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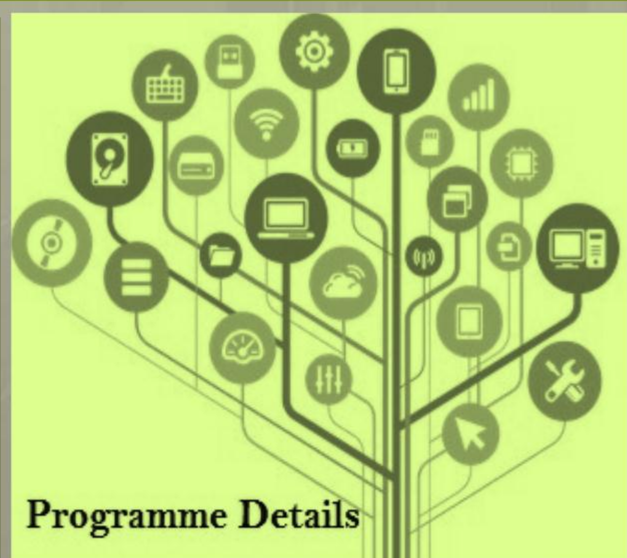
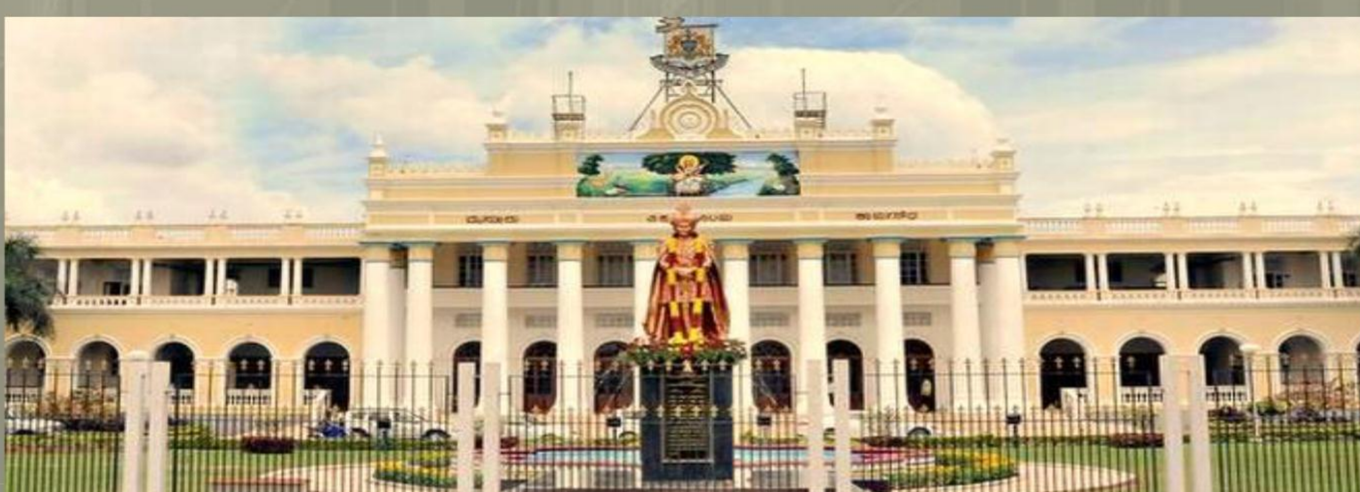
University of Mysore

(Estd.1916)

M.Sc. PHYSICS

Flexible Choice Based Credit System (FCBCS)





UNIVERSITY OF MYSORE

Department of Studies in Physics
Manasagangotri, Mysuru-570006

Regulations and Syllabus
Master of Science in Physics
(Two-year semester scheme)

Under
Flexible Choice Based Credit System (FCBCS)

Chairman
Board of Studies in Physics
University of Mysore
Manasagangotri, MYSURU 570 006

UNIVERSITY OF MYSORE

GUIDELINES AND REGULATIONS

LEADING TO
MASTER OF SCIENCE IN PHYSICS
(TWO-YEAR SEMESTER SCHEME UNDER FLEXIBLE CHOICE BASED CREDIT SYSTEM (FCBCS)

Programme Details

Name of the Department	:	Department of Studies in Physics
Subject	:	Physics
Faculty	:	Science and Technology
Name of the Programme	:	M.Sc. in Physics
Duration of the Programme	:	2 years divided into 4 semesters

Program objectives

- The graduates will develop research skills which might include advanced laboratory techniques, numerical techniques, computer algebra and computer interface.
- The graduates will become effective researcher who will be able provide comprehensible summation of the scientific literature on a given topic of study.
- The graduates will develop the skill to plan, execute and report the results of an extended experimental or theoretical physics based project in research environment.

Programme outcomes

On successful completion of this program the student will be able to:

- Appreciate the importance and significance of physics in understanding the natural events in day-to-day life.
- Apply theoretical knowledge of principles and concepts of physics to practical problems.
- Use mathematical techniques and interpret mathematical models of physical behavior.
- Demonstrate the ability to plan, undertake and execution of the experiments.
- Assess the errors involved in an experimental work and understanding their importance.
- Develop communication skills, both written and oral for specialized and non-specialized audiences.

Programme Specific Outcomes

- Introduce advanced techniques and ideas required in developing area of physics.
- Acquire ability to develop mathematical models for physical systems.
- Gain the knowledge of Physics through theory and practical.
- Understand and apply principles of physics for understanding the scientific phenomenon in classical and quantum physics.
- Understand and apply statistical methods for describing the quantum and classical a particles phenomenon in various physical systems.
- Understand good laboratory practices and safety.
- Develop research oriented skills.
- Make aware and handle the sophisticated instruments/equipments.

Programme Pedagogy

- Class room teaching has been upgraded from black board and chalk to interactive, student friendly smart classrooms.
- One on one interaction with students during tutorial classes.
- Hands on experience for the students are given in the laboratory by allowing them to perform the experiments individually in practical classes.
- Student seminar/research paper presentation in each semester.
- Every semester the students will be subjected to viva voce examinations by examiners.
- Minor research project work is conducted so as to familiarize the students with the research works.
- Literature review in the form of dissertation.
- Invited talks from eminent scientists from national and international institutes/universities.

SCHEME OF EXAMINATION AND DETAILS OF COURSE PATTERNS FOR M.Sc., DEGREE COURSE (FCBCS)

I Semester Physics (Minimum 18 and Maximum 24 credits)

Sl.No.	Code	Title of the Paper	Course Type	Credit pattern			Total Credits
				L	T	P	
1	18401	Classical Mechanics	HC	3	0	0	3
2	18402	Mathematical Methods of Physics 1	HC	3	0	0	3
3	18403	Mathematical Methods of Physics 2	HC	3	0	0	3
4	18404	Classical Electrodynamics and Optics	HC	3	0	0	3
5		Computer Lab CL-A	HC	0	0	2	2
6		Optics Lab 1	SC	3	0	0	3
7		Electronics Lab1	SC	3	0	0	3

II Semester Physics (Minimum 18 and Maximum 24 credits)

Sl.No.	Code	Title of the Paper	Course Type	Credit pattern			Total Credits
				L	T	P	
1	18411	Continuum Mechanics and Relativity	HC	3	0	0	3
2	18412	Thermal Physics	HC	3	0	0	3
3	18413	Quantum Mechanics 1	HC	3	0	0	3
4	18414	Spectroscopy and Fourier Optics	HC	3	0	0	3
5		Computer Lab CL-B	HC	0	0	2	2
6		Optics Lab 2	SC	0	0	4	4
7		Electronics Lab 2	SC	0	0	4	4
8	18415	Modern Physics	OE	3	1	0	4

III Semester Physics (Minimum 20 and Maximum 24 credits)

Sl.No.	Code	Title of the Paper	Course Type	Credit pattern			Total Credits
				L	T	P	
1	18421	Nuclear and Particle Physics	HC	3	0	0	3

2	18422	Condensed Matter Physics	HC	3	0	0	3
3		Nuclear Physics Lab	HC	0	0	4	4
4		Condensed Matter Physics Lab 1	HC	0	0	4	4
Students are permitted to register for any one of the following groups							
5	18423	Nuclear Physics 1	SC	3	0	0	3
6		Nuclear Physics Lab 1*	SC	0	0	2	2
7	18424	Solid State Physics 1	SC	3	0	0	3
8		Solid State Physics lab1**	SC	0	0	2	2
9	18425	Theoretical Physics 1	SC	3	0	0	3
10		Theoretical Physics Lab 1 [+]	SC	0	0	2	2
Students are permitted to register for any one of the following groups							
11	18426	Accelerator Physics	SC	3	0	0	3
12	18427	Liquid Crystals	SC	3	0	0	3
13	18428	Atmospheric Physics	SC	3	0	0	3
14	18429	Numeric Methods	SC	3	0	0	3
15		Methods of Material Characterization	SC	1	0	2	3
16	18430	Python Programming	SC	2	0	1	3
17		Minor Project	SC	2	0	1	3
18	18431	Energy Science	OE	3	1	0	4

IV Semester Physics (Minimum 20 and Maximum 24 credits)

Sl.No.	Code	Title of the Paper	Course Type	Credit pattern			Total Credits
				L	T	P	
1	18441	Quantum Mechanics 2	HC	3	0	0	3
2		Cond. Matter Physics Lab 2	HC	4	0	0	4
3		Nuclear Physics Lab [b]	HC	0	0	4	4
Students are permitted to register for any one of the following groups							
4	18442	Nuclear Physics 2*	SC	3	0	0	3
5	18443	Nuclear Physics 3*	SC	0	0	3	3
6		Nuclear Physics Lab 2*	SC	0	0	2	2
7	18444	Solid State Physics 2**	SC	3	0	0	3
8	18445	Solid State Physics 3**	SC	3	0	0	3
9		Solid State Physics Lab 2**	SC	0	0	2	2
10	18446	Theoretical Physics 2 +	SC	3	0	0	3
11	18447	Theoretical Physics 3 +	SC	3	0	0	3
12		Theoretical Physics Lab2 +	SC	0	0	2	2
Students are permitted to register for any one of the following groups							
13	18448	Nuclear Spectroscopy Methods	SC	3	0	0	3
14	18449	Modern Optics	SC	3	0	0	3
15	18450	Electronics	SC	3	0	0	3
16	18451	Biophysics	SC	3	0	0	3
17		Minor Project	SC	3	0	0	3
18	18452	Radiation Physics and Dosimetry	OE	3	0	0	3

[a] For students who have opted PHY311.

b For students who have opted PHY312.

* Compulsory for students who have completed PHY303.

** Compulsory for students who have completed PHY304. +

Compulsory for students who have completed PHY305.

FIRST SEMESTER PHYSICS
HARD CORE

COURSE –I:CLASSICAL MECHANICS

Objectives:

- To study the importance of Lagrangian and Hamiltonian formulation and their applications.
- To understand the mechanics of the rigid bodies.

Course outcome:

- By learning classical mechanics students will be able solve physical problems in real situation and to understand the motion of heavenly bodies. They will also learn to solve the problems related to atomic and molecular spectra, nuclear physics, molecular biology etc.
- This paper provides knowledge about mechanics of a system of particles and rigid bodies. The necessity of Lagrangian and Hamiltonian formulations to the general theory of small oscillations is important to understand the properties of atoms in solid, coupled mechanical oscillators and electrical circuits.

- Familiarize the students with the governing laws for our surrounding environment.
- Importance of the Lagrangian formulism in the field of physics.

COURSE CONTENT:

Mechanics of a system of particles: Conservation of linear and angular moment in the absence of (net) external forces and torques using centre of mass. The energy equation and the total potential energy of a system of particles using scalar potential.

The Lagrangean method: Constraints and their classifications. Generalized coordinates. Virtual displacement, D'Alembert's principle and Lagrangian equations of the second kind. Examples of (I) single particle in Cartesian, spherical polar and cylindrical polar coordinate systems, (II) Atwood's machine and (III) a bead sliding on a rotating wire in a force-free space, (IV) Simple pendulum. Derivation of Lagrange equation from Hamilton principle.

Motion of a particle in a central force field: Binet equation for central orbit (Lagrangean method).

Hamilton's equations: Generalized momenta. Hamilton's equations. Examples- simple harmonic oscillator, simple pendulum, compound pendulum, motion of a particle in a central force field, charged particle moving in an electromagnetic field and Hamiltonian for a free particle in different coordinates. Cyclic coordinates. Physical significance of the Hamiltonian function. Derivation of Hamilton's equations from a variational principle.

Canonical transformations: Definition, Generating functions (Four basic types), examples of Canonical transformations. Harmonic oscillator as an example to canonical transformation, infinitesimal contact transformation. Poisson brackets; properties of Poisson brackets, angular momentum and Poisson bracket relations. Equation of motion in the Poisson bracket notation. The Hamilton-Jacobi equation; the example of the harmonic oscillator treated by the Hamilton-Jacobi method.

Mechanics of rigid bodies: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of rigid body. Moment of inertia tensor, principal moments of inertia, products of inertia, the inertia tensor. Euler equations of motion for a rigid body. Torque free motion of a rigid body. Precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body.

Small oscillations of mechanical system: Introduction, types of equilibria, quadratic forms of kinetic and potential energies of a system in a equilibrium, general theory of small oscillations, secular equation and Eigen value equation, small oscillations in normal coordinates and normal modes, examples of two coupled oscillators, vibrations of a linear triatomic molecule.

References

- Upadhyaya J.C., Classical Mechanics, Himalaya Publishing House, Mumbai. 2006. (Unit 1. Chapter 1 and 2 page No. 1-50.)
- Goldstein H., Poole C. and Safko J., Classical Mechanics, 3rd Edn., Pearson Education, New Delhi. 2002. (Unit 1, Chapter 1 page 1-14, 16-21, 24-29)
- Srinivasa Rao K.N., Classical Mechanics, Universities Press, Hyderabad. 2003.
- Takwale R.G. and Puranik S., Introduction to Classical Mechanics, Tata McGraw, New Delhi,1991.
- Landau L.D. and Lifshitz E.M., Classical Mechanics, 4th Edn., Pergamon Press, 1985.

COURSE –II :MATHEMATICAL METHODS

Objectives:

- To give the basic ideas regarding the tensor analysis, special functions and linear vector space.
- To enhance the mathematical skills necessary to approach problems in quantum mechanics.

Course outcome:

- From this course, students are able to understand mathematical tools essential for learning classical mechanics, quantum mechanics, statistical mechanics, thermodynamics, nuclear physics, solid state physics.

Pedagogy:

- Teaching, PPT and presentations.
- Practical problems are given as assignment.

COURSE CONTENT:

Tensor analysis: Curvilinear coordinates, tensors and transformation theory: tensors of rank r as a r-linear form in base vectors. Transformation rules for base vectors and tensor components. Invariance of tensors under transformation of coordinates. Sum, difference and outer products of tensors, contraction. Curvilinear coordinates in the Euclidean 3-space. Covariant and contravariant basis vectors. Covariant and contravariant components of the metric tensor. Raising and lowering of indices. Differentials of base vector fields. Christoffel symbols. Covariant differentiation. The contracted Christoffel symbol. Grad, divergence, curl and Laplacian in arbitrary curvilinear coordinates.

Special functions: Differential equations, Hermite and Lagaurre functions: Partial differential equations, Separation of variables- Helmholtz equation in cartesian, cylindrical and spherical polar coordinates. Differential equations: Regular and irregular singular points of a second order ordinary differential equations. Series solutions–Frobinius method. Examples of Harmonic oscillator and Bessel's equation. Linear dependence and independence of solutions-Wronskian. Hermite functions: Solution to the Hermite equation, Generating functions, Recurrence relations, Rodrigues representation, Orthogonality. Laguerre functions: Differential equation and its solution,-Laguerre polynomials, Generating function, Recurrence relations, Rodrigues representation, Orthogonality. Associated Laguerre functions: Definition, Generating function, Recurrence relations and orthogonality. The gamma function and beta function; definition and simple properties.

Linear vector space: Definition. Linear dependence and independence of vectors. Dimension. Basis. Change of basis. Subspace. Isomorphism of vector spaces. Linear operators. Matrix representative of a linear operator in a given basis. Effect of change of basis. Invariant subspace. Eigenvalues and eigenvectors. Characteristic equation. The Schur canonical form. Diagonalisation of a normal matrix. Schur's theorem.

References:

- Arfken G.B. and Weber H.J., Mathematical Methods for Physicists, 4th Edn., Academic Press, New York (Prism Books, Bangalore, India), 1995.
- Harris E.G., Introduction to Modern Theoretical Physics, Vol. 1, John Wiley, New York, 1975.
- Srinivasa Rao K.N., The Rotation and Lorentz groups and their Representations for Physicists, Wiley Eastern, New Delhi, 2003.
- Shankar R., Principles of Quantum Mechanics, 2nd Edn., Plenum Press, New York, 1984.

COURSE III: MATHEMATICAL METHODS

Objectives:

- To study the rotation group and Fourier transform analysis to enhance the mathematical skills necessary to approach problems in research and advanced physics courses.

Course outcome:

- This course enables students to learn advanced mathematical tools to understand the classical mechanics, quantum, mechanics, quantum field theory, particle physics, nuclear physics etc. This course is very important in pursuing research for the students.

Pedagogy:

- Usage of the mathematical tool called groups to solve advanced problems and the application of it to the different field of physics.

COURSE CONTENT:

Linear representations of groups: Groups of regular matrices; the general linear groups GL(n, C) and GL(n, R). The special linear groups SL(n, C) and SL(n, R). The unitary groups U(n) and SU(n). The orthogonal groups O(n, C), O(n, R), SO(n, C) and SO(n, R).

Rotation group The matrix exponential function—Definition and properties. Rotation matrix in terms of axis and angle. Eigen values of a rotation matrix. Euler resolution of a rotation. Definition of a representation. Equivalence. Reducible and irreducible representations. Schur's lemma. Construction of the $D^{1/2}$ and D1 representation of SO(3) by exponentiation. Mention of the D^j irreps SO(3). [16 hours]

Special functions: Sturm Liouville theory, Bessel functions, Legendre functions and Spherical harmonics: Sturm Liouville theory: Self adjoint ODE's, Hermitian operators, completeness of eigenfunctions, Green's function—eigenfunction expansion. Bessel functions: Bessel functions of the first kind $J_v(x)$. Bessel differential equation, generating function for $J_v(x)$, integrals for $J_0(x)$ and $J_v(x)$, reccurence formulae for $J_v(x)$, orthogonal properties of Bessels polynomials. Legendre functions: Legendre differential equation, Legendre polynomials, generating functions, recurrence formulae, Rodrigues representation, orthogonality. Associated Legendre polynomials. The differential equation, orthogonality relation. Spherical harmonics: Definition and orthogonality.

Fourier transforms and integral equations: Integral transforms, Development of the Fourier integral. Fourier transforms-inversion theorem. Fourier transform of derivatives. Convolution theorem. Momentum representation, Integral equations: Types of linear integral equations—definitions. Transformation of a differential equation into an integral equation. Abel's equation, Neumann series, separable kernels.

References:

- Srinivasa Rao K.N., The Rotation and Lorentz Groups and their Representations for Physicists, Wiley Eastern, New Delhi, 1988.
- Arfken G.B. and Weber H.J., Mathematical Methods for Physicists, 5th. Edn., Academic Press, New York, 2001.Page no.621–630, 675–694, 741–770.
- Guptha B.D., Mathematical Physics, 4th Edn, 2011. Page no. 8.48–8.83, 8.16- 8.48

COURSE IV: CLASSICAL ELECTRODYNAMICS, PLASMA PHYSICS AND OPTICS Objectives:

- To evaluate the fields and forces in electrodynamics and magneto dynamics to provide concepts of relativistic electrodynamics and its applications in branches of physical sciences.

Course outcome:

- This course demonstrates the aspects of electrodynamics, plasma physics and optics.
- Students will be able to tackle real life problems in the field of communication, handling electrical circuits etc.

Pedagogy:

- Interactive classes are conducted by the help of the animations using the video..

COURSE CONTENT:

Electric multipole moments: The electric dipole and multipole moments of a system of charges. Multipole expansion of the scalar potential of an arbitrary charge distribution.

Potential formulation: Maxwell equations in terms of electromagnetic potentials. Gauge transformations. The Lorentz, Coulomb and radiation gauges.

Fields of moving charges and radiation: The retarded potentials. The Lienard Wiechert potentials. Fields due to an arbitrarily moving point charge. The special case of a charge moving with constant velocity.

Radiating systems: Radiation from an oscillating dipole. Power radiated by a point charges—Larmor formula. Lienard's generalisation of Larmor formula. Energy loss in bremsstrahlung and linear accelerators. Radiation reaction—Abraham-Lorentz formula.

Relativistic electrodynamics: Charge and fields as observed in different frames. Covariant formulation of electrodynamics-Electromagnetic field tensor-Transformation of fields - Field due to a point charge in uniform motion-Lagrangian formulation of the motion of charged particle in an electromagnetic field.

Plasma physics: Quasineutrality of a plasma-plasma behaviour in magnetic fields, Plasma as a conducting fluid, magnetohydrodynamics, magnetic confinement, Pinch effect, instabilities, Plasma waves.

Electromagnetic waves: Monochromatic plane waves—velocity, phase and polarization. Propagation of plane electromagnetic waves in (a) conducting media and (b) ionized gases. Reflection and refraction of electromagnetic waves—Fresnel formulae for parallel and perpendicular components. Brewster law. Normal and anomalous dispersion—Clausius-Mossotti relation.

Interference: General theory of interference of two monochromatic waves. Twobeam and Multiple-beam interference with a plane-parallel plate. Fabry-Perot interferometer—etalon construction, resolving power and its application. Interference filters.

Diffraction: Integral theorem of Helmholtz and Kirchoff. Fresnel-Kirchoff diffraction formula—conditions for Fraunhofer and Fresnel diffraction. Fraunhofer diffraction due to a circular aperture.

References:

- Griffiths D.J., Introduction to Electrodynamics, 5th Edn., Prentice-Hall of India, New Delhi, 2006.

- Jackson J.D., Classical Electrodynamics, 2nd Edn., Wiley-**Eastern Ltd, India, 1998.** • **Born M.** and Wolf E., Principles of optics, 6th Edn., Pergamon Press, Oxford, 1980.
- Matveev A.N., Optics, Mir Publishers, Moscow, 1988.
- Laud B.B., Electromagnetics, Wiley Eastern Limited, India, 2000.

COURSE V: Computer Lab CL-A

Objectives:

- To study the Linux operating system, LATEX.
- To study and understand the high level languages useful for the numerical computations.

Course outcome:

- This course will allow students to understand the use of the computer programs for the operating systems and it motivates them to write their own programs.

Pedagogy:

- Teaching and writing the program using PPT/ICT.
- Assigning the students to solve a physical problem with the help of the computer program.

COURSE CONTENT:

Linux operating system basics (4 sessions) : Login procedure; creating, deleting directories; copy, delete, renaming files; absolute and relative paths; Permissions—setting, changing; Using text editor.

Scientific text processing with LATEX: Typeset text using text effects, special symbols, lists, table, mathematics and including figures in documents.

Using the plotting program GNUPLOT (2 sessions) : Plotting commands; To plot data from an experiment and applying least-squares fit to the data points. Including a plot in a LATEX file.

Using the mathematics package OCTAVE (2 sessions) To compute functions, matrices, eigenvalues, inverse, roots.

SOFT CORE

COURSE VI : Optics Lab

Objectives:

- To understand the properties of the light and lasers.
- To have a hands on experience for handling the optical instruments and spectrometer.

Course outcome:

- The students will have an in depth knowledge about the properties and various phenomenon related to optics.
- Students will be able to describe features of real optical systems in terms of optical experiments.

Pedagogy:

- Familiarizing the students with the optical instruments of different wavelengths.
- Teaching the students about the practical skills to set up new experiments. Any ten of the following experiments:
- Verification of the Brewster law of polarisation.
- Verification of Fresnel laws of reflection from a plane dielectric surface.
- Determination of the inversion temperature of the copper-iron thermocouple.

- Birefringence of mica by using the Babinet compensator.
- Birefringence of mica by using the quarter-wave plate.
- Experiments with the Michelson interferometer.
- Determination of the refractive index of air by Jamin interferometer.
- Determination of the size of lycopodium spores by the method of diffraction haloes.
- Determination of wavelength by using the Fabry-Perot etalon.
- Dispersion of the birefringence of quartz.
- The Franck-Hertz experiment.
- Experiments with the laser.
- Determination of the Stokes vector of a partially polarised light beam
- Determination of the modes of vibration of a fixed-free bar.

COURSE VII: Electronics Lab

Objectives:

- To study the characteristics of electronic components and measuring instruments.
- To calculate and obtain different oscillator outputs and gain of Op-Amps with different configuration.

Course outcome:

- Able to analyze the characteristics of different components and electronic circuits.

Pedagogy:

- Familiarizing the students with the electronic instruments.
- Teaching the students about the practical skills regarding the electronic circuit

construction. Any ten of the following experiments:

- Regulated power supply.
- Active filters : low pass (single pole).
- Active filters : high pass (double pole).
- Voltage follower.
- Colpitts' oscillator.
- Opamp as an integrator and differentiator.
- Opamp as a summing and log amplifier.
- Opamp as an inverting and non-inverting amplifier.
- Coder and encoder.
- Half adder and full adder.
- Boolean algebra-Logic gates.
- Opamp astable multivibrator.

SECOND SEMESTER

HARD COURE

COURSE I: CONTINUUM MECHANICS AND RELATIVITY

Objectives:

- To study the fluid mechanics and continuum mechanics of solid media.
- To study the relativistic mechanics of a material particle and theory of relativity.

Course outcome:

- This course helps the students the significance and applications of special theory and general theory of relativity.
- It also gives the importance of continuum mechanics. By this course student can gain the knowledge about satellite communication and real problems with the fluids.

Pedagogy:

- Familiarizing the students with the use of advanced mathematical concepts to solve the practical problems.

COURSE CONTENT:

Continuum mechanics of solid media: Small deformations of an elastic solid; the strain tensor. The stress tensor. Equations of equilibrium and the symmetry of the stress tensor. The generalised Hooke law for a homogeneous elastic medium; the elastic modulus tensor. Navier equations of motion for a homogeneous isotropic medium.

Fluid mechanics: Equation of continuity. Flow of a viscous fluid—Navier-Stokes equation and its solution for the case of a flow through a cylindrical pipe. The Poiseuille formula.

Minkowski space time: Real coordinates in Minkowski space time. Definition of 4-tensors. The Minkowski scalar product and the Minkowski **metric $\eta_{ij} = \mathrm{diag}(1, -1, -1, -1)$. Orthogonality of 4-**vectors. Raising and lowering of 4-tensor indices. Time like, null, and space like vectors and world-lines. The light-cone at an event.

Relativistic mechanics of a material particle: The proper-**time interval $d\tau$ along the world**-line of a material particle. The instantaneous (inertial) rest-frame of a material particle and the components of 4-velocity, 4-acceleration and the 4-momentum vector in this frame. Statement of second law of Newton in this frame. Determination of the fourth component F_4 of the 4-force along the world-line of the particle. Motion of a particle under the conservative 3-force field and the energy integral. The rest energy and the relativistic kinetic energy of a particle.

Einstein's equations: The Principle of Equivalence and general covariance, inertial mass, gravitational mass, E¨otv¨os experiment, gravitation as space time curvature, Gravitational field equations of Einstein and its Newtonian limits.

The Schwarzschild metric: Heuristic derivation of the Schwarzschild line element. Motion of particles and light rays in the Schwarzschild field. Explanation of the (a) perihelion advance of planet Mercury, (b) gravitational red shift and (c) gravitational bending of light. A brief discussion of the Schwarzschild singularity and the Schwarzschild black hole.

References:

- Landau L.D. and Lifshitz E.M., Fluid Mechanics, Pergamon Press, 1987.
- Landau L.D. and Lifshitz E.M., Theory of Elasticity, Pergamon Press, 1987.
- Synge J.L., Relativity: The Special Theory, North-Holland, 1972.
- Landau L.D. and Lifshitz E.M., The Classical Theory of Fields, 4th Edn., (Sections 1 to 6, 16 to 18, 23 to 25, 26 to 35), Pergamon Press, Oxford, 1985.
- Wald R.M., General Relativity, The University of Chicago Press, Chicago, 1984.
- Schutz B.F., A First Course in General Relativity, Cambridge University Press, Cambridge, 1985.
- Bergman P., Introduction to Theory of Relativity, Prentice-Hall of India, 1969.
- Rindler R., Relativity: Special, General and Cosmological, Oxford University Press, 2006.

COURSE II: Thermal

Objectives:

- To study the thermodynamics of physical problems.
- To study the classical and quantum statistical mechanics and applications of quantum statistics.

Course outcome:

- This course reveals the concepts of thermodynamics, both classical and quantum statistical mechanics. This course is very essential in dealing with the system of large particles, heat transfer and dynamics of biological molecules.

Pedagogy:

- Explanation of the thermo dynamical parameters with the use of the physical models.
- Understanding the concepts of statistics and probability with the help of the video.

Course Contents:

Thermodynamics preliminaries: A brief overview of thermodynamics, Maxwell's relations, specific heats from thermodynamic relations, the third law of thermodynamics. Applications of thermodynamics: Thermodynamic description of phase transitions, Surface effects in condensation. Phase equilibria; Equilibrium conditions; Classification of phase transitions; phase diagrams; Clausius-Clapeyron equation, applications. Van der Waals equation of state. Irreversible thermodynamics—Onsager's reciprocal relation, thermoelectric phenomenon, Peltier effect, Seebeck effect, Thompson effect, systems far from equilibrium.

Classical statistical mechanics: Phase space, division of phase space into cells, ensembles, ergodic hypotheses, average values in phase space, density distribution in phase space. Liouville theorem, statistical equilibrium, postulate of equal a priori probability, Stirilings formula, concept of probability, microstates and macrostates, general expression for probability, the most probable distribution, Maxwell-Boltzmann distribution, microcanonical ensemble, canonical ensemble, grand canonical ensemble, partition function of system of particles, translational partition function (monoatomic). Boltzmann theorem of equipartition of energy, vibrational partition function of diatomic molecules (Einstein relations), rotational partition function (diatomic).

Quantum statistical mechanics: The postulates of quantum statistical mechanics. Symmetry of wave functions. The Liouville theorem in quantum statistical mechanics; condition for statistical equilibrium; Ensembles in quantum mechanics; The quantum distribution functions (Bose Einstein and Fermi Dirac); the Boltzmann limit of Boson and Fermion gases; the derivation of the corresponding distribution functions.

Applications of quantum statistics: Equation of state of an ideal Fermi gas (derivation not expected), application of Fermi-Dirac statistics to the theory of free electrons in metals. Application of Bose Einstein statistics to the photon gas, derivation of Planck's law, comments on the rest mass of photons, Thermodynamics of Black body radiation. Bose-Einstein condensation.

References:

- Agarwal B.K. and Eisner M., Statistical Mechanics, New Age International Publishers, 2000.
- Roy S.K., Thermal Physics and Statistical Mechanics, New Age International Pub., 2000.
- Huang K., Statistical Mechanics, Wiley-Eastern, 1975.
- Laud B.B., Fundamentals of Statistical Mechanics, New Age International Pub., India, 2000, p6–39, p77–105.
- Gopal E.S.R., Statistical Mechanics and Properties of Matter, Ellis Horwood Ltd., UK, 1976, p34–77.
- Schroeder D.V., An Introduction to Thermal Physics, Pearson Education New Delhi, 2008.
- Salinas S.R.A., Introduction to Statistical Physics, Springer, 2004.

COURSE III: Quantum Mechanics

Objectives:

- To study the formalism, concepts of time-dependent and time-independent perturbation theory and their applications to physical situations.

Course outcome:

- This course conveys to deal with the phenomenon happening at the smaller scales.
- It equips the students with the tools for understanding the subnuclear processes. This is useful in understanding the phenomenon applied to the nanoscience and nanotechnology.

Pedagogy:

- To introduce the basic concepts of the quantum mechanics.
- Application of the quantum ideas to solve various problems in physics.

Course Contents:

Introduction: The wave function, the Schrodinger equation, the statistical interpretation, probability, discrete and continuous variables, normalisation, momentum, the uncertainty principle [Griffiths, Chap. 1].

The time-independent Schrodinger equation: Stationary states, the infinite square well, the harmonic oscillator, algebraic and analytic methods, the free particle, the delta-function potential, the finite square well

Formalism: Hilbert space, observables, eigenfunctions of a Hermitian operator. The generalized statistical interpretation, the uncertainty principle, Dirac notation. [Griffiths, Chap. 3]. Quantum mechanics in three dimensions, Schrodinger equations in spherical coordinates, the hydrogen atom, angular momentum, spin [Griffiths, p143–189]. Identical particles: two particle systems, atoms, solids.

The time-independent perturbation theory: Nondegenerate perturbation theory, first and second order perturbation, degenerate perturbation theory, the fine structure of hydrogen, the Zeeman effect. The variation principle: theory, the ground state of helium, the hydrogen molecule ion, the WKB approximation: the classical region, tunneling [Griffiths, p261–273, 278–282, 289–292, 305–320, 327–337].

References:

- Griffiths D.J., Introduction to Quantum Mechanics, 2nd Edition, Pearson, India, 2005.
- Shankar R., Principles of Quantum Mechanics, 2nd Edn., Plenum Press, New York, 1984.

COURSE IV: Spectroscopy and Fourier Optics

Objectives:

- To provide an understanding the fundamental aspects of spectroscopy and Fourier optics.
- To learn the basic principles and working of NMR, FTIR and Raman spectroscopy.

Course outcome:

- This course is very useful in getting the tools of atomic and molecular spectroscopy. And also it helps in understanding the concepts of modern optics. These tools are directly applicable to handle real life problems of spectroscopy and nonlinear optics.

Pedagogy:

- Understanding the application of the mathematical tools for the spectroscopy field.

Course Contents:

Atomic spectroscopy: Spectroscopic terms and their notations. Spin-orbit interaction, quantum mechanical relativity correction; Lamb shift. Zeeman effect, normal and anomalous Zeeman effect, Paschen-Back effect. Stark effect, Weak field and strong field effects. Hyperfine structure of spectral lines: Nuclear spin and hyperfine splitting, intensity ratio and determination of nuclear spin. Breadth of spectral lines, natural breadth, Doppler effect and external effect.

Nuclear magnetic resonance: Quantum mechanical expression for the resonance condition. Relaxation Mechanisms: Expression for spin lattice relaxation. Chemical shift: spin-spin interaction. Example of ethyl alcohol. Fourier transform technique in NMR. FTNMR spectrometer and experimental procedure. Note on NMR in medicine.

Microwave spectroscopy: The classification of molecules. The rotational spectra of rigid diatomic rotator and spectra of non-rigid diatomic rotator. Note on microwave oven.

Infrared spectroscopy: Vibrational energy of diatomic molecule.Anhormoic oscillator The diatomic vibrating rotator, example of the CO molecule. The vibrations of polyatomic molecules; skeletal and group frequencies. Experimental technique in FTIR.

Raman spectroscopy: The quantum theory of Raman effect. Pure rotational Raman spectra of linear molecules and symmetric top molecules. Vibrational Raman spectra. Rotational fine structure. Instrumentation technique in Raman spectroscopy.

Fourier optics: Spatial frequency filter–effect of a thin lens on an incident field distribution. Lens as a Fourier transforming element. Application to phase contrast microscopy.

Propagation of light in an anisotropic medium: Structure of a plane electromagnetic wave in an anisotropic medium. Dielectric tensor. Fresnel's formulae for the light propagation in crystals. Ellipsoid of wave normals and ray normals. The normal and ray surface. Optical classification of crystals. Light propagation in uniaxial and biaxial crystals. Refraction in crystals. Elements of non-linear optics: Second harmonic generation, optical rectification and phase matching; third harmonic generation.

References:

- Tralli N. and Pomilla P.R., Atomic Theory, McGraw-Hill, New York, 1999.
- Banwell C.N. and McCash E.M., Fundamentals of Molecular Spectroscopy, 4th Edn., Tata McGraw-Hill, New Delhi, 1995.
- Hecht E., Optics, Addison-Wesley, 2002.
- Lipson S.G., Lipson H. and Tannhauser D.S., Optical Physics, Cambridge University Press, USA, 1995.

SOFT COURE

COURSE V: COMPUTER LAB

Objectives:

- To study the Linux operating system, LATEX.
- To study and understand the high level languages useful for the numerical computations.

Course outcome:

- This course will allow students to provide exposure to problem solving through programming.
- Be able to write the program, edit, compile, debug, correct, recompile and run.

Pedagogy:

- To familiarize the students with the advanced computer programmes helpful for the computational studies.

Programming

- Check whether given number is odd or even.
- Find the largest and smallest number in the input set.
- Compute the Fibonacci sequence.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Generate Pascal's triangle.
- To add two m × n matrices.
- To find the sum and average of a data stored in a file.
- Linear least-squares fitting to data in a file.
- To find the trajectory of a projectile shot with an initial velocity at an angle. Also, find the maximum height travelled and distance travelled. Write the trajectory data to a file specified and plot using Gnuplot.

Programming in Perl

- Searching for a pattern in a string
- Counting the number of characters, words and lines in a given file.
- Sorting strings.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Linear least squares fitting to data in a file.

OPEN ELECTIVE

COURSE VIII: Modern Physics

Objectives:

- To provide exposure for non-physics postgraduate student about the basics of the different fields of physics.

Course outcome:

- This course trains the students from other disciplines about the various concepts of physics.

Pedagogy:

- To introduce the basic concepts of physics related to the different fields of science. Paper to be offered to Non-physics postgraduate students

Course Contents:

Nuclear physics: A brief overview of nuclear physics. Nuclear reactions, a brief description of nuclear models. Interactions of X-**rays and** γ-rays with matter, slowing down and absorption of neutrons. Fundamental particles, classification of fundamental particles, fundamental forces, conservation laws in particle physics, a brief outline of the quark model.

Nuclear power: Nuclear fission, fission chain reaction, self sustaining reaction, uncontrolled reaction, nuclear bomb. Nuclear reactors, different types of reactors and reactors in India. Nuclear waste management. Nuclear fusion, fusion reactions in the atmosphere. Radiation effects—dosage calculation. Nuclear energy—applications and disadvantages.

Condensed matter physics: Amorphous and crystalline state of matter. Crystal systems. Liquid crystals. X-ray diffraction—Bragg equation. Structure of NaCl. FTIR—Experiment analysis. NMR— Experiment and analysis. Electrical conductivity of metals and semiconductor. Magnetic materials— para,ferro, ferri and anti-magnetism. Dielectrics—para, ferro, pyro and piezo properties. Symmetry in physics.

Quantum physics: Qualitative discussion. Molecules, atoms, nucleus, nucleons, quarks and gluons. Particle physics (qualitative). Stern-Gerlach experiment and consequences. Uncertainty relation. Hydrogen atom. Positron annihilation. Laser trapping and cooling. Ion traps. Electromagnetic, strong, weak and gravitational forces. Big Bang theory, String theory. Large Hadron Collider experiment, consequences. Higgs Boson.

References:

- Ghoshal S.N., Atomic and Nuclear Physics, Vol.2., S. Chand and Company, Delhi, 1994.
- Evans R.D., Atomic Nucleus, Tata McGraw Hill, New Delhi, 1976.
- Penrose R., Road to Reality, Vintage Books, 2007.
- Ladd M.F.C. and Palmer R.A., Structure Determination by X-ray Crystallography, Plenum Press, USA, 2003.
- De Gennes P.G. and Prost J., The Physics of Liquid Crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
- Myer R., Kennard E.H. and Lauritsern T., Introduction to Modern Physics, 5th Edn., McGraw-Hill, New York, 1955.
- Halliday D., Resnick R. and Merryl J., Fundamentals of Physics, Extended 3rd Edn., John Wiley, New York, 1988.

THRIED SEMESTER

HARD COURE

COURSE I: NUCLEAR AND PARTICLE

Objectives:

- To impart knowledge about properties of nucleus, nuclear models, nuclear reactions and interaction of nuclear radiation with matter.
- To study the nuclear forces and elementary particles interaction.

Course outcome:

- This course has direct outcome on students to get the overview of properties of nucleus, its different models, nuclear decays, techniques in nuclear detection and particle physics.
- This course motivates to take up research work in the field of high energy physics.

Pedagogy:

- Explaining different types of nuclear models using video.
- Basic concepts regarding the subatomic particles and their constituents are introduced.

Course Contents:

Properties of the nucleus: Nuclear radius-determination by mirror nuclei, mesic X-rays and electron scattering methods. Nuclear moments-spin, magnetic dipole moment. Relation between J and μ on the basis of single particle model. Determination of nuclear magnetic moment by molecular beam experiment. Electric quadrupole moment.

Nuclear models: Liquid drop model-Weissacker's formula and its application to (i) stability of isobars and (ii) fission process. Shell model-single particle potentials, spinorbit coupling. Magic numbers. Fermi gas model-well depth, level density and nuclear evoparation.

Nuclear reactions: Q-values. Threshold energy. Reactions induced by proton, deutron and particles. Photodisintegration.

Nuclear decay modes: Beta decay: Beta ray spectrum, Pauli neutrino hypothesis, mass of the neutrino from beta ray spectral shape, Fermi theory of beta decay, Kurie plot, ft- values and forbidden transitions. Methods of excitation of nuclei. Nuclear isomerism. Mossbauer effect (qualitative only). Auger effect.

Interaction of nuclear radiation with matter and detectors: Energy loss due to ionization for proton-like charged particles. Bethe-Bloch formula. Range-energy relations. Ionization and radiation loss of fast electrons (Bremsstrahlung) (qualitative only). Interaction of gamma and X-rays with matter. Brief description of NaI (Tl) gamma ray spectrometer. Boron triflouride counter.

Nuclear reactors: Condition for controlled chain reactions, slowing down of neutrons, logarithmic decrement in energy, Homogeneous spherical reactor, Critical size. Effect of reflectors. Breeder reactor (Qualitative discussion).

Nuclear forces and elementary particles: General features of nuclear forces: General features of nuclear forces; spin dependence, charge independence, exchange character etc. Meson theory of nuclear forces- Yukawa's theory. Properties of pi mesons, charge, isospin, mass, spin and parity, decay modes, meson resonances.

Particle interactions and families: Conservation laws—classification of fundamental forces and elementary particles. Associated particle production, Gellmann-Nishijima scheme, strange particles.

CP violation in Kaon decay. Symmetries—Eight-fold way symmetry, quarks and gluons. Elementary ideas of the standard model.

References:

- Tayal D.C., Nuclear Physics, Himalaya Publishing House, New Delhi, 2012 (Unit 1. Chapter 1. Page 6-14. Page 30- 35, 40-49. Chapter 9. Page 355-369. Chapter 10. Page 401-411.)
- Krane K.S., Introductory Nuclear Physics, Wiley, New York, 1987. (Unit 1. Chapter 16 page 605-610.)
- Ghoshal S.N., Nuclear Physics, S.Chand and Company, Delhi, 1994. (Unit 2: Chapter 5 page 137-155, Chapter 6 page 187-204, 222, 262, Chapter 13, page 647-651, chapter 15, page 717-721.)
- Wong S.S.M., Introductory Nuclear Physics, Prentice Hall of India, Delhi, 1998.
- Khanna M.P., Introduction to Particle Physics, Prentice Hall of India, Delhi, 2008.
- Kapoor S.S. and Ramamoorthy V., Nuclear Radiation Detectors, Wiley Eastern, Bangalore, 2007.

COURSE II: CONDENSED MATTER

Objectives:

- To understand the X-ray crystallography and experimental techniques.
- To provide knowledge of crystal growth, liquid crystals, crystal lattice dynamics and magnetic properties of solids.
- To study about the conductivity of superconductors and semiconductors
- To study the characteristics of various semiconductor devices.

Course outcome:

- This course conveys the picture of tools in solid state physics such as, crystallography, semiconductor physics and superconductors. This enables the students to pursue research in materials science.

Pedagogy:

- Fundamental concept regarding the interactions of the electromagnetic radiations with the matter and basics of crystallography is explained.
- Introducing current advanced topics in the field of semiconductors and superconductors.

Course Contents:

X-ray crystallography: Crystalline state. Reference axes, equation of a plane, Miller indices. Symmetry operations. Two and three dimensional point groups. Lattices; two dimensional lattices, choice of unit cell [Buerger, p12–20, 23–45]. Three-dimensional lattices; crystal systems and Bravais lattices [Ladd and Palmer, p55–66]. Screw and glide operations. Space groups; analysis of the space group symbol. Diffraction of X-rays by crystals: Laue equations. Reciprocal lattice [Sherwood, p272– 288]. Bragg equation. Equivalence of Laue and Bragg equations [Ladd and Palmer, p114–121]. Atomic scattering factor (qualitative).

Experimental techniques: Brief introduction to single crystal and powder methods.

Electron and neutron diffraction: Basic principles. Differences between them and X-ray diffraction. Applications (qualitative) [Vainshtein, p336–338,350–352, 355-357].

Crystal growth: Czochralski, Kyropoulus, Stockbarger-Bridgman and zone refining techniques [Rose et al., p146–154].

Liquid crystals: Morphology. The smectic (A-H), nematic and cholesteric phases. Birefringence, texture and X-ray studies in these phases [Gray and Goodby]. Orientational order and its determination in the case of nematic liquid crystals.

Crystal lattice dynamics: Vibration of an infinite one-dimensional monoatomic lattice, First Brillouin zone. Group velocity. Finite lattice and boundary conditions. Vibrations of a linear diatomic lattice—optical and acoustical branches; relation [Wahab, p288–305].

Magnetic properties of solids: Diamagnetism and its origin. Expression for diamagnetic susceptibility. Paramagnetism. Quantum theory of paramagnetism. Brillouin function. Ferromagnetism. Curie-Weiss law. Spontaneous magnetisation and its variation with temperature. Ferromagnetic domains. Antiferromagnetism. Two sub-lattice model. Susceptibility below and above Neel's temperature [Dekker, p446–490].

Superconductivity: Experimental facts. Type I and type II semiconductors. Phenomena logical theory. London equations. Meissner effect. High frequency behaviour. Thermodynamics of superconductors. Entropy and Specific heat in the superconducting state. Qualitative ideas of the theory of superconductivity [Kittel, p333–364].

Semiconductors: Intrinsic Semiconductors. Crystal structure and bonding. Expressions for carrier concentrations. Fermi energy, electrical conductivity and energy gap in the case of intrinsic semiconductors. Extrinsic Semiconductors; impurity states and ionization energy of donors. Carrier concentrations and their temperature variation. Qualitative explanation of the variation of Fermi energy with temperature and impurity concentration in the case of impurity semiconductors [Mckelvey, p256–277].

Semiconductor devices: Brief discussion of the characteristics and applications of, phototransistors, JFET, SCR and UJT.

References:

- Buerger M.J., Elementary Crystallography, Academic Press, UK, 1956.
- Ladd M.F.C. and Palmer R.A., Structure Determination by X-ray Crystallography, Plenum Press, USA, 1977.
- Sherwood D., Crystals, X-rays and Proteins, Longman, UK, 1976.
- Rose R.M., Shepard L.A. and Wulff J., The Structure and Properties of Materials Vol. 4, Electronic properties, Wiley Eastern, 1965.
- Vainshtein B.K., Modern Crystallography, Vol. I, Springer-Verlag, Germany, 1981.
- Gray G.W. and Goodby J.W.G., Smectic Liquid Crystals: Textures and structures, Leonard Hill, USA, 1984.
- Dekker A.J., Solid State Physics, Prentice Hall, 1985.
- Kittel C., Introduction to Solid State Physics, 7th Edn., John Wiley, New York, 1996.
- Mckelvey J.P., Solid State and Semiconductor Physics, 2nd Edn., Harper and Row, USA, 1966.
- Streetman B.G., Solid State Electronic Devices, 2nd Edn., Prentice-Hall of India, New Delhi, 1983.
- De Gennes P.G. and Prost J., The Physics of Liquid Crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
- Wahab M.A., Solid State Physics, Narosa Publishing House, New Delhi, 1999.
- Pillai S.O., Solid State Physics, New Age International Publications, 2002.

COURSE III: NUCLEAR PHYSICS

Objectives:

- To impart advanced knowledge about nuclear detectors and nuclear pulse techniques.
- To study the timing spectroscopy and gamma ray spectroscopy.

Course outcome:

- This course of nuclear physics provides insight in to the concepts such as, detectors and its electronics and the models to understand the properties of nucleus. This has direct impact of undertaking the research in both experimental and theoretical nuclear physics.

Pedagogy:

- Various types of nuclear detectors and their working principles are explained.

Course Contents:

Nuclear detectors: Scintillation processes in inorganic crystals (NaI(Tl)). Semiconductor detectors—Diffused junction, Surface barrier and Lithium drifted detectors Relation between applied voltage and depletion layer thickness in junction detectors, Hyper pure germanium detectors, Cerenkov detectors.

Nuclear pulse techniques: Preamplifier circuits. Charge sensitive and voltage sensitive preamplifiers. Linear pulse amplifiers. Linearity, stability, pulse shaping, pulse stretching. operational amplifiers. Analog to digital converters. Scalars, Schmidt trigger as a pulse discriminator, Single channel analyser-Integral and differential discriminators. Multichannel Analysers, memory devices and online data processing.

Shell model: Motion in a mean potential. Square well and simple harmonic oscillator potential well, spin-orbit interaction and Magic numbers. Extreme single particle model, Ground state properties of nuclei based on shell model. Nordheim's Rules.

Collective model: Evidences for the collective motion. Nuclear rotational motion. Rotational energy spectrum and nuclear wave functions for even-even nuclei. Odd- A nuclei energy spectrum and wave function.

Nilsson model: Nilsson diagrams.

Many body self-consistent models: Hartree-Fock model.

Timing spectroscopy: Coincidence and anti-coincidence circuits. Delay circuits. Time to amplitude conversion- Start-stop and overlap converters.

Gamma ray spectroscopy: Life time measurements. Gamma-gamma, beta-gamma angular correlation studies. Angular distribution of gamma rays from oriented nuclei. Polarization of gamma rays.

References:

- Mermier P. and Sheldon E., Physics of the Nuclei and Particles, Vol. 1 and 2, Academic Press, New York 1970.
- Segre E., Nuclei and Particles, Benjamin Inc, New York, 1977.
- Arya A.P., Fundamentals of Nuclear Physics, Allyn and Bacon, USA, 1968.
- Blatt J.M. and Weisskopf V.F., Theoretical Nuclear Physics, Wiley and Sons, New York, 1991.
- Siegbahn K., The alpha, beta and gamma ray Spectroscopy: Vol. 1 and 2, North Holland, Amsterdam, 1965.
- Price J.W., Nuclear Radiation Detectors, McGraw Hill, New York, 1965.

- Kapoor S.S. and Ramamoorthy V., Nuclear Radiation Detectors, Wiley Eastern, Bangalore, 1993.
- Kowalski E., Nuclear Electronics, Springer Verlag, Berlin,1970.
- Leo W.R.,Techniques for Nuclear and Particle Physics Experiments, Springer Verlag, 1992.
- Roy R.R. and Nigam B.P., Nuclear Physics, New Age International, New Delhi, 1986.
- Hans H.S., Nuclear Physics—Experimental and Theoretical, New Age International Publishers, 2001.

COURSE IV: CONDENSED MATTER PHYSICS

LAB Objectives:

- To study the magnetic properties of the given samples.
- To understand the properties of the semiconductors and their applications in real life.

Course outcome:

- This course trains the students to handle experiments in the field of condensed matter physics independently.

Pedagogy:

- Various parameters regarding the magnetism and semiconductors are explained.
- Determination of the paramagnetic susceptibility of the given salt by Quincke's method
- Study of mercury spectrum by superimposing it on brass spectrum
- Sodium spectrum analysis by using Edser-Butler fringes
- Temperature coefficient of resistance of a thermister
- Analysis of the powder X-ray photograph of a simple cubic crystal
- Thermionic work function of a metal (Richardson-Dushmann formula)
- Energy gap of a semiconductor
- Determination of Stefan'sconstant
- Frank Hertz experiment
- Magnetic Hysterisis
- Measurement of magneto resistance of semiconductors

SOFT COURE

COURSE V: NUCLEAR PHYSICS LAB

Objectives:

- To learn about the nuclear properties using the electronics basic ideas.

Course outcome:

- Be able to understand the design of the nuclear equipments.
- Be able to analyze the data and correlate with the nuclear properties.

Pedagogy:

- Practical applications of the electrical circuits to explain the nuclear phenomenon is explained.

Course Contents:

For those who have opted for PHY303

Any five of the following experiments:

- Cockroft-Walton voltage multiplier.
- Coincidence circuit.

- Linear pulse amplifier.
- Transistorised binary circuit.
- Pulse shaping circuits.
- Linear Gate.
- Randomocity of radioactive decay.
- Nomogram method : Measurement of endpoint energy of beta rays.
- Study of linearity of the NaI(Tl) gamma ray spectrometer with SCA and hence determination of energy of unknown gamma source.
- Determination of the rest mass energy of the electron using MCA.
- Study of the variation of resolution of NaI(Tl) spectrometer as a function of energy.

COURSE VI: NUCLEAR PHYSICS LAB

Objectives:

- To understand and demonstrate the nuclear physics experiments.
- To study and understand the working of the electrical instruments used in the construction of nuclear devices.

Course outcome:

- This course trains the students to handle experiments related to nuclear physics independently.

Pedagogy:

- Basic principles of the nuclear radiations are

explained. Any eight of the following experiments

- Half-life of Indium-116 measurement.
- Energy Resolution of a NaI(Tl) scintillation spectrometer.
- Compton scattering—determination of the rest energy of an electron.
- Beta absorption coefficient measurement.
- Dekatron as a counter of signals.
- Gamma-ray absorption coefficient measurement.
- End-point energy of Beta particles by half thickness measurement.
- Common Source amplifier.
- Astable multivibrator using timer IC 555.
- Dead time of the G.M. counter.

COURSE VII : Solid State Physics

Objectives:

- To provide detailed knowledge about the electrical, magnetic properties of solids.
- To provide the significance and applications of the band theory of solids.

Course outcome:

- This course gives deep insight in to the concepts of solid state physics, dielectric properties of solids, magnetic properties, band theory of solids and superconductivity.
- This course makes the students to take up specific research in the field of materials science and theoretical solid state physics.

Pedagogy:

- Ideas regarding the different types of the magnetic materials are introduced.
- Applications of superconducting materials and crystals are introduced.

Course Contents:

Dielectric properties of solids: Macroscopic description of static dielectric constant, the static electronic and ionic pollarizabilities of molecules, orientation polarization, the static dielectric constant of gases, Local electric field at an atom. Lorentz field, field of dipoles inside cavity. The static dielectric constant of solids, Clausius- Mossotti relation, the complex dielectric constant and dielectric losses. Polarization catastrophe. Dielectric losses and Debye relaxation time. Classical theory of electronic polarization and optical absorption.

Ferroelectricity: Basic properties of ferroelectric materials. Classification and properties of ferroelectrics. Dipole theory of ferroelectricity, objections against the dipole theory, ionic displacements and behavior of Barium titanate above the curie temperature, theory of spontaneous polarization of Barium titanate. Thermodynamics of ferroelectric transitions. Landau theory of phase transitions, Dielectric constant near the curie point. Ferroelectric domains.

Magnetic properties: Definition of Magnetisation and susceptibility. Hunds rule. Calculation of L,S and J for 3d and 4f shells. Setting up of Hamiltonian for an atom in an external magnetic field. Based on this, explanation of diamagnetism, Van Vleck Paramagnetism and quantum theory of paramagnetism using the above hamiltonian,in solids(see Ashcroft and Mermin). Interpretation of the Weiss field interms of exchange integral(Page 473-474, A J Dekker). Calculation of the singlet-triplet splitting, Spin Hamiltonian and Heisenberg model.(as given in Ashcroft N.W. and Mermin N.D)

Zero-temperature properties: Ground state of the Heisenberg ferromagnet. First excitation of one-dimensional ferromagnetism at zero-temperature: spin waves in onedimensional ferromagnetism and anti-ferromagnetism.Low-temperature behaviour of ferromagnets: Bloch's T3/2 law.(as given in Ashcroft N.W. and Mermin N.D and C Kittel)

Magnetic resonance: Phenomenological description, Relaxation mechanisms,Derivation of Casimir-Durpe relation. Nuclear Magnetic moments, condition for resonance absorption, Setting up of Bloch's equations, obtaining solutions for the steady state case and that of the weak RF field, expression for power absorption, change of inductance near resonance. Dipolar line width in a rigid lattice (as given 498-512 of A J Dekker).

Band theory of solids: Statement and proof of Bloch theorem. Explanation of periodic potentials in solids. Reciprocal lattice, periodic boundary conditions, density of states. Construction of Brillouin zones for a square lattice. Nearly free electron model and solution at the boundary. Discussion of energy gap using nearly free electron model.Tightly bound electron approximation, application to simple cubic , BCC and FCC lattices. Constant energy surfaces, Fermi surfaces.square lattice. Overlapping of bands.(as given in A J Dekker)

Superconductivity: Elementary ideas of BCS theory. Formation of Cooper pairs and explanation based on theory (as given in Ibach and Luth). Energy gap, Meissner effect, flux quantisation, Josephson tunnelling,Josephson junction.Theory for DC and AC bias. High Tc superconductors.(as given in Ibach and Luth)

Elastic constants of crystals: Definition of elastic strains and stresses in a solid. Elastic compliance and stiffness constants, Applications to cubic crystals and isotropic solids. Elastic waves and experimental determination of elastic constants (as given in C Kittel).

References:

- Dekker A.J., Solid State Physics, Prentice Hall, 1985.page no. 133-157,185-209
- Kittel C., Introduction to Solid State Physics, 7th Edn., John Wiley, New York, 1996.
- Ashcroft N.W. and Mermin N.D., Solid State Physics, Saunders College Publishing, 1996.
- Iback H and Luth H., Solid State Physics, Narosa, New Delhi, 1996.

- Pillai S.O., Solid State Physics, New Age International Publications, 2002.
- Wahab M.A., Solid State Physics, Narosa Publishing House, New Delhi, 1999.

COURSE VIII : Solid State Physics Labl ****

COURSE IX: THEORETICAL

Objectives:

- To study the advanced concepts of special theory of relativity.
- To familiarize the students with advanced mathematical concepts.

Course outcome:

- This course gives theoretical tools to general theory of relativity, Riemannian geometry, gravitational field and Quantum field theory.
- This is an essential training towards students taking research in astrophysics, theoretical physics etc.

Pedagogy:

- Advanced mathematical and quantum ideas are incorporated.

Course Contents:

General theory of relativity: Tensor calculus and Riemannian geometry: Covariant differentiation, Parallel transport, Geodesies, The curvature tensor

Riemannian geometry: Riemannian space, The determinant of gμν. Metrical Densities, The Connection of a Riemannian Space: Christoffel Symbols, Geodesies in a Riemannian Space, The Curvature of a Riemannian Space: The Riemann Tensor.

Gravitational field: The Principle of Equivalence, The Field Equations of General Relativity, Metrics with Spherical Symmetry, The Schwarzschild Solution. Geodesies in the Schwarzschild Space, Advance of the Perihelion of a Planet, The Deflection of Light Rays, Red Shift of Spectral Lines, The Schwarzschild Sphere. Gravitational Collapse. Black Holes.

Quantum field theory-1: Classical and quantum fields: Particles and fields, Discrete and continuous mechanical systems, Classical scalar fields, Maxwell fields Quantum Theory of Radiation: Creation, annihilation, and number operators, Quantized radiation field, Fock states, Emission and absorption of photons by atoms, Rayleigh scattering, Thomson scattering, and the Raman effect.

References:

- Papapetrov A., Lectures on General Relativity, D. Reidel Publishing Company, USA, 1974.
- Dirac P.A.M., The General Theory of Relativity, John Wiley and Sons, New York, 1975.
- Adler R., Bazin M. and Schiffer M., Introduction to General Relativity, McGraw-Hill Kogakusha, Ltd. New Delhi, 1965.
- Hartle J.B., Gravity: An introduction to Einstein's General Relativity, Benjamin Cummings Pub. Co., USA, 2002.
- Sakurai J.J., Advanced Quantum Mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
- Griffiths D., Introduction to Elementary Particles, John Wiley and Sons, New York, 1987.
- Gasiorowicz S., Elementary Particle Physics, John-Wiley, New York, 1966.
- Muirhead H., The Physics Of Elementary Particles, Pergamon Press, London, 1965.

COURSE X: THEORETICAL LAB-1

Objectives:

- To understand and apply the theoretical ideas for various problems.

Course outcome:

- Be able to write the Lagrangian and Hamiltonian of various

system. For those who have opted for PHY305

Any five of the following experiments:

- Calculation of Christoffel symbols.
- Geodesics and curvature calculations.
- Exterior Schwarzschild metric calculations.
- Robertson-Walker metric calculations.
- Lagrangian and Hamiltonian, Euler Lagrange equations for Schroedinger field.
- Lagrangian for Maxwell's field and The field equations.
- Symmetries of the Lagrangian and Constants of motion.
- Operator algebra-BCH formula.
- Relativistic kinematics-1: Relations between center of momentum and laboratory frames.
- Relativistic kinematics-2: Non-relativistic limit of relativistic kinematics.

COURSE XI : ACCELERATOR

Objectives:

- To provide the significance and applications of ion sources, ion optics and focusing.
- To give exposure about particle and electron accelerators and its applications.

Course outcome:

- This course is an application and technological training for the students to learn tools in the theory and construction of accelerators. This course enables to take students to pursue research in high energy physics, materials science and nuclear physics.

Pedagogy:

- Basic ideas of the principle and working of the accelerators are explained.

Course Contents:

Ion sources: Brief introduction to ion sources for positive and negative ions. Ion production. Semi classical treatment of ionization, Townsend theory-comparison of theory and experiment for ion production. Examples of ion sources-properties of ion sources. Insulation at high voltages-Spark voltage. Paschen's law for gas breakdown.

Ion optics and focussing: Focussing properties of linear fields. Electrostatic and magnetic lenses.

Particle accelerators: Introduction, development of accelerators. Direct-voltage accelerators: Cockroft-Walton generator, Van de Graff generator, Tandem accelerators, Pelletron. Resonance accelerators: Cyclotron—fixed and variable energy, principles and longitudinal dynamics of the uniform field cyclotron. Linear accelerators.

Electron accelerators: Betatron, Beam focusing and Betatron Oscillation, Microtron. Synchronous accelerators: Principle of phase stability, Mathematical theory for Principle of phase stability. Electron synchrotron. Proton synchrotron. Alternating gradient machines: Alternating gradient principle, AG proton synchrotron.

References:

- Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion Implantation, Sputtering and their applications, Academic Press, London, 1976.

- Humphrey S. Jr., Principles of Charged Particle Acceleration, John Wiley, 1986.
- Arya A.P., Fundamentals of Nuclear Physics, Allyn and Bacon, USA, 1968.
- Ghoshal S.N., Atomic and Nuclear Physics, Vol. 2, S.Chand and Company, Delhi, 1994.
- Varier K.M., Joseph A. and Pradyumnan P.P., Advanced Experimental Techniques in Modern Physics, Pragathi Prakashan, Meerut, 2006.

COURSE XII: Liquid Crystals

Objectives:

- This course is to study anisotropic fluids, long and short range order in nematics and its dynamical properties.
- It explores the exotic application of liquid crystals in the electronic appliances.

Course outcome:

- This course demonstrates the properties of liquid crystals and classification. This has direct impact on taking research in liquid crystals display.

Pedagogy:

- Introducing another branch of the condensed matter physics for the students.
- Various parameters are responsible for their applications are explained.

Course Contents:

Anisotropic fluids: Main Types and properties: Introduction. The building blocks. Small organic molecules. Long helical rods. Associated structures. Nematics and Cholesterics. Nematics proper. Static pretransitional effects above T'_{N-I}.The cholesterics. A distorted form of the nematic phase. Smectic. Smectic A. Smectic B. Smectic C. Other mesomorphic phases. Exotic smectics; long range order in a system of long rods. Lyotropic systems. Remarkable features of liquid crystals. Applications of liquid crystals.

Long and short range order in nematics: Definition of an order parameter. Microscopic approach. Order parameter from optical method, from diamagnetic anisotropy. Mean field theory with S2 interaction (Maier-Saupe).

Static distortion in nematics: Long range distortions, distortion free energy. Magnetic field effects— Molecular diamagnetism, Magnetic coherence length.

Defects and textures in nematics: Observations. Black filaments. Schlieren structures. Types of defects (qualitative discussion only).

Smectics: Continuum description of smectics A and C, Mean field description of S_A-N transition.

Dynamical properties of nematics: Experiments measuring the Leslie coefficients— Laminar flow under a strong orienting field, Attenuation of ultrasonic shear waves, Laminar flow in the absence of external fields. Convective instabilities under electric fields—Basic electrical parameters, Experimental observations at low frequencies, The Helfrich interpretation. Extension to higher frequencies (qualitative).

Cholesterics: Optical properties of an ideal helix—The planar texture, Bragg reflection, Transmission properties at arbitrary wavelengths (normal incidence), The Mauguin limit, Rotatory Power. Agents influencing the pitch—Physicochemical factors, External fields(qualitative). Textures in cholesterics.

References:

- De Gennes P.G. and Prost J., The Physics of Liquid Crystals, 2nd Edn., Clarendon Press, Oxford, 1998.

- Chandrashekhar S., Liquid Crystals, Cambridge University Press, 1977.
- Gray G.W., Molecular Structure and the Properties of Liquid Crystals, Academic Press, 1962.
- Maier G., Sackmann E. and Grabmanier I.G., Applications of Liquid Crystals, Springer Verlag, 1975.
- Gray G.W. and Goodby J.W., Smectic Liquid Crystals (Textures and structures), Leanard Hill, London, 1984.

COURSE XIII: Atmospheric Physics

Objectives:

- To give exposure to students about atmospheric composition, aerosols, structures of clouds and atmospheric radioactivity and electricity.

Course outcome:

- This course gives overview of atmospheric physics. This enables understanding concepts like atmospheric composition, radiations entering atmosphere, aerosols, atmospheric conductivity and electricity. This makes the students to undertake research in weather monitoring.

Pedagogy:

- Basic ideas regarding the composition and different phenomenon of the atmosphere is introduced.

Course Contents:

Atmospheric composition: Energy in the atmosphere, heating of the atmosphere, motions in the atmosphere. Variations in atmospheric composition, Structure on the basis of composition. Thermal structure of the atmosphere.

Thermodynamics: Entropy of dry air, vertical motion of saturated air, tephigram, potential energy of an air column.

Dynamics: Escape of hydrogen, photodissociation of oxygen, photo chemical processes. Equations of motion, the geostrophic approximation, cyclostrophic motion.

Terrestrial and extra terrestrial radiation: General features of direct, diffuse and global radiation-attenuation of direct solar radiation-Rayleigh and Mie scattering. Angstrom turbidity formula for all aerosols. Direct transmittance due to continuum attenuation, diffuse spectral irradiance due to Rayleigh and aerosol scattering.

Aerosols: Production and properties of aerosols. Aerosol optical depth, Beer's law— Sun photometer. Optical filters.

Clouds: Microphysics of clouds, Macrocharacterization of clouds. Radiative transfer in clouds and aerosols.

Atmospheric radioactivity: Background Radiation, Radioactivity in Atmosphere, Radon, Properties of radon, Origin of radon, Radon entry into the atmosphere: Diffusion, Advection and Convection. Health Effects: Dose.

Atmospheric electricity: The generation of an ion, The mobility of ions, Ion size. Recombination of ions. Ions in an electric field, Ionizing agencies, radioactivity. The conductivity of the atmosphere and its origin, Measurement of conductivity of the atmosphere near the ground. Relationship between ions and conductivity. The current voltage characteristics in a gas under conditions of volume ionization.

References:

- Salby M.L., Fundamentals of Atmospheric Physics, Academic Press, USA, 2006.
- Houghton J., The Physics of The Atmosphere, Cambridge University Press, 2002.
- Siddhartha K., Atmosphere, Weather and Climate, Kisalaya Publications, 2000.
- Lutgens F.K. and Tarbuk E.K., The Atmosphere: An Introduction to Meteorology,
- Prentice Hall, USA, 1986.
- Holton, J.R., Dynamic Meteorology, 3rd edition, Academic Press, USA, 1992.
- Keshvamurthy R.N. and Shankar Rao M., The Physics of Monsoons, Allied Publishers, 1992.
- Iqbal M., An Introduction to Solar Radiation, Academic Press, USA, 1983.
- Wilkening M., Radon in the Environment, Elsevier Science Publishers, The Netherlands, 1990.
- Israel H., Atmospheric Electricity-Vol II, Israel Program for Scientific Translations, Jerusalem, 1973.

COURSE XIV: Numerical Methods

Objectives:

- To give an introduction to computer arithmetic and various numerical methods.
- To enable students to use numerical techniques to tackle problems in physics.

Course outcome:

- This course demonstrates the students with the computational tools for solving physics problems. This enables students to have idea about computer arithmetic, algorithm, numerical interpolations, integration and solutions. This is very useful in taking up research in computational physics.

Pedagogy:

- Familiarizing the students with the use of the mathematical tools to interpret the outcomes of the results.

Course Contents:

Computer arithmetic: Integers; Floating point representation of numbers; Arithmetic operations with normalisation; Errors in representation; Commonly used number types and their limits like max. and min. integer, float, double precision, long, etc.

Iterative methods: Bisection method, Newton-Raphson method, Secant method, the method of successive approximations. Solution of a polynomial equation.

Linear algebraic equations: The Gauss elimination method, LU decomposition method, Gauss-Jordon method, An introduction to the solution of simultaneous nonlinear equations.

Interpolations: Introduction, Newton interpolation formulae, extrapolation, Lagrange interpolation. spline interpolation.

Least-squares approximation of functions: Introduction, linear regression, algorithm for linear regression. Polynomial regression, fitting exponential and trigonometric functions.

Numerical integration: Trapezoidal method, Simpson's rule, errors and algorithms. Gaussian quadrature formulae.

Numerical solution of differential equations: Euler method, Runge-Kutta methods, Runge-Kutta 4th order formulae, predictor-corrector method. Comparison of predictorcorrector and Runge-Kutta methods.

References:

- Atkinson K.E., An Introduction to Numerical analysis, John Wiley and Sons, USA, 1988.
- Press W.H., Flannery B.P., Teukolsky S.A. and Vetterling W.T., Numerical Recipes in C, Cambridge University Press, UK, 1989.
- Krishnamurthy E.V. and Sen S.K, Numerical Algorithms, Affiliated East West Press Pvt. Ltd., India, 1993.
- Rajaraman V., Computer Oriented Numerical Methods, Prentice Hall of India Pvt. Ltd., India, 2001.

COURSE XV: Methods of Material Characterization Objectives:

- To study the importance of X-ray powder diffraction technique, this helps to determine crystallite size and strain.
- To study the electrical and thermal characterization of some semiconductor devices, crystals and polymeric materials.
- The importance of spectrochemical characterization such as mass spectroscopy, NMR spectroscopy, FTIR and UV-visible spectroscopic techniques for structural analysis of the compounds.

Course outcome:

- This course is an advanced application of the experimental techniques required for research areas in materials science.
- This gives insight about X-ray diffraction, electrical and thermal characterization, spectrochemical characterization. This gives hands-on training to the students on characterization techniques.

Pedagogy:

- Basic ideas of the principle and working of the advanced research equipments.

X-ray powder diffraction: Geometry of a diffractometer, X-ray source, and optics, detector, specimen, diffraction pattern, sources of information. Phase diagram determination. Long range order determination. Determination of crystallite size and strain.

Course Contents:

Electrical and thermal characterization: Electrical analysis: DC electrical characteristics of semiconductor devices, crystals and polymeric materials. C-V and DLTS characterization of semiconductor devices. Thermal analysis: Basic principles of TGA, DTA and DSC. The differences between DTA and DSC. Instrumentation; Power compensated DSC, heat flux measurement in DSC.

Spectrochemical characterization: Elemental analysis, identification of different elements present in a sample; Mass spectroscopy, instrumentation, measurement of accurate molecular weight and isotopic abundance; Nuclear magnetic resonance spectroscopy, instrumentation, assignments of ^{1}H and ^{13}C NMR peaks, structural elucidation of organic compounds using NMR spectroscopy; Fourier transform infrared spectroscopy, ATR enabled FTIR spectrometer, identification of different functional groups; UV-visible spectroscopy, dual beam UV-visible spectrometer, estimation of energy gap using UV-visible spectrum.

Any six experiments:

- Structure determination: Hexagonal structure.
- Phase diagram determination.
- Long range order determination.
- Determination of crystallite size and strain.
- Estimation of conductivity/resistivity of the materials.
- Estimation of interface and oxide trapped charges of MOS devices.
- Estimation of ideality factor, current gain and early voltage of BJTs.

- Estimation of doping concentration, activation energy of defects, density of defects and capture cross section.
- Estimation of melting point and decomposition of the materials.
- Determination of energy gap using UV-Vis spectrum.
- Identification of functional groups using FTIR spectrum
- Elemental analysis of a material.
- Determination of molecular weight using NMR / mass spectrometer.

References:

- Azaroff L., and Buerger M. J., The Powder Method in X-ray Crystallography, McGraw-Hill, USA, 1958.
- Suryanarayana C., and Grant Norton M., X-ray Diffraction, A Practical Approach, Plenum Press, UK, 1998.
- Schroder D., Semiconductor Materials and Device Characterization, John Wiley and Sons, USA, 1990.
- Brown M. E., Introduction to Thermal Analysis: Techniques and Applications, Chapman and Hall, USA, 1988.
- Hohne G., Hemminger W. F., and Flammersheim H. J., Differential Scanning Calorimetry (2nd Edition), Springer, USA, 2003.
- Kemp W., Qualitative Organic Analysis: Spectrochemical Techniques, McGraw-Hill, New York, 1986.
- Banwell C. N., and McCash E. M., Fundamentals of Molecular Spectroscopy, McGraw-Hill, New York, 1994.
- Gunther H., NMR Spectroscopy: Basic Principles, Concepts and Applications in chemistry, John Wiley and Sons, USA, 2013.
- Woodward L. A., Introduction to the Theory of Molecular Vibrations And Vibrational Spectroscopy, Oxford University Press, UK, 1972.
- Perkampus H. H., UV-vis Spectroscopy and its Applications, Springer Science and Business Media, 2013.

COURSE XVI : Python Programming

Objectives:

- To learn the concepts of python program, which enables to write scientific programs.
- The importance of python program and compared to other programs.

Course outcome:

- Be able to connecting to web servers, searching texts with regular expressions, reading and modifying files.
- Be able to analyze and debug the errors in the program.

Pedagogy:

- To update the skills of the students to make them a skilled programmer.

Course Contents:

Introduction to programming: Problem solving by computers; Flowcharts; Algorithms; Elements of programming; Brief introduction to object-oriented programming.

Computer arithmetic: Integers; Floating point representation of numbers; Arithmetic operations with normalisation; Errors in representation; Commonly used number types and their limits like max. and min. integer, float, double precision, long, etc.

Programming in python: Introduction; Types and operations : Numbers, strings, lists and dictionaries, tuples, files; Statements : Assignment, Control flow; Functions : scope and arguments; Modules.

List of programs:

- Check whether given number is odd or even.
- Find the largest and smallest number in the input set.
- Compute the Fibonacci sequence.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Generate Pascal's triangle.
- Sum of two matrices.
- Product of two matrices.
- Linear, exponential and power least-squares fitting to data in a file.
- To find the trajectory of a projectile shot with an initial velocity at an angle. Also, find the maximum height travelled and distance travelled. Write the trajectory data to a file specified and plot using Gnuplot.

References:

- Lutz M. and Ascher D., Learning python, Second edition, O'Reilly, USA, 2003.
- Python online documentation.
- Swaroop C.H., A byte of python, (free online book), http://www.swaroopch.com/notes/Python.

Note:

- This paper comprises both theory and labwork. The question paper will be a mixed one to be answered in a computer lab only.
- This paper is mostly for students who do not have any prior programming training/experience.

COURSE XVII: MINOR PROJECT

Objectives:

- To define and address a research problem.
- To design and perform novel experiments.
- To interpret the results and correlation with the standard error deviation.

Course outcome:

- Understanding and designing experiments based on the specific research problem.
- Compiling and analyzing the research data.
- Able to write a comprehensive project report, leads to publication.

Project work will be on defined research topic allotted to the students. The students will present their research results and could publish in peer reviewed journals.

OPEN ELCTIVE

COURSE XVIII: ENERGY SCIENCE

Paper offered to non-physics postgraduate students

Objectives:

- To provide exposure for non-physics postgraduate student about renewable energy sources, solar technology, biogas technology and their applications for daily life.

Course outcome:

- This course trains the students from other disciplines other than physics to have an insight about renewable energy.
- This gives the usage of renewable energy resources, solar cell and biogas technologies.

Pedagogy:

- Introduction of novel technologies in the field of renewable energy are explained.

Course Contents:

Renewable energy resources: Forms enery. Basics of thermodynamics: Heat capacity. Heat transfer mechanism, Entropy, first and second law of Thermodynamics. Carnot cycle, Rankine cycle. Fossil fuels and time scale of fossil fuels. Solar energy: Sun as a source of energy and its energy transport to the earth. Extraterrestrial and terrestrial solar radiations. Measurement techniques of solar radiations using pyranometer and pyrheliometer.

Materials and solar cell technology : Single, poly and amorphous silicon, GaAs, CdS , fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells, photovoltaic systems, and technical problems. Wind Energy Origin and classification of winds, Aerodynamics of windmill: Maximum power, and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: The present Indian Scenario. [16 hours]

Biomass energy and biogas technology: Nature of Biomass as a fuel, Biomass energy conversion processes, Direct combustion: heat of combustion, combustion with improved Chulha and cyclone furnace; Dry chemical conversion processes: pyrolysis, gasification, types of gasification Importance of biogas technology, anaerobic decomposition of biodegradable materials, Factors affecting Bio-digestion, Types of biogas plants, Applications of biogas.

Tutorial

References:

- Peter A., Advances in Energy Systems and Technology, Academic Press, USA, 1986.
- Neville C.R., Solar Energy Conversion: The Solar Cell, Elsevier North-Holland, 1978.
- Dixon A.E. and Leslie J.D., Solar Energy Conversion, Pergamon Press, New York, 1979.
- Ravindranath N.H., Biomass, Energy and Environment, Oxford University Press, 1995.
- Cushion E., Whiteman A. and Dieterle G., World Bank Report, 2009.

FOURTH SEMESTER

HARD CORE

COURSE I: Quantum Mechanics 2

Objectives:

- To understand the concepts of the time-dependent perturbation theory, adiabatic approximation and their applications to physical situations.
- To understand the basics of scattering theory.
- To provide extended knowledge of quantum mechanics with relativistic quantum mechanics and field quantization.

Course outcome:

- This course concerns with the specialized training in theoretical physics. Including deeper and wider concepts in theoretical physics. By the end of this course, students will be able to have deeper understanding of time dependent perturbation theory, relativistic quantum mechanics and Dirac quantum mechanics. This helps student to take up further research in theoretical physics.

Pedagogy:

- Usage of the advanced quantum mechanical tools to explain the perturbation and scattering theories.

Course Contents:

Time-dependent perturbation theory: Two-level systems, emission and absorption of radiation, spontaneous emission. Rabi oscillations.

Adiabatic approximation: The adiabatic theorem, Berry's phase, sudden approximation.

Scattering: Introduction, scattering cross section, partial wave analysis, the Born approximation, Rutherford scattering, The Lippmann- Schwinger equation [Griffiths, Chap. 9–11].

Relativistic kinematics: Relativistic kinematics of scattering and reactions. Elastic, Inelastic reactions, decay of a particle **$A \rightarrow B+C$, $A+B \rightarrow C$, $P + P^{-} \rightarrow P + P^{-} + P + P^{-}$.**

Relativistic quantum mechanics: Klein Gordon equation, plane-wave solutions, negative energy. Equation of continuity. The difficulties of the Klein-Gordon equation. The Dirac equation: The free-particle Dirac equation in the Hamiltonian form. The algebra of Dirac matrices, plane wave solutions of the free-particle equation, the two-component form of the solution in the Dirac-Pauli representation, standard normalization of the solutions. Non-relativistic reduction and g factor.

Spin of the Dirac particle:J Non L-conservation **S** of the angular momentum operator ; the spin operator and the conservation of = + . Helicity. A brief discussion of the hydrogen atom according to Dirac theory, energy spectrum of the hydrogen atom. Negative energy states and anti-particles. Dirac operators in the Heisenberg representation, velocity, Zitterbewegung.

Field quantization: The Lagrangian formalism for a classical field; Euler-Lagrange equations. Quantization of the electromagnetic field. Creation and annihilation operators. Number representation. Quantization of the Dirac field.

References:

- Griffiths D.J., Introduction to Quantum Mechanics, 2nd Edition, Pearson, India, 2005.
- Sakurai J.J. and Tuan S.F. (Editor), Modern Quantum Mechanics, Addison Wesley, India, 1999.
- Sakurai J.J., Advanced Quantum Mechanics, Addison-Wesley, Harlow, England, 1999. Sons, New York, 1987.
- Gasiorowicz S., Elementary Particle Physics, John-Wiley, New York, 1966.
- Muirhead H., The Physics of Elementary Particles, Pergamon Press, London, 1965.

COURSE II: NUCLEAR PHYSICS LAB

Objectives:

- To study and understand the working of the nuclear equipments.
- To understand the properties of the radioactive elements and their radiations.

Course outcome:

- This course trains the students to handle experiments in specialized area of nuclear physics independently. More focused experiments are going to be handled by the students.

Pedagogy:

- Applications of the nuclear phenomenon are

understood. For those who have completed PHY312

Any eight of the following experiments

- Half-life of Indium-116 measurement.
- Energy Resolution of a NaI(TI) scintillation spectrometer.
- Compton scattering determination of the rest energy of an electron.
- Beta absorption coefficient measurement.
- Dekatron as a counter of signals.
- Gamma-ray absorption coefficient measurement.
- End-point energy of beta particles by half thickness measurement.
- Common source amplifier.
- Astable multivibrator using timer IC 555.
- Dead time of the G.M. counter.

References

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COURSE IV: NUCLEAR PHYSICS

Objectives:

- To impart wide theoretical knowledge about nuclear fission, nuclear reactors beta and gamma decay.
- To understand the key features of the working of the nuclear reactors.

Course outcome:

- This course concerns with the specialized training in nuclear physics. Including deeper and wider concepts in nuclear physics. By the end of this course, students will be able to have deeper understanding of reactor theory and nuclear decays. This helps student to take up further research in nuclear physics.

Pedagogy:

- Basic ideas of harnessing the power of the nuclear energy.

Course Contents:

Nuclear fission: Nuclear fission, Mass-energy distribution of fission fragments. Statistical model of fission.

Reactor theory-1: Neutron and its interaction with matter-collision kinematics,differential elastic scattering cross sections, isotropic scattering, The criticality condition for a reactor. Neutron transport equation using elementary diffusion theory. One group critical equation, The critical size-on the basis of Fermi Age theory.

Reactor theory-2: Reactors- One group theory, spherical and cylindrical homogenious reactor. The effective multiplication factor. Reflector reactors: effects of reflector. One group method of a homogenious reactor with reflector. reflector savings. Infinite multiplication factor, critical size and critical mass. Heterogeneous reactor systemcalculation of thermal utilization factor. Fast Breeder reactor, Evaluation of Buckling using One group model.

Beta decay: Classification of beta interactions. Matrix elements. Fermi and GamowTeller selection rules for allowed beta decay. The non conservation of parity in beta decay. Wu et al. experiment. The universal Fermi interaction.

Gamma decay: Electromagnetic interactions with nuclei. Multipole transitions. Transition probabilities in nuclear matter. Weisskopf's estimates. Structure effects. Selection rules. Internal conversion Photo disintegration of deuteron and radiative capture of neutron by proton.

References:

- Glasstone S. and Edlund M.C., Elements of nuclear reactor theory, D. Van Nostrand Co., USA, 9th Print, 1963. Unit 1 Chapter 5–6 page 90-135, Unit 2. Chapter 7 page 191-290
- Garg S., Ahmed F. and Kothari I.S., Physics of nuclear reactors, Tata McGrawHill, New Delhi, 1986.
- Unit 1. Roy R.R. and Nigam B.P., Nuclear physics, New Age International, New Delhi, 1986. Chapter 5, page 162-165.
- Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers, 2001.
- Unit 2 Ghoshal S.N., Nuclear physics, Vol. 2., S.Chand and Company, Delhi, 1994. Chapter 15, page 714-730.

COURSE V : NUCLEAR PHYSICS LAB 3

Objectives:

- To give an in depth knowledge in nuclear reactions and nucleon-nucleon scattering processes.
- To study the special features of heavy ion physics.

Course outcome:

- Be equipped with the specialized training in nuclear physics. Including deeper and wider concepts in nuclear physics. By the end of this course, students will be able to have deeper understanding of two particle systems, nuclear reactions and heavy ion physics. This helps student to take up further research in nuclear physics.

Pedagogy:

- Different types of the nuclear reactions are introduced to the students.

Course Contents:

Two particle systems: Deuteron: Schrodinger equation for a two nucleon system. Theory of the ground state of the deuteron under central and non central forces. Excited states of the deuteron. Rarita-Schwinger relations. Deuteron magnetic and quadrupole moments.

Nucleon-nucleon scattering processes: Theory of s-wave scattering of neutrons by free protons and experimental results. Wigner's formula for n-p scattering. Theory of scattering of slow neutrons by bound protons (Ortho and Para hydrogen) and experimental results. Effective range theory for n-p scattering. S-wave theory of proton proton scattering. Mott's modification of Rutherford's formula. Pion-nucleon scattering experimental results, (3/2,3/2) resonance.

Nuclear reactions-1: Plane wave theory of direct reactions. Born approximation- (Plane wave)-Butler's theory. Cross section for nuclear scattering and reactions. Shadow scattering, Breit-Wigner resonance formulae.

Nuclear reactions-2: Bohr's independence hypothesis. The compound nucleus (CN) reactions, decay rates of CN, Statistical theory of nuclear reactions. Evaporation probability and cross sections for specific reactions.

Optical model: Giant resonances, Kapur-Pearls' dispersion formula for potential scattering. Direct reactions: Kinematics of stripping and pickup reactions. Theory of stripping and pickup reactions. Inverse reactions.

Heavy ion physics: Special features of heavy ion Physics. Remote heavy ion electromagnetic interactions. Coulomb excitations. Close encounters. Heavy ion scattering. Grazing interactions. Particle transfer. Direct and head on collisions, compound nucleus and quasi molecule formation.

References:

- Roy R.R. and Nigam B.P., Nuclear Physics—Theory and Experiment, New Age International Ltd, New Delhi, 1986.
- Hans H.S., Nuclear physics—Experimental and Theoretical, New Age International Publishers 2001.
- Sachtler G.R., Nuclear Reactions, Addison Wesley, New York, 1983.
- Mermier P. and Sheldon E., Physics of Nuclei and Particles, Vol. 2, Academic Press, USA, 1971.
- Jackson D.F., Nuclear Reactions, Chapman and Hall, London, 1975.

COURSE VI: NUCLEAR PHYSICS LAB 2

Objectives:

- To study and understand the working of the in-depth phenomenon of nuclear equipments.
- To train the students to have a hands on experience with various nuclear instruments.

Course outcome:

- This course trains the students to handle experiments in specialized area of nuclear physics independently. More focused experiments are going to be handled by the students.

Pedagogy:

- Hands on experience on handling the GM counter

instruments. For those who have completed PHY313

Any five of the following experiments:

- Schmitt trigger.
- Variable delay line.
- Pulse recorder.

- Internal conversion using MCA.
- Feather analysis: End-point energy of beta rays measurement.
- Z dependence of external Bremsstrahlung radiation.
- Fermi-Kurie plot : Determination of the end-point energy of beta rays using a plastic scintillation detector.
- Dead time of a GM counter by two source method.
- Determination of source strength by gamma-gamma coincidence.
- Determination of source strength by beta-gamma coincidence.

COURSE VII: SOLID STATE PHYSICS 2

Objectives:

- To explain the description of a crystal structure in terms of atomic positions, unit cells, crystal symmetry and physical significance.
- To give students the knowledge of reciprocal space, Laue diffraction and experimental techniques such as, X-ray photography with oscillation, Weissenberg, precession cameras and single-crystal X-ray diffractometer.
- To guide students to interpret results of crystal structure analysis and to analyse using SHELX-program

Course outcome:

- This course concerns with the specialized training in solid state physics. Including deeper and wider concepts in solid state physics. By the end of this course, students will be able to have deeper understanding of XRD of crystals, structure analysis and Imperfections in solids. This helps student to take up further research in materials science.

Pedagogy:

- Advanced crystallographic tools are very essential to conduct research in the field of condensed matter physics.

Course Contents:

X-ray diffraction by crystals: The reciprocal lattice. Ewald sphere and construction. Scattering by an electron and atom. Atomic scattering factor. Anomalous scattering. Fourier analysis and inversion of Fourier series. Physical significance. Geometrical structure factor of the unit cell. Absent reflections and space groups [Sherwood, p290– 302, p320–332, p342–358].

Experimental techniques: Weissenberg and precession methods. Cell parameter and space group determination. Molecular weight determination. Low angle scattering. Reduction of intensities to structure amplitudes. Various corrections. Absolute scale factor and temperature factor from statistical methods. Statistical method for finding the presence of center of symmetry [Stout and Jensen, p90–91, 94–106, 117–120, 122– 128, 148–156, 195–211].

Structure analysis: Fourier analysis of electron density. Patterson synthesis. Harker sections and lines. Heavy atom methods. Direct methods for phase determination. The inequality relations. Difference Patterson synthesis and error Fourier synthesis. Figure of merit. Cyclic Fourier refinement, Difference Fourier synthesis Refinement of structures: The least squares method. Accuracy of the parameters. Bond lengths and angles

SAXS: Particle size. Study of fibre structures.

Imperfections in solids: Different types of imperfections. Schottky and Frenkel defects. Expression for energy for the formation of Frenkel and Schottky defects. Diffusion in metals. Kirkendall effect. Ionic conductivity in pure and doped halides. Photoconductivity (as in Kittel). Dislocations: Buerger's Vector. Expression for strain in the case of edge and screw dislocations. Low-angle grain boundaries (as in Wahab and Kittel).

Synthesis and Device fabrication of Nanomaterials: Bottom-Up approach: Sol-gel synthesis, hydrothermal growth, thin-film growth, physical vapor depositon, chemical vapor depostion. Top-Down Approach: Ball milling, Microfabrification, Lithography, Ion-beam lithography(Page 129-142, Ramachandra Rao and Shubra Singh).

Luminescence: General remarks, Excitation and Emission. Franck-Condon principle. Decay mechanisms—Temperature dependent and independent decays. Thermoluminescence and glow curve. Gudden-Pohl effect (as in Dekker). [16 hours]

References:

- Stout G.H. and Jensen L.H., X-ray Structure Determination, MacMillan, USA, 1989.
- Ladd M.F.C. and Palmer R.A., Structure Determination by X-ray crystallography, Plenum Press, USA, 2003.
- Sherwood D., Crystals, X-rays and Proteins, Longman, London, 1976.
- Ramachandra Rao M.S. and Shubra Singh, Nan science and Nanotechnology, Wiley, 2013.
- Wahab M.A., Solid State Physics, Narosa Publishing House, New Delhi, 1999.
- Azaroff L.V., Introduction to Solids, McGraw-Hill Inc, USA, 1960.
- Weertman J. and Weertmann J.R., Elementary Dislocation Theory, McMillan, USA, 1964.
- Pillai S.O., Solid State Physics, New Age International Publications, 2002.

COURSE VIII: SOLID STATE PHYSICS 3

Objectives:

- To impart the deep knowledge about free electron theory of metals, elemental and compound semiconductors.
- To study about theory of advanced impurity semiconductors and semiconductor devices.

Course outcome:

- This course concerns with the specialized training in Solid state physics. Including deeper and wider concepts in solid state physics. By the end of this course, students will be able to have deeper understanding of free electron theory of metals, theory of semiconductors and semiconductor devices. This helps student to take up further research in materials science.

Pedagogy:

- Advanced topics explaining the properties of the metals and semiconductors are introduced.

Course Contents:

Free electron theory of metals: Boltzmann transport equation, Sommerfeld's theory of electrical conductivity, mean free path in metals, temperature dependence of resistivity on temperature and impurities. Matthiessens rule. Electron-phonon collisions. Thermal conductivity of insulators, Umklapp processes. Electrical conductivity of metals at high frequencies. Plasma frequency. Transparency of alkali metals to UV radiation. Anomalous skin effect. Plasmons. Field enhanced emission, Schottky effect. Hall effect and magnetoresistance in metals. Cyclotron frequency.

Elemental and compound semiconductors: A brief discussion on elemental and compound semiconductors and their properties [Streetman, p61–95].

Impurity semiconductors: Carrier concentrations. Effect of temperature and impurity density. Electrical neutrality condition. Fermi energy. Variation of Fermi energy with temperature and impurity density, when the Boltzmann approximation is valid,. Effect of impurity density at very low temperatures. Mobility of current carriers. Effect of temperature and impurity. Electrical conductivity. Effect of temperature, impurity concentration and the energy band gap. Impurity band conductivity. Hall effect in semiconductors: Expression for Hall co-efficient in terms of mobility of current carriers and carrier densities. Hall mobility and Hall factor. Effect of temperature, impurity concentration and magnetic field. Magneto-resistance phenomenon (qualitative).

Cyclotron resonance: Cyclotron resonance in Si and Ge semiconductors. Effective mass tensor. Variation of cyclotron resonance frequency with orientation of the crystal in the magnetic field [Mckelvey, p270–300].

Excess carriers in semiconductors: Generation and recombination rates. Excess carriers. Continuity equations for excess carriers; Einstein equations, Expression for the diffusion length of electrons and holes [Mckelvey, p320–335]. High field transport in semiconductors—electron temperature. Gunn effect, Expression for drift velocity. Superlattice phenomenon [Roy, p29–39].

Semiconductor devices: The pn junction diode. Formation of space charge region. Expressions for barrier potential, barrier thickness and contact field. Effect of the applied field on the above junction parameters. Transition capacitance associated with the space-charge region. Expressions for current **densities using continuity equations for excess carriers. Transistors; dc current gain, α and β and cut-**off frequencies [Mckelvey, p390–441].

References:

- Dekker A.J., Solid State Physics, Prentice Hall, 1985.
- Mckelvey J.P., Solid State and Semiconductor Physics, 2nd Edn., Harper and Row, USA, 1966.
- Roy D.K., Physics of Semiconductor Devices, University Press, Hyderabad, 1992.
- Schur M., Physics of Semiconductor Devices, Prentice-Hall of India, New Delhi, 1999.
- Wilson J. and Hawkes J.F.B., Optoelectronics—An introduction, 2^{nd} Edn., Prentice-Hall of India, New Delhi, 1996.
- Streetman B.G., Solid State Electronic Devices, 2^{nd} Edn., Prentice-Hall of India, New Delhi, 1983.
- Omar M.A., Elementary Solid State Physics, Addison Wesley, New Delhi, 2000.
- Wahab M.A., Solid State Physics, Narosa Publishing House, New Delhi, 1999.

COURSE IX : SOLID STATE PHYSICS LAB 2

Objectives:

- To study the magnetic properties of the materials.
- To study the characteristics of the semiconductors and their applications.

Course outcome:

- This course trains the students to handle experiments in specialized area of Condensed matter physics independently. More focused experiments are going to be handled by the students.

Pedagogy:

- Different applications of the semiconductors devices are

introduced. For those who have completed PHY314

Any five of the following experiments:

- Photovoltaic cell.
- Photoconductive cell.
- Hall effect in semiconductors.
- Determination of the energy gap of semiconductors by four-probe method.
- Temperature variation of the junction voltage of a p-n diode.
- Temperature variation of the reverse saturation current in a p-n diode.
- Depletion capacitance of a junction diode.
- Determination of material constant of an intrinsic semiconductor.

- Schottky effect.
- Ionic conductivity of an alkali halide crystal.
- Dielectric constant and its temperature variation.
- Ultrasonic velocity and elastic constants of a solid.
- Determination of Curie temperature of a magnetic material.

COURSE X: THEORETICAL PHYSICS LAB 2

Objectives:
- To make students to apply their theoretical knowledge to solve various problems.

Course outcome:
- Understand and to be able to solve the problem.

Pedagogy:
- Use of the advanced mathematical concepts to solve complex physics

problems. For those who have completed PHY315
Any five of the following experiments:
- Density matrix description of polarization of light.
- Double scattering of spin-1/2 particles on spin-zero targets.
- Second order QED processes (Compton scattering).
- Evolution of matrix elements between coupled angular momentum states.
- Dirac matrix representations.
- Algebra of Dirac matrices.
- Electron-proton scattering, Rosenbluth formula.
- Relativistic kinematics-3: Study of decay and production processes.
- Feynman diagrams and calculations.
- Energy matrix calculation.

COURSE XI: THEORETICAL PHYSICS 2
Objectives:
- To study the application of the quantum ideas for various phenomenon.
- To study the various methods describing nuclear phenomenon and potentials.

Course outcome:

- This course concerns with the specialized training in theoretical physics. Including deeper and wider concepts in theoretical physics. By the end of this course, students will be able to have deeper understanding of quantum features of radiation field, quantization of the Dirac field and covariant perturbation theory. This helps student to take up further research in theoretical physics.

Pedagogy:
- Theories explaining the nuclear interactions and the radiation fields are explained.

Quantum features of radiation field: Optical resonance, damping, Theory of chaotic light, coherence, temporal, spatial, mutual coherence, line broadening, natural and Doppler width, collision broadening. Quantized States of radiation field; Coherent states and their properties, BCH formula, P, Q and Wigner distribution functions, Squeezed states of light and their properties; applications. Correlation functions, Brown-Twiss correlations.

Quantization of the Dirac field: Second quantization, positron operators and positron spinors, Electromagnetic and Yukawa couplings. Weak interactions and parity non-conservation: Classification of interactions, parity and hyperon decay, Fermi theory of beta decay, the two-component neutrino. Pion decay and the CPT theorem.

Covariant perturbation theory: Natural units and dimensions, S-matrix expansion in the Interaction representation. Unitarity, First order processes: Matrix element for electron scattering. Cross section for Mott scattering. Helicity change and spin projection operator. Pair annihilation, pair creation, hyperon decay. S-matrix for two photon annihilation, electron propagator, matrix element for Compton scattering, Feynman rules. Cross section for two photon annihilation.

References:

- Loudon R., The Quantum Theory of Light, Clarendon Press, Oxford, 1973.
- Mandel L. and Wolf E., Optical Coherence and Quantum Optics, Cambridge University Press, 1995.
- Louisell W.H., Quantum Statistical Properties of Radiation, John Wiley and Sons, New York, 1973.
- Sakurai J.J., Advanced Quantum Mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
- Griffiths D., Introduction to Elementary Particles, John Wiley and Sons, New York, 1987.
- Gasiorowicz S., Elementary Particle Physics, John-Wiley, New York, 1966.
- Muirhead H., The Physics of Elementary Particles, Pergamon Press, London, 1965.

COURSE XI: THEORETICAL PHYSICS 3

Objectives:

- To study the in depth properties of the atoms.
- To study the usage of the tensors to understand the different properties of the atoms.

Course outcome:

- This course concerns with the specialized training in theoretical physics. Including deeper and wider concepts in theoretical physics. By the end of this course, students will be able to have deeper understanding of Quantum features of radiation field, quantization of the Dirac field and covariant perturbation theory. This helps student to take up further research in theoretical physics.

Pedagogy:

- Basic and advanced ideas regarding the use of the different quantum operators and different transformations are explained.

Course Contents:

Angular momentum theory and applications: Angular momentum: Transformations under rotations. Coupling of three and four angular momenta. Racah coefficients, Wigner *9j* symbols, applications. Wigner-Eckart theorem. Projection theorem. *j-j* and *L-S* coupling. Angular momentum in nuclear reactions, Spherical tensors. Evaluation of matrix elements between coupled angular momentum states. Vector spherical harmonics. Gradient theorem (without proof). Multipole radiation.

Density matrix: Pure states and mixed states. Density operator, properties and equation of motion. Polarization of light, states of polarized light, Jones matrices, Jones formalism, Stokes parameters, Poincar´e sphere, Mueller matrices and Mueller formalism, Mueller matrices and their characterization, Few illustrative examples; comparison of Jones and Mueller formalisms. Pancharatnam phase, dynamical phase, cyclic evolution of polarization state on Poincar´e sphere.

Spin density matrix: The spin density matrix *(ρ)*, multipole parameters, combined systems, diagonalization of **ρ**. Oriented and non-oriented systems, Polarized and aligned systems, Spherical tensor basis and SU(N) basis. Spin and helicity in a relativistic process. Effect of Lorentz and discrete transformations on helicity states. Wick and Wigner rotations, pure rotation, pure boost and parity. Polarization in scattering of spin 1/2 particles.

References:

- Sakurai J. J. and Tuan S. F. (Editor), Modern Quantum Mechanics, Addison Wesley, India, 1999.
- Rose M.E., Elementary Theory of Angular Momentum, John Wiley and Sons, USA, 1957.
- Edmonds A. R., Angular Momentum in Quantum Mechanics Princeton University Press, USA, 1996.
- Blum K., Density Matrix Theory and Applications, Plenum Press, New York, 1981.
- Loudon R., The Quantum Theory Of Light, Clarendon Press, Oxford, 1973.
- Mandel L. and Wolf E., Optical Coherence and Quantum Optics, Cambridge University Press, 1995.
- Pancharatnam S., Collected works, Oxford University Press, 1975.
- Louisell W.H., Quantum Statistical Properties of Radiation, John Wiley and Sons, New York, 1973.
- Leader E., Spin in particle physics, Cambridge University Press, London, 2001.

COURSE XII: THEORETICAL PHYSICS LAB 2

Course outcome

COURSE XIII: Nuclear Spectroscopy Methods

Objectives:

- To study the basics and principle of the different types of scattering.
- To study the theory and experimental techniques to study positron annihilation.

Course outcome:

- This course is an application oriented in techniques of nuclear spectroscopy. Student will learn instrumentation related to nuclear spectroscopy technique. The fields of study are ion implantation, Compton scattering and positron annihilation. After the course, student can take up research in one of the above mention fields and also in materials science.

Pedagogy:

- Different types of scattering and the methods of the ion implantations were discussed.

Course Contents:

Ion implantation and backscattering spectroscopy: Ion implantation, Implantation technique, Ion beam diffusion, Thermal annealing and sputtering, Analysis techniques. Backscattering, energy loss and straggling. Kinematics factor, differential scattering cross sections, depth scale, backscattering yield, instrumentation. Application to elemental and compound targets. Axial and planar half angles. Estimates of minimum yield. Lattice location of impurities, alignment procedures. Ion induced X-rays. Application of ion implantation.

Compton scattering: Compton scattering from free electrons. Effects of external potential. Klein-Nishina cross sections for polarized and unpolarized radiation. Compton profiles, momentum distributions and impulse compton profiles. calculation of Compton profiles for electron models. Relativistic profile corrections: experimentation. Discussion of methodology including sources, detectors and geometry. Data accumulation, analysis and multiple scattering corrections. Discussion of experimental results for some simple metals, ionic and covalent crystals.

Positron annihilation spectroscopy: The positron and its discovery, positronium, its characteristics, formation. Spur model and ore gap model of positronium formation. Quenching and enhancement. Theory of 2-gamma and 3-gamma annihilations. Positron and positronium states in solids: trapping of positrons. Two state trapping model.

Experimental methods of positron annihilation spectroscopy: Positron lifetime techniques (PLT), angular correlation of annihilation radiation (ACAR), Doppler broadening (DB) and coincidence DB. Methods of data analysis: PLT and ACAR. Experimental results of some metals and defected materials. Interpretation of the experimental results. PAS in the study of polymers. Multiparameter techniques. A brief mention of slow positron beams.

References:

- Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion Implantation, Sputtering and their Applications, Academic Press, London, 1976.
- Chu W.K., Mayer J.W. and Nicholate Mar A.O., Backscattering Spectroscopy, Academic Press, New York, 1978.
- Mayer J.W. and Rimini B. (Eds.), Ion Beam Handbook for Material Analysis, Academic Press, 1977.
- Williams B. (Ed.), Compton Scattering, McGraw-Hill, New York, 1977.
- Hautojarvi P. (Ed.), Positrons in Solids, Springer Verlag, New York, 1979.
- Fava R.A. (Ed.), Methods of Experimental physics, Academic Press, New York, 1980.
- Schradev D.M. and Jean Y.C., Positron and Positronium Chemistry, Elsevier Science Publication, Amsterdam, 1988.
- Jayaram B., Mass Spectrometry–Theory and Applications, Plenum Press, New York, 1966.

COURSE XIV: MODERN OPTICS

Objectives:

- To study the applications of the quantum ideas to the field of optics.
- To impart the knowledge of quantum theory of light and quantized radiations field.

Course outcome:

- This course is about application of the theoretical physics. Students will learn the concepts of practical nature of polarization of light , quantum features of radiation field and quantized radiation field. After the course they can take up research in theoretical physics.

Pedagogy:

- Different optical phenomenon and their quantum theoretical explanation are discussed.

Polarization of light: Pure states and mixed states. Density operator, properties and equation of motion. Polarization of light, states of polarized light, Jones matrices, Jones formalism, Stokes parameters, Poincar´e sphere, Mueller matrices and Mueller formalism, Mueller matrices and their characterization, Few illustrative examples; comparison of Jones and Mueller formalisms. Pancharatnam phase, dynamical phase, cyclic evolution of polarization state on Poincar´e sphere; Applications of the concept of Pancharatnam phase, [16 hours]

Quantum features of radiation field: Planck's law of radiation and Einstein coefficients, Thermal equilibrium, Semi-classical theory of two level atoms, quantum theory of B coefficient, Optical resonance, damping, Theory of chaotic light, coherence, temporal, spatial, mutual coherence, line broadening, natural and Doppler width, collision broadening.

Quantized radiation field: Quantization of radiation field, states of radiation field; Fock states and phase eigenstates; Interaction of radiation with matter, theory of spontaneous emission; coherent states and their properties, BCH formula, P, Q and Wigner distribution functions, squeezed states of light and their properties; applications. Correlation functions, Brown-Twiss correlations.

References:

- Loudon R., The Quantum Theory of Light, Clarendon Press, Oxford, 1973.
- Mandel L. and Wolf E., Optical Coherence and Quantum Optics, Cambridge University Press, 1995.

- Louisell W.H., Quantum Statistical Properties of Radiation, John Wiley and Sons, New York, 1973.
- Blum K., Density Matrix Theory and Applications, Plenum Press, New York, 1981.
- Pancharatnam S., Collected works, Oxford University Press, 1975.

COURSE XV: ELECTRONICS

Objectives:

- To study the basics of electronics.
- To study and understand the working of various electronic components that together constitutes the research equipments.

Course outcome:

- This course will enable students to understand the electronics of different device and circuits. They will have picture on Op-Amps, oscillators, digital electronics and logic circuits. This will help students to design electronics experiments independently.

Pedagogy:

- The fundamental principles of the electronic circuits and their applications were discussed.

Transistor amplifiers: BJT transistor modelling, hybrid equivalent model, voltage divider bias, CE and emitter follower configurations, frequency response. Hybrid model equivalent circuit concept.

Feedback amplifier: Feedback concept, feedback connections type, practical feedback circuits.

Oscillators: Oscillator operation, phase shift oscillator, Wein-bridge oscillator, Crystal oscillator: BJT version.

FET amplifiers: FET small signal model, biasing of FET, Common drain common gate configurations, MOSFETs, FET amplifier and its frequency response.

Operational amplifiers: Concepts of differential amplifier, Ideal op-amp, op-amp parameters, ideal voltage transfer curve, open loop and closed op-amp configurations, inverting amplifier, non inverting amplifier, limitations of open loop op-amp configurations.

Operational amplifier applications: Summing, scaling and averaging amplifiers, voltage to current converter with grounded load, current to voltage converter, integrator, differentiator,. V to I and I to V converters, Log and antilog amplifiers, Wave form generators, phase shift oscillator, Wein bridge oscillator. Non-linear circuit applications: Crossing detectors, 555 timer as a mono-stable and astable multivibrators, active filters—first and second order low pass and high pass filters, Butterworth filters.

Digital electronics: Boolean laws and theorems, addition and subtraction based on 1's and 2's complements, families of gates, RS and JK flip-flops, The master-slave JK flip-flop, D and T flipflops. Karnaugh maps for 3 and 4 variables, decoders-BCD decoders, encoders.

Combinational logic circuits: Shift registers-series, series in-series out and parallel in parallel out. Half and full adders, registers, counters - binary ripple counters, synchronous binary counters, counters based on shift registers, synchronous counters, synchronous mod-6 counter using clocked JK flip-flops. synchronous Mod-6 counter using clocked D, T, or SR flip-flops. memory cells, memory registers

References:

- Boylestad R.L. and Nashelsky L., Electronic Devices and Circuit Theory, 4th Edn., Pearson Education, 2006.
- Bell D.A., Operational Amplifiers and Linear Circuits, 2nd Edn., Pearson Education, 2004.
- Gaekwad R.A., Operational Amplifiers and Linear Integrated Circuits, Prentice-Hall of India, New Delhi, 1993.
- Malvino A.P. and Leach D.P., Digital Principles and Applications, 4th Edn., Tata McGraw Hill, 1988.
- Arivazhagan S. and Salivahananan S., Digital Circuits and Design, Vikash Publishing House Pvt. Ltd.New Delhi, 2001.

COURSE XVI : Biophysics

Objectives:

- The applications of X-ray diffraction method to understand the biological problems.
- To study the different techniques to obtain the structure of the protein, this helps to understand the function of the protein.

Course outcome:

- This course deals with the essential tools for studying biophysics, basics concepts relating physics and biology. It finds large applications in the modern research area. Thus makes the students to have a prior knowledge about research work.

Pedagogy:

- Structure elucidation of the biological molecules using spectral analysis are explained.

The broad characteristics of a typical cell-cell organelles-The molecular composition of a cell. Biological molecules and their general character-cell behaviour-Viruses-genetics and biophysics. Molecular physics. The conservation of energy in biological process Metabolism or chemical energy turnover-Statistical thermodynamics and biology-The theory of absolute reaction rates-Thermal inactivation-The entropy transfer of living organisms-Information theory-relation between information and entropy-Information content of some biological systems-Information content of a bacterial cell.

Determination of size and shape of molecules-random motion-diffusion-sedimentation optical methods-rotational diffusion and birefringence. X-ray analysis and molecular structure-diffraction of x-rays crystal structure and the unit cell. Diffraction patterns of some protein fibers-the structure of globular proteins-the structure of polypeptide chains-the pleated sheets and beta-keratin-the alpha-helix and alpha-keratin the structure of nuclei acids polymers - the structure of nucleoproteins-the analysis of virus structures.

Absorption spectroscopy-vibrations of polyatomic molecules-characteristic bond frequencies-Raman spectra and the dipolar nature of amino acids- the vibrational spectra of proteins-the energy levels of hydrogen bonded structures- Absorption coefficient and cross section- experimental techniques for absorption measurements- Absorption by oriented diples - dichroic ratios of proteins and nucleic acids electronic spectra of polyatomic molecules-Ultraviolet absorption by proteins and nucleic acids- The fine structure in spectra-polarized ultra violet light- electron spin resonance (briefly)-Nuclear magnetic resonance (brief).

References:

- Setlow R.B. and Pollard E.C., Molecular Biophysics, Pergamon Press, LondonParis 1962.
- Volkenshtein M.V., Biophysics, Mir Publishers, Moscow, 1983.
- Sam K., Biophysics, Rajat Publication, 2005.
- Rodney C., Biophysics, Johy-Wiley, 2004.
- Glaser R., Biophysics-An Introduction, Springer, 2004.

- Nihaluddin, A Textbook of biophysics, Sonali Publications, 2009.

COURSE XVII: Minor Project

Objectives:
- To address a small research problem.
- To design, perform and interpret the experimental results.

Course outcome:
- Designing experiments based on the research problem.
- Understanding, compiling and analyzing the data.
- Able to write a comprehensive project report.
- Able to publish research article in a peer reviewed journals.

Project work will be carried on a defined research topic allotted to the students. The students will present a research paper published recently in peer reviewed journals preferably in the area of project work.

OPEN ELECTIVE

XVIII: RADIATION PHYSICS AND DOSIMETRY

Objectives:
- To study the basics and principle of the radioactivity.
- To study the interactions of the radiations with the matter and the use of the detectors.

Course outcome:

- This course is an application oriented in techniques of radiation physics. This will enable students to deal with radiation detection tools, its measurements and devices. This will help students to take up further research or projects in radiation physics, nuclear physics and particle physics.

Pedagogy:
- Discussion on the various types of interaction of the radiations with the matter.
- Basic details about the radiations.

Radioactivity: Radioactive decay law, successive disintegration (no derivation), Secular equilibrium, transient equilibrium, natural radioactive series, units of radioactivity.

Background Radiation: Classification of radiation, background radiation, characteristic radiation, continuous radiation. Radioactivity in atmosphere. Radon, properties of radon, origin of radon, radon in the atmosphere.

Interaction of Photons with Matter: General aspects, attenuation coefficients, classical, coherent and incoherent scattering, photoelectric effect, pair production. interactions of charged particles with matter: general aspects, stopping power range, heavy charged particles, light charged particles, energy deposition, radiation yield, Bremsstrahlung targets. [16 hours]

Dosimetric principles, quantities and units: Fluence and energy fluence, Absorbed dose, Kerma, Inter relationships, fluence and dose (electrons), energy fluence and kerma (photons), Kerma and dose (electronic equilibrium), Kerma and exposure. Inhalation dose, ingestion dose, working level.

Radiation Dosimeters and Detectors: Desirable properties, ionization chambers and electrometers, environmental dosimeters, TLD, solid state nuclear track detectors.

Tutorial

References:

- Krane K.S., Introductory Nuclear Physics, Wiley, New York, 1955.
- Krane K., Modern Physics, John Wiley and Sons, Inc. 1998.
- Evans R.D., The Atomic Nucleus, Tata McGraw Hill, New Delhi, 1980.
- Wilkening M., Radon in the Environment, Elsevier Science Publishers, AE Amsterdam, The Netherlands, 1990.
- Kapoor S.S. and Ramamoorthy V., Nuclear Radiation Detectors, Wiley Eastern, Bangalore, 2007.