

GENERIC ELECTIVE COURSES (GE)

Course Code: GE 1

Course Title: MECHANICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of mechanics learnt at school in a more advanced perspective and goes on to build new concepts. It begins with dynamics of a system of particles and ends with the special theory of relativity. Students will appreciate the concept of rotational motion, gravitation and oscillations. The students will be able to apply the concepts learnt to several real world problems. A brief recapitulation of vector algebra and differential equations is also done to familiarize students with basic mathematical concepts which are necessary for a course on mechanics.

Course Learning Outcomes: Upon completion of this course, students are expected to understand the following concepts.

- Laws of motion and their application to various dynamical situations. And their applications to conservation of momentum, angular momentum and energy.
- Motion of a simple and compound pendulum
- Application of Kepler's laws to describe the motion of satellites in circular orbit.
- The concept of geosynchronous orbits
- Concept of stress and strain and relation between elastic constants
- Postulates of Special Theory of Relativity, Lorentz transformation, relativistic effects on the mass and energy of a moving body.

In the laboratory course, after acquiring knowledge of how to handle measuring instruments (like vernier calliper, screw gauge and travelling microscope) student shall embark on verifying various principles and associated measurable quantities.

THEORY (Credit: 03; 45 Hours)

Unit 1: Recapitulation of Vectors and Ordinary Differential Equation Hours: 8

Vector algebra, scalar and vector product, gradient of a scalar field, divergence and curl of vectors field

Ordinary Differential Equations: First order homogeneous differential equations, second order homogeneous differential equation with constant coefficients

Unit 2: Fundamentals of Dynamics

Hours: 10

Review of Newton's laws of motion, dynamics of a system of particles, centre of mass, determination of centre of mass for discrete and continuous systems having spherical symmetry, Conservation of momentum and energy, Conservative and non-Conservative forces, work – energy theorem for conservative forces, force as a gradient of potential energy.

Unit 3: Rotational Dynamics and Oscillatory Motion

Hours: 14

Angular velocity, angular momentum, torque, conservation of angular momentum, Moment of inertia, Theorem of parallel and perpendicular axes, Calculation of moment of inertia of discrete and continuous objects (1-D and 2-D).

Idea of simple harmonic motion, Differential equation of simple harmonic motion and its solution, Motion of a simple pendulum and compound pendulum

Unit 4: Gravitation

Hours: 5

Newton's Law of Gravitation, Motion of a particle in a central force field, Kepler's Laws (statements only), Satellite in circular orbit and applications, geosynchronous orbits

Unit 5: Elasticity

Hours: 3

Concept of stress and strain, Hooke's law, elastic moduli, twisting torque on a wire, tensile strength, relation between elastic constants, Poisson's ratio, rigidity modulus

Unit 6: Special Theory of Relativity

Hours: 5

Postulates of Special Theory of Relativity, Lorentz transformation, length contraction, time dilation, relativistic transformation of velocity, relativistic variation of mass, mass-energy equivalence

References:

Essential Readings:

- 1) Vector Analysis – Schaum's Outline, M.R. Spiegel, S. Lipschutz, D. Spellman, 2nd Edn., 2009, McGraw- Hill Education.
- 2) An Introduction to Mechanics (2/e), Daniel Kleppner and Robert Kolenkow, 2014, Cambridge University Press.
- 3) Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education
- 4) Mechanics, D. S. Mathur, P. S. Hemne, 2012, S. Chand.
- 5) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.

Additional Readings:

- 1) Feynman Lectures, Vol. 1, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
- 2) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

- 3) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.
- 4) Engineering Mechanics, Basudeb Bhattacharya, 2/e, 2015, Oxford University Press.
- 5) Physics for Scientists and Engineers, Randall D Knight, 3/e, 2016, Pearson Education.

PRACTICAL (Credit: 01; 30 Hours)

The teacher is expected to give basic idea and working of various apparatus and instruments related to different experiments. Students should also be given knowledge of recording and analyzing experimental data.

Every student should perform at least 06 experiments from the following list.

- 1) Measurement of length (or diameter) using vernier calliper, screw gauge and travelling microscope.
- 2) Study the random error in observations.
- 3) Determination of height of a building using a sextant.
- 4) Study of motion of the spring and calculate (a) spring constant and, (b) acceleration due to gravity (g)
- 5) Determination of moment of inertia of a flywheel.
- 6) Determination of g and velocity for a freely falling body using digital timing technique.
- 7) Determination of modulus of rigidity of a wire using Maxwell's needle.
- 8) Determination of elastic constants of a wire by Searle's method.
- 9) Determination of value of g using bar pendulum.
- 10) Determination of value of g using Kater's pendulum.

References (for Laboratory Work):

- 1) Advanced practical physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Engineering practical physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
- 3) Practical physics, G. L. Squires, 2015, 4/e, Cambridge University Press.
- 4) A text book of practical physics, I. Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.
- 5) B. Sc. practical physics, Geeta Sanon, R. Chand and Co., 2016.

Course Code: GE 2

Course Title: MATHEMATICAL PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

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

Course Learning Outcomes: At the end of this course, the students will be able to,

- Understand functions of several variables.
- Represent a periodic function by a sum of harmonics using Fourier series and their applications in physical problems such as vibrating strings etc.
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method.
- Understand properties and applications of special functions like Legendre polynomials, Bessel functions and their differential equations and apply these to various physical problems such as in quantum mechanics.
- Learn about gamma and beta functions and their applications.
- Solve linear partial differential equations of second order with separation of variable method.
- Understand the basic concepts of complex analysis and integration.
- During the tutorial classes, students' skill will be developed to solve more problems related to the concerned topics.

Unit 1:

Hours: 6

Fourier series: Periodic functions. Orthogonality of sine and cosine functions, Convergence of Fourier series and 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 (Fourier Cosine Series and Fourier Sine Series).

Unit 2:

Hours: 10

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 and Bessel Differential Equations.

Unit 3:

Hours: 14

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

(4 Hours)

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

(10 Hours)

Unit 4:

Hours: 15

Complex Analysis: Functions of complex variable, limit, continuity, Analytic function, Cauchy-Riemann equations, singular points, Cauchy Goursat Theorem, Cauchy's Integral Formula, Residues, Cauchy's Residue Theorem.

References:

Essential Readings:

- 1) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
- 2) Complex Variables and Applications, J. W. Brown and R. V. Churchill, 7th Ed. 2003, Tata McGraw-Hill.
- 3) Advanced Mathematics for Engineers and Scientists: Schaum Outline Series, M. R Spiegel, 2009, McGraw Hill Education.
- 4) Applied Mathematics for Engineers and Physicists, L.A. Pipes and L.R. Harvill, 2014, Dover Publications.
- 5) Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd Ed., 2006, Cambridge University Press.

Additional Readings:

- 1) Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, 2017, Laxmi Publications Private Limited.
- 2) Advanced Engineering Mathematics, D. G. Zill and W.S.Wright, 5 Ed., 2012, Jones and Bartlett Learning.
- 3) An introduction to ordinary differential equations, E.A.Coddington, 2009, PHI Learning.
- 4) Differential Equations, George F. Simmons, 2007, McGraw Hill.
- 5) Mathematical methods for Scientists and Engineers, D.A.Mc Quarrie, 2003, Viva Books.

Course Code: GE 3

Course Title: WAVES AND OPTICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This coursework reviews the concept of waves and optics learnt at school level from a more advanced perspective and builds new concepts. This course is divided into two main parts. The first part deals with vibrations and waves. The second part pertains to optics and provides the details of interference, diffraction and polarization.

Course Learning Outcomes: After the completion of this course, the students will have learnt the following.

- Simple harmonic motion, superposition principle and its application to find the resultant of superposition of harmonic oscillations.
- Concepts of vibrations in strings.
- Interference as superposition of waves from coherent sources.
- Basic concepts of Diffraction: Fraunhofer and Fresnel Diffraction.
- Elementary concepts of the polarization of light.

THEORY (Credit: 03; 45 Hours)

Unit 1:

Hours: 10

Superposition of Harmonic Oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear harmonic oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses.

Unit 2:

Hours: 5

Waves Motion: Types of waves: Longitudinal and Transverse (General idea). Travelling waves in a string, wave equation. Energy density. Standing waves in a string - modes of vibration. Phase velocity.

Unit 3:

Hours: 12

Interference of Light: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and division of wave front. Young's Double Slit experiment. Fresnel's Biprism. Phase change on reflection: Stoke's

treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: measurement of wavelength and refractive index.

Unit 4:

Hours: 12

Diffraction: Fraunhofer diffraction - Single slit, Double slit and Diffraction grating. Fresnel Diffraction - Half-period zones, Zone plate, Fresnel Diffraction pattern of a straight edge using half-period zone analysis.

Unit 5:

Hours: 6

Polarization: Transverse nature of light waves. Plane polarized light. Production and detection of linearly polarized light. Malus's Law. Idea of circular and elliptical polarization.

References:

Essential Readings:

- 1) The Physics of Waves and Oscillations: N K Bajaj, Tata Mcgraw Hill
- 2) Optics: Ajoy Ghatak, Seventh edition, Mcgraw Hill
- 3) Principle of Optics: B. K. Mathur and T. P. Pandya, Gopal Printing Press
- 4) Optics: Brij Lal and N. Subramanyam, S. Chand
- 5) The Fundamentals of Optics: A. Kumar, H. R. Gulati and D. R. Khanna, R. Chand

Additional Readings:

- 1) Vibrations and Waves: A. P. French, CRC
- 2) The physics of Vibrations and Waves: H. J. Pain, Wiley
- 3) Fundamentals of Optics: Jenkins and White, McGraw Hill
- 4) Optics: E. Hecht and A R. Ganesan, Pearson, India
- 5) Introduction to Optics: F. Pedrotti, L. M. Pedrotti and L. S. Pedrotti, Pearson, India

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 05 experiments out of the list following experiments.

- 1) To determine the frequency of an electrically maintained tuning fork by Melde's experiment and to verify $\lambda^2 - T$ Law.
- 2) To study Lissajous Figures.
- 3) Familiarization with Schuster's focusing and determination of the angle of prism.
- 4) To determine the refractive index of the material of a prism using sodium light.
- 5) To determine the dispersive power of a prism using mercury light.
- 6) To determine wavelength of sodium light using Newton's rings.
- 7) To determine wavelength of sodium light using a plane diffraction grating.
- 8) To verify Malus's Law.
- 9) To determine the wavelength of Laser light using single slit diffraction. (Due care should be taken not to see Laser light source directly as it may cause injury to eyes.)

References (for Laboratory Work):

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, Asia Publishing House
- 2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, Kitab Mahal
- 3) An advanced course in practical physics, D. Chattopadhyay and P. C. Rakshit, New Central Book Agency

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 number 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 its 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 Ferromagnetism and Ferromagnetic Domains (qualitative treatment only), B-H curve, soft and hard material and their applications (discussion only) as cores in generators, transformers and electromagnets, energy loss in 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

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	--	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, *if*, *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

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

- 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.
- Generate data for coordinates of a projectile and plot the trajectory.
- 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

- Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
- Solve transcendental equations like $\alpha = \tan(\alpha)$.
- To approximate n th 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	--	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.

Course Code: GE 6

Course Title: INTRODUCTORY ASTRONOMY

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Course Objectives: This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

Course Learning Outcomes: After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India's contribution to astronomy, both in ancient times and in modern era.

Unit 1:

Hours: 8

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

Unit 2:

Hours: 6

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax

method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

Unit 3:

Hours: 7

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.

Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope

Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

Unit 4:

Hours: 8

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings

Exoplanets: Detection methods and characterization

Unit 5:

Hours: 12

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter

Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type1a), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

Unit 6:

Hours: 4

Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

References:

Essential Readings:

- 1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
- 2) Fundamental of Astronomy, H. Karttunen et al. Springer
- 3) Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Addison-Wesley Publishing Co.
- 4) Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, Saunders College Publishing.
- 5) The Molecular Universe, A.G.G.M. Tielens (Sections I, II and III), Reviews of Modern

Physics, Volume 85, July-September, 2013

- 6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

Useful websites for astronomy education and citizen science research platform

- 1) <https://aladin.u-strasbg.fr/>
- 2) <http://www.astrometrica.at/>
- 3) <https://www.sdss.org/>
- 4) <http://stellarium.org/>
- 5) <https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/>
- 6) <https://setiathome.berkeley.edu/>
- 7) <https://www.radathomeindia.org/>

Additional Readings:

- 1) Explorations: Introduction to Astronomy, Thomas Arny and Stephen Schneider, McGraw Hill
- 2) Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
- 3) Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
- 4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
- 5) The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books