M.Sc. (Physics)
Programme Structure

Revised: 2021

CENTRAL UNIVERSITY OF KERALA

(Department of Physics)

Introduction

M.Sc. Programme in Physics has been structured to a programmme that aims at moulding the learner into a professional physicist. The main feature of the curriculum is to address building strong foundations and skills in applying the knowledge to important areas of research and industry. It is spread over four semesters, has kept good proportion of theory and lab, and has a wide spectrum of courses for the students to choose from.

Programme Outcome

A student who has completed M.Sc. in Physics shall be acquiring knowledge and skills needed to take a career in physics, either in academia or industry. The programme is structured to impart strong foundation in the subject so that the student shall be capable of moving to any area of specialisation. The programme gives much emphasis to problem solving with the aim of creating critical thinking and ability to apply theory to various situations in research both in pure and applied physics. Laboratory courses are framed with the fact that physics is basically an experimental science. A large number of elective courses are offered for the student to choose from, reflecting the current trend in the developments in the subject. Students are trained to apply computational techniques with ease. It is an aim of the programme to impart maximum hands-on training in every component of the syllabus taught. Our assessment methods have strong flavour of testing the skills of problem solving, and we place utmost importance to implement continuous evaluation for all courses. Our overall aim is to transform the student into a profession physicist.

Programme specific outcome

On completion of M.Sc. (Physics) programme students should be able to achieve the following programme-specific outcomes:

- Strong foundations in basic physics
- Outstanding problem solving skills
- Acquire practical knowledge in using computation as a tool for research
- Exposure to a vast spectrum of areas of current research fields

- Training in using research level instruments
- Capability of critical thinking in applying the theory into research
- Strong mathematical and analytical skills
- Skills to work in selected industrial settings
- Good communication skills
- A passion for Physics

List of Courses

Course Code	Course Title	Credits
First Semester		
PHY 5101	Mathematical Methods in Physics	4
PHY 5102	Classical Mechanics	4
PHY 5103	Classical Electrodynamics	4
PHY 5104	Electronics: Devices and Circuits	4
PHY 5105	Experimental Physics I	4
Second Semester		
PHY 5201	Quantum Mechanics I	4
PHY 5202	Statistical Mechanics	4
PHY 5203	Condensed Matter Physics	4
PHY 5204	Computational Physics	4
PHY 5205	Experimental Physics II	4
Third Semester		
PHY 5301	Quantum Mechanics II	4
PHY 5302	Atomic, Molecular and Optical Physics	4
PHY 5303	Nuclear and Particle Physics	4
PHY 5304	Experimental Physics III	4
Fourth Semester		
PHY 5490	Dissertation	4
Elective Courses		
PHY 5001	Advanced Electronics	3
PHY 5002	Computer Simulations in Physics	3
PHY 5003	Advanced Mathematical Physics	3
PHY 5004	Advanced Solid State Physics	3
PHY 5005	Quantum Computation	3
PHY 5006	Density Functional Theory Methods	3
PHY 5007	Magnetic Materials and Devices	3
PHY 5008	Nuclear Reactions	3
PHY 5009	Advanced Quantum Mechanics	3

PHY 5010	Synthesis of Materials	3
PHY 5011	Materials Characterization Techniques	3
PHY 5012	Optical Communication	3
PHY 5013	Quantum Optics	3
PHY 5014	Photonic Crystals	3
PHY 5015	Nonlinear Dynamics and Chaos	3
PHY 5016	Introductory Plasma Physics	3
PHY 5017	Laser Plasma Interactions	3
PHY 5018	Semiconductor Optoelectronics	3
PHY 5019	Physics of Lasers	3
PHY 5020	Introduction to Nanophotonics	3
PHY 5021	Introduction to Nanoelectronics	3
PHY 5022	RF to Terahertz Systems	3
PHY 5023	Physics of Atmospheres	3
PHY 5024	Introduction to Astrophysics	3
PHY 5025	Soft Matter Physics	3
PHY 5026	Microwave Measurements and Characterization	3
PHY 5027	Semiconductor Devices	3
PHY 5028	Computational Quantum Mechanics	3
PHY 5029	Electrodynamics of Superconductors	3
PHY 5030	Computational Electromagnetics	3
PHY 5031	Simulation of Electronic Circuits	3
PHY 5032	Nuclear Instrumentation	3
PHY 5033	Introduction to Nonlinear Optics	3
PHY 5034	Introduction to General Theory of Relativity	3
PHY 5035	Mechanics of Solids and Fluids	3
PHY 5036	Applications of Lasers	3
PHY 5037	Quantum Transport in Low Dimensional Systems	3
PHY 5038	Summer Project	3
PHY 5039	Molecular and Optical Physics	3
PHY 5040	Concepts of Modern Physics	3
PHY 5041	Basic Electronics for Scientists	3
PHY 5042	Modern Optics	3
PHY 5043	Machine Learning for Physicists	3
PHY5044	Introduction to Nanoscience and Nanotechnology	3

PHY5045	Nanoscale Materials and Devices : Synthesis and Characterization	3

PHY5101 Mathematical Methods in Physics

Course Code	PHY5101	Semester	I
Course Title	*Mathematical Methods in Physics*		
Credits	4	Type	Core

Course Outcome

The purpose of the course is to introduce students to methods of mathematical physics and to develop required mathematical skills to solve advanced problems in quantum mechanics, electrodynamics and other fields of theoretical physics.

Course Structure

Contents: (1) Complex numbers and analytical functions. CR conditions. Complex integration. Taylor and Laurent series. Calculus of Residues. Conformal mappings. (2) Beta and Gamma functions. Power series solutions of Bessel differential equations. Definition and properties of important special functions. (3) Fourier series and transforms. Laplace transforms. Applications to the solution of differential equations. (4) Sturm-Lioville problem, Orthogonal functions and Greens function method. (5) Introduction to tensors and tensor calculus. (6) Basic concepts of group theory.

Suggested Books

- K. Hoffman and R. Kunz, Linear Algebra, Prentice Hall (1978)
- C.Harper, Introductory Mathematical Physics, Prentice Hall (1978)
- P. Dennery and A. Krzywiki, Mathematics for Physicsists, Dover (1996)
- K.F. Riley, M.P.Hobson and S.J.Bence, Mathematical Methods for Physics and Engineering, Cambridge (2006)
- G.B.Arfken and H.J.Weber, Mathematical Methods for Physicists, Academic Press (1995)
- V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, Ane Books, 2019.

PHY5102 Classical Mechanics

Course Code	PHY5102	Semester	I
Course Title	*Classical Mechanics*		
Credits	4	Type	Core

Course Outcome

We expect students to assimilate strong understanding of classical physics problems and their solutions through various routes. Introduction to central force and Rigid body based problems are also aimed at. Students will also be provided basic understanding of chaos.

Course Structure

Contents: Newtonian mechanics of a single particle and a system of particles. Non-inertial systems and Coriolis force. Constraints and generalized coordinates. Principle of least action and Lagrange's equations. Hamiltonian and Hamilton's equations of motion. Cyclic coordinates, symmetry and conservation. Noether's theorem. Canonical transformation and applications. Hamilton-Jacobi theory. Action-angle variables. Poisson Brackets. Central force motion, Kepler problem. Motion of rigid bodies. Small oscillations and normal modes. Basic ideas of fluid dynamics. Concept of chaos.

Suggested Books

- H. Goldstein, Safko and Poole, Classical Mechanics, Pearson (2007)
- Landau and Lifshitz, Mechanics, Butterworth (1981)
- F. Scheck, Mechanics, Springer (2007)
- G.J.Sussman and J. Wisdom, Structure and Interpretations of Classical Mechanics, Pearson (2001)

PHY5103 Classical Electrodynamics

Course Code	PHY5103	Semester	I
Course Title	*Classical Electrodynamics*		
Credits	4	Type	Core

Course Outcome

(1) To train students in applying the laws of classical electrodynamics to modern experimental systems.
(2) To teach students how the laws of electrodynamics is used in modern communication systems
(3) To develop skills in numerically solving probleams of practical interest.

Course Structure

Contents: Electrostatics: Calculation of fields and potentials. Conductors. Boundary value problems. Multipole expansion and method of images. Electrostatics with dielectrics. Electrostatic energy. Magneto-statics: Ampere's theorem and Biot Savart law. Induction and Maxwell's equation. Electromagnetic waves and Poynting theorem. Waves in dielectrics and conducting media. Scalar and vector potential. Waves at boundary, reflection and refraction. Polarization. Rectangular waveguides and dielectric slab waveguides. Radiation from accelerating charges. Dipole antenna. Special theory of relativity and Lorentz transformation of fields.

Suggested Books

- D. J. Griffiths, Introduction to Electrodynamics, Pearson (2012)
- J.D. Jackson, Classical Electrodynamics, Wiley (2007)
- A. Zangwill, Modern Electrodynamics, Cambridge (2013)

PHY5104 Electronics: Devices and Circuits

Course Code	PHY5104	Semester	I
Course Title	*Electronics: Devices and Circuits*		
Credits	4	Type	Core

Course Outcome

Basic understanding of principle and operation of semiconductor devices. Design of electronic circuits using diodes, BJT, FET, OPAMP for different applications. Basic knowledge on storage of information in computer and conversion of data to analog form.

Course Structure

Contents: (1) Review of Network theorems. PN junction and diode. Special diodes and circuit applications. Transistors and biasing. Small signal amplifiers. Feedback and applications. Oscillators. Field effect transistors. (2) Operational amplifiers and basic OPAMP configurations. Ideal OpAmp circuits. Feedback in OpAmp circuits. Analogue simulation and solution of differential equations. (3) Elements of digital electronics.
(4) Microprocessor, basic architecture and simple programs using 8085. (5) Optoelectronic devices: characteristics and basic applications.

Suggested Books

1. Niel Storey, Electronics: A Systems Approach, Pearson (2008)
2. A.P.Malvino, Electronic Principles, McGraw Hill (2006)
3. S. Franco, Design with Operational Amplifiers, McGraw Hill (2002)
4. R.L.Boylestad, and L. Nashelsky, Electronic Devices and Circuit Theory, Prentice Hall (2008)
5. M.M.Mano, Digital Design, Pearson (2013)
6. M. Senthil Kumar and M.Saravanan, Microprocessors and Microcontrollers, Oxford (2010)

PHY5105 Experimental Physics I

Course Code	PHY5105	Semester	I
Course Title	*Experimental Physics I*		
Credits	4	Type	Core

Course Outcome

Students achieve ability to:

1. Learn various experimental and computational tools thereby developing analytical abilities to address real world problems.

2. Adopt the skills related to research, education, and industry-academia.

3. Understand the behaviour of electronic components and perform analysis and design of bias circuits for diodes, transistors etc.

Course Structure

Theory: Research methodology. Role of hypothesis. Errors in experiment. Error analysis. Curve fitting: practical methods.

General Physics Lab: Cornu's experiment, Wien's displacement law. Microwave propagation along lines, laser optics lab (beam profile, diffraction, etc), e/m experiment, Planck's constant, Stefan's constant, Brewster's angle, Goy's method etc.

Electronics Lab: Network theorems, Transistor biasing, amplifiers: frequency response, operational amplifier circuits, oscillators. high impedance amplifiers, FET characteristics, amplitude modulation, half and full adder circuits, flip-flops, microprocessor experiments etc.

Suggested Books

1. G.L. Squires, *Practical Physics*, Cambridge (2011)
2. D.W. Preston and E.R. Dietz, The Art of Experimental Physics, Wiley (1991)
3. R.A. Dunlap, Experimental Physics: Modern Methods, Oxford (1997)
4. A.C.Melissinos and J. Napolitano, Experiments in Modern Physics, Academic Press (2003)
5. S. Franco, Design with Operational Amplifiers, McGraw Hill (2002)
6. M.M.S. Anand and L.K.Maheshwari, Laboratory Experiments and PSpice Simulation in Analogue Electronics, PHI (2006)
7. D.M.Kaplan and C.G.White, Hands-n Electronics, Cambridge (2003)

PHY5201 Quantum Mechanics I

Course Code	PHY5201	Semester	II
Course Title	*Quantum Mechanics I*		
Credits	4	Type	Core

Course Outcome

Quantum Mechanics is one of the most interesting topics of modern Science. This branch of science has wide applications in Physics, chemistry and industry. The purpose of the course is to introduce students to the fundamental aspects of quantum physics and develop required skills to address advanced problems in quantum mechanics. This course is a foundation level course, which is followed by a more advanced paper in Semester 3, that is Quantum Mechanics II, where the subject is taught in advance level.

Course Structure

Contents: Postulates of quantum mechanics. The Schrödinger equation and superposition principle. Stationary states. Completeness of eigenstates. Operator algebra. Vector spaces and linear transformation. Bra-ket notation. Change of basis. Hilbert space and representation. Commuting observables, simultaneous measurement and Heisenberg uncertainty principle. Application to one dimensional time independent potentials. Potential barriers and tunneling. Linear harmonic oscillator. Three dimensional potentials. Quantum mechanics of angular momentum. Eigenvalues for angular momentum operators. Spin and spin operators. Spherically symmetrical potential. Detailed study of hydrogen atom problem.

Suggested Books

1. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson (2005)
2. R. L. Liboff, Introductory Quantum Mechanics, Pearson (2007)
3. E. Merzbacher, Quantum Mechanics, Wiley (2004)
4. N. Zettili, Quantum Mechanics: Concepts and Aplications, Wiley (2009)
5. H.C. Verma, Quantum Physics, TBS publishers, 2012
6. J.J. Sakurai, Advanced Quantum Mechanics, Pearson education, 2012

PHY5202 Statistical Mechanics

Course Code	PHY5202	Semester	II
Course Title	*Statistical Mechanics*		
Credits	4	Type	Core

Course Outcome

(1) To understand the relationship between macroscopic and microscopic physics using ideas of statistics.
(2) To learn the basic methods statistical mechanics
(3) To understand how statistical mechanics is useful in describing problems of solid state physics.

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Course Structure

Contents: Review of classical thermodynamics. Quantum states of a system. Phase space and ensembles. Canonical ensemble. Partition function and relation to thermodynamics. Identical particles. Partition function for identical particles. Maxwell's distribution of molecular speeds. Planck's distribution. Systems with variable number of particles. Statistical mechanics of identical particles. Fermions and Bosons. Application to interacting particles (optional). Thermodynamics of phase transitions and critical phenomena. Ising model.

Suggested Books

1. Roger Bowley and M. Sanchez, Introductory Statistical Mechanics, OUP (2007)
2. Kerson Huang, Introduction to Statistical Physics, CRC (2009)
3. F.Reif, Fundamentals of Statistical and Thermal Physics, Levant Books (2010)
4. Linda E. Reichl, A Modern Course in Statistical Physics, Wiley (2009)
5. H.B. Callen, Thermodynamics and an Introduction to Thermostatistics, Wiley (2006)
6. D.V. Shroeder, An Introduction to Thermal Physics, Addison Wesley (1999)
7. R.K. Pathria & Paul D. Beale, Statistical Mechanics, Academic Press, 2011.

PHY5203 Condensed Matter Physics

Course Code	PHY5203	Semester	II
Course Title	*Condensed Matter Physics*		
Credits	4	Type	Core

Course Outcome

In depth understanding of the origin of the physical properties of matter, historical evolution of theoretical models and their modifications based on experimental data which instil original interest in students to pursue research in condensed matter physics and related areas of physics.

Course Structure

Contents: Lattice structure and reciprocal lattice. Crystal structure. Free electron model: Drude and Sommerfeld theories. Fermi liquid theory. Screening and Coulomb interaction. Bloch theorem and Kronig Penny model. Band structure. Nearly free electron model and tight binding method. Lattice vibration, phonons and heat capacities of solids. Effective mass treatment of conduction. Superconductivity: two fluid description, BCS concepts and Josephson effects. Magnetic properties and optical properties of solids. Introduction to nanostructures (qualitative).

Suggested Books

- Aschcroft and N.D.Mermin, Solid State Physics, Thomson Press India (2003)
- C. Kittel, Solid State Physics, Wiley (2007)
- Ali Omar, Elementary Solid State Physics, Pearson (1999)
- M. Marder, Condensed Matter Phyiscs, Wiley (2010)
- Dan Wei, Solid State Physics**,** Cengage (2009)

PHY5204 Computational Physics

Course Code	PHY5204	Semester	II
Course Title	*Computational Physics*		
Credits	4	Type	Core

Course Outcome

(1) To train students in using modern mathematical techniques in performing numerical computation.
(2) To rain students in handling modern UNIX based systems
(3) To teach basic simulation technics used in physics
(4) To impart skills in using these technics in practice

Course Structure

Contents: Numerical methods for solving nonlinear equations, interpolation, system of equations, differentiation, integration and solution of differential equations. Treatment of boundary value problem. Fourier transformation and FFT. Method of least square.

Elements of Unix operating system, Unix tools for science: vi editor, GNUPlot, Latex for typesetting, GCC compilers. Concepts of object oriented programming. Introduction to parallel processing and high performance computing. Detailed study of a high level language like Fortran, C/C++, Matlab/Octave.

Random number generation and Monte Carlo integration. Random walk and percolation models. Numerical solution of Schrodinger equation for one dimensional potentials using finite difference methods. Treatment of hydrogen atom. Periodic potentials and band structure (one dimension). Numerical method of solving equations of motion. Introduction to molecular dynamics and Monte Carlo simulation. Simulation of chaotic systems.

Laboratory work: Practical implementation of numerical methods and simulations in computational lab sessions using any programming language

Suggested Books

1. Tao Pang, Computational Physics, Cambridge
2. D.P.Landau, Survey of Computational Physics, Academic Press
3. Paul DeVries and J. Hasbun, Introduction to Computational Physics,
4. Philipp Scherer, Computational Physics, Springer (2010)
5. N.J.Giordano, Computational Physics, Prentice Hall (1997)

PHY5205 Experimental Physics II

Course Code	PHY5205	Semester	II
Course Title	*Condensed Matter Physics*		
Credits	4	Type	Core

Course Outcome

In Students achieve ability to:

1. Set up testing strategies and select proper instruments to evaluate performance characteristics of electronic circuit

2. hands on training on different types of electronic circuit and analyse their operation at different operating conditions

Course Structure

Theory: Measurement and instrumentation. Transducers. Bridge circuits. Noise reduction techniques. 555 timer and PLL applications. Active filters.

General Physics: Thermo-luminescence, optoelectronics devices, dielectric constant, Faraday rotation, magnetic hysteresis, Franck-Hertz experiment, Compton effect, Balmer series, GM counter etc.

Electronics: Instrumentation amplifier, active filters, multivibrators, waveform generation, PLL: capture range and lock range, FM modulation and detection, transducer with bridge, AC bridge circuits, A/D and D/A converter, precision voltmeter, peak detector etc.

(Selection of experiments shall be done by instructor)

Suggested Books

1. D.W. Preston and E.R. Dietz, The Art of Experimental Physics, Wiley (1991)
2. R.A. Dunlap, Experimental Physics: Modern Methods, Oxford (1997)
3. A.C.Melissinos and J. Napolitano, Experiments in Modern Physics, Academic Press (2003)
4. S. Franco, Design with Operational Amplifiers, McGraw Hill (2002)
5. M.M.S. Anand and L.K.Maheshwari, Laboratory Experiments and PSpice Simulation in Analogue Electronics, PHI (2006)
6. A.Peyton, Analogue Electronics with Op-Amps, Cambridge (1993)
7. T.H. O'Dell, Circuits for Electronic Instrumentation, Cambridge (2005)

PHY5301 Quantum Mechanics II

Course Code	PHY5301	Semester	III
Course Title	*Quantum Mechanics II*		
Credits	4	Type	Core

Course Outcome

(1) To teach students in computing time-evolution of wavefunctions in various physical model systems.
(2) To train students in applying approximations methods in problems of practical interest.
(3) To expose students to the areas of modern quantum mechanics like field theory and relativistic quantum mechanics

Course Structure

Contents: Time evolution in quantum mechanics. Time development operator. Pictures of quantum mechanics. Canonical quantization. Coordinate and momentum representation. Density operator, density matrix. Intrinsic angular momentum, spin and rotation. Spin operator and Pauli matrices. Addition of angular momentum. Identical particles.

WKB approximation for bound states. Bound state perturbation theory: degenerate and non-degenerate cases. Variational method. Linear variational problem. Applications to molecular system. Time dependent perturbation methods. Fermi's golden rule. Scattering problems. Cross section. Born approximation and partial wave analysis. Creation and annihilation operator. Quantized fields. Quantum field description, Bosons and Fermions. Applications to many particle systems. Klein-Gordon and Dirac equations. Dirac's theory of electron.

Suggested Books

1. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson (2005)
2. R. L. Liboff, Introductory Quantum Mechanics, Pearson (2007)
3. E. Merzbacher, Quantum Mechanics, Wiley (2004)
4. N. Zettili, Quantum Mechanics: Concepts and Aplications, Wiley (2009)
5. L. Schiff, Quantum Mechanics, McGraw Hill (1969)
6. Y.V.Nazarov, Advanced Quantum Mechanics, Cambridge (2013)
7. H.C. Verma, Quantum Physics, TBS publishers, 2012
8. J.J. Sakurai, Advanced Quantum Mechanics, Pearson education, 2012

PHY5302 Atomic, Molecular and Optical Physics

Course Code	PHY5302	Semester	III
Course Title	*Atomic, Molecular and Optical Physics*		
Credits	4	Type	Core

Course Outcome

Understanding of structure, ground state and excited states of atoms, ions and molecules. How to understand emission and absorption of radiation by atoms and molecules. Knowledge on principle of NMR, ESR and Mossbauer spectroscopy.

Course Structure

Contents: (1) Models of many electron atoms. Energy levels and spin-orbit interaction. Emission and absorption of radiation and transition probability. Selection rules. Einstein's coefficients. Broadening of spectral lines. (2) Molecular structure. Rotation, vibration and electronic spectra of molecules. (3) Nonlinear spectroscopy. Laser cooling and trapping of atoms. Atom interferrometer. Magnetic resonance, NMR and ESR. Mossbauer effect. (4) Fermat's principle, Lagrangian and Hamiltonian approach to light propagation. Fresnel-Kirchhoff diffraction formula and applications. Coherence.

Suggested Books

1. B.H.Brandsen and C.J. Joachain, Physics of Atoms and Molecules, Pearson (2003)
2. W. Demtroder, Atoms, Molecules and Photons, Springer (2010)
3. Arul Das, Atomic and Molecular Spectroscopy, PHI (2003)
4. Colin Banwell & Elaine Mccash, Fundamentals of Molecular Spectroscopy, McGraw Hill Education, 2001.
5. Prof. H. E. White, Introduction to Atomic Spectra, McGraw-Hill Book Co., Inc., 1934

PHY5303 Nuclear and Particle Physics

Course Code	PHY5303	Semester	III
Course Title	*Nuclear and Particle Physics*		
Credits	4	Type	Core

Course Outcome

The aim of this course is to introduce the students to the sub-atomic world and interactions manifested there at high energies. The course starts on introductory level and develops to advanced topics. The course improves the knowledge of the students and inspire many of them to pursue research careers in this field. We encourage the students to explore international collaborations and opportunities.

Course Structure

Contents: Basic properties of atomic nucleus. Relationship between nuclear radius and mass number. Nuclear forces, nucleons, spin and isotropic spin. Mirror nuclei. Stability of nuclei, binding energy. Nuclear models: semi empirical mass formula, liquid drop model. Shell model, magic numbers, Parity of nuclear states, Meson theory of nuclear forces. Radioactivity: theory of alpha, beta and gamma decay. Nuclear reactions. Fission and fusion. Conserved quantities in nuclear reactions. Forces in nature. Interactions and particles. Leptons. Hardons. Elementary particle quantum numbers. Quarks. CP violation. The standard model.

Suggested Books

1. B.Martin, Nuclear and Particle Physics: An Introduction, Wiley (2006)
2. K. Heyde, Basic Ideas and Concepts in Nuclear Physics, CRC Press (2004)
3. K.S.Krane, Introductory Nuclear Physics, Wiley (1987)
4. D. Griffiths, Introduction to Elementary Particles, Wiley (2008)

PHY5304 Experimental Physics III

Course Code	PHY5304	Semester	III
Course Title	*Experimental Physics III*		
Credits	4	Type	Core

Course Outcome

Students get training in

1. Modern instrumentation

2. Nuclear detector handling, Data analysis,

3. Soft skill development

4. Scientific paper writing

Course Structure

Experiments:

Nuclear Physics: GM counter, scintillation counter, alpha, and gamma detectors, analysis of nuclear reaction data.
Solid state physics: Hall effect, four probe, band gap measurement, optoelectronic devices, Kerr effect, analysis of X-ray diffraction data. Thin film preparation.
Spectroscopy: Zeeman effect, Laser Raman spectra, constant deviation spectrograph, ESR, NMR, Ellipsometry.

Mini project:
Students shall take up one extended experiment involving writing of report in the form of a manuscript.

PHY5490 Dissertation

Course Code	PHY5490	Semester	IV
Course Title	*Dissertation*		
Credits	4	Type	Core

Course Structure

Every student shall work on a research project under a faculty member of the department or faculty from other department, or from other institution (if required) and submit a Dissertation at the end of the semester. Allotment of the supervisors shall be done by the Head of the Department, taking into consideration the interest of the student and consent of a teacher. As far as possible, equal distribution of students should be maintained per faculty member, and the allotment may be done during the last phase of third semester. The supervisor shall act as the instructor for this course on Dissertation and make continuous assessment for 75 % of marks based on the understanding, literature survey, experimental/theoretical formulation, performance, interpretation of results and writing of Thesis. An end semester evaluation for 25% based on a viva voce examination shall be conducted at the end of the fourth semester by a panel consisting of the supervisor and another faculty member nominated by the Head. Grading shall be done by the programme committee.

PHY 5001 Advanced Electronics

Course Code	PHY5001	Semester	
Course Title	*Advanced Electronics*		
Credits	3	Type	Elective

Course Outcome

This is the second course in electronics for students of physics. Expected course outcome is to (i) introduce advanced analog circuits and their applications for instrumentation, and (ii) to give hands on training in laboratory.

Course Structure

Contents: Ideal Op-Amp circuits. Circuit with resistive feedback: Current to voltage and voltage to current converters. Current amplifiers. Instrumentation amplifiers and applications. Active filters. Open loop and closed loop response. Op-Amp noise. Nonlinear circuits: Voltage comparators. Schmitt triggers. Precision rectifiers. Analogue switches, peak detectors and sample and hold circuits. Signal generators. Voltage reference and regulators. D-A and A-D converters. Nonlinear amplifiers and Phase Locked Loops. Elements of signal processing. Practical exercises for design and testing shall be assigned by the teacher.

Suggested Books

1. Sergio Franco, Design With Operational Amplifiers and Analog Integrated Circuits, McGraw Hill (2012)
2. R. A. Gayakwad, Op-Amps and Linear Integrated Circuits, Prentice Hall (2002)
3. T.H. O’Dell, Circuits for Electronic Instrumentation, Cambridge (2005)
4. A.Peyton, Analogue Electronics with Op-Amps, Cambridge (1993)

PHY5002 Computer Simulations in Physics

Course Code	PHY5002	Semester	
Course Title	*Computer Simulation in Physics*		
Credits	3	Type	Elective

Course Outcome

This course in intended to give a hands-on training to students in using simulational techniques for research work in modern physics. Basically the very important models of monte-carlo and molecular dynamics are used to teach how the advanced simulational techniques are actually implemented. It is also the aim of the course to add research oriented work to be implemented individually so that the concepts are actually translated into practice.

Course Structure

Contents: (1) Random number generation. Simple sampling Monte Carlo methods: Percolation and random walk models. Importance sampling and Metropolis algorithm. Ising model, finite size scaling and application to phase transition. Quantum Monte Carlo methods. Introduction to polymers and Protein folding. (2) Molecular Dynamics: Verlett algorithm. MD for different ensembles. Application to simple systems. Melting transition. Quantum MD methods. (3) High performance computing and program development for parallel execution. (4) Practical implementation of these methods on computer.

Suggested Books

1. D.P.Landau and K.Binder, A Guide to Monte Carlo Simulation in Statistical Physics, Cambridge (2000)
2. M.P.Allen and D.J.Tildsley, Computer Simulation of Liquids, Oxford (1987)
3. N.J. Gordano and H. Nakanishi, Computational Physics, Addison Wesley (2005)

PHY5003 Advanced Mathematical Physics

Course Code	PHY5003	Semester	
Course Title	*Advanced Mathematical Physics*		
Credits	3	Type	Elective

Course Outcome

Main objective of the course is to give students a solid understanding of the foundations of modern mathematics, used in theoretical physics.

Course Structure

Contents: Topics include the following: Set theory and functions. Mappings. Linear operators. Topological space. Metric space. Compact and connected spaces. Basic ideas of measure and integration. Bounded linear operators. Spectral Theory. Hilbert space and application to quantum mechanics and/or electrodynamics.

Suggested Books

1. P. Szekeres, A Course in Modern Mathematical Physics, Cambridge (2004)
2. E. Kreyszig, Introductory Functional Analysis and Applications, Wiley (1989)
3. G.W. Hanson, Operator Theory for Electromagnetics, Springer (2011)

PHY5004 Advanced Solid State Physics

Course Code	PHY5004	Semester	
Course Title	*Advanced Solid State Physics*		
Credits	3	Type	Elective

Course Outcome

Expose students to many body interactions giving magnetically ordered states, superconductivity and other exotic phenomena such as quantum Hall effect, quantisation of conductance etc. This is expected for students who seriously consider research in condensed matter physics.

Course Structure

Contents: (1) Bloch theorem and band structure calculation: Tight binding. Nearly free electron approximation. K.p theory. Discussion of computational methods. (2) Electronic quasiparticles: Effective mass. Excitons. Properties of metals and semiconductor. Band bending and hetero-structures. Quantum confinement. Landau levels. (3) Quantized waves: Phonons, photons. Field operators. Interaction of quasiparticles: electron-phonon, electron-electron interactions. Introduction of many body description for electron gas, magnetism and superconductivity. (4) Instructor shall select other topics of current research interest.

Suggested Books

1. Y.V.Nazarov, Advanced Quantum Mechanics, Cambridge (2013)
2. A.L.Fetter and J.D. Walecka, Quantum Theory of many Particle Systems, Dover (2003)
3. M.P. Marder Condensed Matter Physics, Wiley (2011)
4. D.W.Snoke, Solid State Physics, Pearson (2009)

PHY5005 Quantum Computation

Course Code	PHY5005	Semester	
Course Title	*Quantum Computation*		
Credits	3	Type	Elective

Course Outcome

(i) To introduce the basic concepts of quantum computation and information
(ii) To explain how practical quantum computers are designed
(iii) To explain basic quantum algorithms

Course Structure

Contents: This course is an introduction to the theory of quantum information science, quantum computation and communication. Outline: Quantum bits and gates. Experimental methods from atomic physics and optics. Two-qubit gates. Quantum measurement and entanglement. Quantum computing: elementary algorithms. Trapped atoms and ions. NMR techniques. Parallelism. Classical and quantum information. Introduction to quantum communication and cryptography.

Suggested Books

1. J. A. Jones and D. Jaksch, Quantum Information, Computation and Communication, Cambridge (2012)
2. M.A. Nielsen and I. L. Churag, Quantum Computation and Quantum Information, Cambridge (2011)
3. N. David Mermin, Quantum Computer Science: An Introduction, Cambridge (2007)

PHY5006 Density Functional Theory Methods

Course Code	PHY5006	Semester	
Course Title	*Density Functional Theory Methods*		
Credits	3	Type	Elective

Course Outcome

(i) To introduce the basic concepts of density functional theory
(ii) To introduce how it is practically implemented using standard codes
(iii) To impart practical training in using DFT methods by executing actual projects in computational lab.

Course Structure

Contents: This course is a practical oriented introduction to density functional theory. Topics may cover the following: Basic concepts of density functional theory. Computational approaches. Basis functions. Plane waves and pseudo-potentials with applications to the electronic structure of solids. Optical properties. Gaussian functions and molecular systems. Practicals: Students shall work on a number of problems from Solid State Physics and Molecular systems using standard software like VASP, Quantum Espresso, Sieata and Gaussian.

Suggested Books

1. D. Sholl and J. A. Steckel, Density Functional Theory: A Practical Introduction, Wiley (2009)
2. R. Martin, Electronic Structure: Basic Theory and Practical Methods, Cambridge (2004)

PHY5007 Magnetic Materials and Devices

Course Code	PHY5007	Semester	
Course Title	*Magnetic Materials and Devices*		
Credits	3	Type	Elective

Course Outcome

To understand different magnetic materials present in the world. Use of different magnetic materials for their specific applications in different fields. Components presents in magnetic storage applications and materials suitable for the applications and their properties.

Course Structure

Contents: Introduction to magnetization and magnetic materials. Ferrimagnetism and anti-ferrimagnetism. Anisotropy and tensor permeability. Magnetoresistance. Exchange bias. Magnetic nanoparticles and thin films. Applications and devices for magnetic data storage, magneto-optics and magneto-optic recording. Magnetic semiconductors and insulators. Multiferroic phenomena.

Suggested Books

1. N.A.Spaldin, Magnetic materials: Fundamentals and Applications, Cambridge (2003)
2. J.M.D.Coey, Magnetism and Magnetic materiasl, Cambridge (2010)
3. S.P.Gubin, Magnetic Nanoparticles, Wiley (2009)

PHY5008 Nuclear Reactions

Course Code	PHY5008	Semester	
Course Title	*Nuclear Reactions*		
Credits	3	Type	Elective

Course Outcome

This course is an advance level elective course. The course develops expertise in Nuclear reactions, and different theoretical formalisms in nuclear Physics including contemporary topics. Detailed coverage of fission reactor is provided. The course enhances student's knowledge to take up challenges in reactors-based projects.

Course Structure

Contents: (1) Nuclear shell model and collective models. (2) Nuclear reactions. Cross section, resonance, compound nucleus formation, continuum theory, statistical theory, heavy ion reactions. Sub-barrier and above barrier fusion. Coupled channels theory. (3) Nuclear fission: Fission and liquid drop model. Fragment characteristics. Heavy ion induced fission. angular distribution. Anisotropy, fragment mass distribution, statistical models. (4) Reactor physics: Fick's law, energy loss in elastic collisions, Fermi age theory, criticality, typical reactors.

Suggested Books

1. R.R. Roy and B.P. Nigam, Nuclear Physics, Theory and Experiment, New Age International (1996)
2. B.R.Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley (2002)
3. K.S.Krane, Introduction to Nuclear Physics, Wiley (1987)

PHY5009 Advanced Quantum Mechanics

Course Code	PHY5009	Semester	
Course Title	*Advanced Quantum Mechanics*		
Credits	3	Type	Elective

Course Outcome

The main expected outome is the understanding of the theory of quantized fields. It is expected that students shall gain skill in applying the concepts to problems in many body theory.

Course Structure

Contents: (1) Second quantization: Classical description of fields, Lagrangian and Hamiltonian of fields. Second quantization of Schrodinger field. Second quantization for Bosons and Fermions. Field operators. Examples. (2) Dirac Equation: Derivation. Properties. Continuity equation. Non-relativistic limit. Lorentz transformation. Orbital angular momentum and spin. Coulomb potential. Physical interpretation and hole theory. Charge conjugation. Invariance and conservation laws. Time reversal. (3) Quantization of Relativistic fields: Quantization of Dirac field. Spin statistics theorem. Lagrangian density for electromagnetic field and its quantization. Photon propagator. (4) Interacting Fields: Fermions in an external field. Interaction of electrons with radiation field. Quantum electrodynamics. Interaction representation. Perturbation theory. S matrix. Wick's theorem. Scattering process. Feynman diagrams.

Suggested Books

1. F. Schwable, Advanced Quantum Mechanics, Springer (2004)
2. B. Sakurai, Advanced Quantum Theory, Pearson (2001)
3. Paul Roman, Advanced Quantum Theory, Addison Wesley (1991)
4. Y. Nazarov, Advanced Quantum Mechanics, Cambridge (2012)

PHY5010 Synthesis of Materials

Course Code	PHY5010	Semester	
Course Title	*Synthesis of Materials*		
Credits	3	Type	Elective

Course Outcome

This is a skill based course in which students will be given basic understanding of sample synthesis through wet chemistry routes as well as physical depositions methods. Virtual demonstration is provided based on animations and videos. Basic properties are also discussed

Course Structure

Contents: (1) Vacuum techniques, pumps and gauges. Experimental techniques. (2) Cryogenic techniques. Liquefaction of gases, various methods. Maintenance of low temperatures. Adiabatic demagnetization. Measurement of low temperatures. (3) Thin film techniques: properties, fabrication, thermal evaporation, sputter deposition, thickness measurements quartz crystal monitor, optical interference method, energy loss method, thin film optics. (4) Growth of materials: Bulk powder synthesis, Synthesis of one dimension, two dimensional and three dimensional structures. Molecular assembly, ordered structures. Photonic band gap structures, Meta-materials. Nanoscale architecture. (Physical and chemical methods)

Suggested Books

1. S. Dushman, and J.L.Laffer, Scientific foundations of vacuum techniques, Wiley (1962)
2. K. L. Chopra, Thin film phenomena, Mc Graw Hill (1979)
3. Meissel and Glang, Hand book of thin film technology, McGraw Hill (1970)
4. L. Jackson, Low Temperature Physics, Wiley (1955)
5. F. Din and A. H. Cocker, Low Temperature Techniques, Wiley (1960)

PHY5011 Materials Characterization Techniques

Course Code	PHY5011	Semester	
Course Title	*Materials Characterization Techniques*		
Credits	3	Type	Elective

Course Outcome

Again it is a skill oriented course in which hands on as well as virtual demonstration based training is provided in various high end characterisation tools.

Course Structure

Contents: The course is a survey of various materials characterization techniques used in solid state physics and nuclear physics. The lectures will be supplemented with hands-on training with available instruments. The topics shall include the following: (1) X-Ray Diffraction. (2) Atomic Force Microscopy. (3) Scanning Electron Microscopy & EDAX. (4) Transmission electron microscopy. (5) Raman spectroscopy. (6) Fourier Transform IR spectroscopy. (7) Vibrating sample magnetometer. (8) Nuclear techniques.

Suggested Books

1. Y. Leng, Materials Characterization, Wiley (2013)
2. R.P. Prasankumar (Ed.), Optical techniques for Solid State Materials Characterization, CRC Press (2013)

PHY5012 Optical Communication

Course Code	PHY5012	Semester	
Course Title	**Optical Communication**		
Credits	3	Type	Elective

Course Outcome

The expected outcome is a solid understanding of the elements of modern optical communication systems, right from propagation in simple optical fibers to optical circuits.

Course Structure

Contents: (1) Evolution of Optical Communication. Optical fibers: Waveguide theory and dispersion properties. Nonlinear properties. Characterization and splicing, fabrication of fibers. Light sources: laser diode and LEDs. Modulation. Photodetectors: optical receiver operation and noise. (2) Digital transmission systems. Point to point links, system considerations. Coherent systems, heterodyne and homodyne detection. WDM concepts and components, operational principles of WDM. (3) Optical amplifiers, Erbium doped fiber amplifiers, Gain and power conversion efficiency. (4) Optical solitons: basic principles and applications.

Suggested Books

1. G.P. Agrawal, Fiber-Optic Communication Systems, Wiley (2012)
2. V.K.Jain and J. Franz, Optical Communications: Components and Systems, Narosa (2002)

PHY5013 Quantum Optics

Course Code	PHY5013	Semester	
Course Title	*Quantum Optics*		
Credits	3	Type	Elective

Course Outcome

The expected outcome is a solid understanding of the ideas of quantization of fields and its application to basic optical phenmena.

Course Structure

Contents: (1) Quantization of electromagnetic field. Field quantization. Fock slates, coherent slates, coherence properties of EMF. Photon correlation measurements, photon counting measurements. Representation of EMF. Photon statistics, photon number representation. (2) Density of states and density matrix. Squeezed light: generation and application of squeezed light, coherent interaction of light with matter, Maxwell - Bloch equations. Spontaneous decay of two level atoms. (3) Optical Instability: dispersive and absorptive cases. Bell's inequalities in quantum optics. EPR argument. Experimental studies, non-demolition measurements. Quantum coherence**.** (4) Deflection of atoms by light. Kapitza- Dirac effect. Optical Stern -Gerlach experiment, Interaction between Atoms and quantized field. Dressed fields, Jaynes - Cummings model.

Suggested Books

1. D.F. Walls, G.J.Milburn, Quantum Optics, Springer (2008)
2. M.O.Scully and M.S. Zubairy, Quantum Optics, Cambridge (1997)

PHY5014 Photonic Crystals

Course Code	PHY5014	Semester	
Course Title	*Photonic Crystals*		
Credits	3	Type	Elective

Course Structure

Contents: Overview of photonic crystals. Electromagnetic waves in periodic media. Bloch theorem and plane wave expansion method. Photonic band gap. Computation of bands by plane wave expansion method. Applications of photonic crystals, defect mode propagation. Instructor may include selected topics of current interest, and include hands-on sessions for computational or experimental work.

Suggested Books

1. J.D.Joannopaoulos, R.D.Meads, S.C.Johnson, and N.Joshua, Photonic Crystals: Molding the Flow of Light, Princeton Press (2011)
2. J.M.Lourtioz, H. Benisty, Photonic Crystals, Springer (2006)
3. D.S.Prather and A Sharkawy, Photonic Crystals: Theory, Applications and Fabrication, Wiley (2009)

PHY5015 Nonlinear Dynamics and Chaos

Course Code	PHY5015	Semester	
Course Title	*Nonlinear Dynamics and Chaos*		
Credits	3	Type	Elective

Course Outcome

(1) To introduce the fixed point analysis for dynamical systems
(2) To characterize nonlinear effects in time evolution
(3) To understand the nature of chaos and to characterize chaotic dynamical systems
(4) To provide hands-on computational learning for analysing dynamical systems

Course Structure

Contents: Dynamical systems: discrete and continuous. Time evolution. Phase space trajectories. Fixed point analysis. Equilibrium points. Nonlinear systems and linearization. Classifications of dynamical systems. Examples. Limit cycles, attractors. Integrability and KAM theorem. Deterministic chaos. Bifurcation and route to chaos. Poincare section. Sensitivity to initial conditions and Lyapunov exponent. Fractals. Examples like logistic map, Van der Pol oscillator, Lorenz systems, nonlinear electronic systems etc. Computer simulation methods for analysis of chaotic systems. A set of practicals based on computer simulation and/or laboratory work may be included by the instructor.

Suggested Books

1. Goldstein, Classical Mechanics, 3rd Ed. Person (2001)
2. F. Verhulst, Nonlinear differential equations and dynamical systems, Springer (2006)
3. T.W.B.Kibble, Classical Mechanics, 5th Ed., Imperial College Press (2004)

PHY5016 Introductory Plasma Physics

Course Code	PHY5016	Semester	
Course Title	*Introductory Plasma Physics*		
Credits	3	Type	Elective

Course Outcome

(5) To learn the basic properties of plasma and to understand how plasma is described.
(6) To learn the dynamical processes and waves in plasma.
(7) To learn the nature of laser-plasma interaction.
(8) To understand how plasma is simulated using particle-in-cell method.

Course Structure

Contents: Basic plasma properties. Debye shielding, plasma temperature, plasma parameters. Single particle motion in electric and magnetic fields, adiabatic invariants. Plasma as a fluid and equation of motion. Vlasov equations and kinematic theory. Waves in plasma: classification and dispersion relations. Plasma instabilities. Simple cases of laser-plasma interactions. Optional: Particle in cell simulation of plasmas. Simple one-dimensional electrostatic code. Practicals based on PIC codes may be introduced.

Suggested Books

1. F.F.Chen, Introduction to Plasma Physics and Controlled Fusion, Springer (2007)
2. J.B.Bittencourt, Fundamentals of Plasma Physics, Springer (2006)
3. U.S.Inan and M. Golkoski, Principles of Plasma Physics for Engineers and Scientists, Cambridge (2010)

PHY5017 Laser Plasma Interactions

Course Code	PHY5017	Semester	
Course Title	*Laser Plasma Interactions*		
Credits	3	Type	Elective

Course Outcome

The aim of the course is to introduce the main concepts of laser plasma interaction using the model of Vlasov equations and particle-in-cell simulation.

Course Structure

Contents: Basic concepts and two-fluid description of plasma. Vlasov equation and moments. Electromagnetic waves in plasma. Propagation inhomogeneous plasma. Collisional absorption of em waves. Parametric excitation of electron and ion waves. Stimulated scattering mechanisms. Particle -in cell method for simulating plasma. One dimensional PIC code and experiments. (Instructor shall introduce topics of curent interest).

Suggested Books

1. W.L. Kruer, The Physics of Laser Plasma Interactions, Westview (2003)
2. C.K.Birdsal and A.B.Langdon, Plasms Physics via Computer Simulation, CRC Press (2004)

PHY5018 Semiconductor Optoelectronics

Course Code	PHY5018	Semester	
Course Title	*Semiconductor Optoelectronics*		
Credits	3	Type	Elective

Course Outcome

The overall aim of this course is to give fundamental knowledge of various properties of semiconducting materials and optoelectronic devices in order to be able to understand present and future technologies for applications in optical communications, energy conversion etc. This course will also aim to improve the skill of students for the fabrication of various high efficient optoelectronics devices.

Course Structure

Contents: Semiconductor physics: Crystal structure, growth and properties of common semiconductors, superlattices, quantum wells, wires and dots. Strain and lattice mismatch. Bloch theorem and theory of band structure calculation of semiconductors. Band structure modifications. PN junction, diode equation. Photon emission and absorption. Excitons. Solar cells. Light emitting diodes and semiconductor lasers. Optoelectronic circuits. Recent advances in the field.

Suggested Books

1. Jasprit Singh, Electronic and Optoelectronic Properties of Semiconductor Structures, Cambridge (2007)
2. Adrian KItai, Principles of Solar Cells, LEDs and Diodes, Wiley (2011)
3. J. Piprek, Semiconductor Optoelectronic Devices, CBSPD (2004)

PHY5019 Physics of Lasers

Course Code	PHY5018	Semester	
Course Title	*Physics of Lasers*		
Credits	3	Type	Elective

Course Outcome

The aim of the course is to introduce the basic concepts of lasers and rate equations.

Course Structure

Contents: Einstein's theory of spontaneous and stimulated emission. A and B coefficients. Conditions for laser action. Laser cavity modes. Mode locking and Q-switching. Laser rate equations. Classification of lasers and examples.

Suggested Books

1. W.T. Silfvast, Laser Fundamentals, Cambridge (1996)
2. A. Ghatak and Thyagarajan, Lasers: Theory and Applications, MacMIllan (1991)
3. L.V.Tarasov, LaserPhysics, Mir Publishers (1985)
4. K. Shimoda, Introduction to Laser Physics, Springer (1990)

PHY5020 Introduction to Nanophotonics

Course Code	PHY5020	Semester	
Course Title	*Introduction to Nanophotonics*		
Credits	3	Type	Elective

Course (learning) Outcome

(1) To understand the basic physics of nano systems having application in optics
(2) To learn the applications of photonic crystals and subwavelength optical elements
(3) To learn the physical properties of semiconductor nanosystems.

Course Structure

Contents: Confinement of photons and electrons. Similarity with optical and electronic structures. Optical tunneling. Light in periodic structures and photonic crystal. Bloch waves and band structure. Properties and applications of photonic crystals. Waveguides based on photonic crystals. Microcavities and microlasers. Near field optics. Optical properties of metals. Plasmons and metals nanoparticles. Metal-dielectric nanostructures and meta-materials. Surface plasmon polaritons in subwavelength guiding. Semiconductor nanostructures (Quantum wells, wires and dots) and their optical properties. Nanocomposites. Random Lasers. Bio-nano photonics. Discussion of current topics of research.

Suggested Books

1. S.V. Gaponenko, Introduction to Nanophotonics, Cambridge (2010)
2. L.Novotny and B. Hecht, Principles of Nano-Optics, Cambridge (2007)
3. S.A Maier, Plasmonics: Fundamentals and Applications, Springer (2007)

PHY5021 Introduction to Nanoelectronics

Course Code	PHY5021	Semester	
Course Title	*Introduction to Nanoelectronics*		
Credits	3	Type	Elective

Course Outcome

Introducing the basic concepts of size quantisation, quantum tunneling, classical and semiclassical transport, fabrication of nanoscale devices, and various emerging phenomena such as quantum Hall effect, Coulomb blockade, nanoscale devices for sensing, detectors etc. This course is designed to someone who wishes to specialise in nanoscale transport.

Course Structure

Contents: (1) Low dimensional structures: Quantum wells, two dimensional electron gas. Energy band transition. Quantum wires and nanowires. Quantum dots and nanoparticles. Fabrication techniques. Carbon nanotubes. (2)Quantum Transport: Classical and semiclassical transport. Conductance of wires. Ballistic transport. Quantum resistance and conductance. Spin transport. (3) Nanoelectronics: Potential energy profile of interfaces. Tunneling. Field emission. Gate oxide tunneling. Double barrier tunneling and resonant tunneling devices. (4) Coulomb blockade. Quantum dot coupled to leads. Nano-capacitor. Tunnel junction under current source. SET oscillations. Coulomb blockade in quantum dot circuits. Single electron transistors. CNT and QW channels. Molecular transistors.

Suggested Books

1. G.W. Hanson, Fundamentals of nanoelectronics, Pearson (2010)
2. C.Kittel, Solid State Physics, 8th Edition, Wiley (2009)
3. S. Gapenenko, Introduction to Nanophotonics, Cambridge (2010)

PHY5022 RF to Terahertz Systems

Course Code	PHY5022	Semester	
Course Title	*RF to Terahertz Systems*		
Credits	3	Type	Elective

Course Outcome

(1) To introduce basic concepts of microwave, millimeter wave and tera-hertz systems
(2) To teach the dispersion analysis of waveguide systems and devices operating in these regions

Course Structure

Contents: This course is an introduction to high frequency electronics exploiting electromagnetic spectrum from RF to the optical region. Topics include (1) Theory of waveguides including classic, planar systems and microstrip systems. (2) transmission line theory and network analsysis. (3) Waveguide devices. (4) Active components and microwave semiconducting devices. (5) Superconducting microwave devices. (6) Antennas and radiation pattern. (7) Terahertz wave generation and applications. (8) Experimental and/or computational assignments can be introduced for lab-intensive course by the teacher.

Suggested Books

1. D.M.Pozar, Microwave Engineering, Wiley (1998)
2. R.A.Lewis, Terahertz Physics, Cambridge (2013)
3. K. Chang, RF and Microwave Wireless Systems, Wiley (2000)
4. S. Liao, Microwave Devices and Circuits, Pearson (2000)

PHY5023 Physics of Atmospheres

Course Code	PHY5023	Semester	
Course Title	*Physics of Atmosphere*		
Credits	3	Type	Elective

Course Outcome

(3) To understand the structure and dynamics of atmosphere
(4) To learn the basic equations for modelling dynamics of atmosphere, and their basic applications
(5) To understand the physics of clouds and rain formation

Course Structure

Contents: (1) Planetary atmospheres: hydrostatics and thermodynamics. Radiation, absorption and emission and equilibrium. Greenhouse effect. Global radiation budget. Middle and upper atmosphere. (2) Dynamics of atmosphere: Equations of motion, geostrophic approximation. Thermal wind. Equation of continuity. Waves: sound, gravity waves, Rossby waves. Vorticity. Turbulence and Ekman pumping. (3) Cloud Microphysics: Cloud formation and particles. Precipitation formation. (4) Numerical modeling. Application to weather prediction. Discussion of special topics of interest.

Suggested Books

1. J. Houghton, The Physics of Atmospheres, Cambridge (2002)
2. J.B.Holton, An Introduction to Dynamic Meteorology, Academic Press (2004)
3. H.R. Pruppachar and J.D.Klett, Microphysics of Clouds and Precipitation, Kluwer (1996)

PHY5024 Introduction to Astrophysics

Course Code	PHY5024	Semester	
Course Title	*Introduction to Astrophysics*		
Credits	3	Type	Elective

Course Outcome

(1) To instruct the main concepts and theories of astrophysics at graduate llevel.

Course Structure

Contents: Universe, its scales and contents. Properties of stars. Radiative transfer through stellar atmosphere. Opacity. Equations of stellar structure. Stellar models. Main sequence, red giants and white dwarfs. Nuclear reaction rates, nucleosynthesis and stellar evolution. Solar neutrino experiments. Degeneracy pressure in Fermi gas, Chandrasekhar limit. Neutron stars, pulsar, supernova. Galaxy and Interstellar matter.

Suggested Books

1. Arnab Rai Chaudhuri, Astrophysics for Physicists, Cambridge (2010)
2. M. Schwarzschild, Structure and Evolution of Stars, Princeton University Press (1958)

PHY5025 Soft Matter Physics

Course Code	PHY5025	Semester	
Course Title	*Soft Matter Physics*		
Credits	3	Type	Elective

Course Outcome

To introduce the physics of materials systems falling under the categories of polymers, colloids, liquid crystals etc., and the physical mechanisms governing their physical properties

Course Structure

Contents: This course is an introduction to the soft matter physics, materials systems falling under the categories of polymers, colloids, liquid crystals etc., and the physical mechanisms governing their physical properties. Topics include: Classification based on physical properties. The glass transition: models and experiments. Fractal growth phenomena. Introduction to polymers. Chain-dimension and structure. Polymers in solution, Flory-Huggins theory. Properties of polymers. Liquid crystals and their properties. The instructor can include topics of current interest, experimental and /or computational aspects etc.

Suggested Books

1. M. Kleman, O.D. Laurentovich, Soft Matter Physics, Springer (2002)
2. M. Marder, Condensed Matter Physics, Wiley (2010)
3. Hamley, I.W. Introduction to Soft Matter (Wiley) Chichester (2000)

PHY5026 Microwave Measurements and Characterization

Course Code	PHY5026	Semester	
Course Title	*Microwave Measurements and Characterization*		
Credits	3	Type	Elective

Course Outcome

To introduce basic concepts of microwave, millimeter wave and tera-hertz systems used for material characterization

Course Structure

Contents: Electromagnetic properties of materials. Microwave electronics for materials characterization. Reflection and transmission/reflection methods. Resonator methods. Resonator-perturbation methods. Planar circuit methods. Measurements of permittivity and permeability tensors. Application to ferroelectric and chiral materials. Transport property measurement. Dielectric measurements at high temperature. Lab exercise for materials characterization can be included.

Suggested Books

1. L.F. Chen, C.K. Ong, C.P. Neao, V.V.Varadan and V.K.Varadan, Microwave Electronics, Measurements and Microwave Characterization, Wiley (2004)
2. V.Teppati, A. Ferraro and M. Sayed, Modern RF and Microwave Measurement Technique, Cambridge (2013)

PHY5027 Semiconductor Devices

Course Code	PHY5027	Semester	
Course Title	*Semiconductor Devices*		
Credits	3	Type	Elective

Course Outcome

(1) To introduce the physics of semiconductors at advanced level
(2) To apply these concepts to the analysis and design of devices

Course Structure

Contents: (1) Semiconductor Materials. Band structure and semiconductor statistics. Mobilities and drift velocities. Hall effect and magnetoresistance. Quasi Fermi levels, generation and recombination of carriers. Boltzmann transport equations and scattering rates. High field effects. PN junction and diode equation. Depletion and diffusion. Tunnel diode, breakdown. Heterojunctions. (2) Metal oxide semiconductor capacitor. MIS structure. MOSFET: principle of operation. gradual channel approximation. Charge control model. Velocity saturation. Short channel effects. Threshold voltage. (3) Bipolar junction transistors: principle of operation. Ebers-Moll Model, current-voltage characteristics, non-ideal and limiting effects at extremes of bias. (4) Classical and semiclassical transport: conductance of wires - Ballistic transport - quantum resistance and conductance - Carbon nanotubes and nanowires - Spin transport. Molecular Electronics. (5) Fabrication techniques (Optional)

Suggested Books

1. M. Shur, Physics of Semiconductor Devices, PHI (1990)
2. S.M. Sze, Semiconductor Devices: Physics and Technology, Wiley (2012)

PHY5028 Computational Quantum Mechanics

Course Code	PHY5028	Semester	
Course Title	*Computational Quantum Mechanics*		
Credits	3	Type	Elective

Course Outcome

(1) To introduce how Schrodinger equation can be solved for atms, olecules and solids.
(2) To introduce desisty functional theory and methods
(3) To provide practical skills in writing codes by students

Course Structure

Contents: (1) Numerical solution of Schrodinger equation: finite difference methods. Time domain methods for TDSE. Three dimensional problems. (2) Variational method and generalized eigenvalue problem. Basis functions: Slater type and Gaussian type. Plane wave basis. (3) Many electron systems: Hartree and Hartree Fock methods. Density functional theory (DFT). Kohn-Sham equations. Local density approximations. Applications. (4) Periodic solids and Bloch theorem. Band structure calculation. Tight binding method. Plane wave and pseudo potentials. APW approach. (5) Practical implementation of these methods, program development and application of standard software (Gaussian, VASP, Quantum Espresso etc)

Suggested Books

1. J. M. Thijssen, Computational Physics, Cambridge (1999)
2. P. Harrison, Quantum Wells, Wires and Dots, Wiley (1997)
3. S. Datta, Quatum Transport: From Atoms to Transport, Cambridge (2005)

PHY5029 Electrodynamics of Superconductors

Course Code	PHY5029	Semester	
Course Title	*Electrodynamics of Superconductors*		
Credits	3	Type	Elective

Course Outcome

(1) To discuss the physics of vortex motion in type-II supeconductors
(2) To use these concepts in understanding the working of superconducting circuit elements relevant to modern applications

Course Structure

Contents: Review of the properties of superconductors. High frequency electrodynamics in two-fluid model: complex conductivity, surface impedance and dissipation. Ginzberg-Landau equations. Critical field and current, coherence length. Flux quantization. Magnetic properties of type II superconductors. Interaction between vortices. Equilibrium vortex lattice. Flux pinning, creep and flow. Flux flow resistivity. Critical state model, Anderson-Kim model. Josephson effects. Weak links. RCSJ model. SQUID devices and applications. Tigh Tc materials. Lawrence-Doniac model. Anisotropic GL limit. Cross over to 2D behaviour. Applications to high frequency electronics.

Suggested Books

1. M. Tinkham, Introduction to Superconductivity, McGraw Hill (1996)
2. C. Poole, Superconductivity, Academic Press (2007)

PHY5030 Computational Electromagnetics

Course Code	PHY5030	Semester	
Course Title	*Computational Electromagnetics*		
Credits	3	Type	Elective

Course Outcome

(1) To give a hands-on training to students in practically solving Maxwell equatins with appropriate boundary conditions.

(2) To introduce major computational methods used in research

Course Structure

Contents: (1) Formulation of boundary value problems in time domain and frequency domain for microwave and optical applications. Scattering problems. (2) Principles of standard methods of solving EM Boundary Value Problems: Finite difference, Finite element, Variational methods, method of moments, finite difference time domain method (FDTD), Monte Carlo methods. General principles and algorithms. (3) Practical implementation of these methods using any language for typical waveguide problems. Standard tools (commercial or free) for EM simulation may be introduced. Detailed study including formulation, program development and implementation of a problem of practical interest, may be done by each student.

Suggested Books

1. M.S. Wartak, Computational Photonics, Cambridge (2013)
2. D. Sullivan, Electromagnetic Simulation Using the FDTD Method, Wiley (2013)
3. N. D. Sadiku, Numerical Techniques in Electromagnetics using MATLAB, CRC Press (2009)

PHY5031 Simulation of Electronic Circuits

Course Code	PHY5031	Semester	
Course Title	*Simulation of Electronic Circuits*		
Credits	3	Type	Elective

Course Outcome

To give a hands-on training to students in practically solving electronic circuit problems using industry standard SPICE tool

Course Structure

Contents: (1) SPICE: The program and structure. SPICE capabilities. SPICE Commands and compilation. (2) Simulation of AC and DC circuits, PN diodes and transistors. Amplifier circuits. (3) Elements of semiconductor physics and operation of PN junction, BJT, JFET and MOSFET and thyristors. (4) Modeling of Operational Amplifiers and ICs, and applications (5) Simulation of digital circuits. (6) Other tools for electronic circuit simulation. (7) Advanced modeling of semiconductor devices. (8) Practicals involving simulation of example circuits from all topics.

Suggested Books

1. M.H.Rashid, SPICE for Circuits and Electronics, Prentice Hall (1989)
2. S. Sandler, SPICE Circuit Handbook, McGraw Hill (2010)
3. G. Massabrio and P. Antognetti, Semiconductor Device Modeling with Spice, Tata MacGraw Hill (2010)

PHY5032 Nuclear Instrumentation

Course Code	PHY5032	Semester	
Course Title	*Nuclear Instrumentation*		
Credits	3	Type	Elective

Course Outcome

This course provides a comprehensive coverage of various instrumentation and techniques followed in Accelerator based Nuclear Physics Research. Detailed description of world class experimental facilities like accelerators, mass spectrometers etc provide opportunities to the student to learn cutting edge technologies used in modern physics research. This course is a pre-Ph D course work in majority of the laboratories across the world. The hands -on training in Nuclear Physics Lab along with the course improves the practical skills of the students. Technologies discussed in this course are used in multi-disciplinary subjects.

Course Structure

Contents: (1) Detectors: Solid state detector. Gas detector. Ionization chamber. Proportional counter. (2) Interaction of radiation with matter. Gamma detectors. Scintillators. Electron multipliers and micro-channel plated. (3) Particle identification techniques. Signal processing and date acquisition systems. Signal amplifiers. CAMAC, SCA and multi-channel analyzer. (4) Recoil spectrometeres. Gas filled and vacuum spectrometers. Large array detector assemblies. (5) Accelerators: types and applications.

Suggested Books

1. G. F. Knoll, Radiation Detection and Measurements, Wiley (1979)
2. S. Tavernier, Experimental Techniques in Nuclear and Particle Physics, Springer (2010)

PHY5033 Introduction to Nonlinear Optics

Course Code	PHY5033	Semester	
Course Title	*Introduction to Nonlinear Optics*		
Credits	3	Type	Elective

Course Outcome

To introduce the concepts and methods of nonlinear optics at advanced level

Course Structure

Contents: Origin of optical nonlinearity. Second harmonic generation. Self refraction of optical beams. Optical bistability. Phase conjugation. Stimulated Brillouin and Raman scattering. Propagation in nonlinear waveguides and fibers. Solitons in optical fibers and waveguides. Applications to optical communication and signal processing.

Suggested Books

1. P. B. Banerjee, Nonlinear Optics, CRC Press (2003)
2. Boyd, Nonlinear Optics, Elsevier (2008)
3. Ferreira, M., Nonlinear Effects in Optical Fibers, Wiley (2011)
4. G.P.Agrawal, Nonlinear Fiber Optics, Academic Press (2012)

PHY5034 Introduction to General Theory of Relativity

Course Code	PHY5034	Semester	
Course Title	*Introduction to General Theory of Relativity*		
Credits	3	Type	Elective

Course Outcome

The aim of the course is to introduce the important concepts of general theory of relativity, and cosmology.

Course Structure

Contents: The course is an introduction to the concepts of general relativity and cosmology. Topics to include: Tensor analysis and special theory of relativity, curvature of space-time. Physics in curved space. Principles of General Theory of relativity. Gravitation. Physics of weak gravitational field. Einstein's field equation. Solutions to Einstein's equation. Gravitational radiation. Spherical solutions for stars. Shwarzschild solution. Black Holes. Introduction to cosmology and relativistic Astrophysics: Expanding universe. Early universe and Observational Cosmology.

Suggested Books

1. B. Schutz, A First Course in General Relativity, Cambridge (2012)
2. S. Weinberg, Gravitation and Cosmology, Wiley (2008)

PHY5035 Mechanics of Solids and Fluids

Course Code	PHY5035	Semester	
Course Title	*Mechanics of Solids and Fluids*		
Credits	3	Type	Elective

Course Outcome

The aim of this course is the introduction of the basic concepts oof the theory of elasticity, and that of fuild mechanics, with reevant modrrn applications.

Course Structure

Contents: This course is an introduction to the theory of continuous media, i.e., solids and fluids. (1) Description of elastic media. Stress and strain tensors. Strain energy. Hook's law. Elastic properties of isotropic media. Elastic waves in isotropic medium and crystals. Surface waves. (2) Description of fluids. Equation of continuity and Lioville's theorem. Equations of motion. Bernoulli theorem. Flows of fluids. Waves: gravity waves and ripples. Shallow water waves. 2D steady irrotational flow of incompressible fluids. Imperfect fluid and Navier-Stokes equation. (3) Discussion of topics of special interest, like seismic waves, liquid crystals, ultrasonic devices.

Suggested Books

1. L. Landau and E.M.Lifshitz, Theory of Elasticity, Elsevier Ed. (2005)
2. L. Landau and E.M.Lifshitz, Fluid Mechanics, Elsevier Ed. (2005)
3. N. Rana and P. Joag, Classical Mechanics, Tata McGraw Hill (2001)

PHY5036 Applications of Lasers

Course Code	PHY5036	Semester	
Course Title	*Applications of Lasers*		
Credits	3	Type	Elective

Course Outcome

The aim of this course is to introduce the main application of lasers in inductry and in research. The instructor can introduce relevant areas of application in the course with current interest.

Course Structure

Characteristics of laser beam: directionality, coherence, intensity, monochromaticity, polarization, speckles. Techniques for the control of laser output: overview. Applications of lasers in communication, materials processing, medicine, instrumentation. LIDAR. Optical computing. Holography. Instructor may include other applications of lasers of current interest.

Suggested Books

1. W.T. Silfvast, Laser Fundamentals, Cambridge (1996)
2. A. Ghatak and Thyagarajan, Lasers: Theory and Applications, MacMIllian (1991)
3. L.V.Tarasov, LaserPhysics, Mir Publishers (1985)
4. K. Shimoda, Introduction to Laser Physics, Springer (1990)

PHY5037 Quantum Transport in Low Dimensional Systems

Course Code	PHY5037	Semester	
Course Title	*Quantum Transport in Low Dimensional Systems*		
Credits	3	Type	Elective

Course Outcome

The purpose f this course is to introduce (i) the transport properties of low dimensional solids, and (ii) its applications in nano-systems.

Course Structure

Boltzmann transport equation. Transport in large and small systems. Electrochemical potential, Fermi energy and band bending. Two dimensional electron gas, heterostructures and MOSFET. Ballistic transport. 1D transport, cyclotron motion and focussing. Two dimensional systems in magnetic field: Landau levels and quantum Hall effects. Quantum dots and antidots: Coulomb blockade, quantum capacitance, Aharanov - Bohm effect. Effect of Coulomb interactions in 2D and 1D systems: fractional quantum Hall effect, Luttinger liquid and Wigner crystallization.

Suggested Books

1. John H. Davis, Physics of low dimensional semiconductors, An Introduction, Cambridge (1997)
2. M.J.Kelly, Low Dimensional Semiconductors, Clarendon Press (1995)

PHY5038 Summer Project

Course Code	PHY5038	Semester	
Course Title	*Summer Project*		
Credits	3	Type	Elective

Course Outcome

The purpose of this course is to institutionalize the intership and other short term summer projects done by students in other institutions, so that they can substitute it as an elective course.

Course Structure

Contents: This course gives opportunity to a student who is undergoing a summer research project in another Institution during the summer vacation between second and third semesters, to convert the work done into an elective course of third semester. A letter of invitation/selection from the Institution, and a certificate issued by the mentor/Institution regarding the successful completion of the project should be produced at the beginning of the third semester. The Head shall allot a course instructor and register for this course in the third semester. The student shall prepare a term paper/report, under the supervision of the instructor. Evaluation shall be done by the Instructor, based on the reports of the external supervisor, and a Viva-voce examination conducted based on the report. Grades shall be awarded in the third semester.

PHY5039 Molecular and Optical Physics (For otherdepartments)

Course Code	PHY5018	Semester	
Course Title	*Molecular and Optical Physics*		
Credits	3	Type	Elective

Course Outcome

The aim of the course is to intrduce the physical foundations of spectroscopy to non-physics major students so that they can use these ides in effectively using spectroscopic ideas in their research.

Course Structure

Contents: Basics of electromagnetism, Maxwell equations. Electromagnetic waves. Elements of geometrical optics. Interference, diffraction and polarization. Quantum theory of light. Photoelectric effect. Bohr atom model. Quantum mechanical view of atoms and molecules. Atomic nucleus and radioactivity. Atomic spectra. Molecular spectroscopy. Magnetic resonance. Introduction to lasers and important applications.

Suggested Books

1. Arthur Beiser, Concepts of Modern Physics, McGraw Hill (2009)
2. Halliday, Resnick and walker, Fundamentals of Physics, Wiley (2012)

PHY5040 Concepts of Modern Physics (For otherdepartments)

Course Code	PHY5040	Semester	
Course Title	*Concepts of Modern Physics*		
Credits	3	Type	Elective

Course Outcome

The course is intended to introduce the main contents of quantum physics for students specializing in other branches of science.

Course Structure

Contents: A survey of landmark experiments and theoretical concepts in modern physics, and its mathematical representation. Topics shall include Special relativity, blackbody radiation, quantum theory, wave mechanics, atoms, molecules, nuclei, solids, elementary particles and universe.

Suggested Books

1. Arthur Beiser, Concepts of Modern Physics, McGraw Hill (2009)
2. Halliday, Resnick and walker, Fundamentals of Physics, Wiley (2012)
3. Feynman, Robert B. Leighton and Matthew Sands, Feynman Lectures on Physics, Pearson Ed (2012)

PHY5041 Basic Electronics for Scientists (For otherdepartments)

Course Code	PHY5041	Semester	
Course Title	*Basic Electronics for Scientists*		
Credits	3	Type	Elective

Course Outcome

The course is intended to give a hands-on introduction to the basi concepts of electronics to students of other science departments, for enabling them to understand the woring of instruments used by them.

Course Structure

Contents: Electrical current and Kirchhoff laws. Resistor, capacitors and inductors. Network analysis. Circuit analysis involving L,C, and R elements. Basic semiconductor physics, pn junction diodes. Diode circuits. Transistors and amplifiers. FETs, Operational amplifiers. Simple applications. Electronic systems. Feedback, oscillators. Transducers, signal conditioning and analysis.

Laboratory work will be associated with lectures which involves construction and building of circuits as well as simulation of circuits using software.

Suggested Books

1. Horowitz and Hill, Art of Electronics, Cambridge (2008)
2. Niel Storey, Electronics, Systems Approach, Prentice Hall (2009)
3. D. L. Eggleston, Basic Electronics for Scientists and Engineering, Cambridge (2011)

PHY5042 Modern Optics

Course Code	PHY5042	Semester	
Course Title	*Modern Optics*		
Credits	3	Type	Elective

Course Outcome

The aim of this course is to intrduce the new developments in optics for postgraduate student. It is assumed that the student would learn elements of diffraction theory of Kirchhoff, laser, waveguide optics including subwavelength optics and nao-optics.

Course Structure

1. Review of Electromagnetic theory and spectral representation of light, 2. Scalar and vectorial diffraction theory, 3. Propagation and focusing of optical fields., 4. Basic theory of laser, 5. Dielectric waveguides and basic introduction to fibre optics. Graded index waveguides, 6. Photonics crystals and applications. Topological Photonics, 7. Surface plasmons and polaritons, 8. Localization of light, meta-materials, optical micro cavities,(Brief introduction) 9. Elements of quantum optics, 10. Introduction to the trends in Nano-optics and photonics

Suggested Books

1. Lukas Novotney, *Principles of nano-Optics*, Cambridge (2012)

2. J. D. Jackson, *Classical Electrodynamics*, Wiley (1998)

3. G.R. Fowles, *Introduction to Modern Optics*, Dover (1989)

4. John D. Joannapoulos, *Photonic Crystals: Molding the Flow of Light*, MIT Press (2008)

PHY5043 **Machine Learning for Physicists**

Course Code	PHY5043	Semester	
Course Title	*Machine Learning for Physicists*		
Credits	3	Type	Elective

Course Outcome

The aim of this course is to familiarise students to the areas of artificial intelligence which are useful in computational physics, and in their application in software industry. Students acquire practical skills needed in moving to fields outside physics, especially in data science, and it enhances their employability. Topics included are, but not limited to, the following.

Course Structure

1. Overview of machine learning and AI. 2. Overview of computational aspects of optimisation, linear algebra and statistics.3. Methods of regression and applications 4. Introduction to neural networks, and training data with back propagator algorithms 5. Support vector machines and classification 6. Unsupervised learning, k-Means algorithm, dimensionality reduction and principal component analysis 7. Application to Ising model and other examples from physics 8. Hands-on practice using Matlab, or Python tools, and standard data sets.

Suggested Books

1. Trevor Haste, et.al., *The Elements of Statistical Learning,* Springer (2008)

2. Aurelien Geron, *Hands-on Machine Learning with Scikit-Learn and Tensor Flow*, O'Reilly (2017)

3. Joel Franklin, *Computational Methods for Physics*, Cambridge (2013)

4. Pankaj Mehta, "A high bias low-variance introduction to Machine Learning for physicists", *Physics Reports,* (2019) 1-124

PHY5044 Introduction to Nanoscience and Nanotechnology

Course Code	PHY5044	Semester	
Course Title	*Introduction to Nanoscience and Nanotechnology*		
Credits	3	Type	Elective

Course Outcome

An introductory course on the topic in which basic introduction to nanoscience and nanotechnology is provided. Students will understand basic nanostructures and their special properties

Course Structure

Background of Nanoscience , Historical revolutions in Nanoscience and Nanotechnology, Concept of Surface to Volume ratio, 0 dimensional (OD) systems, Quantum dots, Quantum cages and Quantum cubes, One dimensional (1D) (Nanotubes, Nanorods, Nanowires, Nanoneedles, Nanofibres and Nanowhiskers, , 2D materials – Graphene and Beyond graphene, Quasi 2D systems and super lattices, 3D nanoparticles, metal oxides, semiconductors, composites, core shell systems, Quantum confinement, Density of states in 1-D, 2-D and 3-D confined systems, Size dependent optical(blue shift, SPR), magnetic (Superparamagnetism, single domain) electronic, physical/chemical properties, Applications of nanomaterials and nanotechnology, Introduction to Nanobiotechnology and nanotoxicology

Suggested Books

1. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2010.
2. Physical Fundamentals of Nanomaterials, A volume in Micro and Nano Technologies, Bangwei Zhang, Elsevier Inc. 2018.
3. Chemistry of nanomaterials: Synthesis, properties and applications by C. N. R. Rao H.C. Mult. Achim Müller and A. K. Cheetham, Wiley VCH, 2015
4. Processing & properties of structural naonmaterials - Leon L. Shaw, Nanochemistry: A Chemical Approach to Nanomaterials, Royal Society of Chemistry, Cambridge UK 2005.

PHY5045 Nanoscale Materials and Devices : Synthesis and Characterization

Course Code	PHY5045	Semester	
Course Title	*Nanoscale Materials and Devices : Synthesis and Characterization*		
Credits	3	Type	Elective

Course Outcome

It's another skill oriented course in which students will get hands on training on various aspects of wet chemical and physical deposition of nanostructures as well as high end sample characterisation tools.

Course Structure

General Synthesis approaches, Top Down and Bottom Up, Introduction to Thin Films and Superlattices, Wet chemical synthesis strategies : CBD, Dip coating, Spin coating, Spray pyrolysis, SILAR, Langmuir Blodgette, Vacuum Techniques : Physical deposition Techniques -Vacuum Evaporation, PLD, RF Sputtering, E Beam Evaporation , Chemical Vapor deposition Techniques, (CVD, MOCVD, PECVD), Molecular beam epitaxy, Lithography Techniques : **Top Down** – Photolithography, Direct Laser write lithography, Vapor phase lithography, Nanolithography, Nanoimprint lithography, E Beam lithography ; **Bottom Up** – Dip Pen and Fountain Pen lithography, Nanoscale devices- fabrication, introduction to NEMS, Characterisation Techniques, XRD, UV Vis, PL, Electrical, AFM, SEM, TEM

Suggested Books

1. W. Gaddand, D. Brenner, S. Lysherski and G. J. Infrate (Eds), Handbook of nanoscience, Engg. and Technology, CRC Press, 2012.
2. G. Cao, Naostructures and Nanomaterials: Synthesis, properties and applications, Imperial College Press, 2011.
3. J. George, Preparation of thin films, Marcel Dekker, InC., New York, 2005.
4. C. N. R. Rao, A. Muller, A. K. Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH Verlag Gmbh & Co, Weinheim, 2015.