PH1050 Foundation of Computational Physics

Description: Learning Objectives: To motivate the need for a computational approach in Physics. To develop the skill of using numerical techniques to solve basic physics problems. To introduce programming skills using interactive platforms such as Mathematica and Python. To develop analytical skills through visualization and data plotting. Learning Outcome: Students must be able to use interactive platforms to execute basic numerical tasks and data analysis. This will assist them in solving basic numerical physics problems.

Course content: Overview of various interactive platforms (Mathematica, Matlab, Python, and other programming languages) and their utility in Physics.

Part-A (Data Analysis and Numerical Problem Solving through Mathematica)Preface of Mathematica (What Mathematica is all about, how it works, few basic commands); Functions; Plotting of multi-variable functions; 2D and 3D visualizations; Polynomial data fitting (linear, least square, spline); Data interpolation; Probability and Statistics; Regression analysis; Error analysis, Random number generator; Solving algebraic expressions, Numerical precision; Matrix algebra: Finding eigenvalues and eigenvectors; Calculus: Differentiation and Integration

Part-B (Learning through Python)Introduction to Python, Basic Commands, Importing Modules (Numpy, Scipy, Matplotlib) Revisit of the problems and concepts discussed in part-A through Python

Part-C (Application of Mathematica/Python to solve problems in physics)Central Force Problem, Harmonic Oscillator, Waves & Oscillations, Electricity and Magnetism, Data Analysis

TextBooks:

1. S. Wolfram, The Mathematica Book (5th Ed.), Champaign, IL: Wolfram Research (2003)
2. Alex Martelli, Python in a Nutshell (2nd Ed.) Oâ€TM Reilly, CA, 2006

ReferenceBooks:

1. R. L. Zimmerman, F. I. Olness, Mathematica for Physics (2nd Ed) Addison Wesley (2002)
2. M. Lutz, Learning Python, (5th Ed.) Oâ€TMReilly, CA, (2013)

PH1010 Physics I

Description: Use of vectors in practical mechanics. Unit vectors in spherical and cylindrical polar coordinates. Conservative vector fields and their potential functions -gravitational and electrostatic examples. The gradient of a scalar field. Equipotentials, states of equilibrium. Work and energy, conservation of energy. Motion in a central force and conservation of angular momentum. Physics concepts in vector fields, Continuity equations, and conservation principles for matter, energy, and electrical char.

Course content: Use of vectors in practical mechanics. Unit vectors in spherical and cylindrical polar coordinates. Conservative vector fields and their potential functions -gravitational and electrostatic examples. The gradient of a scalar field. Equipotentials, states of equilibrium. Work and energy, conservation of energy. Motion in a central force and conservation of angular momentum. Physics concepts in vector fields, Continuity equations, and conservation principles for matter, energy, and electrical charge. Flux the divergence of a vector. Gauss' theorem, physical applications in gravitation and electrostatics. Irrotational versus rotational vector fields. The physical significance of circulation, curl of a vector field. Stokes' theorem, physical applications. Oscillatory motion, Wave motion in one dimension. Wave equation and traveling wave solutions. Wave velocity, group velocity, and dispersion. Shallow water waves. Wave equation in three dimensions, spherical waves.

Reference Books:

1. Kittel C., Knight W.O., and Ruderman M.A., Mechanics - Berkeley Physics Course, Vol. 1, Tata McGraw-Hill
2. Purcell E.M. Electricity and Magnetism - Berkeley Physics Course, Vol.2, Tata McGraw-Hill
3. Crawford F.S. - Waves and Oscillations, Berkeley Physics Course, Vol. 3, McGraw-Hill
4. Feynman R.P., Leighton R.B. and Sands M. (Narosa) The Feynman Lectures on Physics, Vol. 1
5. Feynman R.P., Leighton R.B. and Sands M. (Narosa) The Feynman Lectures on Physics, Vol. 26. Davis D. (Academic) - Classical Mechanics

PH1030 Physics Lab

Course content: Experiments in Mechanics Properties Materials, Heat, Electromagnetism, and Optics.

Reference Books:

1. Smith E. V. -Manual of Experiments in Applied Physic$, London,'" Butterworth, 1970.
2. Workshop B.L., and Flint H.P. -Advanced Practical Physics for Students, Methuen and Co. Ltd. London.
3. Jerrad H.G. and Mc Neil D.B. -Theoretical and Experimental Physics.
4. Fretter W.B.Introduction to Experimental Physics, Blackiee
5. M. Nelkon and J.rlJl. Ogborn -Advanced Level Practical Physics, English Language Book Society, 1955.

PH1080 Thermodynamics & Kinetic Theory

Description: To introduce to the student basic concepts like entropy, etc. kinetic theory, and laws of thermodynamics to enable them to use and apply them in later courses like Statistical Physics, Condensed Matter Physics, etc. Also, introduce and familiarize the student's other important formulations like thermodynamic potentials, etc., and study phenomena like liquefaction of gases, phase transformations, and other phenomena. This course aims to take the students from the elementary thermodynamics to the threshold of Statistical Physics.

Course content: Overview and introduction: characteristic features of macroscopic systems, conditions of equilibrium. The basic problems of thermodynamics. Specification of the state of a system. The number of states accessible to a macroscopic system, constraints, equilibrium and irreversibility, interaction between systems, and the first law of thermodynamics. Thermal interaction: Approach to thermal equilibrium, temperature, systems in contact with a heat reservoir, probability of occurrence of a state. Classical approximation, Maxwell Velocity distribution, the equipartition theorem, and the specific heat of solids. General thermodynamic interaction between systems. Dependence of the number of states on the external parameters. General thermodynamic relation at equilibrium. Thermodynamic potentials. Legendre Transformations. Second and third law of thermodynamics. Equilibrium conditions of isolated systems and a system in contact with a reservoir. Equilibrium between phases. Gibbs phase rule. Elementary kinetic theory of transport process. Viscosity, conductivity, self-diffusion, electrical conductivity. Boltzmann transport equation.

Text Books:
Concepts in Thermal Physics, S.J. Blundell and K. M. Blundell, Oxford University Press, 2012

Reference books:
1. F. Rief, Statistical Physics, Berkeley Volume 5 (Tata McGraw Hill, special Indian edition 2008)
2. H .B.Callen, Thermodynamics and an introduction to Thermostatistics (John Wiley and Sons 1985)
3. K.P.N.Murthy, Excursions in Thermodynamics and Statistical Mechanics, Universities Press 2009
4. H. Gould and J. Tobochink, Thermal and Statistical Physics Princeton University Press in 2010

<u>PH1020 Physics II</u>

Description: To enable the students to a) describe electromagnetic phenomena using the language of vector calculus. b) determine electric and magnetic fields arising from simple configurations of static charges as well as steady currents in a vacuum and in the matter. c) solve problems involving the propagation of electromagnetic waves in a vacuum and in the matter. d) apply the methodology of quantum mechanics to simple systems.

Course content:
Unit 1: Electrostatics and magnetostatics Maxwellâ€™s equation-I, work and energy in electrostatics, displacement and polarization, boundary conditions. Maxwellâ€™s equation-II, Ampereâ€™s law, magnetic vector potential, magnetism in the matter.
Unit 2: Electrodynamics and electromagnetic radiation Lorentz force, Faradayâ€™s law and Lenzâ€™s law, electromagnetic induction. Displacement current, Maxwellâ€™s equations III and IV, energy stored in an electromagnetic field, electromagnetic waves in vacuum and in the matter, Snellâ€™s law.
Unit 3: Introduction to quantum mechanics The quantum nature of radiation, interference experiment with radiation and particle beams. Postulates of quantum mechanics, Schrodinger wave equation. Applications to simple physical systems such as free particle, particle in a box and barrier penetration, spin, and two-state Systems.

Text Books:

1. Introduction to Electrodynamics David J. Griffiths, Pearson Education India Learning Private Limited; 4 Edition (2015)
2. Intro to Quantum Mechanics David J. Griffiths, Pearson Education India Learning Private Limited (2015)
3. Fundamentals of Physics II - Electromagnetism, Optics, and Quantum Mechanics: 2 (The Open Yale Courses) R. Shankar Yale University Press; 1 edition (2016)

Reference Books:

1. The Feynman Lectures on Physics Vol 2, Richard P. Feynman and R. B. Leighton Narosa Publishing House (2008)
2. The Feynman Lectures on Physics Vol 3, Richard P. Feynman and R. B. LeightonNarosa Book Distributors (2008)
3. Quantum physics C Verma, TBS, 2nd edition

EP2102 Classical Dynamics

Course Content: Lagrangian formulation: Degrees of freedom, constraints, generalized coordinates and velocities, Lagrangian, Euler- Lagrange equation, examples. Symmetries and conservation laws: Conservation of momentum, angular momentum and energy, virial theorem; Central force motion: Kepler problem, Scattering in a central potential, Rutherford formula. Small oscillations: Perturbations away from equilibrium, stability analysis, normal modes and normal coordinates, examples (molecular dynamics).

Rigid body motion: Motion in non-inertial frames, Coriolis force, degrees of freedom of a rigid body, moment of inertia tensor, principal axes, Euler angles and Euler equations of motion, example (symmetric top).

Hamiltonian formalism: Legendre transforms, generalized momenta, Hamiltonian, Hamilton's equations, phase space and phase trajectories, examples, conservative versus dissipative systems (simple examples). Canonical transformations: Poisson brackets, Louiville's theorem, Generating functions, Action-angle variables Elements of time-independent perturbation theory, introduction to non-integrable systems.

Special relativity: Postulates of relativity, Lorentz transformations, length contraction and time dilation, Doppler effect, velocity addition law, four-vector notation.

Course References:

1. H. Goldstein, C. Poole and J. Safko,Classical Mechanics, 3rd Edition (Pearson Education, India, 2002).
2. Jorge V. Jose, and Eugene J. Saletan, Classical Dynamics, A contemporary approach, Cambridge Univ. Press, 1998.
3. David Morin, Introduction to Classical Mechanics, with problems and solutions, Cambridge Univ. Press, 2008.
4. L. D. Landau and E. M. Lifshitz, Mechanics, Course of Theoretical Physics, Volume 1, Third Edition (Pergamon Press, New York, 1976).

5. S. T. Thornton and J. B. Marion, Classical dynamics of particles and systems, (Cengage Learning, 2008)

EP2110 Introduction to Mathematical Physics

Description: Learning Objectives: To gain a working knowledge of mathematical methods used in physics.Learning Outcomes: At the end of the course, the student (i) will know elementary ideas in linear algebra, special functions, and complex analysis, and (ii) will be able to apply these to solve problems in classical, statistical, and quantum mechanics as well as electromagnetism

Course content: Linear vector spaces, Basis sets. Orthogonality and completeness. Linear maps and dual space, Bra, and ket notation. Inner product; Linear operators and Matrices, Hermitian and unitary operators, Normal matrices and their diagonalization, Cayley-Hamilton theorem.New vector spaces from old: Direct sum and tensor products, outer product of matrices; Examples: Vectors and Tensors in R^3, Rotation group in 2 and 3 dimensions. Spin and C^2, Pauli matrices. Generators of rotations. Multiple spins and the tensor product, Hilbert space. Dirac delta function, representation, and properties.

Examples: L_2(S^1) and Fourier Series; L_2(R) and Fourier transforms; Convolution in Fourier Series and Transforms; L_2(S^2) and spherical harmonics. Families of orthogonal polynomials as basis sets in function space, Legendre, Hermite, Laguerre, Chebyshev, and Gegenbauer polynomials, Generating functions. Expansion of functions, Inversion formulas.Elements of analytic function theory, Cauchy-Riemann conditions, Cauchy's integral theorem and integral formula, Singularities-poles and essential singularities, residue theorem, and contour integration. Occurrence of Laplace, Poisson, Helmholtz wave and diffusion equations in physical applications, Elementary properties of these equations and their solutions.

Text Books:
1. P. Dennery and A. Krzywicki, Mathematics for physicists (Dover Publications, 1996)
2. J. Hefferon, Linear Algebra (Chapters 2 and 3), (Orthogonal Press, 2014), Freely available at: http://joshua.smcvt.edu/linearalgebra/
3. G. Arfken and H. J. Weber, Mathematical Methods for Physicists (7th Edition) (Academic Press, 2012).

Reference Books:
1. K.F.Riley, M.P.Hobson, and S.J. Bence, Mathematical Methods for physics and engineering (Cambridge U. Press, 2006).
2. L.A.Pipes and L.R.Harwell, Applied Mathematics for Engineers and Physicists (McGraw-Hill).
3. B.Friedman, Principles, and Techniques of Applied Mathematics (Dover, 1990).
4.D.W.Lewis, Matrix Theory (Allied Publishers, 1991).
5. M.P.Boas, Mathematical Methods in the Physical Sciences (2nd Edition) (Wiley, 1983)

EP2210 Quantum Mechanics

Description: To introduce the students to the foundations and application of quantum mechanics. At the end of the course, the student will know (i) basic postulates of quantum mechanics and quantum mechanical description of physical systems, and (ii) theoretical, mathematical, and numerical tools to set- up and solve problems involving quantum systems in a given external potential.

Course content: Experiments leading to origins of quantum mechanics; Double slit experiment and its significance; Postulates of Quantum Mechanics: Physical observables and Operators, Expectation values and quantum fluctuations, measurement of physical observables, time-dependent Schrodinger equation; Solutions of time-independent Schrodinger equation in one dimension and their applications; The mathematical framework of quantum mechanics: Hilbert spaces, Hermitian operators, orthonormal bases, generalized uncertainty principle, Unitary transformations; Solutions of time-independent Schrodinger equation in three dimensions and their applications: Schrodinger equations in three dimensions, Central potential - particle in a box, simple harmonic oscillator, the Hydrogen atom, degeneracy of energy eigenstates and its implications; Angular momentum and Spin; Introduction to perturbation theory.

Text Books: To be prescribed by the instructor.

Reference Books:

1. D. J. Griffiths, Introduction to Quantum Mechanics, Third Edition (Cambridge University Press Education, 2018).
2. R. Shankar,Principles of Quantum Mechanics, Second Edition (Springer, Delhi, 2008).
3. W. Greiner, Quantum Mechanics, Fourth Edition (Springer, Delhi, 2004).
4. P. A. M. Dirac, The Principles of Quantum Mechanics, Fourth Edition (Oxford University Press, Oxford, 1958).
5. R. P. Feynman, The Feynman Lectures on Physics, Vol. III.
6. R. L. Liboff, Introductory Quantum Mechanics, Fourth Edition (Pearson Education, Delhi, 2003).
7. E. Merzbacher, Quantum Mechanics, 2nd Edition, Wiley International Student Edition. (1970).
8. J.J. Sakurai, Modern Quantum Mechanics, Revised Edition, Addison-Wesley International Student Edition (1994).
9. S. Gasiorowicz, Quantum Physics, 2nd Edition, Wiley and Sons (1996).
10. L. D. Landau and E. M. Lifshitz, Quantum Mechanics (Course of Theoretical Physics, Volume 3), Third Edition (Pergamon Press, New York, 1977)

EP3190 EP Lab 2

Description: The course will deal with interesting phenomena that are not only relevant from a fundamental point of view but often have important applications. The aim is to bring students laboratory experiences, in pragmatic terms, which stress the acquisition of practical skills, equipment familiarity, observational skills, interpretation of data, and a critical approach to experimentation. Undergraduate students, however, have some different perceptions of laboratory aims and rate highly those activities associated with educational processes, for example, the links which they observe to exist between theoretical material and laboratory work.

Course Content: The course accommodates experiments based on the (i) mechanics, (ii) electricity and magnetism, (iii) optics, (iv) electronics and (v) thermodynamics.

Text Books:
B. L. Worsnop and H. T. Flint, Advanced Practical Physics for Students, Methusen and Co. (1950).

Reference Books:
1. E. V. Smith, Manual for experiments in applied physics, Butterworths (1970).
2. R. A. Dunlap, Experimental physics: Modern methods, Oxford University Press (1988).
3. D. Malacara (ed), Methods of experimental physics: Series of volumes, Academic Press Inc. (1988).
4. Roman Kezerashvili, College physics laboratory experiments: electricity, magnetism, optics, New York: Gurami Pub., (2003).
5. S. Panigrahi & B. Mallick, Engineering Practical Physics, Cengage Learning India Pvt. Ltd., (2015).
6. Michael Nelson and Jon M. Ogborn, Advanced level Physics Practicals, 4th Edition, reprinted Heinemann Educational Publishers, (1985).
7. Indu Prakash and Ramakrishna, A Text Book of Practical Physics, 11th Edition, Kitab Mahal, New Delhi, (2011).
8. D. P. Khandelwal, A Laboratory Manual of Physics for Undergraduate Classes, Vani Publication, (1985)

EP3110 Electromagnetics and Applications

Description: Learning objectives This is an intermediate-level course in electromagnetic fields and assumes a background in electrostatics, magnetostatics, and introductory knowledge in electrodynamics. The main objective is to introduce electromagnetic fields with emphasis on analytical rigor and physical reasoning required for solving problems having a direct application. The course will also provide sufficient background to motivate students to take up advanced levels courses such as electromagnetic scattering, computational electrodynamics, etc. Learning outcomes Upon successful completion, the students will have learned i) the importance of constitutive properties of materials and their use in applications, ii) the effect of boundaries and be able to develop and analyze optical coatings, iii) time-dependent formulation of potentials, and fields, and fields dues to moving charges, iv) the fundamental ideas in electromagnetic scattering with relevance to applications and v) the concept of waveguides and propagation of guided electromagnetic waves.

Course content: Maxwell’s equations and wave propagation Maxwellâ€™s equations in general form â€“ wave equation â€“ electromagnetic wave propagation in different media: metals, dielectrics, and lossy media â€“ models for complex permittivity: Drude, dipolar relaxation, and oscillator models â€“ Hagen-Reuben equation â€“ Kramer-Kronig relations. Electromagnetic waves at boundaries EM waves and interfaces â€“ reflection and refraction of S- and P-polarized waves at the interface between free space and different (dispersive, absorbing, and conducting) media for normal and oblique incidences â€“ reflectance and transmittance at multiple interfaces â€“ Transfer matrix method â€“ applications to multilayer structures: antireflection coatings, dielectric mirrors, and Fabry-Perot etalon. Time-dependent potentials and fields Time-dependent potential formulation â€“ Gauge transformation â€“ continuous source distribution and retarded potentials â€“ time-dependent formulation of Coulombâ€™s and Biot-Savart Law, Jefimenkoâ€™s equations â€“moving point charge â€“ Lienard-Wiechert potential â€“ field due to a moving point charge. Electromagnetic radiation and scattering Electromagnetic radiation â€“ radiation from oscillating electric and magnetic dipoles â€“ time-averaged energy density, pointing vector, and radiated power â€“ half-wave antenna - classical theory of scattering by an electron - Thomson scattering â€“ scattering due to atoms and molecules â€“ Rayleigh scattering â€“ scattering by a collection of charges â€“ X-ray diffraction - Interaction of electromagnetic fields with sub-wavelength structures and introduction to plasmonics. Guided electromagnetic waves Propagation between parallel conducting plates â€“ guided waves â€“ propagation of TE and TM waves in hollow rectangular waveguides â€“ TEM waves and coaxial transmission lines â€“ standing waves and resonant cavities â€“ spherical cavities and Schumann resonances.

Text Books:

1. Introduction to electromagnetism, 3rd edition, David J Griffiths, Phi learning pvt ltd, 1999.
2. Electromagnetic Fields, 2nd edition. Roald K. Wangsness, Wiley, 1986.
3. Optical properties of thin solid films, O.S. Heavens, Dover Publications, 1991.

Reference Books:

1. Principles of optics, 4th edition (reprint), M. Born and E. Wolf, Pergamon, Oxford, 1986.
2. Classical electrodynamics, J.D. Jackson, John_Wiley, New York, 1974.
3. Handbook of optical properties: Thin films for optical coatings, Volume I, Rolf E. Hummel and Karl H. Guenther, CRC Press 1995.
4. Classical electrodynamics, J. Schwinger, Lester L. DeRaad, Jr, Kimball A. Milton and Wu-yang Tsai, West view press, 1998

EP3290 EP Lab 3

Description: This lab course offers practical hands-on experience in designing and making electronic circuits, optical experiments such as interferometers, microwave wavelength measurement, Joule-Thompson effect, laser beam parameters, lifetime measurement in lasers, etc.

Course content: White light interferometer - Nanometer step measurements Multi-SIM- Filters DC Power supply Wave shaping circuits using Passive, Active components State variable filters- using Op-Amp Introduction to Q-switched Nd: YAG Laser - LIBS- Lifetime measurement Laser beam parameters Photoconductivity, The Joule Thomson, effect Thermal coefficient of material using Interferometer Horn Antenna-Lloydâ€™s Mirror Solving Simultaneous Equation & Second Order Differential Equation Fourier analysis, Computational Physics Couple Pendulum.

Text Books: Manual provided by Physics department, IIT Madras

Reference books: Manual provided by Physics department, IIT Madras

EP3220 Solid State Physics

Description: This is a foundational course covering essential concepts and applications in Solid State Physics. The course aims to provide a broad and structured platform towards the study of physical properties of solid-state systems.

Course content: Crystalline and noncrystalline materials - Crystal symmetry - point groups, bravais lattices, and space groups - crystal systems - Miller indices - hexagonal close-packed, diamond, alkali halide, zinc sulphide, and cesium chloride structures - reciprocal lattice â€“ X-ray diffraction - bonding in solids - quasi-crystals. Imperfections in crystals Lattice vibrations - phonons â€“ Phonons -Einstein and Debye theories of specific heats - Thermal expansion and thermal conductivity. Free electrons in solids - Drude expression for electrical conductivity and Ohm's Law - Wiedemann - Franz law - electronic specific heat of metals. Periodic potential and band structure - Brillouin Zones - metals, insulators, and semiconductors - effective mass and holes in semiconductors - carrier equilibrium in intrinsic and doped semiconductors - Hall effect - pn junction - superconductors. Dielectrics - polarization mechanisms - internal electric field - (Clausius - Mossotti relation) - Dielectric loss - ferroelectrics. Para, dia, and ferromagnetism -Curie Weiss law and molecular field - exchange interactions - hysteresis loop - domains. Reflection, scattering, refraction, and transmission of light through media - optical properties of metals â€“ luminescence.

Text Books:
1. A.J. Dekker, Electrical Engineering Materials, Prentice-Hall, Englewood Cliffs (1958).
2. Kittel, Introduction to Solid State Physics, 7th or 8^{th} Edition, Wiley Eastern Ltd., New Delhi (1996).
3. John Wulff, The structure and properties of Materials, in 4 volumes, Wiley Eastern Ltd., New Delhi (1965).
4. Van Vleck, Materials Science for Engineers, Addison Wesley, New York (1985)