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
5) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
6) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
7) Computational Problems for Physics, R. H. Landau and M. J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – DSC - 8: THERMAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Thermal Physics DSC – 8	4	3	0	1	--

LEARNING OBJECTIVES

This course deals with the relationship between the macroscopic and microscopic properties of physical systems in equilibrium. It reviews the concepts of thermodynamics learnt at school from a more advanced perspective and how to develop them further to build new concepts. The course gives an understanding about the fundamental laws of thermodynamics and their applications to various systems and processes. It also includes a basic idea about the kinetic theory of gases, transport phenomena involved in ideal gases, phase transitions and behaviour of real gases. The students will be able to apply these concepts to several problems on heat. The lab course deals with providing the knowledge of the concepts of thermodynamics studied in the theory paper with the help of experiments and give the students a hands-on experience on the construction and use of specific measurement instruments and experimental apparatuses used in the Thermal Physics lab, including necessary precautions.

LEARNING OUTCOMES

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

- Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics.
- Understand the concept of reversibility, irreversibility and entropy.
- Understand various thermodynamic potentials and their physical significance with respect to different thermodynamic systems and processes.
- Deduce Maxwell's thermodynamical relations and use them for solving various problems in Thermodynamics.
- Understand the concept and behaviour of ideal and real gases.
- Apply the basic concept of kinetic theory of gases in deriving Maxwell-Boltzman distribution law and its applications.
- Understand mean free path and molecular collisions in viscosity, thermal conductivity, diffusion and Brownian motion.
- While doing the practical, the students will have an opportunity to understand and hence use the specific apparatus required to study various concepts of thermodynamics. Hence, the student will be able to comprehend the errors they can encounter while performing the experiment and how to estimate them.

SYLLABUS OF DSC - 8

THEORY COMPONENT

Unit – I - Zeroth and First Law of Thermodynamics (6 Hours)

Fundamental idea of thermodynamic equilibrium and Zeroth Law of Thermodynamics, concept of work and heat, First law of Thermodynamics and its differential form, internal energy, applications of First law: General relation between C_P and C_v, work done during various processes (all four) and related problems, adiabatic lapse rate, Compressibility and Expansion Co-efficient for various processes.

Unit – II - Second law of Thermodynamics (6 Hours)

Reversible and Irreversible processes, Carnot engine and Carnot's cycle, Refrigerator, efficiency of Carnot engine and refrigerator, Second Law of Thermodynamics: Kelvin-Planck and Clausius statements and their equivalence, Carnot's theorem, Applications of Second Law of Thermodynamics in the light of Phase Change, Thermodynamic Scale of Temperature and its equivalence to Perfect Gas Scale.

Unit – III – Entropy (6 Hours)

Concept of Entropy, Entropy changes in Reversible and Irreversible processes with examples, Clausius Theorem, Clausius inequality, Second Law of Thermodynamics in terms of Entropy. Temperature-Entropy diagrams for Carnot's cycle and related problems, Entropy of perfect and real gases, conceptual problems related to Entropy during a Phase Change, Nernst Heat Theorem: Unattainability of Absolute Zero and Third Law of Thermodynamics.

Unit – IV - Thermodynamic Potentials and Maxwell's Relations (12 Hours)

Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, Magnetic work and basic idea about cooling due to adiabatic demagnetization, Phase Transitions : First order and Second order Phase Transitions with examples, Clausius Clapeyron Equation, Ehrenfest Equations, Derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of C_P – C_v, TdS equations, Energy equations, evaluation of C_P /C_v and Ratio of Adiabatic to Isothermal elasticity.

Unit – V - Kinetic Theory of Gases and Molecular Collisions (8 Hours)

Constrained maximization using Lagrange multipliers, Maxwell-Boltzmann law of distribution of velocities in an ideal gas and its experimental verification with any one method. Mean, Root Mean Square and Most Probable Speeds, Maxwell-Boltzmann equation for distribution of Energy: Average Energy and Most Probable Energy, Mean Free Path, Collision Probability, estimation of Mean Free Path, transport phenomena in ideal gases: viscosity, thermal conductivity and diffusion with continuity equation

Unit – VI - Real Gases (7 Hours)

Behaviour of Real Gases: Deviations from the ideal gas equation, Andrew's experiments on CO_2 Gas, Virial equation, Continuity of liquid and gaseous states, Boyle temperature, Van der Waals equation of state for real gases (derivation not required), comparison with experimental curves: P-V diagrams, value of critical constants, law of corresponding states, free adiabatic expansion of a perfect gas, Joule Thomson Porous - Plug Experiment, Joule Thomson Coefficient for Ideal and Van der Waals Gases, Temperature of Inversion and Joule Thomson cooling.

References:

Essential Readings:

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

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons).
2) Thermal Physics: C. Kittel and H. Kroemer, 1980, 2nd Edition, W.H. Freeman
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company
4) Thermal Physics :concepts and practices, 2012, A. L. Wasserman, Cambridge University Press
5) Fundamentals of Thermal and Statistical Physics, 1965, Frederick Reif, McGraw-Hill.

PRACTICAL COMPONENT

(15 Weeks with 2 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) To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using Carey Foster’s Bridge.
5) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge.
6) To study the variation of thermo-emf of a thermocouple with difference of temperature of its two junctions using a null method.
7) To calibrate a thermocouple to measure temperature in a specified range by direct method and/or by using Op Amp and to determine Neutral Temperature.
8) To determine the coefficient of thermal conductivity of Copper (Cu) by Angstrom’s method.

References (for Laboratory Work):

1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics : Indu Prakash and Ramakrishna, 11th Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4th Ed, 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 , 1985, Cambridge University Press.
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, 2001, S. Chand and Co.
8) B.Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – DSC - 9: LIGHT AND MATTER

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Light and Matter DSC – 9	4	2	0	2	--

LEARNING OBJECTIVES

The objective of this course reviews the concepts of light and matter, their properties and their dual nature. This course provides an in depth understanding of dual nature of light, interference and diffraction with emphasis on practical applications of both. It prepares the student for the modern physics and quantum mechanics courses.

LEARNING OUTCOMES

On successfully completing the requirement of this course the student will have the skill and knowledge to,

- Appreciate the dual nature of light which is part of the electromagnetic spectrum and the dual nature of matter simultaneously.
- Understand the phenomena of interference and diffraction exhibited by light and matter, their nuances and details.
- Delve in to the depth of understanding wave optics with its various kinds of interference and diffraction exhibited by light.

- Demonstrate basic concepts of diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhofer and Fresnel diffraction.
- Learn about the application of matter waves in latest technological developments of electron microscope e.g. SEM and TEM used widely for characterization in several fields of physics such as material science, nanotechnology etc.
- In the laboratory course, students will gain hands-on experience of using various optical instruments, measurement of resolving power and dispersive power, and making finer measurements of wavelength of light using Newton's rings experiment. They will also find wavelength of Laser sources by single and double slit experiment, wavelength and angular spread of He-Ne Laser using plane diffraction grating.

SYLLABUS OF DSC - 9

THEORY COMPONENT

Unit – I - Duality of Light and matter (5 Hours)

Light an EM wave - Hertz's experiments; Particle characteristics by photoelectric effect and Compton effect (concepts only) and wave characteristics by interference and diffraction.
Wave properties of particles: de Broglie hypothesis, wavelength of matter waves; particle wave complementarity: Velocity of de Broglie wave and need of a wave packet; Group and phase velocities and relation between them; equivalence of group and particle velocity, dispersion of wave groups.

Unit – II – Interference (10 Hours)

Division of amplitude and wave-front. Two-slit interference experiment with photons: Young's double slit experiment. Lloyd's mirror. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringe). Newton's Rings: Measurement of wavelength and refractive index. Single photon interference. Two-slit interference experiment with electrons.

Unit – III – Diffraction (15 Hours)

Fraunhofer diffraction: Single slit, double slit, diffraction grating, resolving power of grating.
Fresnel diffraction: Fresnel's assumptions, Fresnel's half-period zones for plane wave, explanation of rectilinear propagation of light, theory of a zone plate: multiple foci of a zone plate, Fresnel diffraction at straight edge, a slit and a wire by Fresnel half period zones.
Diffraction of photons (e.g. X-rays, gamma rays etc.) and particles by matter, experimental study of matter waves: Davisson-Germer experiment; Electron microscope: applications SEM, TEM.

References:

Essential Readings:

1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2) Modern Physics by R. A. Serway, C. J. Moses and C. A. Moyer, Thomson Brooks Cole, 2012.
3) Modern Physics for Scientists and Engineers by S. T. Thornton and A. Rex, 4th Edn., Cengage Learning, 2013.
4) Optics, Ajoy Ghatak, McGraw-Hill Education, New Delhi, 7th Edn.
5) Fundamentals of Optics, F. A. Jenkins and H. E. White, 1981, McGraw-Hill.

6) Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.
7) A Textbook of Optics N. Subrahmanyam, Brij Lal, M. N. Avadhanulu, S. Chand & Co Ltd.
8) Introduction to Optics I - Interaction of Light with Matter, Ksenia Dolgaleva, (2021), Morgan and Claypool.
9) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.
10) Modern Physics, G. Kaur and G. R. Pickrell, 2014, McGraw Hill.
11) Schaum's Outline of Beginning Physics II | Waves, electromagnetism, Optics and Modern Physics, Alvin Halpern, Erich Erlbach, McGraw Hill.
12) Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edn., Tata McGraw-Hill Publishing Co. Ltd.

Additional Readings:

1) Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
2) Introduction to Optics, Pedrotti Frank L. Cambridge University Press.
3) Optics, Eugene Hecht, 4th Edn., 2014, Pearson Education.
4) Six Ideas that Shaped Physics: Particle Behave like Waves, T. A. Moore, 2003, McGraw Hill.
5) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
6) Quantum Mechanics: Theory and Applications, (2019), (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi
7) Optics, Karl Dieter Moller, Learning by computing with model examples, 2007, Springer.
8) Modern Physics for Scientists and Engineers, J. R. Taylor, C. D. Zafiratos, M. A. Dubson, (2017), Viva Books Pvt Ltd.
9) Physics of Atom, Wehr, Richards and Adair, (2002) Narosa.

PRACTICAL COMPONENT

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

Mandatory activity:

- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Applications of the specific experiments done in the lab.
- Familiarization with Schuster's focusing; determination of angle of prism.

At least 6 experiments from the following list.

1) Determination of refractive index of material of prism using mercury (Hg) light.
2) To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
3) To determine wavelength of sodium light using Newton's Rings.
4) To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
5) To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
6) To determine dispersive power of a plane diffraction grating using mercury lamp.
7) To determine resolving power of a plane diffraction grating using sodium lamp.

8) To determine the wavelength of laser source using diffraction of single slit.
9) To determine the wavelength of laser source using diffraction of double slit.
10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed., 2011, Kitab Mahal.
3) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edn., reprinted 1985, Heinemann Educational Publishers.
4) A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
5) B.Sc. Practical Physics, Geeta Sanon, R.Chand & Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 1: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics DSE – 1	**4**	**4**	**0**	**0**	--

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.

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 **(16 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, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**
Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**
The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. 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 **(8 Hours)**
Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

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).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 2: NUMERICAL ANALYSIS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
NUMERICAL ANALYSIS DSE – 2	4	2	0	2	--

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

Unit – I **(3 Hours)**

Approximation and Errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem. Floating Point Computation, overflow and underflow. Single and double precision arithmetic. Rounding and truncation error, absolute and relative error, error propagation.

Unit – II **(8 Hours)**

Linear Systems: Solution of linear systems by Gaussian elimination method, partial and complete pivoting, LU decomposition, norms and errors, condition numbers, Gauss-Seidel method, diagonally dominant matrix and convergence of iteration methods. Solution of

Tridiagonal systems; Eigenvalue Problem: Power method, inverse power method.

Unit – III **(5 Hours)**

Interpolation: Lagrange and Newton's methods (divided difference) for polynomial interpolation, theoretical error of interpolation. Inverse Interpolation. Optimal points for interpolation and Chebyshev Polynomials. Minimax Theorem (Statement only)

Unit – IV **(7 Hours)**

Numerical Integration: Newton Cotes quadrature methods. Derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial. Error and degree of precision of a quadrature formula. Composite formulae for Trapezoidal and Simpson methods. Gauss Quadrature methods. Legendre, Lagaurre and Hermite quadrature methods.

Unit – V **(7 Hours)**

Initial and Boundary Value Problems: Solution of initial value problems by Euler, modified Euler and Runge Kutta (RK) methods. Local and global errors, comparison of errors in the Euler and RK methods.

Finite difference and shooting method for solving two-point linear boundary value problems.

References:

Essential Readings:

1) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
2) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
3) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

Additional Readings:

1) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
2) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenger, New Age Publishers (2012).

PRACTICAL COMPONENT

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

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. Assessment is to be done not only on the programming but also on the basis of formulating the problem. The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods. The students should be encouraged to develop and present an independent project. At least 10 programs must be attempted (taking at least two from each unit).The implementation can be either in Python/ C++/Scilab.

Unit 1 - Linear Systems:

a) Solve a system of linear equations using Gauss Elimination method with pivoting (application to electric networks).
b) Solve a system of linear equations using Gauss-Seidel method and study the convergence (application to spring mass system).
c) Determine the inverse of a square matrix using Gauss-Jordan method.
d) Solve a tri-diagonal system of linear equations.
e) Study an example of ill-conditioned systematic
f) Find the LU equivalent of a matrix.
g) Determine the largest and smallest eigenvalues using Power and inverse power methods. Consider a case where power method fails.

Unit 2 - Interpolation:

a) Given a dataset (x, y) with equidistant x values, prepare the Newton's forward difference, backward difference and divided difference tables.
b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x-values.
c) Given a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.
e) Compare the interpolating polynomial approximating a given function in a given range obtained with uniformly spaced points and by Chebyshev points.
f) Compare the Chebyshev and Maclaurin series expansions of an exponential or sinusoidal function.

Unit 3 - Integration:

a) Use integral definition of error function to compute and plot erf(x) in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for small and large values of x.
b) Use the definition of erf(x) and numerically take the limit x going to infinity to get the value of Gaussian integral using Simpson method. Compare the result with the value obtained by Gauss Hermite and Gauss Lagaurre methods.
c) Verify the degree of precision of each quadrature rule.
d) Use Simpson methods to compute a double integral over a rectangular region.
e) Approximate the value of π by evaluating the integral $\int_0^\infty \frac{1}{x^2+1} dx$using Simpson, Gauss Hermite and Gauss Lagaurre methods.

Unit 4 - Initial Value Problems (IVP):

a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors takes over.
b) Solve a system of n first order differential equations by Euler and RK methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
c) Solve a physics problem like free fall with air drag or parachte problem using RK method.
d) Solve a compound spring system (3 springs) by solving a system of differential equations using Euler and RK for a given set of initial conditions.
e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

Unit 5 - Boundary value problems (BVP):

a) Solve a linear BVP using shooting and finite difference method and compare the results.
b) Solve a non-linear BVP using the finite differnce and shooting method and compare the results.
c) Determine the temperature distribution along a rod made of two dissimilar materials (of different thermal conductivities) welded together when temperatures at two ends are maintained at given temperatures.
d) Design a physics problem that can be modelled by a BVP and solve it by any method.

References for laboratory work

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
5) Computational Problems for Physics, R.H. Landau and M.J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

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

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

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
HEAT AND THERMODYNAMICS PHYSICS DSC – 3	4	2	0	2	--

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-emf 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, 1981, Tata McGraw-Hill.
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, 1988, Narosa.
4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, 2009, Oxford University Press.
5) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, 1981, S. Chand.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons)
2) Thermal Physics: C. Kittel and H. Kroemer, 1980, 2^{nd} Edition, W.H. Freeman
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 thermos-emf 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, 1971, Asia Publishing House.
2) A Text Book of Practical Physics: Indu Prakash and Ramakrishna, 11^{th} Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4^{th} Ed, 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, 1985, Cambridge University Press.
6) B.Sc. Practical Physics: Harnam Singh, Dr P. S. Hemne, revised edition 2011, S. Chand and Co.
7) B. Sc. Practical Physics: C. L. Arora, 2001, S. Chand and Co.
8) B. Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 13a: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics PHYSICS DSE 13a	4	4	0	0	--

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.

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 **(16 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, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**

Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**

The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. 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 **(8 Hours)**

Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

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).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 13b: MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
MATHEMATICAL PHYSICS I PHYSICS DSE – 13b	**4**	**4**	**0**	**0**	--

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 2^{nd} order with variable coefficients using Frobenius mehod.
- Learn beta and gamma functions.
- Learn complex analysis.

SYLLABUS OF PHYSICS DSE 13b

THEORY COMPONENT

Unit – I **(16 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 **(10 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 **(14 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

Unit – IV **(20 Hours)**

Complex Analysis: Introduction to complex variables, Functions of Complex variable, limit, continuity, Analytic functions, Cauchy-Riemann equations, singular points, Cauchy Integral Theorem, Cauchy's Integral Formula, Residues, Cauchy's residue theorem, application of contour integration in solving real integrals.

References:

Essential Readings:

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

Additional Readings:

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

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Physical Science Courses (with Electronics) with Physics and Electronics discipline as Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 5: HEAT AND THERMODYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
HEAT AND THERMODYNAMICS PHYSICS DSC 5	4	2	0	2	--

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-Boltzman 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-emf across two junctions of a thermocouple with temperature etc.

SYLLABUS OF PHYSICS DSC – 5

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, 1981, Tata McGraw-Hill.
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, 1988, Narosa.
4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, 2009, Oxford University Press.
5) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, 1981, S. Chand.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons)
2) Thermal Physics: C. Kittel and H. Kroemer, 1980, 2nd Edition, W.H. Freeman
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 thermos-emf 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, 1971, Asia Publishing House.
2) A Text Book of Practical Physics: Indu Prakash and Ramakrishna, 11th Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4th Ed, 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, 1985, Cambridge University Press.
6) B.Sc. Practical Physics: Harnam Singh, Dr P. S. Hemne, revised edition 2011, S. Chand and Co.
7) B. Sc. Practical Physics: C. L. Arora, 2001, S. Chand and Co.
8) B. Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 6: COMMUNICATION ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
COMMUNICATION ELECTRONICS PHYSICS DSC – 6	**4**	**2**	**0**	**2**	--

LEARNING OBJECTIVES

This paper aims to describe the concepts of electronics in communication. Communication techniques based on analog modulation, analog and digital pulse modulation including PAM, PWM, PPM, ASK, PSK, FSK are described in detail. Communication and Navigation systems such as GPS, satellite and mobile telephony systems are introduced.

LEARNING OUTCOMES

At the end of this course, students will be able to develop following learning outcomes:

- This paper aims to describe the concepts of electronics in communication. In this course, students will receive an introduction to the principle, performance and applications of communication systems.
- Students will learn the various means and modes of communication. They will gain an understanding of fundamentals of electronic communication system and electromagnetic communication spectrum with an idea of frequency allocation for radio communication system in India.
- They will gain an insight on the use of different modulation and demodulation techniques used in analog communication
- Students will be able to analyse different parameters of analog communication techniques.
- They will learn the need of sampling and different sampling techniques where they can sample analog signal.
- Students will learn the generation and detection of a signal through pulse and digital modulation techniques and multiplexing.
- They will gain an in-depth understanding of different concepts used in a satellite communication system.
- This paper will essentially connect the text book knowledge with the most popular communication technology in real world.

SYLLABUS OF PHYSICS DSC 6

THEORY COMPONENT

Unit – I **(10 Hours)**

Electronic communication: Introduction to communication – means and modes. Power measurements (units of power). Need for modulation. Block diagram of an electronic communication system. Brief idea of frequency allocation for radio communication system in India (TRAI). Electromagnetic communication spectrum, band designations and usage. Channels and base-band signals.

Analog Modulation: Amplitude Modulation: Frequency spectrum of AM waves, average power, average voltage, modulation index, AM-modulator circuits (collector modulation), AM-demodulator (diode detector), single side band generation and detection.

Angle Modulation: Frequency and phase modulation, frequency spectrum of FM waves, intersystem comparisons (FM and AM), FM generation using VCO, FM detector (slope detector)

Unit – II **(5 Hours)**

Analog Pulse Modulation: Channel capacity, Sampling Theorem and Nyquist Criterion, Basic Principles – Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), Pulse Position Modulation (PPM), modulation and detection technique for PAM only, Multiplexing – Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM).

Unit – III **(6 Hours)**

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation (PCM), Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK)

Unit – IV **(6 Hours)**

Satellite Communication: Introduction, Geosynchronous satellite orbits, geostationary satellite advantages of geostationary satellites. Transponders (C - Band), Uplink and downlink, path loss, Satellite visibility, Ground and earth stations. Simplified block diagram of the earth station.

Unit – V **(3 Hours)**

Mobile Telephony System: Basic concept of mobile communication, frequency bands used in mobile communication, the concept of cell sectoring and cell splitting, SIM number, IMEI number, GPS navigation system (qualitative idea only).

References:

Essential Readings:

1) Communication Electronics, Principles and Applications, L. E. Frenzel, Tata McGraw-Hill.
2) Communication Systems: Analog and Digital, R. P. Singh and S. D Sapre, Tata McGraw-Hill.
3) Analog and Digital Communications, H. Hsu, Schaum's Outline Series, Tata McGraw-Hill.
4) Electronic Communications Systems: Fundamentals Through Advanced, Wayne Tomasi, Fifth Edition, Pearson.
5) Communication Systems, S. Haykin, Wiley India

Additional Readings:

1) Electronic Communication, L. Temes and M. Schultz, Schaum's Outline Series, Tata McGraw- Hill.
2) Electronic Communication Systems, G. Kennedy and B. Davis, Tata McGraw-Hill
3) Analog and Digital Communication Systems, M.J. Roden, Prentice Hall of India.

PRACTICAL COMPONENT

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

Every student must perform at least 06 experiments.

1) To study AM – Generation and Detection circuit
2) To study FM – Generation and Detection circuit
3) To study Time Division Multiplexing (TDM)
4) To study Pulse Amplitude Modulation (PAM)
5) To study Pulse Width Modulation (PWM)
6) To study Pulse Position Modulation (PPM)
7) To study Amplitude Shift Keying (ASK)
8) To study Frequency Shift Keying (FSK)
9) To study Phase Shift Keying (PSK)

References (for Laboratory Work):

1) Introduction to Analog and Digital Communication – by M. A. Bhagyaveni, R. Kalidoss and K. S. Vishvaksenan, River Publishers Series in Communications
2) Communication Systems – by Michael Moher Simon Haykin, Wiley
3) Wireless Communication – by Goldsmith Andrea, Cambridge University Press
4) Digital Communications: Fundamentals & Applications – Bernard Sklar and Pabitra Kumar Ray, Pearson Education India

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 1: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics PHYSICS DSE 1	4	4	0	0	--

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.

SYLLABUS OF PHYSICS 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 **(16 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, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**
Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**
The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. 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 **(8 Hours)**
Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

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).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 2: MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
MATHEMATICAL PHYSICS I Physics DSE 2	**4**	**4**	**0**	**0**	--

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 2^{nd} order with variable coefficients using Frobenius mehod.
- Learn beta and gamma functions.
- Learn complex analysis.

SYLLABUS OF PHYSICS DSE 2

THEORY COMPONENT

Unit – I **(16 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 **(10 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 **(14 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

Unit – IV **(20 Hours)**

Complex Analysis: Introduction to complex variables, Functions of Complex variable, limit, continuity, Analytic functions, Cauchy-Riemann equations, singular points, Cauchy Integral Theorem, Cauchy's Integral Formula, Residues, Cauchy's residue theorem, application of contour integration in solving real integrals.

References:

Essential Readings:

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

Additional Readings:

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

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

GENERIC ELECTIVE (GE – 4): INTRODUCTION TO ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
INTRODUCTION TO ELECTRONICS GE – 4	4	2	0	2	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This paper aims to introduce fundamentals of electronics to students not majoring in physics. Basics of Analog and Digital Electronics are envisioned to be introduced with emphasis on applications of diodes, transistor (BJT), operational amplifier, 555 timer, number systems, basic gates and digital circuits.

LEARNING OUTCOMES

At the end of this course, students will be able to imbibe the following learning outcomes:

- This paper aims to describe the concepts of basic electronics in real-life. In this course, students will receive an introduction to the principle, performance and applications of basic electronic components.
- The students will gain an insight on the existence of analog and digital signals and their necessity. Specifically they would know the difference between active and passive electronic components including filters.
- Students will learn about diodes and its uses in rectification (analog) and switching properties thereof (digital). They will gain an insight into working principle of Photodiodes, Solar Cells, LED and Zener Diode as Voltage Regulator.
- They will gain an understanding of construction and working principle of bipolar junction transistors (BJTs). Specifically, they would understand the fundamentals of amplification.
- Students will be able to seamlessly understand and work on different numbers systems including binary, octal, hexadecimal besides decimal.
- They will learn about the existence of digital gates besides their need in electronic decision making thus laying the foundation for basic artificial intelligence.
- Students will learn the fundamentals of operation amplifier and their regular application including those used to sum, subtract and compare two or more signals.
- They will gain an in-depth understanding of working of Cathode Ray Oscilloscope which effectively acts as an electronic stethoscope for analysis of electronic signal in any laboratory.
- This paper will essentially connect the text book knowledge with the most common electronic components available that influence design of technology in a real world.
- The project component included in the practical section is envisaged to impart much needed

hands-on skill sets to the student. Therein he/she gets an experience in correctly choosing components required to build an electronic circuit, identifying the procurement source (online/offline) besides gaining valuable experience in trouble-shooting

SYLLABUS OF GE - 4

THEORY COMPONENT

Unit – I **(4 Hours)**

Analog and digital signals, Active and passive electronic components, RC integrator and differentiator (use as low pass and high pass filter): Qualitative analysis and frequency response.

Unit – II **(6 Hours)**

I-V characteristics of a diode and it's applications as rectifier (Half and full wave rectifier configurations), Clipper and Clamper circuits (Qualitative Analysis only). Principle and working of Photodiodes, Solar Cells, LED and Zener Diode as Voltage Regulator.

Unit – III **(4 Hours)**

Input and output characteristics of a bipolar junction transistor (BJT) in CB and CE configurations, identifying active, cut-off and saturation regions. Transistor parameters alpha and beta, and relation between them. Application of BJT as a switch and an amplifier in CE configuration (Graphical Analysis)

Unit – IV **(6 Hours)**

Review of basic and Universal Logic Gates, Binary to decimal and Decimal to binary conversion, binary addition and subtraction using 2's complement, Half and Full Adder, Half and Full Subtractor using NAND Gates.

Unit – V **(6 Hours)**

Operational Amplifier (Black Box Approach): Pinout diagram of IC 741; Characteristics of Op-amp (Voltage Gain, offset voltage, slew rate, CMRR, Bandwidth, Input Impedance and Output Impedance). Open loop configuration and its application as a comparator and zero crossing detector. Closed Loop Configuration and its Applications as Inverting and Non-inverting Amplifier (Voltage gain using concept of virtual ground), Summing Amplifier and Subtractor

Unit – VI **(4 Hours)**

Block diagram of CRO, Voltage and frequency measurement. Pinout diagram of IC 555 and its application as Astable Multivibrator.

References:

Essential Readings:

1) Electronic Devices, Thomas L Floyd; Pearsons Education
2) Op Amps and Linear Integrated Circuits, Ramakant A Gaekwad, Pearson Education
3) Microelectronic circuits, A. S. Sedra, K. C. Smith, A.N. Chandorkar, Oxford University Press.
4) Electronic Principles, A. Malvino, D. J. Bates, 7th Edition, 2018, Tata Mc-Graw Hill Education.

5) Electronic Devices and circuit theory, R. L. Boylestad & L. D. Nashelsky, Pearson Learning
6) Digital Principles and Applications, Donald P Leach, Albert Paul Malvino and Goutam Saha, Pearson Education, Tata Mc-Graw Hill.

Additional Readings:

1) Electronic Fundamental and Applications, John D Ryder; PHI Learning
2) Electronic Devices and Circuits, J. Millman and C. C. Halkias, Tata Mc-Graw Hill.

PRACTICAL COMPONENT

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

Every student must perform either "04 Experiments and 01 Project" or "At least six experiments"

1) Voltage and frequency measurement using CRO
2) Study of RC circuits as an Integrator and Differentiator
3) IV characteristics for pn junction diode and Zener diode
4) Study of Zener diode as voltage regulator circuit
5) Study of transistor characteristics in CE configuration
6) Half Adder and Full Adder using NAND gates
7) Half Subtractor and Full Subtractor using NAND gates
8) Design Astable Multivibrator using IC 555
9) Study the Frequency Response of Op Amp in Inverting and Non Inverting configurations.
10) Study of zero crossing detector using Op amp IC 741
11) Addition of two dc voltages using OP Amp in inverting and non-inverting configurations.

References (for Laboratory Work):

1) An Analog Electronics Companion: Basic Circuit Design for Engineers and Scientists – by Scott Hamilton, Cambridge University Press
2) Practical Electronics – by Ralph Morrison, Wiley
3) Practical Electronic Design for Experimenters (ELECTRONICS) – by Louis E. Frenzel, McGraw Hill Education
4) Practical Electronics for Inventors – by Paul Scherz and Simon Monk, McGraw Hill
5) Analog Electronics with Op-amps: A Source Book of Practical Circuits (Electronics Texts for Engineers and Scientists) – by Anthony Peyton and Vincent Walsh, Cambridge University Press

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 5): SOLID STATE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
SOLID STATE PHYSICS GE – 5	4	3	1	0	Knowledge of basic physics	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon its atomic and molecular constituents. It also communicates the importance of solid state physics in modern society. Emphasis should be given on the applications and uses of solids.

LEARNING OUTCOMES

On successful completion of the module students should be able to,

- Elucidate the concept of lattice, basis and symmetry in crystals. Learn to appreciate structure and symmetry of solids.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids: origin of energy bands.
- Introduction to dia-, para-, ferri and ferro-magnetic properties of solids and their applications.
- Introduction to dielectric properties exhibited by solids and the concept of polarizability.
- Introduction to superconductivity.

SYLLABUS OF GE - 5

THEORY COMPONENT

UNIT – I **(21 Hours)**

Review of Atomic Structure and bonding in solids: Classification of matter as solid, liquid and gas: salient features and properties, Qualitative discussion on Rutherford Model and Bohr model of atom, qualitative idea about discrete energy levels, wave-mechanical concept of the atom, forces between atoms, Ionic bonding, covalent bonding, metallic bonding, Hydrogen bonding and Van der Waals bonding, Properties of solids exhibiting different bonding.

Crystal structure: Periodicity in crystals: lattice points and space lattice, translational, rotational and reflection symmetry elements, lattice with a basis and crystal structure, unit cells and lattice parameters, Bravais lattices (in 2D and 3D) and crystal systems SC, BCC and FCC lattices, conventional and primitive unit cell, Wigner Seitz unit cell, amorphous and crystalline materials. Planes, Miller Indices, directions, density of atoms in different planes, interplanar spacing, concept of Reciprocal Lattice, Brillouin Zones (2 D lattice).

Atomic Packing and Imperfections in crystals: Packing of spheres in 2D and 3D, hexagonal

close packing, packing fraction of SC, FCC, and BCC. Point defects and line defects and their consequences on the crystal properties
X-rays: Their generation and properties, Bragg's law and Laue Condition, single crystal method and powder diffraction method, simple problems related to X-Ray diffraction in SC, BCC, FCC.

UNIT – II **(4 Hours)**
Elementary Lattice Dynamics: Lattice vibrations and phonons: linear monoatomic and diatomic chains, acoustic and optical phonons, qualitative description of the phonon spectrum in solids.

UNIT – III **(10 Hours)**
Electrical properties of metals: Free electron theory of metals (Drude model), its success and drawbacks, concept of relaxation time, collision time and mean free path, electrical conductivity, mobility and Ohm's law, thermal conductivity of metals, Wiedemann-Franz-Lorentz law.
Band Theory: The Kronig-Penney model (Qualitative idea), Band Gap, direct and indirect bandgap, concept of effective mass, Hall Effect (Metal and Semiconductor).
Optical properties of solids: (Qualitative) Absorption process, transmission and reflectance in solids. Discussion on photoconductivity, photoluminescence.

UNIT – IV **(3 Hours)**
Magnetic Properties of solids: Dia-, Para-, Ferri- and Ferro- magnetic Materials, definition in terms of susceptibility.Weiss's Theory of FerromagnetismandFerromagnetic Domains (qualitative treatment only),B-H curve, soft and hard material and their applications(discussion only) as cores in generators, transformers and electromagnets, energy lossin Hysteresis curve.

UNIT – V **(4 Hours)**
Dielectric Properties of solids: Dipole moment, polarization,local electric field in solids. Depolarization field, electric susceptibility, various sources of polarizability,piezo-, pyro- and ferroelectric materials and their applications(discussion only) as transducers, pickups, sensors, actuators, delay lines.

UNIT – VI **(3 Hours)**
Superconductivity: (Qualitative treatment only) Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, applications of superconductors. Discussion on applications in MRI, particle collider, power transmission, magnetic levitation etc.

References:
Essential Readings:

1) Solid State Physics, M. A. Wahab, 2015, 3rd Ed,Narosa Publications.
2) Solid State Physics, S. O. Pillai, New Age International Publishers
3) Introduction to Solid State Physics, Charles Kittel, 8th Ed., 2004, Wiley India Pvt. Ltd.
4) Elements of Solid State Physics, J. P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.
5) Solid State Physics, A. J. Dekker, 2008, Macmillan Education.

Additional Readings:

1) Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
2) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning.
3) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
4) Solid State Physics, Rita John, 2014, McGraw Hill
5) Superconductivity: A Very short Introduction – Stephen J Blundell – Audiobook
6) Crystallography applied to solid state physics, A. R. Verma and O. N. Srivastava, New Age International Publishers (2005)

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 7): BIOLOGICAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
BIOLOGICAL PHYSICS GE – 7	4	3	1	0	NIL	Physics and Astrophysics

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.
- Appreciate how fundamental principles of physics can be applied to gain an understanding of biological systems.
- 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 modelling of certain aspects of living systems.
- Get exposure to models of evolution.

SYLLABUS OF GE 7

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. Molecular motors: Transport along microtubules. Flagellar motion: 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.

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).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 8):

NUMERICAL ANALYSIS AND COMPUTATIONAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
NUMERICAL ANALYSIS AND COMPUTATIONAL PHYSICS GE – 8	4	2	0	2	Differential calculus, integration and ordinary differential calculus at the class 12 level.	Physics and Astrophysics

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. To expose students to fundamental computational physics skills and hence enable them to solve a wide range of physics problems.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Develop numerical methods to understand errors and solution of Algebraic and Transcendental equations.
- Understand interpolation, least square fitting, Numerical differentiation, Numerical integration and solution of ordinary differential equations.
- In the laboratory course, the students will learn to,
    - apply appropriate numerical method to solve selected physics problems using user defined and inbuilt functions.
    - solve non-linear equations
    - perform least square fitting of the data taken in physics lab by user defined functions.
    - Interpolate a data by polynomial approximations
    - numerically integrate a function and
    - solve first order initial value problems numerically.

SYLLABUS OF GE - 8

THEORY COMPONENT

Unit – I **(8 Hours)**

Errors and iterative Methods: Truncation and Round-off Errors. Floating Point Computation, Overflow and underflow. Single and Double Precision Arithmetic, Iterative Methods. Review of Taylor's Theorem and Mean value Theorem (No proofs).

Solutions of Algebraic and Transcendental Equations: Bisection method, Secant Method, Newton Raphson method. Comparison and error estimation

Unit – II **(10 Hours)**
Interpolation: Concept of Interpolation, Lagrange Form of interpolating polynomial, Newton's Forward and Backward Differences, Newton's Forward and Backward Interpolation Formulas. Regression: Algorithm for Least square fitting of a straight line, Fitting a Power function, and Exponential Function using conversion to linear relation by transforming the variables.

Unit – III **(7 Hours)**
Numerical Differentiation: Approximating the derivative of a function given in the form of discrete data, Numerical Computation of First and second order derivative of a function given in closed form (using Taylor's expansion) , errors in Numerical Differentiation.
Numerical Integration: Newton Cotes Quadrature methods for evaluation of definite integrals numerically, Trapezoidal Rule, Simpson's 1/3 and 3/8 Rules. Derivation of composite formulae for these methods and discussion of error estimation.

Unit – IV **(5 Hours)**
Solution of Ordinary Differential Equations: First Order ODE's: solution of Initial Value problems: (1) Euler's Method and (2) Runge Kutta methods

References:
Essential Readings:
1) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., Wiley India Edition (2007)
2) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn. PHI Learning Pvt. Ltd.(2012)
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

Additional Readings:
1) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
2) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
3) Computational Problems for Physics, R.H. Landau and M. J. Páez, CRC Press (2018).

PRACTICAL COMPONENT

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

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- The course will consist of practical sessions and lectures on Python.
- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.
- At least 6 programs must be attempted (taking at least one from each unit).

Unit I

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, formatting in the print statement

Control Structures: Conditional operations, i*f, if-else, if-elif-else, while* and *for* Loops, indentation, break and continue, List comprehension. Simple programs for practice like solving quadratic equations, temperature conversion etc.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules. Writing functions to perform simple operations like finding largest of three numbers, listing prime numbers, etc. Generating pseudo random numbers

Recommended List of Programs

(a) Make a function that takes a number *N* as input and returns the value of factorial of *N*. Use this function to print the number of ways a set of *m* red and *n* blue balls can be arranged.

(b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.

(c) Generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.

Unit II

NumPy Fundamentals: Importing *Numpy*, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using *ones(), zeros(), random(), arange(), linspace()*. Basic array operations (*sum, max, min, mean, variance*), 2-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt().

Plotting with Matplotlib: *matplotlib.pyplot* functions, Plotting of functions given in closed form as well as in the form of discrete data and making histograms.

Recommended List of Programs

(a) Given a function in closed form y=f(x), generate numpy arrays for x and y and plot y as a function of x with appropriate scale and legend.

(b) Generate data for coordinates of a projectile and plot the trajectory.

(c) Given the expressions in closed form, plot the displacement-time and velocity-time graph for the un-damped, under damped critically damped and over damped oscillator.

Unit III

Root Finding

a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.

b) Solve transcendental equations like $\alpha = \tan(\alpha)$.

c) To approximate nth root of a number up to a given number of significant digits.

Unit IV

Least Square fitting

Make function for least square fitting, use it for fitting given data (*x,y*) and estimate the parameters *a, b* as well as uncertainties in the parameters for the following cases:

a) Linear ($y = ax + b$)

b) Power law ($y = ax^b$)

c) Exponential ($y = ae^{bx}$)

Interpolation:

(a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i, y_i) and use this polynomial to find the value of y at a value of x not included in the data.

(b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function f(x) and use it to interpolate at a value of x not used in table.

Unit V

Numerical Differentiation

a) Given displacement at equidistant time values, calculate velocity and acceleration and plot them.

b) Compute the left, right and central approximations for derivative of a function given in closed form. Plot both the function and derivative (forward, backward and central derivatives) on the same graph. Plot the error as a function of step size on a log-log graph , study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.

Numerical Integration:

a) Given acceleration at equidistant time values, calculate position and velocity and plot them.

b) Use integral definition of ln(x) to compute and plot ln(x) in a given range. Use trapezoidal and Simpson methods and compare the results.

c) Verify the rate of convergence of the composite Trapezoidal and Simpson methods by approximating the value of a given definite integral.

References

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., PHI Learning Pvt. Ltd (2012).
5) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., Wiley India Edition(2007)
6) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 9): APPLIED DYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
APPLIED DYNAMICS GE – 9	4	3	1	0	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the main topics of low-dimensional nonlinear systems, with applications to a wide variety of disciplines, including physics, engineering, mathematics, chemistry, and biology. This course begins with the first order dynamical system and the idea of phase space, flows and trajectories and ends with the elementary fluid dynamics. The nature of the subject demands that the tutorials should include only computational problems.

LEARNING OUTCOMES

Upon successful course completion, a student will be able to:

- Demonstrate understanding of the concepts that underlay the study of dynamical systems.
- Learn various forms of dynamics and different routes to chaos.
- Understand basic Physics of fluids and its dynamics

SYLLABUS OF GE 9

THEORY COMPONENT

Unit – I **(22 Hours)**

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Concept of stability and un-stability. Simple mechanical systems as first order dynamical systems: simple and damped harmonic oscillator. Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems. Examples of dynamical systems – Population models e.g. exponential growth and decay, logistic growth, predator-prey dynamics.

Unit – II **(16 Hours)**

Introduction to Chaos: Bifurcations: Saddle-Node bifurcation, Transcritical bifurcation, Pitchfork bifurcation and Hopf bifurcation. Chaos in nonlinear equations: Logistic map and Lorenz equations. Sensitivity to initial states. Parameter dependence: steady, periodic and chaotic states. Cobweb iteration. Simple examples from physics, chemistry, engineering and lifesciences.

Unit – III **(7 Hours)**

Elementary Fluid Dynamics: Basic physics of fluids: The continuum hypothesis-concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity and equation of state.

References:

Essential Readings:

1) Nonlinear Dynamics and Chaos, S. H. Strogatz, Westview Press, 2nd edition, 2014
2) Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer New York, 1995.
3) Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer, 2003.
4) An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press, 2002.
5) Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.