M.Sc. PHYSICS
CHOICE BASED CREDIT SYSTEM (CBCS)

Syllabus
2015 – 2016

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University)

(Established Under Section 3 of UGC Act 1956)

Eachanari Post, Coimbatore – 641 021

Semester – I
L T P C
15PHP101 CONDENSED MATTER PHYSICS 4 - - 4

Course Objectives

- Studying the properties of materials is very important at all times, to choose the correct material for the correct use.
- To aware the students about the field of Condensed matter physics.
- This paper is intended to give the students an idea about importance of crystals and their properties.
- This paper enable the students to understand about the crystal structure, interaction with X-ray, lattice vibrations, defects, electronic properties and the magnetic properties etc.
- To explain the concept of energy bands and effect of the same on electrical properties.
- To learn the importance of different materials in a variety of applications

Course Outcomes (COs)

After successful completion of the course, the student is expected to

1. Differentiate between different Lattice types and explain the concepts of reciprocal lattice and crystal diffraction.
2. Predict electrical and thermal properties of solids and explain their origin.
3. Explain the concept of energy bands and effect of the same on electrical properties.
4. Describe the dielectric properties of insulators.
5. Explain various types of magnetic phenomenon, physics behind them, their properties and applications.
6. Explain superconductivity, its properties, important parameters related to possible applications.
7. learn the importance of different materials in a variety of applications

UNIT – I

Inter planar spacing: Inter planar spacing for SC, FCC, BCC lattices - diamond cubic structure - NaCl structure - The reciprocal lattice and their properties - Bragg condition in terms of reciprocal lattice - Rotatory crystal method of X ray diffraction -Neutron diffraction – experiment.

Lattice: Vibrations of one dimensional diatomic linear lattice-acoustic and optical branches - Semi conductors and their properties - Hall effect - Dielectrics - Lorentz field in dielectrics - The Clausius –Mossoti equation - Ferro electric crystals - Ferro electric domains.

UNIT - II

Crystal defects: Classification of defects - Points defect - The Schottky defect - The Frenkel defect -colour centers - F center - other colour centers - Production of colour centers by X rays or practice irradiation – Defect and energy state.

Dislocations - Slip and plastic deformation - Shear strength of single crystals - Edge dislocation - Screw dislocation - Stress field around an edge dislocation.

Ultrasonics: Non destructive testing and applications.

UNIT - III `

Heat capacity of the electron gas: Experimental electrical resistivity of metals – Free electron theory of metals – Debye's equation - superconductivity - Electron phonon interaction - Cooper pairs – BCS theory - Energy gap and its temperature dependence - London equation – Josephson effect and its applications.

Langevin theory of Para magnetism: Quantum theory of Para Magnetism - Curie law-Ferro Magnetism - Weiss molecular field theory - Domain theory - Anti Ferro magnetism - Neel theory - Ferri Magnetism – Ferrites – spin – waves - Experimental techniques to study the magnetic properties.

UNIT - IV

NANOSCIENCE

Structure: Size dependence of properties – Crystal Structures – Face centred nano particles – Particle size determination – Surface structure - Metal nano particles - Magic numbers – Theoretical model of nano particles – Geometric structure – Reactivity – Fluctuations – Magnetic clusters – Bulk to nano transitions Semi conducting nano particles – optical properties – photo fragmentation – Coulombic explosion.

Polymers: Forming and Characterizing polymers – Polymerisation – Sizes of polymers – Nano crystals – Condensed ring types – Poly diacetylene types – Polymers – Conductive polymers – Supra molecular structures – Transition-metal mediated types – Dendritic molecules – Supra molecular dendrimers – Micellers

UNIT - V

Instrumentation: Working principle, and applications of scanning electron microscope - transmission electron microscope - scanning tunneling microscope - atomic force microscope, and surface plasmon resonance – theories and principles of soft lithography, self assembled monolayers and multilayers.

Suggested Books

1. Kittel. C. 2005, Introduction to Solid State Physics, 8th Edition, Willey Eastern Ltd., New Delhi.
2. Saxena. B.S., R.C.Gupta and P.N.Saxena, 2012, Fundamentals of Solid State Physics, 15th edition, Pragati Prakashan, Meeru.
3. Charles P. Poole Jr., Frank J.Owens, 2003, Introduction to Nano-technology, 1st edition, Wiley India, New Delhi
4. Dekkar. A.J., revised edi, 2000, Solid State Physics, Macmillan India Ltd., New Delhi.
5. Keer. H.V. 1st edition , 2002, Principles of Solid State, New age international., New Delhi.
6. Pillai S.O., 2005, Solid State Physics, 4th Edition, New Age International Publishers Ltd.
7. Mark Ratner, Daniel Ratner, 1st edition ; 2009, Nano-Technology, A gentle introduction to the new big idea, Pearson Education (Singapore) (P) Ltd., New Delhi.
8. Jean-Marie Lehn, 1995, Supramolecular Chemistry – Concepts and Perspectives, Wiley-VCH, Weinheim, Germany Volume 106
9. Jonathan Steed and Jerry Atwood, 2st edition; 2009, Supramolecular Chemistry, Wiley Interscience, London.
10. https://nptel.ac.in/courses/115/106/115106061/
11. http://www-personal.umich.edu/~sunkai/teaching/Winter_2018/phys520.html

12. www-hphys.physics.ox.ac.uk/people/SteveSimon/condmat2012/LectureNotes2012.pdf

Semester I
L T P C
15PHP102 ELECTRONIC DEVICES AND CIRCUITS 4 - - 4

Course Objectives

- This paper contains details of basic electronic components, their characteristics and applications in the construction of different electronic instruments.
- Other than ordinary transistors and diodes special devices are also explained.
- To give an idea about the basics of electronics and electronic devices, which is very important for knowing the basics of any modern instrument.
- To analyze PN junctions in semiconductor devices under various conditions.
- To design and analyze simple rectifiers and voltage regulators using diodes.
- To understand the high frequency application of diodes.

Course Outcomes (COs)

After successful completion of the course, the student is expected to

1. Build, design and analyze analog to digital converter.
2. Design digital and analog systems.
3. Understand the basic operation and working of different diodes like FET, MOSFET, CMOS, etc.
4. Analyze PN junctions in semiconductor devices under various conditions.
5. Design and analyze simple rectifiers and voltage regulators using diodes.
6. Understand the high frequency application of diodes.

UNIT I

Electronic Devices and Applications - Transistor Biasing and Stabilization with design problems, h-parameters and their applications in transistor circuit analysis for CE, CB and CC configurations; FET and MOSFETs: Characteristics and Biasing, Design of biasing circuits, Design and analysis of amplifiers, Numerical problems.

UNIT II

Frequency response of amplifiers General concepts; bode plot; low frequency response: BJT and FET amplifiers; miller effect capacitance; high frequency response of BIT amplifiers; hybrid pie model: short circuit current gain, cut off frequency, and current gain with resistive load; high frequency response of FET amplifiers; frequency response of multistage amplifiers; square wave testing, Numerical problems.

UNIT III

Analysis of compound configurations Cascade connection; Cascade connection; Darlington connection; Bootstrapping principle; Bootstrapped Emitter Follower; Bootstrapped Darlington Emitter Follower; Feedback pair; . CMOS circuits; Current source circuits; Current mirror circuits; Differential amplifier circuits; Numerical problems.

UNIT IV

Power amplifiers Introduction, Series-fed Class A amplifier, Transformer coupled class A amplifier, Class B amplifier operation, Class B amplifier distortion, Power transistor heat sinking, Class C and Class D amplifiers, Numerical problems.

UNIT V

Network theory, mesh and node analysis Kirchhoff's voltage and current law, Network Theorems- Thevein's theorem, Norton's theorem, Superposition Theorem, Maximum power transfer theorem, Problems based on network theorems

Suggested Books

1. L. Boyle stad and Louis Nashelsky, 10th edition, 2013, Electronic devices and circuit theory, Prentice-Hall of India,Delhi.
2. Millman and Halkias, 48th reprint, 2008, Integrated electronics, Tata McGraw-Hill, New Delhi.
3. Malvino A.P., Electronics Principles, 10th edition, 2013, Tata McGraw Hill, New Delhi
4. Mottershed, 1st edition, 1996, Electronic devices and circuits: An introduction, Prentice-Halloflndia, New Delhi.
5. M. S. Ghausi1st edition, 1995, Electronic devices and circuits, CBS.
6. Donald L. Schilling, Charles Belove, 3rd edition, 2009, Electronic circuits discrete and integrated, Tata McGraw-Hill, New Delhi.
7. Millman and Grabel, 2nd edi, 2001, Microelectronics; Tata McGraw-Hill, New Delhi.
8. T.F. Bogart and J.S. beasely and G. Rico, 5th edition, 2000, Electronic devices and circuits, Prentice hall; New Delhi.Hall of India.
9. A.Nagoor Kani, 1st edition, 2014, Circuit theory, RBA publications.
10. PC based instrumentation; Concepts & Practice, N.Mathivanan, 2007, Prentice-Hall of India.
11. https://www.electronics-tutorials.ws/
12. https://www.electrical4u.com/
13. https://learn.careers360.com/physics/electronic-devices-chapter/

Semester I
L T P C

15PHP103 THERMODYNAMICS AND STATISTICAL MECHANICS 5 - - 5

Course Objectives

- Thermodynamics is an important branch of physics, which helps us to understand the different phenomena in the evolution of the universe.
- This paper gives a basic idea about the laws of thermodynamics and statistical processes.
- To apply the knowledge of mathematics, science and engineering fundamentals to model the energy conversion phenomenon.
- To identify and formulate power production based on the fundamentals laws of thermal engineering.
- To instill upon to envisage appropriate experiments related to heat engines.
- To investigate the effectiveness of energy conversion process in mechanical power generation for the benefit of mankind

Course Outcomes (COs)

After successful completion of the course, the student is expected to

1. Identify and describe the statistical nature of concepts and laws in thermodynamics, in particular: entropy, temperature, chemical potential, Free energies, partition functions.
2. Apply the knowledge of mathematics, science and engineering fundamentals to model the energy conversion phenomenon.
3. Identify and formulate power production based on the fundamentals laws of thermal engineering.
4. Investigate the effectiveness of energy conversion process in mechanical power generation for the benefit of mankind
5. Use the statistical physics methods, such as Boltzmann distribution, Fermi-Dirac and Bose-Einstein distributions to solve problems in physical systems.
6. Apply the concepts and laws of thermodynamics to solve problems in thermodynamic systems such as gases, heat engines and refrigerators etc.
7. Study important examples of ideal Bose systems and Fermi systems

UNIT I

Laws of Thermodynamics: Some consequences of the laws of thermodynamics − Entropy − Calculation of entropy changes in reversible processes. The principle of increase of entropy − Thermodynamic potentials − Ehthalpy, Helmholtz and the Gibbs functions − Phase transitions − The Clausius-Clayperon equation − Van der Waals equation of state.

UNIT II

Kinetic Theory: Distribution function and its evolution − Boltzmann transport equation and its validity − Boltzmann's H-theorem − Maxwell-Boltzmann distribution − Transport phenomena − Mean free path- Conservation laws − Hydrodynamics (No derivation).

UNIT III

Classical Statistical Mechanics: Maxwell Boltzmann distribution law: Evaluation of constants - Maxwell's law of distribution of velocities - Most probable speed, Average speed, Root mean square speed - Principle of equipartition of energy - Partition function - Condition for applicability of M.B statistics - Non degenerate and degenerate systems - Maxwell velocity distribution in a given direction - Total internal energy of an ideal gas - Molar heat capacity of a gas at constant volume – Entropy - Helmholtz free energy - Pressure and equation of state of an ideal gas - Limitation of M.B method.

UNIT IV

Quantum Statistical Mechanics: B.E energy distribution for energies in the range E to E + dE – Condition for B.E distribution to approach classical M.B distribution - Bose temperature - Bose Einstein condensation - Planck's law from B.E law - Fermi Dirac distribution law (no derivation) - FD law for the energies in the range E to E+dE – Fermi energy - Effect of temperature - Energy distribution curve - Free electron in a metal - Fermi temperature and Thermionic emission - Richardson Dushmann Equation - Comparison of MB,BE and FD statistics.

UNIT V

Applications of Quantum Statistical Mechanics: Ideal Bose gas : Photons − Black body and Planck radiation − Photons − Specific heat of solids − Liquid Helium.
Ideal Fermi gas : Properties − Degeneracy − Electron gas − Pauli paramagnetism
Ferromagnetism : Ising and Heisenberg models.

Suggested Books

1. Reif F., 2008, Fundamentals of Statistical and Thermal Physics, (Reprint), McGraw Hill International Edition, Singapore.
2. Gupta and Kumar, 1st edition, 1995, Elements of Statistical Mechanics, Pragati Prakashan, Meerut.
3. Huang K., 2nd edition, 2014, Statistical Mechanics, Wiley Eastern Limited, New Delhi
4. Agarwal B.K. and M. Eisner, 3rd edition, 2013, Statistical Mechanics, New age international Limited, New Delhi.
5. Sears N. and L. Salinger, 1989, Thermodynamics, 3rd Ed., Narosa Publishing House, New Delhi.
6. Greiner W., L. Neise and H. Stocker, 1st edition, 2007, Thermodynamics and Statistical Mechanics, Springer Verlag, New York.
7. Singh. K. and S.P. Singh 1st edition, 1984, Elements of Statistical Mechanics, S. Chand & Company Ltd., New Delhi.
8. https://ocw.mit.edu/courses/physics/8-333-statistical-mechanics-i-statistical-mechanics-of-particles-fall-2013/lecture-notes/
9. https://sites.krieger.jhu.edu/jared-kaplan/files/2018/11/StatisticalMechanicsNotes.pdf
10. https://www.thphys.uni-heidelberg.de/~amendola/statphys/statphys.pdf

15PHP104	MATHEMATICAL PHYSICS	L T P C 5 - - 5

Course Objectives

- It is necessary for a physics student to be familiar with different methods in mathematics.
- Give a basic idea about different methods of mathematics, used in Physics.
- To provide students with a repertoire of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering.
- In addition, intended to prepare the student with mathematical tools and techniques that are required in advanced courses offered in the applied physics
- To communicate mathematical and physical knowledge and ideas to the students.
- To learn the fundamentals and applications of Complex Variable, Analyticity, Cauchy-Riemann and Cauchy's Integral.
- To contribute innovations and application of basic research.
- To get knowledge to find the relationship between observation and theory and their use in building the basic concepts of computing.

Course Outcomes (COs)

1. Students will be able to apply integral transform (Fourier and Laplace) to solve mathematical problems of interest in physics, use Fourier transforms as an aid for analyzing experimental data.
2. Manipulating vectors as "atomic" entities without recourse to underlying coordinates
3. Sound grasp of the concept of a vector field
4. Ability to link this idea to descriptions various physical phenomena
5. Intuition of the physical meaning of the various vector calculus operators (div, grad, curl) Students can formulate and express a physical law in terms of tensors, and simplify it by use of coordinate transforms (example: principal axes of inertia).
6. Students will be able to solve some simple classical variation problems.

UNIT - I

Definition of vector space – Linear dependence – Linear independence – Basis – Dimension of a vector space – Representation of Vectors and linear operators with respect to basis – Schmidt orthogonalization process – Inner product.

Tensors : Transformation of coordinates – Summation convention – Contravariant Tensor – Covariant Tensor – Mixed Tensor – Rank of a Tensor – Kronecker delta symbol – symmetric and antisymmetric tensors – Invariant tensors.

UNIT - II

Functions of a complex variable – single and multivalued functions – Cauchy-Riemann differential equation – analytical – line integrals of complex function – Cauchy's integral theorem and integral formula – derivatives of an analytic function – Liouville's theorem - Taylor's series – Laurent's series - Residues and their evaluation - Cauchy's residue theorem – application to the evaluation of definite integrals.

UNIT - III

Fourier Transform – Properties of Fourier transform – Fourier transform of derivatives – Fourier sine and cosine transforms of derivatives – Fourier transform of functions of two or three variables – Finite Fourier transforms – Simple Applications of FT

Laplace transform – Properties of Laplace transforms – Laplace Transform of derivative of a function – Laplace transform of integral – Laplace transform of periodic functions - Inverse Laplace Transform – Fourier Mellin Theorem - Properties of inverse Laplace Transform – Convolution theorem – Evaluation of Laplace Transform using Convolution theorem.

UNIT - IV

Fourier series – Dirichlet's theorem – change of interval – complex form – Fourier series in the interval (0, T) – Uses of Fourier series - Legendre's polynomials and functions – Differential equations and solutions – Rodrigues formula – Orthogonality – relation between Legendre polynomial and their derivatives – recurrence relations – Lagurae Polynomials – recurrence relations

UNIT - V

Bessel's functions – differential equation and solution – generating functions – recurrence relations – Bessel function of second order – Spherical Bessel function -

Hermite differential equation and Hermite polynomials – Generating function of Hermite polynomials – Recurrence formulae for Hermite polynomials – Rodrigue's formula for Hermite Polynomials – Orthogonality of Hermite Polynomials – Dirac's Delta Function.

Suggested Book

1. Satya Prakash.,2002. Mathematical Physics , 4th edition, S.Chand & Co, New Delhi.
2. Gupta.B.D., 2002, .Mathematical Physics, 2nd edition, Vikas publishing company, New Delhi.
3. Singaravelu.V., 1995. Numerical methods, 2nd edition, Meenakshi publications, Sirkali.
4. Rajput.B.S., 2003. Mathematical Physics, 16th edition, Pragati Prakashan, Meerut.
5. Gupta. P.P., Yadav., and Malik.,1997. Mathematical Physics, Kedar Nath & Ram Nath, Meerut.
6. Venkataraman.M.K.,1999. Numerical methods in Science & Engineering, 5th edition, The National Publishing Company, Chennai.
7. Butkov, 1968, Mathematical Physics, Addison Wesley, New York
8. A.W. Joshi, 1995, Tensors and Matrices, 3rd Edition, Wiley Interscience, New York.
9. https://nptel.ac.in/courses/115/103/115103036/
10. https://www.physics.uu.se/digitalAssets/405/c_405910-l_1-k_notes_v3_0.pdf

Semester – I
L T P C
15PHP105 CLASSICAL MECHANICS AND RELATIVITY 5 - - 5

Course objective

- Studying Classical Mechanics will gives an idea about how classical physics deal with matter and energy.
- Have a deep understanding of Newton's laws
- Be able to solve the Newton equations for simple configurations using various methods,
- To give an insight into the classical methods of physics.
- The emphasis of the course is on applications in solving problems of interest to physicists.
- Students are to be examined on the basis of problems, seen and unseen.
- To demonstrate knowledge and understanding of the following fundamental concepts in the dynamics of system of particles, motion of rigid body, Lagrangian and Hamiltonian formulation of mechanics.
- To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.
- To develop math skills as applied to physics.
- They will use critical thinking skills to formulate and solve quantitative problems in applied physics.

Course Outcomes (Cos)

- Students can understand the classical laws of motion.
- Competency in using the essential mathematical skills needed for describing mechanics and special relativity
- Understanding of significance of conservation of various physical quantities to discuss the motion of dynamical system.
- Understanding of constraints and their significance to solve the equations of motion of the dynamical system.
- Understanding of necessity of Lagrangian and Hamiltonian formulations for simplified treatments of many complex problems in classical mechanics.
- They can develop problem solving skills.

UNIT - I

Conservation laws: Mechanics of a system of particles – Conservation laws: linear momentum, angular momentum, energy – Constraints, Degrees of freedom – Generalised co-ordinates – Generalized notations – Brachistocrone problems – Atwood's machine.

Hamilton's variational principle – Lagrange's equation of motion from Hamilton's principle, D'Alembert's principle – Applications of Lagrange's equation of motion – Linear harmonic oscillator – Simple pendulum – particle moving under a central force – particle moving on the surface of earth, cylinder rolling on inclined plane, electric circuit – Superiority of Langrange's approach over Newtonian's approach.

UNIT – II

Phase space: Hamiltonian – Hamilton's canonical equations of motion – Physical significance of H – Advantage of Hamiltonian approach – Hamilton's canonical equation of motion in different coordinate systems – Hamilton-Jacobi method – Kepler's problem solution by Hamilton-Jacobi method – Action and angle variables – Solution of Harmonic oscillator by action angle variable method – canonical or contact transformation – Condition for a transformation to be canonical.

Poisson brackets – Invariance of Poisson brackets with respect to canonical transformation – Equations of motion in Poisson bracket form – Lagrange's bracket – Relation between Lagrange and Poisson brackets

UNIT – III

General features of central force motion – General features of orbits – Centre of mass and laboratory coordinates – Virial theorem – Stable and unstable equilibrium – Properties of T, V and ω for small oscillations – Normal coordinates and normal frequencies of vibrations – Parallel pendula – Double, Triple pendula – Linear triatomic molecule.

Generalized coordinates for rigid body motion – Euler's angles – Angular velocity, momentum of rigid body – moment and products of inertia – Principal axis transformation – rotational kinetic energy of a rigid body – Moment of inertia of a rigid body – motion of a symmetric top under action of gravity.

UNIT - IV

Special Theory of Relativity: Introduction – Galilean transformation and invariance of Newton's laws of motion – Non variance of Maxwell's equations – Michelson Morley experiment and explanation of the null result.

Concept of inertial frame – Postulates of special theory – simultaneity – Lorentz transformation along one of the axes – length contraction – time dilatation and velocity addition theorem – Fizeau's experiment – Four vectors – Relativistic dynamics – Variation of mass with velocity – Energy momentum relationship.

UNIT - V

General theory of Relativity: Introduction – Limitation of special theory of relativity and need for a relativity theory in non-inertial frames of reference. Concept of gravitational and inertial mass and the basic postulate of GTR, gravitation & acceleration and their relation to non-inertial frames of reference – principle of equivalence of principle of general co-variance – Minkowski space and Lorentz transformation.

Suggested Book

1. Goldstein.H.A. 2000, Classical Mechanics, 2nd Edition, Wesley Publishing Company, London.
2. Gupta. S. L., V.Kumar and H.V.Sharma, 2008, Classical Mechanics, 19th Edition, Pragati Prakashan, Meerut.
3. Banerji Sriranjan and Asit Banerjee, 2nd Edition 2013, The Special Theory of Relativity, Printice-Hall of India, New Delhi
4. Aruldhas G.,1st edition, 2008, Classical Mechanics, Printice Hall of India, New Delhi

5. Sardesai D.L., 1st edition, 2004, A Primer of Special Relativity, New Age International Publishers, New Delhi
6. Hartle B. James, 1st edition ,2009, Gravity, An Introduction to Einstein's General Relativity, Dorling Kindersley (India) Pvt. Ltd., Delhi.
7. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press
8. https://ocw.mit.edu/courses/physics/8-09-classical-mechanics-iii-fall-2014/lecture-notes/
9. https://ocw.mit.edu/courses/physics/8-01l-physics-i-classical-mechanics-fall-2005/lecture-notes/
10. https://iopscience.iop.org/book/978-0-7503-1398-8

Semester – I

L T P C

15PHP111 PHYSICS PRACTICALS - I - - 5 3

Course Objective

- To gain practical knowledge by applying the experimental methods to correlate with the Physics theory.
- To learn the usage of optical systems for various measurements.
- Apply the analytical techniques and graphical analysis to the experimental data.
- To develop intellectual communication skills and discuss the basic principles of scientific concepts in a group.
- To experience the practical difficulties to find the physical constant values.
- To apply the theoretical knowledge into the experiments and find the solutions.
- Students will be observe the readings practically.
- Students will experience the phenomena of reflection, refraction, etc.,

Course Outcomes (COs)

1. The course is designed to train the students so that they can efficiently handle various instruments.
2. Students will verify laws studied in the different theory course.
3. Students will measure different properties of materials.
4. Capable to classify the materials with the properties
5. Will overcome the fear of experimental skill
6. Capable to built his own equipments for measuring the properties of materials

ANY TWELVE EXPERIMENTS

1. Viscosity of liquid – Mayer's oscillating disc method.
2. Michelson Interferometer – Determination of λ and dλ.
3. 'e/m' by Thomson's method and Magnetron method.
4. Fresnel's biprism - Determination of Wavelength of monochromatic source.
5. Determination of Plank's constant using Photo cell.
6. Forbe's method – Thermal conductivity.
7. 'e' by Millikan's method.
8. Ferguson's method - Specific heat of a liquid.
9. Faraday effect – Determination of Verdet constant using He-Ne laser.
10. Young's Double slit – Determination of Wavelength of monochromatic source.
11. Regulated dual power supply construction.
12. Astable, monostable and bistable multi-vibrators, using discrete components.

13. Analog computer setup – Solving simultaneous equations.

14. UJT characteristics and relaxation oscillator.

15. FET characteristics and Source follower

Suggested Book

1. Ouseph C.C., U.J. Rao and V. Vijayendran 2007, Practical Physics and Electronics, S.Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai
2. Singh S.P., 2003, Advanced Practical Physics – 1, 13th Edition, Pragathi Prakashan, Meerut
3. Singh S.P., 2000, Advanced Practical Physics – 2, 12th Edition, Pragathi Prakashan, Meerut
4. Gupta S.L. and V.Kumar, 2002, Practical Physics, 25th Edition, Pragathi Prakashan, Meerut

Semester – II
L T P C

15PHP201	QUANTUM MECHANICS - I	6 - - 6

Course Objectives

- Quantum mechanics is the most important branch of physics, as it has got application in any other branch of physics.
- It has revolutionized the whole science, important for any physics student to know the basics of quantum mechanics.
- This paper gives an idea about the development of quantum mechanics.
- This paper explains the shortcomings of quantum mechanics in explaining different subatomic physics and the evolution of quantum mechanics.
- This course is part one of a two semester course focused on a rigorous exposition to the principles of Quantum mechanics.
- The Dirac bra-ket formalism will be introduced and used throughout to present the principles of Quantum Mechanics in a general context.
- We will discuss analytic solutions to the Schriodinger equation for a variety of potentials in one, two and three dimensions.
- The role of symmetries as the underlying principle of Quantum Mechanics will be emphasized throughout the course.
- The use of symmetry principles and operators methods will be discussed.

Course Outcomes (COs)

After the completion of course, students should be able to understand and grasp

1. The basic concepts of quantum mechanics including the solution of wave equation, interpretation of dynamical variables and applying wave mechanics to various situations in terms of boundary value problems so as to understand the quantum well, barriers and particle motion in different types of force field (potentials).
2. Applying special functions as the solutions of differential equation as the wave function/state functions and understanding the physical situations where these can be applied.
3. Calculating states of electrons in hydrogen atom and harmonic oscillators and the interpretation of quantum states.
4. Applying the stationary perturbation problems to various problems including particle states splitting in electric and magnetic field.
5. interpret the wave function and apply operators to it, to obtain information about a particle's physical properties such as position, momentum and energy
6. Be able to solve the Schroedinger equation to obtain wave functions for some basic, physically important types of potential in one dimension, and estimate the shape of the wavefunction based on the shape of the potential

7. Be able to understand the role of uncertainty in quantum physics, and use the commutation relations of operators to determine whether or not two physical properties can be simultaneously measured

UNIT - I

Quantum Theory: Introduction – Limitation of classical physics – Origin of quantum theory – Planck's quantum hypothesis – Einstein's theory of Photoelectric effect –Bohr model of hydrogen atom – Inadequacy of quantum theory.

Wave Mechanics Matter waves – Uncertainty principle –Wave packet – Group and phase velocity – Time-dependent and Time-independent Schrodinger equations for a free particle and particle in a potential – Linear vector space – Hilbert's space – Orthogonal and orthonormal functions – Linear operator – Eigen functions and Eigen values – Hermitian operator – Dirac's notation – Equations of motion – Schrodinger, Heisenberg and Interaction representation.

UNIT - II

One dimensional potential well: Square-well potential with rigid walls – Square-well potential with finite walls – Square-well potential barrier – Alpha emission – Bloch waves in a periodic potential – Linear harmonic oscillator (Schrodinger method and operator method) – Free particle.

UNIT - III

Three dimensional potential Well: Particle moving in a spherically symmetric potential – System of two interacting particles – Rigid rotator – Hydrogen atom – Hydrogenic orbitals – The free particle – Three-dimensional square-well potential - Deutron

Matrix mechanics: Matrix representation of wave function – Matrix representation of operator – Properties of matrix elements – Schroedinger equation in matrix form – Eigen value problem – Unitary Transformations – Linear harmonic oscillator, Matrix method

UNIT - IV

Time-independent Perturbation theory: Basic concepts – Non-degenerate energy levels – First and Second order corrections for energy and wave functions – Ground state of Helium atom – Effect of electric field on the ground state of hydrogen atom (Stark effect) – Degenerate energy levels – Effect of electric field on the n=2 state of hydrogen atom

UNIT - V

Variational method &WKB Approximation: Variational principle – Variation method for excited states – Application of variation method to ground state of helium – The WKB method

Time dependent perturbation theory: Introduction – First-order perturbation – Harmonic perturbation – Transition to continuum states (Fermi's Golden rule) – Absorption and emission of radiation – Transition probability – Selection rules

Suggested Book

1. Aruldhas. G, 2009, Quantum Mechanics, 2nd Edition, Prentice-Hall of India, New Delhi.
2. Schiff Leonard, 1968, Quantum Mechanics, 3rd Edition, McGraw Hill International, Auckland

3. Gupta, Kumar and Sharma, 2002 – 2003, Quantum Mechanics, 22nd Edition, Jai Prakash Nath & Co, Meerut.
4. Satya Prakash, New Edition, 2003, Quantum Mechanics, Kedar Nath & Ram Nath & Co, Meerut.
5. Engen Merzbacher, 1997, Quantum Mechanics, 3rd Edition, Wiley, Weinheim
6. Mathews. P.M. and K. Venkatesan, 2nd Edition, 2013, Textbooks of Quantum Mechanics, McGraw Hill International, Weinheim.
7. Chatwal R.G. and Sk. Anand, 4th edition, 2004, Quantum Mechanics, Himalaya Publishing House, New Delhi
8. Thangappan. V. K., 2nd Edition,1993, Quantum Mechanics, Tata McGraw Hill, New Delhi
9. http://wcchew.ece.illinois.edu/chew/course/QMALL20121005.pdf
10. https://ocw.mit.edu/courses/physics/8-04-quantum-physics-i-spring-2016/lecture-notes/
11. http://pages.physics.cornell.edu/~ajd268/Notes/QM-Notes.pdf
12. http://stanford.edu/~oas/SI/QM/papers/QMGreensite.pdf
13. https://www.ks.uiuc.edu/Services/Class/PHYS480/qm_PDF/QM_Book.pdf

Semester – II
L T P C

15PHP202 **NUCLEAR PHYSICS** **6 - - 6**

Course Objectives

- Nuclear physics is one of the fundamental subjects of physics. It is important to know about the physics of nuclei and the different energies involved in the nuclear processes.
- The aim is to tell them about the stability of nucleus and various other properties.
- The students will learn about various types of radiations and their interaction with matter.
- Nuclear energy is one of the major sources of energy, which, with proper careful usage, can solve the energy crisis to a large extent.
- This paper is intended to give an insight into the different nuclear processes and the fundamental particles, which are the real building blocks of the universe.
- To understand the operation of G.M. counter.
- To study the general properties of nucleus, nuclear forces and nuclear reactions.
- To analyse the B-H curve and their concepts practically.
- To introduce the concept of elementary particles practically.

Course Outcomes (COs)

Students who have completed this course should

1. Understand the relation between the standard model and QCD
2. Understand the importance of models in describing the properties of nuclei and nuclear collisions
3. Be able to make quantitative estimates of phenomena involving nuclei.
4. Students understand the basic principle, type of accelerators, working and operation of Accelerators.
5. Students learn the basic of ion sources, beam transport and application of accelerator in different branches of science.
6. Training given to students and researchers of the Universities to handle such complicated machine.
7. Acquire knowledge in the content areas of nuclear and particle physics, focusing on concepts that are commonly used in this area.

UNIT - I

Nuclear mass and charge: Distribution of nuclear charge - Nuclear mass and binding energy of a nucleus – semi-empirical mass formula – Nature of nuclear force – form of nucleon-nucleon potential – charge independence and charge symmetry of nuclear forces - Bound states of two nucleons-Ground state of Deuterium - Wave mechanics of ground state of Deuterium-Spin states –Pauli's exclusion principle -Tensor force - Exchange force - Low energy Nucleon - Nucleon scattering

UNIT - II

Radioactivity:

Alpha decay: Properties of α particles - Velocity and energy of α particles - Gamow's theory of α particles- Geiger - Nuttall law- α ray energies and fine structure of α rays - α disintegration energy-Low range α particles

Beta decay: Properties of β particles - General features of β ray spectrum – Pauli's hypothesis - Fermi's theory of β particles - Forms of interaction and selection rules - Fermi's and Gamow teller transition

Gamma decay: The absorption of γ rays by matter - Interaction of γ rays with matter - Measurement of γ ray energies - Dumont bent crystal spectrometer method-internal conversion –Applications.

UNIT -III

Nuclear models: Liquid drop model - Bhor Wheeler theory of fission - Condition for spontaneous fission - Activation energy-Seaborg's expression

Shell model: Explanation for magic numbers - Prediction of shell model -Prediction of spin and parity - Nuclear statistics - Magnetic moment of nuclei - Schmidt lines-Nuclear isomerism

Collective model: Explanation of Quadrupole moments - Prediction of sign of electric quadrupole moments. Optical model: Nilsson model - Elementary ideas

UNIT - IV

Nuclear reactions: Nuclear fission and fusion - Kinds of reaction and conservation laws - energetics of nuclear reaction – Applications of Nuclear Energy – Nuclear Reactors - Isospin - Reaction cross section-Continuum theory of nuclear reaction - Resonance - Briet Wigner Dispersion formula - Stages of nuclear reaction - Statistical theory of nuclear reaction - Evaporation probability and cross section – Kinematics of stopping and pickup reaction - Surface reaction

UNIT -V

High energy physics : Types of interaction in nature-typical strengths and time-scales, conservation laws, charge-conjugation, Parity and Time reversal, CPT theorem, GellMann-Nishijima formula, intrinsic parity of pions, resonances, symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quarkconfinement, asymptotic freedom.

Suggested Books

1. Pandya. M.L. and R. P. S. Yadav, 2004, Elements of Nuclear Physics, 1st edition Kedar Nath Ram Nath, Meerut.
2. Dayal. D.C., 4th edition 1992, Nuclear Physics, Himalaya Publishing House, New Delhi.
3. Kenneth S.Karne, 1st edition, 1987, Introducing Nuclear Physics, John Wiley and Sons, New York.
4. Sharma. D.C 1992, Nuclear Physics, - K. Nath & Co, Meerut.

5. Bernard L. Cohen, 1st edition, 1978, Concept of Nuclear Physics, Tata Mc Graw Hill, New Delhi.
6. Devanathan V.,2nd edition, 2008, Nuclear Physics, Narosa Book Distributers Pvt. Ltd., New Delhi.
7. Kaplan Irving, 2002, Nuclear Physics, 2nd Edition, Narosa Book Distributers Pvt. Ltd., New Delhi.
8. https://www.springer.com/gp/physics/particle-nuclear-physics
9. https://iopscience.iop.org/book/978-0-7503-1140-3
10. https://www.wiley.com/en-us/Nuclear+and+Particle+Physics%3A+An+Introduction-p-9780470035474.

Semester – II

L T P C

15PHP203A **MATERIAL SCIENCE** **5 - - 5**

Course Objectives

- One of the main objectives of the course is to familiarize the students with the fundamental concepts of Materials Science and Engineering which will be used as background knowledge for the understanding of specialized courses in the field of Materials Science.
- Study of materials is always important, for any application, including fabrication of satellites.
- To introduce various methods available for characterizing the materials.
- The relationship between the properties, structure and processes of engineering materials is discussed
- The characterization of materials specifically addresses that portfolio with which researchers and educators must have working familiarity.
- This course provides the introduction to the field of materials science

Course Outcomes (COs)

1. The students are exposed with X-ray, thermal, microscopic, and electrical methods of characterization.
2. Understand and describe the fundamental principles behind the methods of characterization which are included in the curriculum
3. Analyze, interpret and present observations from the different methods.
4. Evaluate the uncertainty of observations and results from the different methods.
5. A thorough understanding of the history of materials science with basic understanding of metals, binary alloys, magnetic materials, dielectric materials and polymers
6. Concept of phase, phase diagram, phase boundaries, Invariant points and reactions leading to the understanding of the material synthesis and dependence of properties on thermodynamic parameters
7. Understanding nucleation, growth and phase transformation kinetics

UNIT - I

Nature of thin films: Deposition technology – Distribution of deposits – Resistance heating – Thermal evaporation – Flash evaporation.

Electron beam method – Cathodic sputtering – Glow discharge sputtering – Low pressure sputtering – Reactive sputtering – R. F. sputtering – Chemical and Physics vapour deposition – Chemical deposition.

Thickness Measurement Methods: Mass methods – Optical method – Photometric – Ellipsometry – Interferometry – Other methods – Substrate cleaning.

UNIT- II

Electron Diffraction Technique: Electron diffraction technique – High energy electron diffraction – Low energy electron diffraction – Electron microscopy – Scanning electron microscopy – X-ray photoelectron spectroscopy – Mass spectroscopy – Thermodynamics of nucleation – Nucleation theories – Film growth – Incorporation of defects, impurities etc. in film – Deposition parameters and grain size.

UNIT – III

Single Crystals: Significance of single crystals – Crystal growth techniques – The chemical physics of crystal growth – crystal growth phenomena – Nucleation – Gibbs Thomson equation – for vapour – for solution – Spherical nucleus – Heterogeneous nucleation – Cap shaped nucleus – Disc shaped nucleus –Characterisation techniques – XRD spectra and Analysis.

UNIT IV

Singular and rough faces: Models on surface roughness – The Kossel, Stranski, Volmer (KSV) theory – The Burton, Cabrera and Frank (BCF) theory – BCF theory of solution growth – Periodic Bond chain theory – the Muller – Krumbhaar Model.

The Bridgman and related techniques – Crystal pulling techniques – Convection in melts – Modeling and simulation of bulk crystal growth considering melt dynamics – Melt growth of oxide crystals for saw, piezo electric and non linear optical applications – Liquid encapsulated and Czochralski technique – Zone melting technique – Skull melting process – Heat exchanger method.

UNIT V

Nanotechnology: An introduction – Nanodevices – Carbon nanotubes – Types of Carbon Nanotubes: Single walled, Multiwalled, Torus – Properties: Hardness – Strength – Electrical – Thermal – Optical – Synthesis – Arc discharge – Laser Ablation.

Suggested Book

1. Goswami. A., , 1st edition 2014, Thin film fundamentals, New Age International Pvt Ltd, New Delhi.
2. Meissel. L.T and R. Glang., 1978, Hand book of thin film technology, Tata McGraw Hill, New Delhi.
3. Shalini Suri, , 1st edition 2006, Nano Technology: Basic Science to Emerging Technology, Aph Publishing Corporation.
4. Brice. J.C., , 1st edition, 1986, Crystal growth processes, John Wiley and Sons, New York.
5. Mark C. Hersam (2006), "MSE 376 Nanomaterials," https://nanohub.org/resources/1914.
6. https://nanohub.org/resources/7313.
7. https://ocw.mit.edu/courses/mechanical-engineering/2-674-micro-nano-engineering-laboratory-spring-2016/lecture-notes/MIT2_674S16_Lec7Nano.pdf
8. https://nptel.ac.in/courses/118/104/118104008/

Semester – II
L T P C

15PHP203B ASTRONOMY AND ASTROPHYSICS 5 - - 5

Course Objectives

- Astronomy and Astrophysics is a very fundamental subject in Physics.
- Includes study of the solar system, evolution of stars, different physical processes going on stellar bodies, life cycle of stars etc.
- Students will learn the composition and nature of the universe, from our own solar system, to stars and stellar evolution, interstellar matter, galaxies, and clusters of galaxies.
- Students will explore historic astronomy, some fundamental physics such as Newton's laws and the nature of light, and discuss how astronomers discover the nature of the universe.
- To understand the fundamental methodology of science, including scientific inquiry, data gathering, analysis, generating hypotheses, and testing predictions.
- To connect observations of the Universe with the fundamental laws and principles that govern the behavior of the physical world.

Course Outcomes (COs)

Students will have understanding of

1. Plan and engage in an independent and sustained critical investigation of a chosen research topic to generate new knowledge in an area of astronomy and astrophysics.
2. Systematically evaluate the relevant theory and concepts in astronomy and astrophysics,
3. The theory to appropriate methodologies and evidence and draw appropriate conclusions.
4. Demonstrate capacity for astronomy and astrophysics reasoning through analyzing, proving and explaining concepts from the chosen research area.
5. Identify important constellations – orient in space.
6. Describe the planets of the solar system and their properties.
7. Explore the objects that comprise the solar system, with focus on chemical and atmospheric composition and how these interact to determine the changing nature of planetary environments.

UNIT - I

Astrophysics:

Introduction - Astrophysics and Astronomy - Celestial coordinate systems (Sun-Earth system, Galactic Coordinate system)

UNIT - II

Stellar Structure and Evolution:

Star formation - Stellar Magnitudes - Classification of stars - H-D classification - Saha Equation of ionization - Hertzsprung-Russel (H-R) diagram - Gravitational energy - Virial theorem - Equations of stellar structure and evolution - Pre-main sequence evolution - Jeans criteria for star formation - fragmentation and adiabatic contraction - Evolution on the main sequence - Post main sequence evolution

UNIT - III

Nuclear Astrophysics:

Thermonuclear reactions in stars - pp chains and CNO cycle - Solar Neutrino problem - subsequent thermonuclear reactions - Helium burning and onwards - nucleosynthesis beyond iron - r- and s- processes

Stellar Objects & Stellar Explosions:

Qualitative discussions on: Galaxies – Nabulae – Quasars - Brown dwarfs - Red Giant Stars – Nova - Supernova.

UNIT - IV

Gravitational Collapse and relativistic Astrophysics:

Newtonian theory of stellar equilibrium - White Dwarfs - Electron degeneracy and equation of States - Chandrasekhar Limit - Mass-Radius relation of WD - Neutron Stars - Spherically symmetric distribution of perfect fluid in equilibrium - Tolman-Oppenheimer-Volkoff (TOF) equation – Mass - Radius relations of NS – Pulsars - Magnetars - Gamma ray bursts - Black holes - Collapse to a black hole (Oppenheimer and Snyder) - event horizon - singularity.

UNIT - V

Accretion disks:

Formation of Accretion Disks - Differentially rotation systems in Astrophysics - Disk dynamics - Steady Disks - Disk formation in close binary systems through mass transfer - Accretion onto compact objects.

Suggested Books

1. V.B.Bhatia, , 1st edition, 2001; Textbook of astronomy and astrophysics with elements of cosmology,Alpha science international.
2. K. D. Abhyankar, , 1st edition Astrophysics – Stars and Galaxies,University Press, 2001.
3. S.L.Shapiro and S.A.Teukolsky, , 1st edition Black Holes, White Dwarfs and Neutron Stars (John Wiley, 1983)
4. E.W.Kolb and M.S.Turner, , 1st edition, 2007, The Early Universe Sarth book house and distributers
5. J.V.Narlikar, , 3rd edition 2012 Introduction to Cosmology, Cambridge University Press.
6. A.K.Raychaudhuri, S.Banerji and A.Banerjee, General Relativity, Astrophysics and Cosmology – , 1st edition (Springer-Verla, 1992)

7. S. Banerji and A. Banerjee , General Relativity and Cosmology – , 1st edition (Elsevier, 2007)
8. https://jila.colorado.edu/~pja/astr3730/
9. https://www.slac.stanford.edu/econf/C0307073/papers/LNEA_complete.pdf

Semester – II

		L T P C
15PHP203C	**CRYSTAL GROWTH TECHNIQUES**	**5 - - 5**

Course Objectives

- Will give knowledge on Crystals and its applications in electronics, energetics etc.
- Gives the general characteristics of crystals, methods of preparation etc.
- To give an idea about historical importance of crystals, methods of preparation and characterization of crystals etc.
- This interdisciplinary course unifies various aspects of the recent progress in the physical, chemical and mineralogical materials science.
- This course will provide the basic knowledge of the oxide thin film deposition and the oxide single crystal growth.
- In the latter parts, the basic theory of the single crystal growth and various single crystal growth methods will be explained.

Course Outcomes (COs)

1. The student will learn about the crystal growth mechanisms and techniques.
2. Various thin films deposition techniques and thin film characterization techniques are also covered in the course.
3. Gain the knowledge about phonons and its importance in thermal physics
4. Acquire the theoretical concept behind electrical and thermal properties of metals
5. Understand the fundamental theories to describe the energy bands in metals
6. Gain the knowledge about Semiconductor Crystals and their properties
7. Have the basic understanding of the thin film deposition process through vapor phase.
8. Have the understandings of the thin film deposition by PVD process and CVD process.
9. Have a brief knowledge of the characterization method for the thin film.

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UNIT- I

Crystal Growth phenomena

The historical development of crystal growth – significance of single crystals - crystal growth techniques - the chemical physics of crystal growth - Theories of nucleation - Gibb's Thompson equation for vapour, melt and solution- energy of formation of spherical nucleus-heterogeneous nucleation - kinetics of crystal growth, singular and rough faces, KSV theory, BCF theory - periodic bond chain theory- The Muller- Krumbhaar model.

UNIT- II

Crystal Growth from Melt and Solution Growth

Growth from the melt - the Bridgmann technique – crystal pulling - Czochralski method-experimental set up - controlling parameters advantages and disadvantages.- convection in melts – liquid solid interface shape - crystal growth by zone melting - Verneuil flame fusion technique.

UNIT - III
Low temperature crystal growth
Low temperature solution growth - methods of crystallization - slow cooling - solvent evaporation, temperature gradient methods - crystal growth system - growth of KDP, ADP and KTP crystals - high temperature solution growth - gel growth.

UNIT - IV
Vapour Growth and Epitaxial Growth
Physical vapour deposition - chemical vapour transport – definition - fundamentals, criteria for transport, Specifications, STP, LTVTP & OTP - advantages and limitations of the technique, hydrothermal growth – design aspect of autoclave – growth of quartz, sapphire and garnet.
Advantages of epitaxial growth - epitaxial techniques - liquid phase epitaxy - vapour phase epitaxy - molecular beam epitaxy - chemical beam epitaxy and atomic layer epitaxy

UNIT - V
Materials for Semiconductor Devices
Semiconductor optoelectronic properties - band structure - absorption and recombination, semiconductor alloys - group III-V materials selection - binary compounds, ternary alloys - lattice mismatch - lattice mismatched ternary alloy structures - compositional grading, heteroepitaxial ternary alloy structure - Quaternary alloys - Semiconductor Devices - Laser diodes, light emitting diodes (LED) – photocathodes - microwave Field-Effect Transistors (FET).

Suggested Books:

1. R.A. Laudise, 1970, illustrated edi, The Growth of Single Crystal, Prentice Hall, NJ.
2. A.W. Vere,1987 edition, Crystal Growth: Principles and Progres, Springer press.
3. P.S. Raghavan and P.Ramasamy, 2000, Hard cover edition. Crystal Growth Processes and methods, KRU Publications.
4. F.C. Auluck, A Short course in Solid State Physics, Vol. I, Thomson Press India Ltd.
5. B.R. Pamplin, 2nd edition Crystal Growth, Pergamon, (1980)
6. Heinz K Henish, , 1st edition 1970, Crystal Growth in Gel, Dover Publication
7. Milton Ohring, The Materials Science of Thin Films, Academic Press (2002)
8. S. Wolf and R.N. Tauber, Silicon processing for the VLSI Era: Vol.1-Process Technology, Lattice Press (1999).
9. https://ocw.mit.edu/courses/chemistry/5-069-crystal-structure-analysis-spring-2010/lecture-notes/
10. http://xrayweb.chem.ou.edu/notes/xtalgrow.html

Semester – II
L T P C
15PHP203D **DIGITAL SIGNAL PROCESSING** **5 - - 5**

Course Objectives

- Digital processing of signals has an extensive range of applications, from the military to the medical, from entertainment to mass production.
- In many areas of application the advent of these specially designed DSP devices has started a revolution in engineering which will pervade most areas of modern life.
- To give idea about different classifications of signals, different methods of recording and processing.
- This paper is to give knowledge to students about the theory of signal processing and the different methods involved in it.
- Apply the principles of discrete-time signal analysis to perform various signal operations
- Apply the principles of z-transforms to finite difference equations.
- Apply the principles of Fourier transform analysis to describe the frequency characteristics of discrete-time signals and systems
- To understand the digital filters and their classifications based on the response, design and algorithm.

Course Outcomes (COs)

The students can able to

1. Determine the spectral coefficients and the Fourier series components of discrete-time signals.
2. Determine the frequency response and the z-transform of discrete-time systems.
3. Determine the discrete Fourier transform of discrete-time signals.
4. Calculate the outputs of discrete-time systems in response to inputs.
5. Understand the characteristics field effect transistors
6. Analyze the characteristics of oscillators and wave shaping circuits

UNIT - I
Introduction:
Signals and systems - Classification of signals - Concept of frequency in continuous time and discrete– time signals. Theory of A/D and D/A conversion - Sampling of analog signals - sampling theorem - Quantization of continuous amplitude signals - Quantization of sinusoidal signal - Coding of quantized – samples - Digital to analog conversion

UNIT - II

Discrete- time signals and systems:
Discrete - time linear time-invariant systems-Techniques of analysis of linear systems - Resolution of a discrete time signal into impulses - Response of LTI systems to arbitrary inputs : Convolution sum - Properties of convolution and the interconnection of LTI systems - Casual LTI systems Stability of LTI systems - Systems with finite duration and infinite duration impulse – response

UNIT - III
The Z-transform:
The Direct Z-Transform - The Inverse Z-Transform - Properties of Z-transform - Rational Z-transforms - Poles and zeros - Inversion of Z-transforms. The inverse Z-Transform by contour integration - Power series expansion - Partial fraction expansion – Decomposition of rational Z-transform – Analysis of linear time invariant systems in the Z-domain – one sided Z-Transform.

UNIT - IV
Frequency Analysis of Signals and Systems:
Frequency analysis of continuous - time signals. The Fourier Series for continuous Time Periodic Signals - Power Density Spectrum of Periodic Signals - The Fourier Transform of Continuous -Time Aperiodic Signals - Energy Density Spectrum of Aperiodic Signals - Frequency analysis of discrete time signals – The Fourier Series for discrete time Periodic Signals - Power Density Spectrum of Periodic Signals – Fourier transform for discrete time Aperiodic signal - Convergence of the Fourier Transform - Energy Density Spectrum of Aperiodic signals - Relationship of the Fourier Transform to the Z Transform.

UNIT - V
Discrete Fourier Transform:
Frequency domain sampling and reconstruction of discrete time signals – The Discrete Fourier transform – DFT as a linear transformation - Relationship of the DFT to the other transforms. Properties of DFT - Multiplication of two DFTs and Circular convolution - Linear filtering methods based on DFT - Frequency analysis of signals using the DFT – Discrete cosine transform - Computation of the Discrete Fourier Transform

Suggested Books
1. Oppenheim & Schafer, , 1st edition, Digital Signal Processing, Prentice Hall India – 1995
2. Paulo S.R. Piniz, Eduardo A.B. De Silva and Sergio Netto,2nd+ edition, 2010, Digital Signal Processing, Cambridge University Press
3. Rabiner & Gold, , 1st edition ,Theory and Applications of Digital Signal Processing, Prentice Hall India -1996.
4. Digital Signal Processing Video Prof. T.K. Basu IIT Kharagpur, http://nptel.iitm.ac.in/video.php?subjectId=10810505520.
5. Digital Signal Processing: Principles, Algorithms, and Applications by J. G. Proakis and D. G. Manolakis.
6. https://www.sciencedirect.com/book/9780750689762/digital-signal-processing.
7. https://www.dspguide.com/pdfbook.htm.

Semester – II
L T P C

15PHP203E **COMPUTATIONAL PHYSICS** **5 - - 5**

Course Objectives

- Computational physics may be broadly defined as 'the science of using computers to assist in the solution of physical problems, and to further physics research.
- Computers now play a role in almost every branch of physics like large scale
- Quantum mechanical calculations in nuclear, atomic, molecular and condensed matter physics, large scale calculations in such fields as hydrodynamics, astrophysics, plasma physics, meteorology and geophysics etc.
- The huge increase in the power of computers in recent years has made an impact on the role of computational physics.
- To use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanations.
- This paper gives idea about different types of computations involved in Physics, like curve fitting, interpolation, extrapolation, numerical calculations etc.

Course Outcomes (COs)

At the end of the course students should be able to:

1. The students programming tactics, numerical methods and their implementation like applying to problem in physics, including modeling of classical physics to quantum system as well as data analysis (Linear and non linear) will be improved.
2. Use analysis techniques for propagating error, representing data graphically. Create, solve and interpret basic mathematical tool.
3. independently program computers using leading-edge tools,
4. formulate and computationally solve a selection of problems in physics,
5. Use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanations.
6. Identify and describe the characteristics of various numerical methods.

UNIT - I
Curve Fitting

The least squares method for fitting a straight line, parabola, power and exponential curves with the help of principle of least square fit.

UNIT - II
Interpolation

Introduction to finite difference operators - Newton's forward and backward difference interpolation formulae - Lagrange's interpolation formula - Newton's divided difference formula with error term - interpolation in two dimensions - Cubic spline interpolation end conditions. Statistical tests - Ψ^2- test and T-test.

UNIT - III

Numerical Differentiation and Integration

Numerical differentiation - errors in numerical differentiation - cubic spline method - finding maxima and minima of a tabulated function - Integration of a function with Trapezoidal Rule - Simpson's 1/3 and 3/8 Rule and error 55 associated with each - Romberg's integration - Gaussian integration method - Monte Carlo evaluation of integrals - numerical double integration

Unit IV

Numerical Solution of Ordinary Differential Equations

Euler method - modified Euler method and Runge - Kutta 4th order methods - adaptive step size R-K method - predictor - corrector methods - Milne's method - Adam-Mouton method.

Numerical Solution of System of Equations

Gauss-Jordan elimination Method - Gauss-Seidel iteration method – Gauss elimination method and Gauss-Jordan method to find inverse of a matrix - Power method and Jacobi's method to solve eigenvalue problems.

Unit V

Numerical solutions of partial differential equations

Elementary ideas and basic concepts in finite difference method – Schmidt Method - Crank - Nicholson method - Weighted average implicit method - Concept of stability.

Suggested Books:

1. G. Shanker Rao, K. Keshava Reddy, Mathematical Methods, I.K. , 1st edition 2009, International Publishing House, Pvt. Ltd.
2. S.S. Sastry,5th edition 2013, Introductory Methods of Numerical Analysis, PHI Pvt. Ltd.
3. Tao Pang, , 1st edition , 1997.An Introduction to Computational Physics, Cambridge University Press.
4. Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010)
5. Schaum's Outline of Theory and Problems of Programming with Fortran, S Lipsdutz and A Poe, 1986Mc-Graw Hill Book Co.
6. Computational Physics: An Introduction, R. C. Verma, et al. New Age International Publishers, New Delhi(1999)
7. A first course in Numerical Methods, U.M. Ascher and C. Greif, 2012, PHI Learning
8. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
9. https://onlinecourses.nptel.ac.in/noc20_ph20/preview
10. https://iopscience.iop.org/book/978-1-6817-4896-2

Semester – II
L T P C

15PHP204A **THIN FILM PHYSICS** **5 - - 5**

Course Objectives

The objectives of this course are:

- Introduce physical concepts and mathematical tools used to describe surfaces, interfaces and thin films
- To develop an intuition for surface and thin film physical principles through plotting of functions using Maple
- Relate the mathematical results to practical applications and experiments Develop an appreciation of the mathematical basis for experimental techniques for deposition and analysis of thin films
- Understand physical phenomena that can be exploited for the deposition of thin films Demonstrate knowledge of different thin film deposition strategies.
- To analyse the behavior of the thin films by different characterization methods.
- To know the importance of use of thin films in application and research.

Course Outcomes (COs)

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

1. Discuss the differences and similarities between different vacuum based deposition techniques, evaluate and use models for nucleating and growth of thin films, asses the relation between deposition technique, film structure, and film properties, discuss typical thin film applications.
2. Motivate selection of deposition techniques for various applications.
3. The basic concepts about the thin film technology
4. The importance of use of thin films in application and research.
5. Acquire the knowledge of thin film preparation by various techniques.
6. Apply the knowledge to develop a device.

UNIT - I: Preparation of Thin Films

Spray pyrolytic process – characteristic feature of the spray pyrolytic process – ion plating – Vacuum evaporation – Evaporation theory – The construction and use of vapour sources – sputtering Methods of sputtering – Reactive sputtering – RF sputtering - DC planar magnetron sputtering.

UNIT - II: Thickness measurement and Nucleation and Growth in Thin Film

Thickness measurement: electrical methods – optical interference methods – multiple beam interferometry – Fizeau – FECO methods – Quartz crystal thickness monitor.
Theories of thin film nucleation – Four stages of film growth incorporation of defects during growth.

UNIT - III: Electrical properties of metallic thin films
Sources of resistivity in metallic conductors – sheet resistance - Temperature coefficient of resistance (TCR) – influence of thickness on resistivity – Hall effect and magneto resistance – Annealing – Agglomeration and oxidation.

UNIT - IV: Transport properties of semiconducting and insulating Films
Semiconducting films; Theoretical considerations - Experimental results – Photoconduction – Field effect thin films – transistors, Insulation films Dielectric properties – dielectric losses – Ohmic contracts – Metal – Insulator and Metal – metal contacts – DC and AC conduction mechanism .

UNIT - V: Optical properties of thin films and thin films solar cells
Thin films optics –Theory – Optical constants of thin films – Experimental techniques – Multilayer optical system – interference filers – Antireflection coating, thin films solar cells: Role, Progress, and production of thin solar cells – Photovoltaic parameter, thin film silicon (Poly crystalline) solar cells : current status of bulk silicon solar cells – Fabrication technology – Photo voltaic performance: Emerging solar cells: GaAs and $CulnSe_2$.

Suggested Book:

1. Meissel. L.T and R. Glang., 1978, Hand book of thin film technology, Tata McGraw Hill, New Delhi.
2. Anderson, J.C.1996 Ist edition The use of thin films in physical investigation, Academic press
3. Berry,Hall and Harris.1968,illustrated edition Thin films technology,Van Nostrand Reinhold publishing
4. Chopra, K.L. Ist edition1969 Thin film Phenomena, Mc Graw hill
5. Chopra, K.L. and Das, S.R Ist edition2013 Thin films solar cells.springer
6. George Hass and others (Ed). Physics of thin films, vol. 12.Academic press 1970
7. Holland, L Ist edition 1966. Vacuum deposition of thin films.Weily Publication
8. https://courses.lumenlearning.com/physics/chapter/27-7-thin-film-interference/
9. http://xrayweb.chem.ou.edu/notes/xtalgrow.html
10. https://www.dentonvacuum.com/what-is-thin-film-deposition/

Semester – II
L T P C
15PHP204B **NANOSTRUCTURE AND CHARACTERIZATION** **5 - - 4**

Course Objectives

- This course introduces the fundamentals of nano-scale engineering and manufacturing.
- Current and future applications of nanostructured materials will be reviewed with respect to their impact in commercial products and technologies.
- The main physical forces controlling the nucleation and deposition of nanostructures will be presented allowing a better understanding of key design factors at the nano-scale.
- Well-established and novel synthesis/fabrication methods nanostructures will be critically discussed giving a broad overview of the state-of-the-art nano manufacturing processes.
- The course will cover recent breakthroughs and assess the impact of this burgeoning field.
- Specific nanofabrication topics include epitaxy, beam lithographies, self- assembly, biocatalytic synthesis, atom optics, and scanning probe lithography.
- The course consists of topics in fundamental nanoscale science, plus an overview of areas in nanotechnology.

Course Outcomes (COs)
At the end of the course, Students will understand and:

1. Explain the fundamental principles of nanotechnology and their application to biomedical engineering.
2. Apply engineering and physics concepts to the nano-scale and non-continuum domain.
3. Identify and compare state-of-the-art nanofabrication methods and perform a critical analysis of the research literature.
4. Design processing conditions to engineer functional nanomaterials.
5. Evaluate current constraints, such as regulatory, ethical, political, social and economical, encountered when solving problems in living systems.
6. Evaluate current constraints, such as regulatory, ethical, political, social and economical, encountered when solving problems in living systems.
7. Motivate selection of deposition techniques for various applications

UNIT - I
Low Dimensional Structures

Preparation of quantum nanostructures - size and dimensionality effects - size effects - potential wells - partial confinement - conduction electrons and dimensionality - Fermi gas and density of states - properties dependent on density of states - excitons - single-electron tunneling - Aplications - infrared detectors - quantum dot lasers - superconductivity. Microelectromechanical Systems (MEMS) - Nanoelectromechanical Systems (NEMS) – Fabrication of nanodevices and nanomachines - Molecular and Supramolecular Switches.

UNIT - II
Carbon Nanostructures
Carbon Molecules - Nature of the Carbon Bond - New Carbon Structures - Carbon Clusters - Small Carbon Clusters - Carbon Nano tubes - Fabrication - Structure – Electrical Properties - Vibrational Properties – Mechanical Properties - Applications of Carbon Nano Tubes - Computers - Fuel Cells - Chemical Sensors - Catalysis – Mechanical Reinforcement - Field Emission and Shielding. Solid Disordered Nanostructures - Methods of Synthesis - Failure Mechanisms of Conventional Grain sized Materials – Mechanical Properties – Nano structured Multi layers -Electrical Properties – Porous Silicon - Metal Nano cluster - Composite Glasses.

UNIT - III
Thermal, Microscopic and Infrared Analysis
Thermal analysis – DTA, DSC and TGA – methodology of DTA, DSC and TGA and Instrumentation. Microscopy – Electron microscopy – Principles and instrumentation – resolution limit – scanning tunnelling microscopy – principles – scanning tunnelling microscope - SEM & TEM. Atomic force microscope

UNIT - IV
Instrumentation
IR spectrophotometers – Theory and Instrumentation- Applications. Fourier transform techniques – FTIR principles and instrumentation. Raman spectroscopy – Principles, Instrumentation and Applications. Microwave Spectroscopy -Instrumentation and Applications

UNIT - V
Mass Spectrometry, Resonance Spectroscopy
Mass Spectrometry - Principle – Instrumentation – Types of ions produced in a Mass spectrometer - Interpretation of Mass spectra – Applications. NMR – Principles and Instrumentation – Chemical shift - Spin-spin coupling - Applications of NMR - Electron spin resonance spectrometry – Theory of ESR –Instrumentation - Interpretation of ESR spectra - Applications.

Suggested Books:

1. Charles P. Poole, Jr. and Frank J. Owens, Ist edition 2003, Introduction to Nanotechnology,Wiley,
2. Cornelius T Leondes, MEMS/NEMS: micro electro mechanical systems/nano electromechanical systems Volume 1, Design Methods, Springer, (2006).

3. G. Chatwal & Sham Anand, 5th edition 2013Instrumental methods of Chemical Analysis, Himalaya
4. Norman D Colthup, Lawrence H Daly and Stephen E Wiberley, 3rd edition 1990 Introduction to Infrared and Raman spectroscopy, Academic press, NY.
5. H.H. Willard, L.L. Merrit, J.A.Dean & F.A. Settle,7th Instrumental methods of analysis, CBS Pub.
6. Mark C. Hersam (2006), "MSE 376 Nanomaterials," https://nanohub.org/resources/1914.
7. https://nanohub.org/resources/7313.
8. https://ocw.mit.edu/courses/mechanical-engineering/2-674-micro-nano-engineering-laboratory-spring-2016/lecture-notes/MIT2_674S16_Lec7Nano.pdf
9. https://nptel.ac.in/courses/118/104/118104008/

Semester – II
L T P C
15PHP204C **NONLINEAR DYNAMICS** **5 - - 4**

Course objective:

- It is an applied mathematics course designed to provide an introduction to the theory and basic concepts of Nonlinear Dynamics and Chaos.
- The course concentrates on simple models of dynamical systems, their relevance to natural phenomena.
- The main goal of the course is to introduce and describe nonlinear phenomena in physical systems by only using a minimum background in physics and mathematics.
- The computer exercises is mainly based on the use of MATLAB, but students will be free to use different software tools as desired.
- To make complex arguments that don't follow a pattern, and state the key components.
- Students will learn real-life examples illustrating the main ideas of the course (such as equilbria, stability, bifurcations)

Course Outcomes (COs)

At the end of the course, Students will understand and:

1. Students will be able to read a mathematical text and reproduce its main ideas.
2. Students will be able to make complex arguments that don't follow a pattern, and state the key components.
3. Will be able to give real-life examples illustrating the main ideas of the course (such as equilbria, stability, bifurcations)
4. Will be able to describe qualitatively the behaviour of the solution of a dynamical system without necessarily finding the exact solution.
5. Be able to prove existence of limit cycles using Poincar´e Bendixon.
6. Identify gradient fields and use their special properties to obtain phase portrait.

UNIT - I
Basic Concepts

What is Nonlinearity? Dynamical Systems: Linear and Nonlinear Systems - Linear Superposition Principle - Working Definition of Nonlinearity. Linear and Nonlinear Oscillators - Linear Oscillators and Predictability - Damped and Driven Nonlinear Oscillators - Forced Oscillations – Primary Resonance and Jump Phenomenon (Hysteresis) Secondary Resonances (subharmonic and superharmonic) Nonlinear Oscillations and Bifurcations

UNIT - II

Qualitative Features of non-linear systems

Autonomous and Nonautonomous Systems - Dynamical Systems as Coupled First-Order Differential Equations; Equilibrium Points ; Phase Space/Phase Plane and Phase Trajectories: Stability, Attractors and Repellers ; Classification of Equilibrium Points: Two-Dimensional Case - General Criteria for Stability; Limit Cycle Motion – Periodic Attractor- Poincar´e–Bendixson Theorem. Higher Dimensional Systems - Lorenz Equations ; More Complicated Attractors - Torus - Quasiperiodic Attractor - Poincar´e Map – Chaotic Attractor ; Dissipative and Conservative Systems -Hamiltonian Systems

UNIT - III

Chaos in Dissipative Systems

Bifurcations and Onset of Chaos in Dissipative Systems: Some Simple Bifurcations- Saddle-Node Bifurcation -The Pitchfork Bifurcation - Transcritical Bifurcation - Hopf Bifurcation ; Discrete Dynamical Systems ; The Logistic Map - Equilibrium Points and Their Stability – Periodic Solutions or Cycles -Period Doubling Phenomenon - Onset of Chaos – Lyapunov Exponent - Bifurcation Diagram - exact Solution at $a = 4$

UNIT - IV

Logistic Map: A Geometric Construction of the Dynamics – Cobweb Chaos in Dissipative Nonlinear Oscillators and Criteria for Chaos: Bifurcation Scenario in Duffing Oscillator - Period Doubling Route to Chaos - Intermittency Transition - Quasiperiodic Route to Chaos - Strange

Nonchaotic Attractors (SNAs) ; Lorenz Equations - Period Doubling Bifurcations and Chaos ; Necessary Conditions for Occurrence of Chaos - Continuous Time Dynamical Systems - Discrete Time Systems

UNIT - V

Chaos in Conservative Systems

Poincar´e Cross Section ; Possible Orbits in Conservative Systems – Regular Trajectories - Irregular Trajectories - Canonical Perturbation Theory: Overlapping Resonances and Chaos; H´enon–Heiles System – Equilibrium Points - Poincar´e Surface of Section of the System - Numerical Results; Periodically Driven Undamped Duffing Oscillator ; The Standard Map - 98

Linear Stability and Invariant Curves - Numerical Analysis: Regular and Chaotic Motions; Kolmogorov–Arnold–Moser Theorem (qualitative ideas only).

Suggested Books

1. M.Lakshmanan & S. Rajasekar, Ist edition 2003,Nonlinear dynamics: integrability, chaos, and patterns, Springer Verlag,
2. N. Kumar, Ist edition1999, Deterministic Chaos, Universities Press.
3. RC. Hilborn, 2nd edition2002, Chaos and Nonlinear Dynamics, Oxford UniversityPress.
4. G.L. Baker, and J.P. Gollub,2nd 1996 Chaotic Dynamics: An Introduction, CUP.
5. H.G. Schuster, 4th edition 2005 Deterministic Chaos, Wiley, N.Y.
6. Chaos : Introduction to dynamical systems by K. T. Alligood, T. D. Sauer and J. A. Yorke

7. https://ocw.mit.edu/courses/mathematics/18-385j-nonlinear-dynamics-and-chaos-fall-2004/lecture-notes/
8. https://ocw.mit.edu/courses/mathematics/18-385j-nonlinear-dynamics-and-chaos-fall-2004/lecture-notes/
9. https://www.ioc.ee/~dima/YFX1520/LectureNotes_1.pdf

Semester – II
L T P C
15PHP204D QUANTUM FIELD THEORY 5 - - 4

Course objective:

- The course gives an understanding of the Standard Model of particle physics, which describes the elementary particles and their interactions.
- To understand the basic concepts in quantum field theory and its importance in electromagnetic fields.
- Student will use effective field theory techniques to develop models at large scales
- Student will get knowledge on Path Integral Quantization of Gauge Fields and their applications.
- They can describe the origin of particles and forces.
- To apply Feynman rules to calculate probabilities for basic processes with particles.

Course Outcomes (COs)

Upon successful completion, students will have the knowledge and skills to:

1. Describe the reasons for the failure of relativistic quantum mechanics, such as the causality problem, and the need for quantum field theory
2. Describe the origin of particles and forces
3. Analyse the statistical distributions of identical particles and the repulsive/attractive nature of the forces as a function of spins
4. Apply Feynman rules to calculate probabilities for basic processes with particles (decay and scattering)
5. Obtain classical and/or non-relativistic limits of fully quantum and relativistic models, and identify the relativistic origin of effects such as the spin-orbit interaction
6. Use effective field theory techniques to develop models at large scales

UNIT - I
Path Integrals and Quantum Mechanics

Review of single particle relativistic wave equations – Klein- Gordon equation, Dirac equation, Maxwell and Proca equations; Path integral formulation of quantum mechanics; perturbation theory and the S matrix; Coulomb scattering; Functional calculus: differentiation, generating functional for scalar fields. Functional integration

UNIT - II
Path Integral Quantization of Scalar and Spinor Fields

Free particle Green's functions, Generating functional for interacting field; φ^4 theory – generating functional, 2-point function, 4-point function; generating functional for connected diagrams; fermions and functional methods, The S – matrix and reduction formula, pion-nucleon scattering amplitude, scattering cross-section

UNIT - III

Path Integral Quantization of Gauge Field Fields

Propagators and gauge conditions in QED; Non-abelian gauge fields and Faddeev - Popov method; Self-energy operator and vertex functions; Ward – Takahashi identities in QED, Becchi – Rouet – Stora transformations; Slavnov – Taylor identities.

UNIT - IV

The Weinberg – Salam Model

Field theory vacuum; the Goldstone theorem; Spontaneous symmetry breaking of gauge symmetries; superconductivity; Higgs boson; The Weinberg – Salam model; Experimental confirmation of the models

UNIT – V

The EPR Experiment And Bell's Thorem:

The EPR argument, The BKS theorem, The hidden variable theories, The Bell"s theorem and its proof, Tests of Bell"s inequalities, Alain Aspect"s experiments.

Suggested Books

1. Lewis H. Ryder,Quantum Field Theory, 2nd Edn, Cambridge University Press,(1996)
2. An Introduction To Quantum Field Theory (Frontiers in Physics) Hardcover – 2 October 1995, by Michael E. Peskin (Author), Daniel V. Schroeder.
3. https://plato.stanford.edu/entries/quantum-field-theory/#:~:text=Quantum%20Field%20Theory%20(QFT)%20is,matter%20physics%20and%20statistical%20mechanics.
4. https://www.damtp.cam.ac.uk/user/tong/qft/qft.pdf
5. https://web.physics.ucsb.edu/~mark/ms-qft-DRAFT.pdf
6. Quantum Field Theory, 2nd Edition, Ryder Lewis H.

Semester – II
L T P C
15PHP204E **OPTOELECTRONICS** **5 - - 5**

Course Objectives

- The aim of this course focuses to enable the students to understand optics and non-linear optics concepts in physics
- Optoelectronics is the science that deals with designing devices that can detect or emit light in any part of the spectrum.
- This paper gives an introduction to semiconductors and light.
- The application of optics in electronics, usage of optical waves in communications, optical fibers are explained in this paper.
- The term optoelectronics is a specific discipline of electronics that focuses on light-emitting or light-detecting devices.
- Optoelectronics is the communication between optics and electronics which includes the study, design and manufacture of a hardware device that converts electrical energy into light and light into energy through semiconductors.

Course Outcomes (COs)

1. The students are conversant with the application of optical properties and processes in semiconductor optical sources.
2. The students understand the operation of LEDs and lasers.
3. The students are familiar with the structures and performance of LEDs and lasers.
4. Apply the knowledge of laser in holography
5. Gain the knowledge in Fourier optics and Fourier transforming properties of lenses
6. Understand the concepts of nonlinear optics and harmonic generations.

UNIT - I

Semiconductor Science and Light Emitting Diodes

Semiconductor energy bands - semiconductor statistics – extrinsic semiconductors – compensation doping – degenerate and non degenerate semiconductors – energy band diagrams in applied field - direct and indirect bandgap semiconductors, - p-n junction principles - open circuit- forward and reverse bias – depletion layer capacitance – recombination life time – p-n junction band diagram - open circuit - forward and reverse bias – light emitting diodes – principles - device structures - LED materials, heterojunction high intensity LEDs – double heterostructure – LED characteristics and LEDs for optical fiber communications - surface and edge emitting LEDs.

UNIT - II

Fiber Optics

Symmetric planar dielectric slab waveguide – waveguide condition – single and multimode waveguides – TE and TM modes – modal and waveguide dispersion in the planar waveguide – dispersion diagram – intermodal dispersion – intramodal dispersion – dispersion in single mode fibers – material dispersion – waveguide dispersion – chromatic dispersion – profile and polarization dispersion – dispersion flattened fibers - bit rate and dispersion – optical and electrical bandwidth – graded index optical fiber - light absorption and scattering – attenuation in optical fibers.

UNIT - III

Laser Principles

Laser oscillation conditions - diode laser principles - heterostructure laser diode – double heterostructure – stripe geometry – buried heterostructure – gain and index guiding - laser diode characteristics – laser diode equation - single frequency solid state lasers – distributed feedback –quantum well lasers - vertical cavity surface emitting laser - optical laser amplifiers.

UNIT - IV

Photodetectors and Photovoltaics

Principle of p-n junction photodiode - Ramo’s theorem and external photocurrent - absorption coefficient and photodiode materials – quantum efficiency and responsivity - PIN-photodiode – avalanche photodiode – phototransistor - photoconductive detectors and photoconductive gain – noise in photo-detectors – noise in avalanche photodiode - solar energy spectrum - photovoltaic device principles – I-V characteristics - series resistance and equivalent circuit - temperature effects - solar cell materials, device and efficiencies

UNIT - V

Optoelectronic Modulators

Optical polarization, birefringence, retardation plates, electro-optic modulators – Pockels effect - longitudinal and transverse electro-optic modulators, Kerr effect, Magneto-optic effect, acousto-optic effect – Raman Nath and Bragg-types.

Non-linear optics

Wave propagation in an anisotropic crystal - polarization response of materials to light - second order non-linear optical processes – second harmonic generation - sum and frequency generation, optical parametric oscillation - third order non-linear optical processes - third harmonic generation - intensity dependent refractive index - self-focusing - non-linear optical materials, phase matching - angle tuning - saturable absorption - optical bistability - two photon absorption.

Suggested Books

1. Ajoy Ghatak & Thyagarajan 2nd edition,2013,Laser Fundementals and applications Laxmi Publications (P) Ltd
2. William T. Silfvast, Laser fundamentals, CUP 2nd Edn. 2009.
3. Pallab Bhattacharya, 2nd edition Semiconductor optoelectronic devices: Pearson(2008)

4. Jasprit Singh,1st edition2014 Optoelectronics: An introduction to materials and devices, Mc Graw Hill International Edn.
5. A.Yariv and P. Yeh,1st edition 2003 Optical waves in crystals: Propagation and Control of Laser Radiation, John Wiley and Sons Pub.
6. https://www.elprocus.com/optoelectronics-devices-with-their-applications/
7. https://www.allaboutcircuits.com/technical-articles/an-introduction-to-optoelectronics/
8. https://www.rp-photonics.com/optoelectronics.html

L T P C

15PHP211 **PHYSICS PRACTICALS - II** **5 - - 3**

Course Objective

- To gain practical knowledge by applying the experimental methods to correlate with the Physics theory.
- To learn the usage of optical systems for various measurements.
- Apply the analytical techniques and graphical analysis to the experimental data.
- To develop intellectual communication skills and discuss the basic principles of scientific concepts in a group.
- To make the students understand coherence between theoretical and practical measurement.
- The course as a whole outlines some ways of thinking about analog circuits that hopefully will help to develop intuition.
- To design, fabricate and test small electronic circuit.

Course Outcomes (COs)

1. The course is designed to train the students so that they can efficiently handle various instruments.
2. Students will verify laws studied in the different theory course.
3. Students will measure different properties of materials.
4. Gain the knowledge in quantization of electromagnetic fields.
5. Analyze the characteristics of oscillators and wave shaping circuits
6. Understand the basic concepts of amplifiers and operational amplifiers

ANY TWELVE EXPERIMENTS

1. Fabry – Perot interferometer – Determination of wavelength.
2. Arc spectra – Copper and Iron
3. Determination of V-I characteristics of a solar cell.
4. Susceptibility – Quinke's and Guoy's method
5. Hall Effect
6. Measurement of resistivity and conductivity of dielectric using Four-probe apparatus.
7. Compressibility of a liquid – Ultrasonic Interferometer, and verify with Ultrasonic Diffractometer
8. Determination of Stefan's constant.

9. Kelvin's double bridge – To measure low resistance.
10. Characteristics and an application of SCR
16. Schmidt trigger
17. Op – amp – V to I, I to V converter
18. Op-amp Log and Antilog amplifier.
19. Op – amp –Analog computation second order differential equation
20. Op – amp comparator – Zero crossing detector, Window detector, time marker

Suggested Books

1. Ouseph C.C., U.J. Rao and V. Vijayendran 2007, Practical Physics and Electronics, S.Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai
2. Singh S.P., 2003, Advanced Practical Physics – 1, 13th Edition, Pragathi Prakashan, Meerut
3. Singh S.P., 2000, Advanced Practical Physics – 2, 12th Edition, Pragathi Prakashan, Meerut
4. Gupta S.L. and V.Kumar, 2002, Practical Physics, 25th Edition, Pragathi Prakashan, Meerut

Semester III

L T P C

15PHP301 **QUANTUM MECHANICS – II** **5 - - 5**

Course Objectives

- The aim of this course is to make the students to understand the concepts of quantum physics and their applications in microscopic systems
- This is a continuation of Quantum Mechanics – I.
- More detailed study of problems like scattering problem, relativistic quantum mechanics, quantum electrodynamics etc, are added in this paper.
- To make the students capable of analyzing theoretical problems like interaction of particles, scattering of particles etc.
- to understand and evaluate modern research utilizing quantum theory in condensed matter, nuclear and particle physics.
- To know the basic knowledge on Eigen values and Eigen functions.

Course Outcomes (COs)

1. Students will get the knowledge of non-relativistic and relativistic quantum mechanics including time-dependent perturbation theory, scattering theory, relativistic wave equations, and second quantization.
2. Students will be able to understand concepts and to perform calculations of scattering of particles.
3. Students will be able to understand and evaluate modern research utilizing quantum theory in condensed matter, nuclear and particle physics.
4. Acquire the basic knowledge on eigen values and eigen functions
5. Apply the Schrodinger wave equation to get eigen values of bound systems Understand the matrix formulation in quantum mechanics
6. Acquire the basic knowledge on angular momentum of quantum mechanical systems

UNIT - I

Angular momentum: Angular momentum operators – Angular momentum commutation relations – Eigen values and Eigen functions of L^2 and L_z – General angular momentum – Eigen values of J^2 and J_z – Ladder operators (J_+ and J_-) – Angular momentum matrices – Matrices for J^2, J_z, J_+, J_-, J_x and J_y – Spin angular momentum – Spin ½ systems – Spin vectors for spin ½ systems – Addition of angular momentum – Clebsh-Gordan coefficients.

UNIT -II

Scattering: Scattering cross-section – Scattering amplitude – Partial waves – Scattering by a central potential: partial wave analysis – Significant number of partial waves – Scattering by an attractive square-well potential – Briet-Wigner formula – Scattering length – Expression for phase shift – Integral equation – The Born approximation – Scattering by screened coulomb potential – Validity of Born approximation - Laboratory and center of mass co-ordinate systems.

UNIT - III

Many Electron Problem: Indistinguishable particles, Pauli principle – Inclusion of spin – Spin functions for two electrons – Spin functions for three electrons – The Helium atom – Central field approximation – Thomas-Fermi model of the atom – Hartree equation – Hartree-Fock equation – Molecular orbital theory: Hydrogen molecule ion H_2^+- Valence bond theory – Heitler-London theory of hydrogen molecule.

UNIT - IV

Relativistic quantum mechanics: Klein-Gordan equation – Interpretation of the Klein-Gordan equation – Particle in a coulomb field – Dirac's equation for a free particle – Dirac matrices – Covariant form of Dirac equation – Probability density – Negative energy states – Spin of the Dirac particle – Magnetic moment of the electron – Spin-orbit interaction – Radial equation for an electron in a central potential – Hydrogen atom – Lamb shift.

UNIT - V

Field theory: Introduction – Classical approach to field theory – Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field – Field: Lagrangian and Hamiltonian formulations – Quantum equation for the field – Second quantisation – Quantisation of non-relativistic Schroedinger equation – Creation, annihilation and number operators.

Suggested Book

1. Aruldhas. G, 2008, Quantum Mechanics, 2nd Edition, Prentice-Hall of India, NewDelhi.
2. Gupta, Kumar and Sharma, 2002, Quantum Mechanics, 22nd Edition, Jai Prakash Nath & Co, Meerut.
3. Satya Prakash, 2003, Quantum Mechanics, New Edition Kedar Nath & Ram Nath & Co, Meerut.
4. Leonard Schiff, 1968, Quantum Mechanics, 3rd Edition, McGraw Hill International, Auckland.
5. Engen Merzbacher, 1997, Quantum Mechanics, 3rd Edition, Wiley, Weinheim.
6. Mathews. P.M. and K. Venkatesan, 2nd edition 2013, Textbook of Quantum Mechanics, McGraw Hill International, Weinheim.
7. Chatwal R.G. and Sk. Anand, 4th editin 2004, Quantum Mechanics, Himalaya Publishing House, New Delhi
8. Thangappan. V. K., 2nd edition 1993, Quantum Mechanics, Tata McGraw Hill, New Delhi
9. https://plato.stanford.edu/entries/quantum-field-theory/#:~:text=Quantum%20Field%20Theory%20(QFT)%20is,matter%20physics%20and%20statistical%20mechanics.
10. https://www.damtp.cam.ac.uk/user/tong/qft/qft.pdf
11. https://web.physics.ucsb.edu/~mark/ms-qft-DRAFT.pdf
12. Quantum Field Theory, 2nd Edition, Ryder Lewis H.

Semester III
L T P C

15PHP302 **LASER AND ITS APPLICATIONS** **5 - - 5**

Course Objectives

- Laser is a versatile tool with applications in almost all fields from medical to astronomy, communications, welding, cutting etc.
- This paper explains the characteristics of lasers, different types of lasers and their construction.
- Applications of lasers in different fields are also explained.
- To give exposure to students about the characteristics of different lasers, their fabrication techniques, applications etc.
- To classify fibers as single-mode, multimode step index and multi-mode graded index.
- To understand the concept of different type of lasers and their applications.

Course Outcomes (COs)

Students can understand

1. Acquire fundamentals and principles of Laser action CO2: Understand the basic concepts of different types of lasers
2. Absorption and spontaneous and stimulated emission in two level system, the effects of homogeneous and inhomogeneous line broadening, and the conditions for laser amplification.
3. operations and basic properties of the most common laser types, He-Ne, Argon-ion, and carbon-dioxide, ruby, titanium sapphire, neodymium YAG and glass, knowledge of other main laser types.
4. Classify fibers as single-mode, multimode step index and multi-mode graded index.
5. Describe modes in multimode fibers and mode field parameter in single-mode fibers.
6. They are able to explain the characteristics of lasers, different types of lasers and their construction.

Unit- I

Laser Characteristics: Spontaneous and stimulated emission, Einstein's quantum theory of radiation, theory of some optical processes, coherence and monochromacity, kinetics of optical absorption, line broadening mechanism, Basic principle of lasers, population inversion, laser pumping, two & three level laser systems, resonator, Q-factor, losses in cavity, threshold condition, quantum yield.

Unit – II

Laser Systems: Solid state lasers- the ruby laser, Nd:YAG laser, ND: Glass laser, semiconductor lasers – features of semiconductor lasers, intrinsic semiconductor lasers, Gas laser - neutral atom gas laser, He-Ne laser, molecular gas lasers, CO2 laser, Liquid lasers, dye lasers and chemical laser.

Unit-III

Advances in laser Physics : Production of giant pulse -Q-switching, giant pulse dynamics, laser amplifiers, mode locking and pulling, Non-linear optics, Harmonic generation, second harmonic generation, Phase matching, third harmonic generation, optical mixing, parametric generation and self-focusing of light.

Unit – IV

Multi-photon processes; multi-quantum photoelectric effect, Theory of two-photon process, three- photon process, second harmonic generation, parametric generation of light, Laser spectroscopy : Rayleigh and Raman scattering, Stimulated Raman effect, Hyper-Raman effect, Coherent anti-stokes Raman Scattering, Photo-acoustic Raman spectroscopy.

Unit – V

Laser Applications – ether drift and absolute rotation of the Earth, isotope separation, lasma, thermonuclear fusion, laser applications in chemistry, biology, astronomy, engineering and medicine. Communication by lasers: ranging, fiber Optics Communication, Optical fiber, numerical aperture, propagation of light in a medium with variable index, pulse dispersion.

Suggested Books:

1. Ajoy Ghatak & Thyagarajan 2nd edition,2013,Laser Fundementals and applications Laxmi Publications (P) Ltd
2. Laud, B.B.:1st Edition 1996 Lasers and nonlinear optics, New Age Int.Pub.
3. Thyagarajan, K and Ghatak, A.K.2nd Edition 1981: Lasers theory and applications Plenum press,
4. Ghatak, A.K.and Thyagarajan, K :2nd edition 1999 Optical electronics Cambridge Univ. Press
5. Seigman, A.E.: Lasers (Oxford Univ. Press 1986 New edition)
6. Maitland, A. and Dunn, M.H.1st edition 1969 : Laser Physics N.H.Amsterdam.
7. Hecht, 1st edition 1986 Laser Guide book McGraw Hill, NY.
8. Demtroder, W. : Laser Spectroscopy (Springe series in chemical physics vol.5, Springe verlag, Berlin, 1981).
9. Harper, P.G.and Wherrett B.S. (Ed.): Non-linear-optics (Acad.press, 1977).
10. https://www.rp-photonics.com/laser_applications.html
11. https://wiki.metropolia.fi/display/Physics/Laser+technology%2C+definition%2C+applications%2C+and+challenges#:~:text=Lasers%20are%20powerful%20beams%20of%20electromagnetic%20radiation.&text=Applications%20in%20Medical%20applications%2C%20welding,%2C%20barcode%20scanners%2C%20laser%20cooling.
12. https://www.physics-and-radio-electronics.com/physics/laser/applications oflasers.html

Semester III

L T P C

15PHP303 **SPECTROSCOPY** **5 - - 5**

Course Objectives

- This paper gives an insight into the theoretical and practical aspects of spectroscopy. it is used as a tool for non-destructive testing of samples. It is important to know the physical aspects of spectroscopy.
- The major objectives of this course are to integrate theory and practice and to bring together different branches of both Academic studies and Industrial Research through the presentation of critical aspects of modern Spectroscopy.
- The course will provide a valuable theoretical introduction and an overview of modern topics in spectroscopy, which are of current interest and importance in Semiconductor Industry and Biomedicine.
- To give an understanding of wide range of techniques including optical Nearfield spectroscopy, X-ray, Raman, and FTIR spectroscopy.
- To introduce optical spectroscopy methods that are widely used in physics, chemistry and biological sciences
- To teach the basic aspects of nuclear magnetic resonance (NMR) spectroscopy.

Course Outcomes

After successfully completed course, student will be able to

1. Student shows interest in the phenomenon of the interaction of light with matter in terms of the relationship with the molecular structure
2. Understand quantum chemical principles
3. Student will know the basic physical chemistry law that govern molecular spectroscopy
4. Student will know basic information on molecular methods (IR, Raman, UV-VIS, NMR, EPR)
5. Student will be able to select molecular spectroscopy methods suitable for solving given scientific problem
6. Student will be able to analyze results of measurements using molecular spectroscopy me

UNIT- I

Atomic spectra: Hydrogen spectra – Angular momentum – Larmor precession – Spin-orbit interactions - Spectra of alkali metals – Energy level and spectral transitions of Helium - Normal Zeeman effect – Anomalous Zeeman effect – Paschen back effect – Inference of nuclear spin - Hyperfine structure of spectral lines – Stark effect – Characteristic X-ray spectra

Microwave spectra: Classification of molecules – Interaction of radiation with rotating molecule – Rotational spectra of rigid diatomic molecule – Isotopic effect – Non-rigid rotator – Linear, symmetric and asymmetric top molecules – Quadrapole hyperfine interaction – Microwave spectrometer

UNIT- II

I.R spectroscopy: Practical aspects – Theory of I.R rotation vibration spectra of gaseous diatomic molecules – applications of I.R spectroscopy – Basic principles of F.T.I.R spectroscopy

Raman spectroscopy: Classical and Quantum theory of Raman effect - Rotation vibration Raman spectra of diatomic and polyatomic molecules – Applications - Laser Raman spectroscopy - Surface Enhanced Raman Scattering.

UNIT -III

Electronic spectra: Electronic excitation of diatomic species - Vibrational analysis of diatomic molecules - Deslandre's table - Intensity distribution Frank Condon principle - Rotational structure of electronic bands - Resonance and Normal Fluorescence – Intensities of transitions - Phosphorescence population of triplet state and intensity- Experimental methods - Applications of Fluorescence and phosphorescence.

UNIT- IV

NMR Spectroscopy: Quantum mechanical and Classical description - The Bloch equation - Relaxation process - the experimental technique - Principle and working of high resolution NMR Spectrometer - Chemical shift – Applications of NMR

NQR Spectroscopy: Fundamental requirements - General principle - Experimental detection of NQR frequencies – Interpretation and chemical explanation of NQR spectroscopy – Applications of NQR

UNIT - V

ESR Spectroscopy: Basic principles of ESR - Experiments – ESR spectrometer reflection cavity and microwave bridge – ESR spectrum hyperfine structure - Study of free radicals – Applications of ESR

MOSSBAUER Spectroscopy: The MossBauer effect- the recoilless emission and absorption of - Mossbauer spectrum – Experimental methods- Hyperfine interaction - Chemical Isomer Shift – Magnetic hyperfine and electric quadrupole interaction.

Suggested Books

1. Aruldhas. G., 2008, Molecular Structure and Spectroscopy, 2nd Edition, Prentice Hall of India, New Delhi
2. Straughan.B.P. and S. Walker, 1976, Spectroscopy: Volume 1, Chapman and Hall Ltd, London. (for Unit I)
3. Straughan.B.P. and S. Walker, 1976, Spectroscopy: Volumes 2 & 3, Chapman and Hall Ltd, London.
4. Collen N.Banwell, 4th edition 1994, Fundementals of Moelcular Spectroscopy, Tata McGraw Hill, New Delhi.
5. Chatwall and Anand, 2004, Atomic and Molecular Spectroscopy, 5th Edition, Himalaya Publishing House, New Delhi.

6. Gordon M Barrow,1962, Introduction to Molecular Spectroscopy, McGraw-Hill Inc.,US
7. https://nptel.ac.in/courses/104101099/
8. https://nptel.ac.in/courses/104102113/

Semester III

L T P C

15PHP304A DIGITAL ELECTRONICS AND MICROPROCESSOR 4 - - 4

Course Objectives

- This paper is intended to give an insight into the theory and applications of digital electronics, design of circuits with digital devices, details of microprocessor and its applications.
- The objective of this paper is to give information about different analog electronic circuits and their applications.
- To understand operation of semiconductor devices Digital electronics is very important in present day life due to its applications in almost all fields of life.
- Any signals stored in memory are first digitized.
- It is important to have knowledge about digital electronics.
- To implement mini projects based on concept of electronics circuit concepts.

Course Outcomes (Cos)

At the end of the course, Students can

1. Acquire the basic knowledge of digital logic levels and application of digital electronics circuits.
2. Perform the analysis and design of various digital electronic circuits.
3. Acquired knowledge about Microprocessors and its need.
4. Ability to identify basic architecture of different Microprocessors.
5. Foster ability to write the programming using 8085 microprocessor.
6. Foster ability to understand the internal architecture and interfacing of different peripheral devices with 8085 Microprocessor.

UNIT I

Flip Flops : SR, JK, JK Master Slave, T Flip flop & D Flip Flop (Symbol and Truth table)Registers (Types, shift operations) - Counters (Types, Designing of MOD 5 synchronous Counter, Construction and truth table - verification of MOD 16 Asynchronous UP, Down counter) - Multiplexer And demultiplexer (16:1 and 1:16 description and truth table verification) - Decoders and encoders (Definitions, Seven segment decoder, decimal to BCD encoder)

UNIT II

Special Function ICs: Timer IC 555 (Block diagram, pin description) , Application as Astable, monostable, bistable multivibrator - VCO IC 566 (Block diagram and pin description) - PLL IC 565 (Block diagram and pin description) - Fixed voltage Regulator ICs 7800 and 7900 series - Voltage Regulator IC 723 (description, designing for low and high voltage)

UNIT III

Microprocessor: Microprocessor Architecture, Pin out configuration of 8085-bus organization and timings –address bus, data bus, multiplexing address/data bus and control and status signal, Interrupts: maskable and non-maskable interrupt(concept),8085 interrupt.

UNIT IV

Programming Model of 8085 : Instruction set-Data transfer ,arithmetic, logical and branch instruction-Addressing modes -16 bit data transfer and memory related instructions-stack and subroutine instructions.

Simple Program: 8 bit addition-subtraction-multiplication- finding largest and smallest number, ascending and descending order, 16 bit addition,

UNIT V

Interfacing Peripherals and Applications: Interfacing concepts-peripheral I/O instructions-Interfacing programs- Data Converters, LED interfacing, stepper motor interfacing, Hex Keyboard Interfacing.

Text Book:

Ramesh Gaonkar,6th edition 2013 Microprocessor Architecture, Programming and Application with the 8085 ,Prenram international (P) Ltd.

Suggested Book

1. Floyd, 2003, Digital Fundamentals, 8th Edition, Pearson education, New Delhi.
2. Ramesh Gaonkar 6th edition 2013 Microprocessor Architecture, Programming and Applications with 8085 ,PENRAM International P Ltd
3. Malvino and Leach, 1983, Digital Principles and Applications, 3rd Edition, Tata McGrawHill, New Delhi.
4. Aditya P. Mathur, 1995, Introduction to Microprocessor, 3rd Edition, Tata McGrawHill, New Delhi.
5. Morris Mano. M, 1st 2002, Digital Logic and Computer Design, Prentice Hall, New Delhi.
6. Paul M.Julich and John Hilburn, 1st 1987, Microcomputers / Microprocessors, Prentice Hallof India, New Delhi.
7. Fundamentals of Digital Circuits, A. Anand Kumar, 2nd Edition, 2009, PHI Learning Pvt. Ltd.
8. OP-AMP & Linear Digital Circuits, R.A. Gayakwad, 2000, PHI Learning Pvt. Ltd.
9. https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/
10. https://circuitglobe.com/digital-instrument.html
11. http://ecoursesonline.iasri.res.in/mod/resource/view.php?id=147076.

Semester III

15PHP304B	PHYSICS OF MATERIALS	L	T	P	C
		4	-	-	4

Course Objectives

- This course discusses the properties of materials that engineers need to be aware of.
- This includes mechanical, thermal, electrical, chemical and optical properties.
- All these properties are controlled by the microscopic structure of these materials, and this course will cover the quantum mechanics, atomic physics and thermodynamics that control what materials can do.
- The course will focus on the structure and properties of crystalline materials and on how these properties can be manipulated to create more capable materials.
- To describe a polymer's elastic behavior above and below the glass transition.
- To valuate and select suitable materials for different practical applications;

Course Outcomes (Cos)

Upon successful completion, students will have the knowledge and skills to:

1. Describe the mechanical, electrical, thermal and optical properties of materials;
2. Analyse the importance of material properties for a wide variety of engineering situations;
3. Evaluate and select suitable materials for different practical applications;
4. Recall typical values of the properties of common practical materials;
5. Understand the micro-physics and chemistry responsible for material properties, and analyse how they can be modified.
6. Be able to describe a polymer's elastic behavior above and below the glass transition.

Unit I

Vacuum Technology: Basic ideas about vacuum, Throughput, Conductance, Vacuum pumps : rotary pump, diffusion pump, ion pump, molecular pump, cryopump, Vacuum gauges : pirani gauge, penning gauge, ionization gauge (hot cathode ionization gauge, cold cathode ionization gauge).

Unit II

Thin Film and growth process, Influence of nature of substrate and growth parameters (substrate temperature, thickness, deposition rate). Thin film deposition, techniques: thermal evaporation, chemical vapor deposition, spray pyrolysis, sputtering. Epitaxial growth, Thin film thickness measurement techniques: film resistance method, optical method, microbalance method.

Unit III

Polymers, Ceramics, Liquid Crystals and Nanophase Materials: Characteristics, Application and Processing of polymers : Polymerization, Polymer types, Stress- Strain behaviour, melting and glass transition, thermosets and thermoplasts. Characteristics, Application and Processing of Ceramics, glasses and refrectories, Liquid Crystals : classification and applications, Nanophase materials: synthesis and applications.

Unit IV

Synthesis of Nanomaterials: Introduction, particle size, particle shape, surface interaction of nanoparticles, DLVO theory, Classical nucleation theory for cluster formation. Physical methods: inert gas condensation, Chemical vapour deposition, sputtering , Arc discharge, PLD, mechanical milling, MBE, Electrodiposition, laser pyrolysis. Chemical methods: Introduction, Sol-gel process, Hydrothermal process, Solvothermal synthesis, Metal reduction method, Photochemical synthesis.

Unit V

Characterization of Materials

Powder and single crystal X-ray diffraction, Transmission electron microscopy, Scanning electron microscopy, Low Energy Electron Diffraction (LEED), Auger electron microscopy, Atomic force microscopy.

Suggested Books:

1. A. Roth 3rd edition 1990 Vacuum Technology: A. Roth-North Holland Pub. Co.
2. K.L. Chopra Reprint 1979 Thin Film Phernomeon-R E Kriegn Pub. Co.
3. K.L. Chopra 1st edition 1989 High Temperature Superconductors Subramanyam-Wiley,
4. W.D. Callister 6th edition 2002, WIE Material Science and Engg – Introduction Wiley.
5. J.C. Ying- 1st edition 2001 Nanostructured Materials: -Wiley-. Academic Press,
6. J.M. Walls 1st edition 1989, Methods of Surface Analysis- CUP Archive.
7. https://nptel.ac.in/courses/113/106/113106039/

Semester III

		L	T	P	C
15PHP304C	**REACTOR PHYSICS**	**4**	**-**	**-**	**4**

Course Objectives

- The aim of the basic course on "Reactor Physics for reactor operators" is to provide the reactor operators with a basic understanding of the main concepts relevant to nuclear reactors.
- Seen the education level of the participants, mathematical derivations are simplified and reduced to a minimum, but not completely eliminated.
- The goal is for the students to develop a basic knowledge of the methods employed in veterinary hospitals and clinics to protect employees and the veterinarians themselves against radiation exposure.
- Discuss the difference between a rotating anode and a fixed anode.
- Discuss which types of machines today have fixed and which have rotating anodes.

Course Outcomes (Cos)

Upon successful completion, students will have the knowledge and skills to:

1. express the basic concepts of nuclear physics.
2. an express the radioactive decays
3. able to express Successive Decays
4. explain nuclear reactions
5. explain nuclear fission
6. Understand the guiding principles of reactor safety and the lessons learned from past accidents.

Unit I

Interaction of Neutrons with Matter in Bulk Transport and diffusion equations, transport mean free path, solution of diffusion equation for a point source in an infinite medium and for an infinite plane source in a finite medium, extrapolation length and diffusion length - the albedo concept.

Unit II

Moderation of Neutron Mechanics of elastic scattering, average logarithmic energy decrement, slowing down power and moderating ratio of a medium. Fermi's age theory, solution of age equation for a point source of fast neutrons in an infinite medium, slowing down length, Fermi age.

Unit III

Theory of Homogeneous Bare Thermal Reactor Critical equation, material and geometric bucklings, Neutron balance in a thermal reactor, four factor formula, typical calculations of critical size and composition in simple cases.

Unit IV

Homogeneous Natural Uranium Reactors: Advantages and disadvantages of heterogeneous assemblies, various types of reactors and a brief discussion of their design features.

Unit V

Problems of Reactor Control and Maintenance Role of delayed neutrons, Inhour formula, temperature effects, fission product poisoning, use of coolants and control rods Power Reactors : Fast breeder reactors, dual purpose reactors, concept of fusion reactors.

Text Books

1. The elements of Nuclear reactor Theory: Glasstone & Edlund-Vam Nostrand,1st edition 1952.

2. Raymond L Murray 5th edition 2001 Nuclear energy – An introduction to concept systems and applications of nuclear process.

Semester III

L T P C

15PHP304D PLASMA PHYSICS 4 - - 4

Course Objectives

- Basic theory of plasma, its occurrence in nature, producing plasma experimentally, and their detection are explained in this paper.
- The course covers basic principles on plasmas, waves in plasma, stability analysis of the equilibrium solutions of the equations. Examples are taken from the phenomena in the Earth's ionosphere and magnetosphere.
- To make a simplified model for the Earth´s magnetosphere, and obtain analytical expressions for some characteristic quantitie
- To have a very good knowledge on formulating and modifying the basic dynamic fluid equations to account for the dynamics of plasma media at different levels: from MHD to kinetic scales.
- To describe the propagation of waves in plasmas, and derive the dispersion relation for these waves.

Course Outcomes (Cos)

Upon successful completion, students will:

1. understand and use the basic mathematical formalism needed for describing the dynamics of continuous media.
2. have a very good knowledge on mathematical models for plasma and will be able to distinguish the dynamics of plasmas and neutral fluid media.
3. have a very good knowledge on formulating and modifying the basic dynamic fluid equations to account for the dynamics of plasma media at different levels: from MHD to kinetic scales.
4. be able to describe the propagation of waves in plasmas, and derive the dispersion relation for these waves.
5. have good insight into plasma instabilities and turbulence.
6. be able to make a simplified model for the Earth´s magnetosphere, and obtain analytical expressions for some characteristic quantitie

Unit I

Basics of Plasmas: Plasma - Definition, concepts of plasma parameter, Debye shielding, Motion of charged particles in an electromagnetic field - Uniform electric and magnetic fields, Boltzmann and Vlasov equations, their moments - Fluid equations, Plasma oscillations, Enough exercises.

Unit II

Occurence of plasma in nature, definition of plasma, concept of temperature, Debye shielding and plasma parameter. Single particle motion in uniform E and B, nonuniform magnetic field, grid B and curvature drifts, invariance of magnetic moment and magnetic mirror. Simple application of plasmas.

Unit III

Plasma Waves: Plasma oscillations electron plasma waves, ion waves, electrostatic electron and ion oscillations perpendicular to magnetic field upper hybrid waves, lower hybrid waves, ion cyclotron waves. Light waves in plasma.

Unit IV

Boltzmann and Vlasov Equations: The fokker plank equation, integral expression for collision lern zeroth and first order moments, the single equation relaxation model for collision lern. Application kinetic theory to electron plasma waves, the physics of landau damping, elementary magnetic and inertial fusion concepts.

Unit V

Non-linear Plasma Theories: Non-linear Electrostatic Waves, K dV Equations, Non-linear Schrodinger Equation, Solitons, Shocks, Non-linear Landou Damping.

Suggested Books

1. Introduction to Plasma Physics and Controlled Fusion: F. F. Chen-Springer, 2nd edition 2007
2. An introductory course of Plasma Physics: R. O. Dendy-Cambridge University Press, 1st edition 1995.
3. Ideal Magnetohydrodynamics: J. P. Friedberg-Springer edition, 1st edition 1987
4. Fundamental of Plasma Physics: S. R. Seshadri-American Elsevier Pub. Co., 1st edition 1973.
5. https://ocw.mit.edu/courses/nuclear-engineering/22-611j-introduction-to-plasma-physics-i-fall-2003/lecture-notes/
6. http://www.physics.purdue.edu/~lyutikov/phys670/Gedalinplasma.pdf

Semester III

15PHP304E	GEOPHYSICS	L T P C
		4 - - 4

Course Objectives

- Geophysics is to expose students to a broad spectrum of geophysics, including resource exploration, environmental geophysics, seismology, and tectonics.
- Students in the major obtain a solid foundation in the essentials of mathematics, physics, and geology.
- To build upon that foundation with advanced course work in geophysics to develop the in-depth knowledge they need to pursue advanced graduate study and professional careers in government or the private sector.
- To demonstrate the ability to make observations using a variety of geophysical instruments and laboratory experiments and to reduce, model, and interpret their data and uncertainties
- To know the principles of geophysical measurements with physics-based mathematical models.
- Students will prepare for the research, analyze, and synthesize solutions to an original and contemporary geophysics problem

Course Outcomes (Cos)

Upon successful completion, the students can able

1. demonstrate a fundamental understanding of the physical processes governing the structure and evolution of Earth and planetary systems, including geophysical fluids, environmental hazards, and energy and freshwater resources.
2. demonstrate the ability to quantitatively describe the behavior of natural systems
3. ability to know the principles of geophysical measurements with physics-based mathematical models.
4. demonstrate the ability to make observations using a variety of geophysical instruments and laboratory experiments and to reduce, model, and interpret their data and uncertainties
5. demonstrate the ability to effectively communicate original scientific results as was as evaluate the published and presented results of others.
6. research, analyze, and synthesize solutions to an original and contemporary geophysics problem

Unit I:

The earth as a planet; different motions of the earth; gravity field of the earth, Clairaut's theorem, size and shape of earth; geochronology; seismology and interior of the earth; variation of density, velocity, pressure, temperature, electrical and magnetic properties of the earth; earthquakes-causes and measurements, magnitude and intensity, focal mechanisms, earthquake quantification, source characteristics, seismotectonics and seismic hazards; digital seismographs, geomagnetic field, paleomagnetism; oceanic and continental lithosphere; plate tectonics.

Unit II
Scalar and vector potential fields; Laplace, Maxwell and Helmholtz equations for solution of different types of boundary value problems in Cartesian, cylindrical and spherical polar coordinates; Green's theorem; Image theory; integral equations in potential theory; Eikonal equation and Ray theory. Basic concepts of forward and inverse problems of geophysics, Illposedness of inverse problems.

Unit III
'G' and 'g' units of measurement, absolute and relative gravity measurements; Land, airborne, shipborne and bore-hole gravity surveys; various corrections in gravity data reduction – free air, Bouguer and isostatic anomalies; density estimates of rocks; regional and residual gravity separation; principle of equivalent stratum; upward and downward continuation; wavelength filtering; preparation and analysis of gravity maps; gravity anomalies and their interpretation – anomalies due to geometrical and irregular shaped bodies, depth rules, calculation of mass.

Unit IV
Earth's magnetic field – elements, origin and units of measurement, magnetic susceptibility of rocks and measurements, magnetometers, Land, airborne and marine magnetic surveys, corrections, preparation of magnetic maps, upward and downward continuation, magnetic anomalies-geometrical shaped bodies, depth estimates, Image processing concepts in processing of magnetic anomaly maps; Interpretation of processed magnetic anomaly data.

Unit V
Conduction of electricity through rocks, electrical conductivities of metals, non-metals, rock forming minerals and different rocks, concepts of D.C. resistivity measurement, various electrode configurations for resistivity sounding and profiling, application of filter theory, Typecurves over multi-layered structures, Dar-Zarrouck parameters, reduction of layers, coefficient of anisotropy, interpretation of resistivity field data, equivalence and suppression, self potential and its origin, field measurement, Induced polarization, time and frequency domain IP measurements; interpretation and applications of IP, ground-water exploration, environmental and engineering applications.

Suggested Books

1. William Lowrie, Fundamentals of Geophysics, II Edition, Cambridge University Press, 2007,
1. Telford W.M., L.P.Geldart and R.E.Sheriff, Applied Geophysics, Cambridge University Press, 2008.
2. Stacey, F. D. Physics of the Earth. 3rd ed. Brisbane, Australia: Brookfield Press, 1992. ISBN: 9780646090917.

3. Turcotte, Donald L., and Gerald Schubert. Geodynamics. 2nd ed. Cambridge, UK: Cambridge University Press, 2001. ISBN: 9780521666244.
4. Merrill, Ronald T., et al. The Magnetic Field of the Earth. Burlington, MA: Academic Press, September 15, 1998. ISBN: 9780124912465.
5. https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-201-essentials-of-geophysics-fall-2004/lecture-notes/
6. https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-201-essentials-of-geophysics-fall-2004/
7. http://www.geology.cz/projekt681900/english/learning-resources/Geophysics_lecture_notes.pdf

Semester III

		L	T	P	C
15PHP305A	**SOLAR ENERGY AND ITS UTILIZATION**	**4**	**-**	**-**	**4**

Course Objectives

- Solar energy harvesting and utilizing for day to day purposes has become order of the day.
- The scarcity and increasing need of the fossil fuel has made man to think about alternate sources, the easiest and best being Solar energy.
- To introduce the students to the world of solar energy, its different uses, the different methods of harvesting solar energy.
- To understand the basic concepts of energies produced from various energy sources, advantages and disadvantages.
- To apply systems concepts and methodologies to analyze and understand interactions between social and environmental processes.
- To motivate public to participate in environment protection and improvement.

Course Outcomes (COs)

Students can be able to

1. Impart the knowledge of Storage technologies form the autonomous renewable energy sources.
2. Explain the principles that underlie the ability of various natural phenomena to deliver solar energy.
3. Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.
4. Understand the basic principles in wind energy conversion and advantage and disadvantage of wind energy conversion systems.
5. Gain the knowledge about the energy produced from biomass and biogas.
6. Understand the concepts of solar cell and solar energy

Unit -1

Introduction to Energy Sources : World Energy Features, Indian Energy Scene, Conventional and non-conventional energy sources, Prospects of renewable energy sources.
Solar Energy Source: Introduction, Solar constant, radiation on Earth's surface, Radiation geometry, Radiation measurements, Radiation data, Average solar radiation, radiation on tilted surfaces

Unit – II

Solar Energy collectors : Principle of conversion of energy, Flat plate collector, Transmissivity of cover system, Collector energy balance equation, Thermal Analysis of FPC, Useful heat gain, Focusing collectors, advantages and disadvantages, Factors affecting collector performance.

Application of Solar Energy: Solar Water Heating, Heating and Cooling of Buildings, Thermo electric conversion, Power generation, PV cells, Solar distillation, Pumping, Cooking, Hydrogen production.

Unit – III

Wind Energy: Principle of energy conversion, Power generation, Forces on blades, energy estimation, Wind data, Components of WECS, Classification of WECS, Advantages and Disadvantages, Types of Wind machines, Performance of Wind machines, Applications of wind energy. Problems

Energy from Biomass: Conversion technology, Factors affecting gas generation, classification of biogas plants, Advantages and disadvantages of different types of plants.

Unit – IV

Fuel Cells: Design and Principle of operation, Classification, Types, Advantages and disadvantages, Conversion efficiency, Types of electrodes, Work output and EMF of Fuel Cells, Applications of Fuel Cells.

Thermo Nuclear Fusion Energy: Fusion Reactions, Requirements, Plasma, Magnetic and Inertial Confinement fusion, Muon Catalyzed Fusion, Characteristics of D-T Reaction, Advantages of Nuclear Fusion, Fusion Hybrid, Cold Fusion.

Unit – V

Principles of working: Geothermal, OTEC, Tidal, Waves, and Hydrogen (Generation and Application)

Suggested Books

1. G.D.Rai. Non conventional energy sources, Khanna Publishers
2. S.P.Sukhatme. Solar Energy, Tata McGraw-Hill Publishing Co. Ltd.
3. G.D.Rai. Solar Energy, Khanna Publishers.
4. D. Mukherjee and S. Chakrabarti. Fundamentals of Renewable Energy Systems, New Age International Publishers.
5. D.S. Chauhan and S.K.Srivastava. Non Conventional Energy Resources, New Age International Publishers.
6. Singh, M.P., Singh, B.S. & Soma S. Dey, (2004). Conservation of Biodiversity and Natural Resources. Delhi: Daya Publishing House.
7. J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).
8. https://www.edfenergy.com/for-home/energywise/renewable-energy-sources
9. https://www.nrdc.org/stories/renewable-energy-clean-facts
10. https://www.nationalgeographic.com/environment/energy/reference/renewable-energy/

Semester III

15PHP305B	NANOTECHNOLOGY	L T P C
		4 - - 4

Course Objectives

- This course introduces the fundamentals of nano-scale engineering and manufacturing.
- Current and future applications of nanostructured materials will be reviewed with respect to their impact in commercial products and technologies.
- The main physical forces controlling the nucleation and deposition of nanostructures will be presented allowing a better understanding of key design factors at the nano-scale.
- Well-established and novel synthesis/fabrication methods nanostructures will be critically discussed giving a broad overview of the state-of-the-art nanomanufacturing processes.
- The course will cover recent breakthroughs and assess the impact of this burgeoning field.
- Specific nanofabrication topics include epitaxy, beam lithographies, self- assembly, biocatalytic synthesis, atom optics, and scanning probe lithography.

Course Outcomes (COs)

At the end of the course, Students will understand and:

1. Explain the fundamental principles of nanotechnology and their application to biomedical engineering.
2. Apply engineering and physics concepts to the nano-scale and non-continuum domain.
3. Identify and compare state-of-the-art nanofabrication methods and perform a critical analysis of the research literature.
4. Design processing conditions to engineer functional nanomaterials.
5. Evaluate current constraints, such as regulatory, ethical, political, social and economical, encountered when solving problems in living systems.
6. learn the fundamentals about the different types of nanostrucures

UNIT I

GENERIC METHODOLOGIES FOR NANOTECHNOLOGY

Introduction and classification - What is nanotechnology? - Classification of nanostructures - Nanoscale architecture; Summary of the electronic properties of atoms and solids - The isolated atom - Bonding between atoms - Giant molecular solids - The free electron model and energy bands - Crystalline solids - Periodicity of crystal lattices - Electronic conduction; Effects of the nanometre length scale - Changes to the system total energy - Changes to the system structure - How nanoscale dimensions affect properties.

UNIT II

CARBON NANOSTRUCTURES

Introduction; carbon molecules – nature of the carbon bond – new carbon structures; cabon clusters – small carbon clusters discovery of C60 – structure of C60 and its crystal – alkali doped C60 – superconductivity in C60 – large and smaller fullerenes – other buckyballs; carbon nanotubes – fabrication – structure – electrical properties – vibrational properties – mechanical properties; applications of carbon nanotubes – field emission and shielding – computers – fuel cells – chemical sensors – catalysis – mechanical reinforcement.

UNIT III

INORGANIC NANOSTRUCTURES

Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures - The characterisation of semiconductor nanostructures - Applications of semiconductor nanostructures.

UNIT IV

NANOSTRUCTURED MOLECULAR MATERIALS

Introduction; Building blocks - Principles of self-assembly - Self-assembly methods to prepare and pattern nanoparticles - Templated nanostructures - Liquid crystal mesophases - Macromolecules at interfaces - The principles of interface science - The analysis of wet interfaces - Modifying interfaces - Making thin organic films - Surface effects on phase separation - Nanopatterning surfaces by self-assembly - Practical nanoscale devices exploiting macromolecules at interfaces .

UNIT V

EVOLVING INTERFACES OF NANO

Nanobiology - Introduction - Bio-inspired nanomaterials - Interaction Between Biomolecules and Nanoparticle Surfaces - Different Types of Inorganic Materials Used for the Synthesis of Hybrid Nano-bio Assemblies - Applications of Nano in Biology - Nanoprobes for Analytical Applications - Current Status of Nanobiotechnology - Future Perspectives of Nanobiology; Nanosensors - Introduction - What is a Sensor? - Nanosensors - Order from Chaos - Characterization - Perception - Nanosensors Based on Quantum Size Effects - Electrochemical Sensors - Sensors Based on Physical Properties - Nanobiosensors - Smart Dust; Nanomedicines - Introduction - Approach to Developing Nanomedicines - Various Kinds of Nanosystems in Use Nanodrug Administration - Nanotechnology in Diagnostic Applications - Materials for Use in Diagnostic and Therapeutic Applications - Future Directions.

Suggested Books

1. Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan. Nanoscale Science and Technology, , John Wiley & Sons, Ltd., UK, 2005.

2. Charles P. Poole Jr and Frank J. Owens. Introduction to Nanotechnology, Wiley Interscience, 2003.
3. Bio-Inspired Nanomaterials and Nanotechnology, Edited by Yong Zhou, Nova Publishers.
4. T.Pradeep. Nano:The Essentials: Understanding Nanoscience and Nanotecnology, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.
5. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).
6. Mark C. Hersam (2006), "MSE 376 Nanomaterials," https://nanohub.org/resources/1914.
7. https://nanohub.org/resources/7313.
8. https://ocw.mit.edu/courses/mechanical-engineering/2-674-micro-nano-engineering-laboratory-spring-2016/lecture-notes/MIT2_674S16_Lec7Nano.pdf
9. https://nptel.ac.in/courses/118/104/118104008/

15PHP305C	PARTICLE PHYSICS	L T P C 4 - - 4

Course Objectives

- Particle physics is one of the fundamental subjects of physics.
- It is important to know about the physics of nuclei and the different energies involved in the nuclear processes.
- Particle energy is one of the major sources of energy, which, with proper careful usage, can solve the energy crisis to a large extent.
- This paper is intended to give an insight into the different nuclear processes and the fundamental particles, which are the real building blocks of the universe.
- To understand the importance of models in describing the properties of nuclei and nuclear collisions
- To know the concept of balanced strong interactions, understanding the role of gluons

Course Outcomes (COs)

Students who have completed this course should

1. Understand the relation between the standard model and QCD
2. Understand the importance of models in describing the properties of nuclei and nuclear collisions
3. Be able to make quantitative estimates of phenomena involving nuclei.
4. Understand the different elementary particles and their behaviour.
5. write balanced strong interactions, understanding the role of gluons
6. write balanced weak interactions, understanding the role of W and Z bosons

Unit – I

Nucleon - Nucleon interaction and Hadron Structure : Phenomenological Nucleon - Nucleon potentials - Meson theory - Derivation of Yukawa interaction - Electromagnetic properties of deuteron - Polarisation in nucleon - nucleon scattering - Scattering matrix - Probing charge distribution with electron - Form factors - Proton form factors - Deep inelastic electron - proton scattering - Bjokren scaling and partons - Quarks within the proton - Gluons as mediators of strong interaction.

Unit II

Particle Phenomenology : Pion _ Nucleon scattering - Isospin analysis - Phase shifts - Resonance and their quantum numbers - Production and formation experiments Relativistic kinematics and invariants - Mandelstam variables - Phase space - Decay of one particle into three particles - Dalitz plot.

Unit III

Ionizing radiations : Ionization and transport phenomena in gases - Avalanche multiplication Detector Properties : Detection - Energy measurement - Position measurement Time measurement. Gas Counters : Ionization chambers, - Proportional counters - Multiwire porportional counters - Geiger - Muller counters - Neutron detectors. Solid State Detectors : Semiconductor detectors - Integrating solid state devices - Surface barrier detectors.

Unit IV

Scintillation counters : Organic and inorganic scintillators - Theory, characteristics and detection efficiency. High Energy Particle Detectors : General principles - Nuclear emulsions - Cloud chambers - Bubble chambers - Cerenkov counter.

Unit – V

Nuclear Electronics : Analog and digital pulses - Signal pulses - Transient effects in an R-C circuit - pulse shaping- linear amplifiers - Pulse height discriminators - Single channel analyser - Multichannel analyser.

Suggested Books

1. G.E.Brown and A.D. Jackson, Nucleon - Nucleon Interaction, North - Holland, Amsterdam, 1976
2. S. de Benedetti, Nuclear interaction, John wiley and Sons, New York, 1964.
3. P. Marmier and E. Sheldon, Physics of Nuclei and Particles, Vol. I & II Academic Press, New York 1970.
4. H.A. Enge, Introduction to Nuclear Physics, Addison - Wesley, 1975.
5. S.S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley - Eafstern, New Delhi, 1986.
6. Peacock, John A. Cosmological Physics. New York, NY: Cambridge University Press, 1998. ISBN: 9780521422703.
7. https://ocw.mit.edu/courses/physics/8-952-particle-physics-of-the-early-universe-fall-2004/

		L T P C
15PHP305D	**STATISTICAL PHYSICS**	**4 - - 4**

Course Objectives

- This course will useful to understand the zero-th and first law of thermodynamics and link thermodynamics to the micro description used in classical Statistical Mechanics.
- Statistical Mechanics is a probabilistic approach to equilibrium properties of large numbers of degrees of freedom.
- Students will learn thermodynamics, probability theory, kinetic theory, classical statistical mechanics, interacting systems, quantum statistical mechanics, and identical particles.
- Basic principles are examined in this class, such as the laws of thermodynamics and the concepts of temperature, work, heat, and entropy.
- Topics from modern statistical mechanics are also explored, including the hydrodynamic limit and classical field theories.
- To learn the behavior of Bose and Fermi gases.

Course Outcomes (COs)

1. The student should understand the connection between microphysics and thermodynamics.
2. Understand the basic concepts of classical statistical Physics
3. Understand the basic knowledge of quantum statistical Physics
4. Learn the behavior of Bose and Fermi gases.
5. Apply knowledge of statistical Physics to solve real world physical problems
6. To link thermodynamics to the micro description used in classical Statistical Mechanics.

Unit - I

Statistical basis of thermodynamics: macro states and micro states – connection between statistics and thermodynamics – Classical ideal gas – entropy of mixing and Gibbs paradox – phase space of a classical system – Liouville's theorem and its consequences – microcanonical ensemble – Quantum states and phase space – Equipartition theorem. The canonical ensemble Equilibrium between a system and a heat reservoir – A system in the canonical ensemble – thermodynamic relations – classical systems – Statistics of paramagnetism. The grand canonical ensemble – A system in the grand canonical ensemble Physical significance of statistical quantities – examples.

Unit – II

Fluctuations–fluctuations in microcanonical, canonical and grand canonical ensembles. Quantum Statistics – Quantum mechanical basis – ideal gas in various quantum mechanical ensembles. Gaseous systems composed of molecules with internal motion – monatomic molecules – diatomic molecules – ortho and para hydrogen.

Unit – III

Thermodynamic behaviour of ideal Bose gas – thermodynamics of black body radiationSpecific heats of solids – Einstein and Debye model – Bose-Einstein condensation. Thermodynamic behaviour of an ideal Fermi gas – Magnetic behaviours of an ideal Fermi gas – Pauli paramagnetism – electron gas in metals.

Unit – IV

Brownian motion – Langevin equation for random motion – random walk problem, diffusion – Einstein relation for mobility.

Unit – V

General remarks on the problem of condensation – The Yang-Lee theory. Bragg-Williams approximation. Ising model – solution for a linear chain – Equivalence of Ising model to other models: Lattice gas, Binary alloy.

Suggested Books

1. R. K. Pathria, Statistical Mechanics 2. K. Huang, Statistical Mechanics
2. E. S. R. Gopal, Statistical Mechanics and Properties of matter
3. Landau and Lifshitz , Statistical Physics
4. Kardar, Mehran. Statistical Physics of Fields. Cambridge University Press, 2007. ISBN: 9780521873413.
5. Amit, Daniel J. Field Theory, the Renormalization Group, and Critical Phenomena. Revised 2nd ed. World Scientific Publishing Company, 1984. ISBN: 9789971966102.
6. Feynman, Richard Phillips. Statistical Mechanics: A Set of Lectures. Westview Press, 1998. ISBN: 9780201360769.
7. https://ocw.mit.edu/courses/physics/8-334-statistical-mechanics-ii-statistical-physics-of-fields-spring-2014/index.htm
8. https://ocw.mit.edu/courses/physics/8-333-statistical-mechanics-i-statistical-mechanics-of-particles-fall-2013/
9. https://ocw.mit.edu/courses/physics/8-08-statistical-physics-ii-spring-2005/

15PHP305E	BIOPHYSICS	L T P C 4 - - 4

Course Objectives

- Biophysics deals with the application of physics to biological systems.
- The concepts and techniques of biophysics find applications in bioelectronics, medicine/health, and population dynamics and are closely related to statistical mechanics and transport processes.
- Interdisciplinary skills and knowledge have heralded novel scientific outcomes with benefits to society.
- As such, this course develops foundational thinking and methods that are fundamental to an effective interdisciplinary STEMM workforce.
- Fundamental concepts that underlie biomolecular interactions will be discussed and biophysical methods that are employed for the structural analysis of these systems will be introduced at an elementary level.
- The physical quantities such as temperature, energy, enthalpy, entropy, and free energy will be employed to understand why a biological system choses particular state at conditions under study.

Course Outcomes (COs)

On successful completion of the course students will be able to:

1. Explain models of biological systems and models dealing with statistical mechanics and transport phenomena.
2. Solve qualitative and quantitative problems, using appropriate mathematical and computing techniques.
3. Perform experiments which involve making correct and appropriate use of a range of scientific equipment, keeping an accurate record of experimental work and analysing results and reaching non-trivial conclusions from them.
4. Communicate the results of both theoretical and experimental work in various forms including written reports, oral presentations and poster presentations.
5. Contribute to team and group work for scientific investigations and for the process of learning.
6. Understand transport phenomena of neutral and electrically charged particles and biological systems.

UNIT I

Bio molecules: Organisation of molecules – macromolecules and intermolecular forces – stability of macromolecules – Types of bonds in biological molecules – Biological membranes – lipid composition – protein.

UNIT II

Principles of kinetics of molecules: diffusion – factors affecting diffusion – simple diffusion – Fick's law of diffusion – diffusion of electrolytes – biological significance of diffusion – osmosis – osmotic pressure – laws of osmosis

UNIT III

Dialysis: Principles of dialysis in artificial kidneys – kinds of dialysis – Kinetic theory of surface tension – Factors affecting surface tension – Determination of surface tension of liquids by capillary method

UNIT IV

Principles of Optics in biological studies: Characteristics of light – microscopy – types of microscopes – compound microscope – phase contrast microscope – Optical principle – interference microscope

UNIT V

Photometry of absorptiometry: Important components in instruments of photometry – light source – monochromator – Sample holders – light sensitive detectors.

Suggested Book

1. Subramanian M.A., 2005, Biophysics: Principles and techniques, M.J.P. Publishers, Chennai.
2. Physics in Molecular Biology; Kim Sneppen & Giovanni Zocchi (CUP 2005)
3. Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
4. Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, London & NY, 2013)
5. An Introduction to Systems Biology; Uri Alon (Chapman and Hall/CRC, Special Indian Edition, 2013)
6. Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition)
7. http://www.physics.drexel.edu/~brigita/COURSES/BIOPHYS_2011-2012/
8. https://www.easybiologyclass.com/biophysics-free-online-classes-lecture-notes-references-study-materials/

Semester – III
L T P C

15PHP311 **PHYSICS PRACTICALS - 3** **- - 5 3**

Course Objective

- To understand the Biasing network for BJT and FET, transient analysis and frequency response of BJT and FET in single stage and multistage amplifier
- To understand the frequency response feedback amplifier using BJT and FET and Tuned amplifier
- This course introduces the assembly language programming of 8085 Microprocessor.It gives a practical training of interfacing the peripheral devices with the 8086 microprocessor.
- To apply their knowledge to analog and digital electronics, pulse electronics, analog and digital communication systems, digital signal processing, control systems, and power electronics at a later stage.
- To demonstrate their knowledge in designing the control loops for these processes.
- To apply the theoretical knowledge into the experiments and find the solutions.

Course Outcomes (COs)

On completion of this lab course the students will be able to:

1. Understand and apply the fundamentals of assembly level programming of microprocessors and microcontroller.
2. Work with standard microprocessor real time interfaces including GPIO, serial ports, digital-to-analog converters and analog-to-digital converters;
3. Troubleshoot interactions between software and hardware;
4. Analyze abstract problems and apply a combination of hardware and software to address the problem
5. Students will practically study the working of different electronic components/ circuits.
6. Learn to minimize contributing variables and recognize the limitations of the equipment.
7. Design and construction of circuits using analog component and trouble shooting of the circuits.

ANY TWELVE EXPERIMENTS

1. Arc spectra – Aluminium and Brass
2. (i) Determination of wavelength of He-Ne laser – Ruler method.

   (ii) Determination of thickness of a wire using He-Ne laser.

3. G.M.Counter – Characteristics.
4. Experiment on rotatory dispersion of quartz.
5. Microprocessor – Stepper motor interfacing, ADC interface wave form generation
6. Microprocessor –Traffic control simulation
7. Microprocessor –Hex Key board interfacing
8. Multiplexer and de-multiplexer
9. Ring counter using IC's
10. 4-bit binary adder
11. 4-bit binary subtractor
12. Half adder and Half subtractor
13. Full adder and full subtractor
14. BCD counter, using IC 7490 and 7473.
15. A/D Converters any one method, D/A converter – Binary weighted, Ladder methods

Suggested Books

1. Ouseph C.C., U.J. Rao and V. Vijayendran 2007, Practical Physics and Electronics, S.Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai
2. Singh S.P., 2003, Advanced Practical Physics – 1, 13th Edition, Pragathi Prakashan, Meerut
3. Singh S.P., 2000, Advanced Practical Physics – 2, 12th Edition, Pragathi Prakashan, Meerut
4. Ouseph C.C., U.J. Rao and V.Vijayendran, 2007, Practical Physics and Electronics, S. Viswanathan (Printers & Publishers), Pvt. Ltd., Chennai.

Semester IV

		L T P C
15PHP401	**ELECTROMAGNETIC THEORY AND ELECTRODYNAMICS**	**4 - - 4**

Course Objectives

- The aim of this course is to provide the students with the fundamental principles of electrical energy (electro- magnetism).
- To understand the propagation of waves in different media, its transmission and reception.
- To understand, develop, and design various engineering applications involving electromagnetic fields.
- To expose the students to the ideas of electromagnetic waves and structure of transmission line
- To obtain an understanding of Maxwell's equations and be able to apply them to solving practical electromagnetic fields
- To provide the understanding to the propagation of EM wave in free space, conductors & dielectrics.

Course Outcomes (COs)

Students will:

1. Formulate potential problems within electrostatics, magnetostatics and stationary current distributions in linear, isotropic media, and also solve such problems in simple geometries using separation of variables and the method of images. .
2. Define and derive expressions for the energy both for the electrostatic and magnetostatic fields, and derive Poyntings theorem from Maxwells equations and interpret the terms in the theorem physically.
3. Understand the theories and properties of electrostatics
4. Analyze the interaction of electrostatic properties with matter.
5. Acquire the fundamental knowledge in Magnetostatics
6. Understand the basic concepts of electrodynamics

UNIT- I

Electrostatics: Electric intensity – Electric potential – Gauss Law - Dielectric and its polarization - Electric displacement D – Dielectric constant ε_r – Polarisibiltiy α - Clausius-Mossotti relation (Non-polar molecules) – The Langevin equation (Polar molecules) – Electrostatic energy

Magnetostatics: Current density J – Ampere's law of force – Biot-Savart law – Ampere's circuital law – Magnetic scalar potential ϕ_m (no applications) – Magnetic vector potential A –

Magnetisation and magnetization current – Magnetic intensity – Magnetic susceptibility and Permeability.

UNIT- II

Field Equations and Conservation Laws: Equation of continuity - Displacement currents - The Maxwell's equations derivations - physical significance - Poynting vector - Electro magnetic potentials A and ϕ - Maxwell's equations in terms of Electro magnetic potentials - Concept of gauge -Lorentz gauge - Coulomb gauge

UNIT- III

Propagation of Electromagnetic Waves: Electromagnetic waves in Free space - Isotropic dielectric - Anisotropic dielectric – Conducting media - Ionized gases.

Radiating systems: Oscillating electric dipole – Radiation from an oscillating dipole – Radiation from small current element.

UNIT- IV

Interaction of E.M.Waves with matter (Macroscopic): Boundary conditions at interfaces - Reflection and refraction – Frenel's laws-Brewster's law and degree of polarization - Total internal reflection and critical angle.

Interaction of E.M.Waves with matter (Microscopic): Scattering and Scattering parameters - Scattering by a free electron (Thomson Scattering) - Scattering by a Bound electron (Rayleigh scattering) – Dispersion Normal and Anomalous – Dispersion in gases (Lorentz theory) – Dispersion in liquids and solids.

UNIT – V

Relativistic Electrodynamics: Purview of special theory of relativity – 4-vectors and Tensors - Transformation equations for charge and current densities J and ρ – For electromagnetic potentials A and ϕ - Electromagnetic field tensor $F_{\mu\nu}$ - Transformation equations for the field vectors E and B - Covariance of field equations in terms of 4-vectors - Covariance of Maxwell equations in 4-tensor forms – Covariance and transformation law of Lorentz force.

Suggested Book

1. Chopra & Agarwal 2004, Electromagnetic theory, 6th Edition, Nath & Co, Meerut.
2. Griffiths D., 1998, Introduction to Electrodynamics, 3rd Edition, Printice Hall of India, New Delhi.
3. Jacson. J.D., 1998, Classical Electro dynamics, 3rd Edition, Willey Eastern, New Delhi.
4. Schwaritz. M. 1972, Principles of Electro dynamics, McGraw Hill, Auckland.
5. Jordon and Balmain 2nd edition 2002, EMW radiating systems, Prentice Hall of India Pvt Ltd, New Delhi.
6. Gupta, Kumar and Singh, 2007, Electro dynamics, 19th Edition, Pragati Prakasan, Meerut, New Delhi.
7. Satya Prakash 10th revised 2003, Electromagnetic theory and Electro dynamics, Kedar Nath Ram Nath & Co, Meerut.
8. https://nptel.ac.in/courses/115101008/
9. https://nptel.ac.in/content/syllabus_pdf/104104085.pdf

10. https://ocw.mit.edu/courses/physics/8-02x-physics-ii-electricity-magnetism-with-an-experimental-focus-spring-2005/

		Semester IV
		L T P C
15PHP491	**PROJECT**	**4 - - 4**

Course Objectives

- The aim of the M.Sc. Research project work is to expose the students to preliminaries and methodology of research in Theoretical Physics and Experimental Physics.
- To provides the students to get opportunity and participate in some ongoing research activity and development of a laboratory experiment.
- To provide the student with a broad spectrum of physics projects courses
- To emphasize the role of physics in life and other discipline (chemistry, mathematics and biology)
- To develop the ability of the students to conduct, observe, analyzes and report an experiment and deal with physical models and formulas mathematically.
- To provide the student with different practical, intellectual and transferable skills.
- To understand the objective of a physics laboratory experiment, properly carry out the experiments, and appropriately record and analyze the results.
- To think creatively about scientific problems and their solutions.
- To design experiments, and to constructively question results they are presented with, whether these results are in a newspaper, in a classroom, or elsewhere.

Course Outcomes (COs)

After successful completion of the course, the student is expected to

1. Complete an independent research project, resulting in research outputs in terms of publications in journals and conference proceedings.
2. Demonstrate a depth of knowledge of Physics.
3. Complete an independent research project, resulting in research outputs in terms of publications in journals and conference proceedings.
4. Demonstrate knowledge of contemporary issues in their chosen field of research.
5. Demonstrate an ability to present and defend their research work.

6. Demonstrate an ability to succeed in problem solving in electronics
7. Solve physics problems using qualitative and quantitative reasoning including sophisticated mathematical techniques
8. Conduct independent research or work successfully in a technical position.
9. Successfully pursue career objectives in graduate school or professional schools, in a scientific career in government or industry, in a teaching career, or in a related career.
10. Apply their knowledge to develop the instruments.
11. Verify the basic principles and laws experimentally as a project.

Semester IV

15PHP306	MICROWAVE COMMUNICATION	L T P C
		- - - 4

Course Objectives:

- This course provide a wide understanding of microwave waveguides, passive & active devices, tubes and network analysis.
- An ability to design microwave matching networks.
- An ability to perform microwave measurements.
- An understanding of RADARs and its applications.
- To describe and explain working of microwave tubes and solid state devices.
- To perform measurements on microwave devices and networks using power meter and VNA.

Course Outcomes:

The student after undergoing this course will be able to:

1. Explain different types of waveguides and their respective modes of propagation.
2. Analyze typical microwave networks using impedance, admittance, transmission and scattering matrix representations.
3. Design microwave matching networks using L section, single and double stub and quarter wave transformer.
4. Explain working of microwave passive circuits such as isolator, circulator, Directional couplers, attenuators etc.
5. Describe and explain working of microwave tubes and solid state devices.
6. Perform measurements on microwave devices and networks using power meter and VNA.

UNIT-I

Microwave Fundamentals: Microwave frequency spectrum, Types and characteristics of transmission line, Transmission line equation solution, Reflection coefficient and transmission coefficient, Standing wave and standing wave ratio, Line impedance and admittance, Smith chart.

Unit II

Microwave Passive Devices

Rectangular wave guide, Circular wave guide, Microwave cavities, Microwave hybrid circuit, Directional coupler, Circulators and ferrit devices, Attenuators, Scattering matrix, Isolators.

Unit –III

Microwave Active Devices
Klystron, Reflex Klystron, Velocity modulation, Basic principle of magnetron, Principles and operations of magnetrons and traveling wave tube, Transfer electron devices, Gunn diode, Pin diode.

Unit –IV

Microwave Measurements
Attenuation measurement, Frequency measurement, Power measurement, Reflection coefficient and VSWR measurement, Scattering measurement. Microwave detection, Point contact diode, Schottly barrier diode.

Unit -V

Microwave Applications
Antenna fundamental, Microwave antennas, Antenna basic, Power received from an antenna, Radiation pattern, Radiation resistance, Efficiency, Directivity and gain, Antenna types, Rectangular horn antennas, H and E plane Horn antennas, Pyramidal Horn antenna, Parabolic reflector antenna. Radar system, Basic radar system, Radar range, Moving target indicator,

Suggested Books

1. Microwave Fundamental-Sanjeeva, Gupta and Others, Khanna Publications.
2. Microwave Devices and Circuits -Samull Y. Lio, Prentice Hall of India Pravate Limited, New Delhi. 3rd edition 1997
3. Microwave Communications Components and Circuits-Hunds, Mc Graw Hill, International Edition.1st edition 1989
4. Microwave Techniques -D.C. Agarwal, S. Chand and Company.
5. Microwave Engineering-David M. Pozar, John Wiley and ons, New York. 4th edition 2012
6. Microwave Principles-Herbert S. Reich, C.B.S. Publications. 1st edition 2004

Semester IV
L T P C

15PHP402 **COSMIC RAY PHYSICS** **- - - 4**

Course Objectives:

- This paper gives information about the nature of cosmic rays, detection of cosmic rays, and their analysis.
- To distinguish between mechanical and electromagnetic waves.
- To recognize that electromagnetic waves are transverse waves and travel at the speed of light through a vacuum.
- To give a basic description of cosmic rays.
- To demonstrate an understanding of a cloud chamber.
- To gain a better understanding of subatomic particles.

Course Outcomes:

Students able to

1. The students can use the acquired knowledge about experimental methods in their work in several fields of engineering (measurement techniques, electronics, computers) and knowledge about the basic properties of cosmic rays at their work in the field of medicine and radiology
2. Identify three aspects of contemporary cosmic ray physics which they wish to study in detail.
3. play a role in many different phenomena - e,g, climate
4. the student will have knowledge of the experimental and phenomenological aspects of the origin, nature and propagation of charged cosmic rays and neutrinos and a basic knowledge of the nature of Dark Matter, Gravitational Waves and Cosmic Microwave
5. Background and the related experimental detection techniques.
6. In particular, the student will be able to understand the connection between astrophysics and particle physics.

Unit I

Introduction to Cosmic Rays – The nature of the radiation – the latitude effect and effect of earth's magnetic fields – The primary cosmic ray energy spectrum – components in the primary radiation – Observation of knee and ankle in the energy spectrum – origin of cosmic rays – Possibility of electromagnetic acceleration – Fermi's acceleration mechanism – Supernovae as sources – Other sources – Motion and storage of cosmic rays.

Unit II

Extensive Air Shower (EAS) – Phenomenology – The cascade process – Bhabha's cascade theory – Electromagnetic cascade – Interaction of photons with matter – Interaction of electrons with matter – Lateral spread of EAS particles – EAS cascade – Monte Carlo simulation – Numerical methods – EAS initiated by primary nuclei.

Unit III

General features of EAS – Electromagnetic component – Lateral studies – Hadron component – Temporal structure of Hadrons – Charged to neutral (C/N) ratio – Muon component – Cherenkov light from EAS – Fluorescence light – Radio emission from EAS

Unit IV

Detection of EAS – Electron detectors – Scintillation detectors – Yes/No type detectors – Proportional counters – Fast timing – Muon detectors – Importance of muon detectors in EAS detector arrays – Hadron detectors – Underground detectors – Recording systems – Calibration of the detectors and electrons.

Unit V

Analysis of EAS data – Determination of shower parameters – NKG function – Search for sources – Significance of size spectrum – Relation to the energy spectrum – Knee and Ankle of the energy spectrum – Possible explanations – Models of origin of cosmic rays.

Suggested Books

1. Rao M.V.S and B.V. Sreekantan, Extensive Air Shower, world scientific publishing 1st edition 1998.
2. Hillas A.M., Cosmic Rays, Pergamon Press, New York1st edition 1972.
3. http://neutronm.bartol.udel.edu/catch/cr2.html
4. https://www.classe.cornell.edu/Outreach/
5. https://www.imagesco.com/geiger/radioactive-sources.html

Semester II
L T P C
15OEP201 INTRODUCTION TO ASTRONOMY - - - 3

Course Objectives:

- This is a non-major elective paper for students of other departments.
- This paper gives an overview of the solar system, the stars, their evolution etc., for those who are interested in knowing about our Universe.
- Astronomy and Astrophysics is a very fundamental subject in Physics.
- Includes study of the solar system, evolution of stars, different physical processes going on stellar bodies, life cycle of stars etc.
- Is to apply basic physical principles from a broad range of topics in physics to astronomical situations
- Be able to formulate scientific problems in mathematical terms and apply analytical and numerical methods towards its solution
- Develop skills to design observing projects with research telescopes and projects drawing upon data in the literature and in archives
- Establish competence in focused areas of astrophysical theory and experiment

Course Outcomes:

Upon successful completion of this course, Students will be able to

1. Understand the basic concepts of coordinate systems, coordinate system used in astronomy, and evolution and properties of stellar objects.
2. Understand different mechanisms of energy transfer in stellar objects.
3. Understand the nuclear reactions in stellar objects and their behaviour.
4. Learn the basic concepts of cosmology and astrophysics.
5. Understand the different types astronomy according to the wavelengths of emission
6. Demonstrate a thorough understanding of current accepted theories for the origin of the universe

UNIT I

SUN: Sun, the nearest star to earth – Size, Mass and different layers of Sun – energy production in Sun – Temperature of the core, photosphere and Corona – Corona Heating problem – Solar activities – Sun spot – future of sun.

UNIT II

Planets: Planets of solar system – Orbits of the planets – Moons of the planets – Rings – Size, atmosphere temperature of the planets – Asteroids, Meteorite, Comets – Earth's Moon – Craters in Moon – Water in Moon.

UNIT III

Eclipse: Solar eclipse – Partial, Total, Annular and Hybrid eclipse – Conditions for these eclipses – Lunar eclipse.

Extra Solar Planets: Discovery of extra solar planets – Number of extra solar planets discovered – Telescopes – Invention – Different types of telescopes – Space telescopes

UNIT IV

Evolution of stars – Different stages of evolution – main sequence – white dwarf – supernova – pulsars – quasars – neutron stars – black holes – Chandrasekhar limit – Stellar cluster – Galaxy.

UNIT V

Evolution of the Universe – Big-bang theory – Steady state theory – Introduction to Radio astronomy, Infrared Astronomy, X-ray astronomy and Gamma ray astronomy.

Suggested Book

1. Bhatia V.B., 2001, Text Book of Astronomy and Astrophysics with elements of Cosmology, Narosa Publishing Co., New Delhi.
2. Martin Harwitt, 1998, Astronomical Concepts, 3rd Edition, Springer Verlag, New York
3. Franklin Shu, 1st edition 1982, Physical Universe, University Science Books, U.S.A.
4. E.W.Kolb and M.S.Turner, 1st edition, 2007, The Early Universe Sarth book house and distributers
5. J.V.Narlikar, 3rd edition 2012 Introduction to Cosmology, Cambridge University Press.
6. A.K.Raychaudhuri, S.Banerji and A.Banerjee, General Relativity, Astrophysics and Cosmology – 1st edition (Springer-Verla, 2001)
7. S. Banerji and A. Banerjee, General Relativity and Cosmology – 1st edition (Elsevier, 2007)
8. https://nptel.ac.in/courses/115105046/
9. http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html