CBCS Based M.Sc. Physics Course Structure (w.e.f., Session 2023-24)					
S. No.	**CODE**	**COURSE NAME**	**Category**	**L-T-P**	**CREDITS**
	SEMESTER-I				
1	**PHM401**	Classical Mechanics and Relativity	**C**	4-0-0	4
2	**PHM403**	Electrodynamics	**C**	4-0-0	4
3	**PHM405**	Quantum Mechanics-I	**C**	4-0-0	4
4	**PHM407**	Mathematical Physics	**C**	4-0-0	4
5	**PHM409**	Statistical Physics	**C**	4-0-0	4
6	**PHM411**	Physics Laboratory-I	**C**	0-0-8	4
		TOTAL		**20-0-8**	**24**
		Total Contact Hours		28	
	SEMESTER-II				
1	**PHM402**	Quantum Mechanics-II	**C**	4-0-0	4
2	**PHM404**	Solid State Physics	**C**	4-0-0	4
3	**PHM406**	Electronics	**C**	4-0-0	4
2	**PHM408**	Nuclear and Particle Physics	**C**	4-0-0	4
4	**PHM410**	Physics Laboratory-II	**C**	0-0-8	4
5	**PHM412**	Optical Techniques and Instrumentation	**SEC**	2-0-4	4
		TOTAL		**18-0-12**	**24**
		Total Contact Hours		30	
	SEMESTER-III				
1	**PHM501**	Atomic and Molecular Physics	**C**	4-0-0	4
3	**PHM503**	Introduction to Nanophysics	**C**	2-0-0	2
3	**PHM505**	Physics Laboratory-III	**C**	0-0-8	4
4	**PHM507**	Computational Physics	**SEC**	3-0-2	4
	PHM509	**Generic Elective***	**GE***	3-0-0	3
5	**DSE-I**		**DSE**	3-0-0	3
6	**PHM519**	**Minor Project**	**Project**	0-0-6	4
		TOTAL		**15-0-16**	**24**
		Total Contact Hours		**31**	
	SEMESTER-IV				
1	**DSE-II**		**DSE**	3-0-0	3
2	**DSE-III**		**DSE**	3-0-0	3
3	**PHM518**	**Major Project**	**Project**	0-0-24	16
		TOTAL		**6-0-24**	**22**
		Total Contact Hours		**30**	
	Total credits for all semesters				**94**
*** GENERIC ELECTIVE (GE): Course taken from other Departments**					

S.No.	**CODE**	**COURSE NAME**	**CREDITS**
DISCIPLINE SPECIFIC ELECTIVES (DSE-I)			
1	**PHM511**	Characterization of Solid-State Materials	3
2	**PHM513**	Semiconductor Physics and Devices	3
3	**PHM515**	Astrophysics-I	3
4	**PHM517**	Nonlinear Dynamics and Chaos	3
DISCIPLINE SPECIFIC ELECTIVES (DSE-II)			
1	**PHM502**	Laser Physics	3
2	**PHM504**	Advanced Nuclear and Particle Physics	3
3	**PHM506**	Nanoscience and Nanotechnology	3
4	**PHM508**	Soft Electronic Materials and Devices	3

DISCIPLINE SPECIFIC ELECTIVES (DSE-III)			
1	**PHM510**	Thin Film Technology and Vacuum Science	3
2	**PHM512**	Nanophononics and Nanoplasmonics	3
3	**PHM514**	Optical Fiber Communications	3
4	**PHM516**	Astrophysics-II	3

New course structure will be effective from admissions in 2023-2024. School/Department will not be bound to run all the courses. Minimum number of students may be fixed to run any elective course.

About the Programme

M.Sc. Physics is a two-year (04-semester) program that provides the students a comprehensive insight into the fundamentals and real-world applications of Physics. The Choice Based Credit Scheme (CBCS) evolved into learning outcome-based curriculum framework and provides an opportunity for the students to choose courses from the prescribed courses comprising core, discipline specific electives, generic electives, and skill enhancement courses. The M.Sc. Physics programme is designed to combine a solid foundation in physics with adaptability to a wide range of student interests and career objectives. The Physics Department maintains close association with the Departments of Mathematics, Chemistry, Environmental Sciences, Biotechnology, and the ICT, providing excellent opportunities for interdisciplinary study and research. The Department also participates with other colleges and universities in combined research efforts, including collaborative experiments at regional, national, and international facilities. Close interaction between students and faculty facilitates responsiveness to the needs of each student.

- The primary objective of this programme is to build a strong understanding of pure and Applied Physics through theoretical and practical approaches throughout the programme duration.
- This programme is designed to inculcate scientific attitude enriched with a multidisciplinary perspective in the students which make the generation of youth which can apply the subject knowledge in their careers and life.
- Furthermore, students are also educated and motivated to pursue research in the important areas. It opens many career opportunities for students interested in a wide range of areas.
- The students are updated with the needs of the industry and feel responsible towards the society and the nation.

Programme Objectives and Programme Specific Outcomes

Programmes Objectives	Programme Specific Outcomes
Graduates will demonstrate disciplinary competence and/or professional proficiency.	Students will be able to demonstrate the skills appropriate to postgraduate-level physics, including conceptual problem-solving ability, proficiency in advanced physics, proficiency in theoretical or experimental project design, expertise in employing various simulation tools, proficiency in communication through writing and oral presentations.
Graduates will demonstrate critical thinking skills	Students will complete a minor as well as major thesis/project and a research report.
Graduates will demonstrate ethical values, to include but not limited to a commitment to an exploration of faith and the promotion of science.	Students will successfully analyze the ethical component of issues from the physical sciences.
Graduates will demonstrate the ability to communicate clearly and effectively.	Students will be able to present effective progress reports on their research.
Graduates will demonstrate deliberative reflection for personal and professional formation	Students will write a professional resume and sit for a mock job interview. Students will participate in personal reflection activities.
Graduates will demonstrate the ability to work effectively across race, ethnicity, culture, gender, religion.	Students will demonstrate the ability to work as members of a team. Postgraduate Teaching Fellows will be able to effectively teach in the benefit of the society.

SEMESTER-I

PHM401-CLASSICAL MECHANICS AND RELATIVITY

4-Credits (4-0-0)

Course objective: The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which allow for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics.

Course outcome: The students will be able to apply the Variational principles to real physical problems and will be able to model mechanical systems, both in inertial and rotating frames, using Lagrange and Hamilton equations.

The Lagrangian Formalism: Newtonian mechanics, Dynamics in phase space, Phase trajectories, Linear dynamical systems, Autonomous dynamical systems, Degrees of freedom, generalized coordinates and velocities. Lagrangian, action principle, Euler-Lagrange equations. Constraints.

Applications of the Lagrangian formalism: Changing Coordinate Systems: Rotating Coordinate Systems: Non-inertial frames of reference and pseudo forces: centrifugal Coriolis and Euler forces, Noether's Theorem and Symmetries. Double Pendulum, Spherical Pendulum, Two Body Problem, Restricted Three Body Problem, Charged particle in an electromagnetic field.

The Hamiltonian Formalism: Generalised momenta, Hamiltonian, Legendre transform, Hamilton's equations of motion. Applications to systems with one and two degrees of freedom. Hamiltonian systems and Liouville's theorem. Canonical transformations, Poisson brackets. Action-angle variables.

Some Important Classical Dynamics Problems: Central force problem, Kepler problem, bound and scattering motions. Scattering in a central potential, Rutherford formula, scattering cross-section. Elements of rigid-body dynamics. Euler angles. The symmetric top. Small oscillations Normal mode analysis. Normal modes of a harmonic chain. Elementary ideas on general dynamical systems: conservative versus dissipative systems. Non-integrable systems and elements of chaotic motion.

Special relativity: Inertial frames. Principle and postulate of relativity. Lorentz transformations. Simultaneity, Causality, Length contraction, time dilation and the Doppler effect. Velocity addition formula. The Geometry of Spacetime: The Invariant Interval, The Lorentz Group. Four-vector notation: Invariance in relativity Energy-momentum four-vector for a particle. Relativistic invariance of physical laws.

Texts/References

1. H. Goldstein, **Classical Mechanics**, 2nd Edition, Narosa Pub. House (1989).
2. I. Percival and D. Richards, **Introduction to Dynamics**, Cambridge University Press (1987) [Chapters 4,5,6, 7 in particular. also parts of Chapters 1-3,9, 10].
3. L. D. Landau and E. M. Lifshitz, **"Mechanics**", Butterworth-Heinemann (1977)
4. D. Rindler, **Special Theory of Relativity**, Oxford University Press (1982).
5. Lecture notes by Prof. David Tong, University of Cambridge (http://www.damtp.cam.ac.uk/user/tong/dynamics.html)

PHM403- ELECTRODYNAMICS

4-Credits (4-0-0)

Course objective : To evaluate fields and forces in Electrodynamics using basic scientific method. To provide concepts of relativistic electrodynamics and its applications in branches of Physical Sciences.

Course outcome : Students will be able to explain and solve advanced problems based on classical electrodynamics and to analyses radiation systems in which the electric dipole, magnetic dipole or electric quadruple dominate. The students will understand the covariant formulation of electrodynamics and the concept of retarded time for charges undergoing acceleration.

Electrostatics and Special Techniques: Review of Basic Electromagnetic Theory, Laplace and Poisson equations, Boundary Value Problems, Uniqueness theorem, Method of images, Green function method, Orthogonal functions and expansions, separation of variables, Solution of Laplace/Poisson equation in spherical, Cartesian and cylindrical coordinates, Multipole expansion.

Electric Field in matter: Macroscopic electrostatics, dielectrics and boundary conditions, Boundary value problems with dielectrics, molecular polarizability and electric susceptibility, Models for molecular polarizability, electric-field enhancement.

Electromagnetic Waves: Electromagnetic Waves: Wave in one dimension, EM waves in vacuum and Matter, Absorption and Dispersion, EM waves in Conductors, Guided Waves, TE and TM Waves.

Potential and Fields: Vector and Scalar Potentials: Gauge transformations, Lorentz gauge, Coulomb gauge, Continuous Distribution- Retarded potentials, Jefimenko's Equations, Point Charge- Lienerd-Wiechert Potentials, The Fields of a moving point charge.

Radiation: Dipole radiation, Electric dipole radiation, Magnetic dipole radiation, Radiation from an arbitrary source, Power radiated from point charge, radiation reaction, radiation from accelerated charges applications to communication and radar

Texts/References

1. D. J. Griffith, **"Introduction to Electrodynamics"**, Prentice Hall India (**2009**)
2. J. D. Jackson, **"Classical Electrodynamics"**, Wiley India Pvt. Ltd. (**2000**)
3. J. R. Reitz, F. J. Milford & Frederick, **"Foundations of Electromagnetic Theory",** Narosa Publishing House (**1986**)
4. S. Ramo, J. R. Whinnery and T. V. Duzer, **"Fields and Waves in Communication Electronics"**, J. Wiley (**1965**)
5. E. C. Jordan and K. G. Balsain, **"Electromagnetic Waves and Radiating Systems",** Prentice Hall India (**1968**)
6. Edward M Purcell, **"Berkley Physics Course on Electricity and Magnetism",** Tata McGraw Hill Education Pvt. Ltd, Vol. 2 (**2008**).

PHM405-QUANTUM MECHANICS-I

4-Credits (4-0-0)

Course objective : This course consists of a formal treatment of quantum mechanics. Topics include some fundamental concepts, Schrodinger equation and its application to one dimensional problem like harmonic oscillator, piecewise constant potentials, angular momentum, and the hydrogen like atom and the scattering.

This course is intended to provide you with a basic understanding of the similarities and differences in the behavior of particles in the large (classical mechanics) and small (quantum mechanics) limit. Thus, on one hand you are expected to learn the fundamental postulates of quantum mechanics and some of the more elementary mathematical techniques of quantum mechanics and to appreciate the very peculiar predictions and observations on the small systems. On the other hand, you are also expected to understand the many similarities in the behavior of quantum particles with the macroscopic particles of common everyday experience.

Course outcome: The student has gained knowledge about basic non-relativistic quantum mechanics, apply principles of quantum mechanics to calculate observables on known wave functions, solve time-dependent and time-independent Schrödinger equation for simple potentials like for instance the harmonic oscillator and hydrogen like atoms, as well as the scattering theory. The student can gain about quantum mechanical axioms and the matrix representation of quantum mechanics, angular momentum states, angular momentum addition rules, and general experience with non-relativistic quantum mechanics that is useful for further studies in theoretical physics, as well as nanotechnology.

Preliminary Concepts : Review of Origin of Quantum Mechanics, Schroedinger equation, Continuity equation, Prabability density and Probabilty current density : Particle flux, Normalisation and Orthogonallity condition, Ehrenfest's theorem, expectation value of dynamical quantities ;
Physical Applications of Schroedinger's Equation to One Dimensional Problems : Solutions and applications of time-independent Schroedinger equation for infinite, square, step, rectangular, and double potential wells, quantum tunneling, linear harmonic oscillator ;
Operators: Operator methods, Hermitian operator, linear momentum operator, orbital angular momentum operators, commutation relation, eigen values of orbital angular momentum operators, raising and lowering operators;
Angular Momentum and Matrix representation : Dirac's bra and ket algebra, angular momentum and their properties, spherical harmonics, addition of angular momenta and Clebsch-Gordan coefficients ;
Spherically Symmetric Systems : Hydrogen atom, helium atom; Invariance principle and conservation laws for linear momentum, energy, and angular momentum, parity;
Fundamental Theory of Scattering: Born approximation and its applications to square well potential and Yukawa potential, partial wave analysis, phase shifts, optical theorem, scattering by square well potential and rigid sphere, electron-electron scattering.

Texts/References

1. R. Eisberg and R. Resnick, **"Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles"**, Wiley (**2010**)
2. L. I. Schiff, **"Quantum Mechanics"**, Tata McGraw-Hill (**2010**)
3. E. Merzbecker, **"Quantum Mechanics"**, John Wiley & Sons (**1970**)
4. A. Ghatak and S. Lokanathan, **"Quantum Mechanics: Theory and Applications"**, Kluwer Academic Publishers (**2004**)
5. H. C. Verma, **"Quantum Physics"**, Surya Publications (**2006**)
6. A. Beiser, **"Concepts of Modern Physics",** Tata McGraw-Hill (**1999**)

PHM407-MATHEMATICAL PHYSICS

4-Credits (4-0-0)

Course objective: This course introduces the mathematical methods essential for solving the advanced problems in physics. The knowledge of mathematical concepts and techniques would be beneficial in further research and development as it serves as a tool in almost every branch of science and engineering.

Course outcome: After successful completion of this course, students should be able to learn, understand and apply the concepts/formulas of scalar and vector field, complex variable, Fourier series and transforms, partial differential equations, special functions such as Legendre, Hermite, Bessel and Laguerre functions, Beta and Gamma functions etc. to solve the complex mathematical problems in Physics.

Vector integration, differentiation & their physical interpretation: Scalar and vector field, gradient of a scalar field, divergence & curl of a vector field, Gauss's divergence theorem, Stokes's theorem, orthogonal curvilinear co-ordinates (cylindrical and spherical polar co-ordinates),
Matrix algebra: Solution of linear algebraic equations, characteristic equation and diagonal form, eigen values and eigen vectors, Cayley-Hamilton theorem, functions of matrices, application in solving linear differential equation,
Complex variables & integrations: Cauchy-Riemann conditions, singularities, Cauchy's theorem, Taylor and Laurent expansions, residue theorem, evaluation of definite integrals, Series summation.
Integral transforms, groups & tensors: Gamma function, Beta function, Dirac's delta function, Green's functions, Laplace transforms, Fourier series and transforms, Symmetries & groups: multiplication table and representations, permutation group, translation and rotation groups. Elementary ideas about tensors: covariant, contravariant, and mixed tensors, metric tensor).
Series solution of second order differential equations & Special functions: Second order linear ordinary differential equations with variable coefficients, solution by series expansion, Legendre polynomial, Bessel Function, Hermite and Lagauerre polynomials and their solutions, Sturm-Liouville equation, physical applications, generating functions, recursion relations.

Texts/References

1. P. Dennery and A. Krzywicki, **"Mathematics for Physicists"**, Dover Publications (1996)
2. G. B. Arfken and H. J. Weber, **"Mathematical Methods for Physicists",** Academic Press, London (2001)
3. E. Kreyszig, **"Advanced Engineering Mathematics"**, 5th edition, Wiley Eastern (1991).
4. L. A. Pipes and L. R. Harvill, **"Applied Mathematics for Engineers and Physicists"**, McGraw-Hill, New Delhi (1970)
5. M. R. Spiegel, **"Schaum's Outline Series of Theory and Problems"**, McGraw-Hill, New York, (1968)
6. P. K. Chattopadhyay, **"Mathematical Physics"**, New Age International Publishers (2004)
7. S. S. Sastry, **"Advanced Engineering Mathematics"**, PHI Learning Pvt. Ltd, New Delhi
8. H.K. Dass and Rama Verma, **"Mathematical Physics"**, S. Chand and Company Pvt. Ltd, New Delhi.

PHM409-STATISTICAL PHYSICS

4-Credits (4-0-0)

Course objective: This course will recall about the basics of Thermodynamics, relevant laws, and their relations. This Course (Statistical Physics) deals with the derivation of the macroscopic parameters (internal energy, pressure, specific heat etc.) of a physical system consisting of large number of particles (solid, liquid or gas) from knowledge of the underlying microscopic behaviour of atoms and molecules that comprises it. The main objective of this course work is to introduce the techniques of Statistical physics which has applications in various fields including Astrophysics, Semiconductors, Plasma Physics, Bio-Physics etc. and in many other directions.

Course Outcome: At the end of the course students will be able:

- Difference between the classical and quantum statistics.
- Understand the concepts of microstate, macrostate, phase space, thermodynamic probability and partition function, ensembles.
- Understand the properties and Laws associated with thermal radiation.
- Learn the Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein distribution.
- Apply the quantum statistical probability (distribution) in real system problem such as electrons in solids, liquid Helium gas etc.

Basics of Thermodynamics: Review of basic thermodynamics, laws of thermodynamics, thermodynamic potentials, Maxwell's thermodynamic relations.

Classical Statistics: Foundation of Statistical mechanics, relationship between statistics and thermodynamics, classical and statistical entropy, phase space, Elements of ensemble theory, claasification, macrostates and microstates, stiring's approximation, probability distribution, random walk, thermodynamic probability, most probable distribution, Maxwell-Boltmann distribution, Entropy and thermodynamic probability, Sackur-Tetrode equation, Gibb's paradox, partition function and its connection with thermodynamic quantities, Liouville`s theorem.

Quantum Statistics : Formulation of quantum statistics, system composed of indistinguishable particles, qunatum mechanical ensemble theory, density matrix, Bose-Einstein and Fermi-Dirac distribution, mono-atomic and diatomic gases, Specific heat of solids : Einstein and Debye theory, Ideal Bose and Fermi gases and its thermodynamical behaviour, Bose-Einstein condensation, elementary excitations in liquid helium II, Electron gas.

Elementary kinetic theory of transport processes: Fluctuations: Thermodynamic fluctuations, Boltzmann transport theory, H-theorem, calculation of kinetic coefficients, elementary concepts of plasma kinetic theory, Brownian motion, Einstein and Lengevin theory of Brownian motion.

Texts/References

1. F. Reif, **"Fundamentals of Statistical and Thermal Physics", McGraw Hill (1965).**
2. R. K. Patharia, **"Statistical Mechanics"**, Pergamon Press (**1996**)
3. K. Huang, **"Statistical Mechanics"**, John Wiley & Sons (**1983**).
4. J. K. Bhattacharjee, **"Statistical Mechanics: Equilibrium and Non-Equilibrium Aspects"**, Allied Publishers Pvt. Ltd. (**2001**).
5. L. D. Landau and E. M. Lifshitz, **"Statistical Mechanics",** Butterworth-Heinemann **(1980**).

PHM411-PHYSICS LABORATORY-I

4-Credits (0-0-8)

This will be a 4-credit course with 8- contact hours where students will perform at least eight of the following experiments on Optics, Thermodynamics, Solid State Physics, Atomic Physics, Electrostatics & Electromagnetic (EM) Waves, and Mechanics**:**

1. To determine the Universal Gravitation Constant (G).
2. To study the interference fringes of (i) Equal Inclination, (ii) Equal thickness with a Michelson Interferometer.
3. To determine the speed of light with the Foucault method.
4. To study the Interference and diffraction patterns for single, double, and multiple slits.
5. Determination of wavelength of a monochromatic source with diffraction grating.
6. To determine the conductivity of wood / Masonite / Teflon.
7. To determine the dielectric constant of $BaTiO_3$.
8. To study Hall Effect and determine Hall coefficients.
9. Magneto-resistance and its field dependence.
10. To study the Electro-optic modulation with Kerr effect.
11. To study and verify Bragg diffraction with microwaves and/or X-Rays.
12. To study Electron Spin Resonance (ESR) and determine g-factor for a given spectrum.
13. To determine the Susceptibility of different materials (e.g., Gadolinium)

SEMESTER-II

PHM402-QUANTUM MECHANICS-II

4-Credits (4-0-0)

Course objective : The topics include various approximate methods (time-independent perturbation theory and time-dependent perturbation theory to solve simple problems, the variational method, WKB approximation), symmetries exists in various quantum particles including spins and identical particles and the fundamentals of relativistic quantum mechanics.

Course outcome : The students will be able to solve real world problems and gain knowledge about fundamental quantum mechanical processes in nature.

Time-independent perturbation theory : Harmonic oscillator, Zeeman effect, Stark effect (Non-degenerate and degenerate cases);

Time-dependent perturbation theory : Schroedinger and Heisenberg picture, first order and harmonic perturbations, transition probability, Fermi's golden rule, adiabatic and sudden approximations, beta decay;

Variational method: Principles and application to particle in a box, simple harmonic oscillator, hydrogen atom, helium atom;

WKB approximation : Principles and condition for validity, Bohr's quantization condition, applications to tunneling such as alpha particle, field emission, ammonia molecule;

Symmetry in quantum mechanics: symmetric and anti-symmetric wavefunctions, identical particles, Pauli's exclusion principle, collision of identical particles, spin-statistics connection;

Elements of relativistic quantum mechanics: Klein-Gordon equation and Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretation, non-relativistic limit of Dirac equation, elements of field quantization; Coherent state, squeezed state, number state, quantum entanglement, Landau symmetry, quantum cryptography, quantum computation.

Texts/References

1. P. A. M. Dirac, **"Lectures on Quantum Mechanics"**, Dover Publications (**1964**)
2. A. Messiah, **"Quantum Mechanics"**, Dover Publications, (**1999**)
3. L. I. Schiff, **"Quantum Mechanics"**, Tata McGraw-Hill, Third Edition (**2010**)
4. E. Merzbecker, **"Quantum Mechanics"**, John Wiley & Sons (**1970**)
5. J. J. Sakurai, **"Modern Quantum Mechanics"**, Addison Wesley Pub. Co (**2011**)
6. L. D. Landau and E. M. Lifshitz, **"Quantum Mechanics"**, Elsevier (**2008**)
7. Jasprit Singh, **"Quantum Mechanics: Fundamentals and applications to technology"**, Wiley-VCH Verlag (**2004**)

PHM404-SOLID STATE PHYSICS

4-Credits (4-0-0)

Course objective: This course aims to study of basic phenomena in Solid State Physics. This contains theoretical topics like crystal structure, electronic structure, lattice dynamics, overview of free electron model, origin of bands, magnetic, dielectric, and superconducting properties, and defects in solid state materials. These properties will be understood based on classical and quantum physics principles.

Course outcome: The students will learn the concept of the crystal classes and relationship between the real and reciprocal lattice space. Bragg's conditions for X-ray diffraction in crystals (direct and reciprocal lattice space) will be understood and the conditions for allowed and forbidden reflections in different crystals will be investigated. The students will be able to understand the basics of the optical and acoustic phonons in crystals, and know the temperature dependence of specific heat of solids. They will also understand the basic concepts of the band theory of solids and hence will be able to predict the optical properties of materials and compounds. They will learn the basic properties of superconductors in the frame of BCS theory. Quizzes and the Exams will be conducted to gauge the understanding of these major concepts of this Solid-State Physics Theory course.

Crystal Structure: Basics, periodic structure, symmetry of crystals, concept of point groups, reciprocal **lattice**, crystal diffraction, Brillouin zones, Bragg's law, structure factor, different methods for structure determination, electron, and neutron diffractions.

Phonons: lattice vibrations, vibrations of mono and diatomic lattices, lattice heat capacity, Einstein and Debye models.

Free electron Fermi gas: Overview of ohm's law, electrical conductivity, thermal conductivity, Wiedemann-Franz law, **Plasmons, Polaritons and Polarons:** Overview, **Energy bands:** Bloch's theorem and band structure, Kronig-Penney model, and tight binding approximation.

Semiconductor crystals: effective mass, Elementary concept of semiconductors, intrinsic and extrinsic semiconductors, electron and hole mobilities, impurity band conduction, p-n junction, Schottky barrier.

Dielectric properties: types of polarization, local field and Clausius-Mossotti equation, dielectric constant, and dielectric loss, piezo and ferroelectricity.

Magnetic materials: dia, para, ferro and anti-ferromagnetism; Curie-Weiss law, Pauli paramagnetism.

Superconductivity: Meissner effect, BCS theory, Ginzburg-Landau theory, flux quantization, field penetration and high frequency effects, Josephson junctions, soft and hard superconductors, high temperature superconductors.

Defects & Dislocations: point defects, dislocation theory.

Texts/References

1. C. Kittel, **"Introduction to Solid State Physics"**, Wiley (**1995**).
2. L. V. Azaroff, **"Introduction to Solids"**, Tata McGraw (**1960**).
3. M. A. Wahab**, "Solid State Physics"**, Narosa Publishing House (**1999**).
4. N. W. Ashcroft and N. D. Mermin, **"Solid State Physics"**, Holt, Rinehart and Winston (**1976**).
5. J. M. Ziman, **"Principles of the Theory of Solids"**, CBS Publishing ASIA (**1988**).
6. A. J. Dekker, **"Solid State Physics"**, Prentice-Hall (**1965**).
7. G. Burns, **"Solid State Physics"**, Academic Press, New York (**1985**).
8. M. P. Marder, **"Condensed Matter Physics"**, John Wiley & Sons (**2000**).
9. A. R. Verma and O. N. Srivastava, **"Crystallography Applied to Solid State Physics"**, New Age International Publishers (**2005).**

PHM406-ELECTRONICS

4-Credits (4-0-0)

Course objective: To provide an advanced level understanding of analog and digital electronic devices and circuits to the students who have a basic knowledge of semiconductor physics from the undergraduate level of studies. The objective is also to provide an understanding of computer organization as well as the basics of communication systems.

Course outcome: After successful completion of the course the student is expected to have a thorough knowledge of analog and digital circuits, microprocessor-based systems and basics of communication systems.

Semiconductor device physics: Diodes (Zener and Tunnel), BJT, UJT, SCR, I-V characteristics, and equivalent circuits. JFET, MOSFET, I-V, C-V characteristics, enhancement, and depletion mode MOSFET; Metal-semiconductor junctions, Schottky diode; LED, Photodiode Solar Cells.

Analog circuits: Power amplifiers, classes A, B, AB, C operations; Basic differential amplifier circuit, operational amplifier: characteristics and applications, Multivibrator circuits; Active filters: Butterworth filter, low pass, and high pass filters; RC bandpass filter; Bandreject Filter; Delay equalizer; A/D and D/A converters.

Digital Circuits: Introduction to digital IC parameters (switching time, propagation delay, fan out, fan in etc.). NMOS and CMOS gates (AND, NAND and NOT), Dynamic MOS circuits, MOS shift register, Memory Devices; Random access memory (RAM), Static and dynamic random-access memories; Basics of micro-processor and micro-controller.

Communication Systems: Amplitude, Phase and Pulse-analog modulation: Generation and detection. Model of communication system, classification of signals, representation of signals.

Text/References

1. J. Milman and C.C. Halkias, **"Electronic Devices and Circuits"**, Tata-McGraw-Hill (**2007**)
2. A. P. Malvino, **"Electronics: Principles and Applications",** Tata McGraw-Hill (**1991**)
3. J. Millman and A. Grabel, **"Microelectronics"**, McGraw-Hill (**1987**)
4. Solid State Electronic Devices, **B.G. Streetman** (7th Ed., Pearson, 2015)
5. S. M. Sze and K. K. Ng, "**Physics of Semiconductor Devices"**, Wiley (**2008**)
6. G. B. Clayton, **"Operation Amplifiers"**, ELBS (**1980**)
7. Communication Systems, **Simon Haykins** (5th Ed., Wiley, 2009)
8. Digital Signal Processing, **J. G. Proakis and D. G. Manolakis** (4th Ed., Pearson, 2007)

PHM 408-NUCLEAR AND PARTICLE PHYSICS

4-Credits (4-0-0)

Course objective: To impart knowledge about basic nuclear physics properties and nuclear models for understanding of related reaction dynamics.

Course outcome: Students will have achieved the ability to:

- Explain the ground state properties of the nucleus for study of the nuclear structure behaviour.
- Explain the fusion and fission phenomenon at ground and excited states.
- Work for the various research experiments conducted using different particle accelerators and detectors.
- Demonstrate the shell model and collective model descriptions.
- Apply various aspects of nuclear reactions in view of compound nuclear dynamics.
- Apply the nuclear physics in various medical as well as other industrial fields.
- Explain the basics of elementary particles and their properties.

General properties of nuclei: Fundamental forces and interactions in nature, Review of elementary nuclear properties.

Nuclear Models: Semi-empirical mass formula, liquid-drop model, shell model, validity, limitations, and experimental evidence of shell structure in nuclei, collective model, unified model, meson theory.

Radioactivity: Radioactive decay processes- alpha, beta and gamma decays, Geiger-Nuttal law, internal conversion.

Nuclear Reactions: reactions induced by neutron, proton, alpha particles, beta particles and gamma radiation, reactions at ultra-high energies, theory of compound nucleus formation and its limitations, Nuclear Fission and Fusion.

Accelerators & Detectors: Van de Graff accelerator, cyclotron, betatron, synchrotron, Geiger Muller counter, scintillation counter.

Particle Physics: Elementary Particles: Classification, symmetries and conservation laws, isospin, hypercharge, strangeness, parity etc., quark model, Gell-Mann-Nishijima formula, C (Charge conjugation), P (Parity), and T (Time Reversal) invariance and applications of symmetry arguments to particle reactions, parity non-conservations in weak interactions.

Nuclear Applications*: Environmental monitoring, radioactive dating, radiation detection, medical imaging (e.g., CAT Scans, MRI, NMR), elemental analysis using mass spectroscopy with accelerators, material characterization, opinion formation on the positive aspect (e.g., power generation using nuclear reactors) and negative aspect (weapons of mass destruction) in the backdrop of scientific, humanitarian, and national interests.

* The outlined topics are meant for self-study followed by presentation by the student.

Texts/References

1. B. Cohen, **"Concepts of Nuclear Physics",** Tata McGraw Hill (**2008**).
2. K. S. Krane, **"Introductory Nuclear Physics"**, John Wiley & Sons (**1988**).
3. I. Kaplan, **"Nuclear Physics",** Addison Wesley Pub. Co. (**1955**).
4. R. R. Roy and B. P. Nigam, **"Nuclear physics"**, Wiley (**1967**).
5. M. G. Bowler, **"Nuclear Physics"**, Elsevier Science & Technology (**1973**).
6. R. Eisberg, R. Resnick, **"Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles"**, Wiley (**2010**).
7. D. C. Tayal, **"Nuclear Physics"**, Himalaya Publishing House (2012).

PHM410- PHYSICS LABORATORY-II

4-Credits (0-0-8)

This will be a 4-credit course with 8-contact hours where students will perform at least eight of the following experiments on analog and digital Electronics**:**

1. To trace the I-V characteristic curves of diodes and transistors on a CRO, and learn their uses in electronics circuits.
2. To study regulated power supply using (a) Zener diode only (b) Zener diode with a series transistor, (c) Zener diode with a shunt transistor.
3. To study the characteristics of FET (Field Effect Transistor) and use it to design a relaxation oscillator and measure its frequency.
4. To design a multi-vibrator of given frequency and study its wave-shape.
5. Negative feedback and amplifier characteristics.
6. To design a single stage amplifier (CE) of a given voltage gain and lower cut of frequencies.
7. To design a RC coupled two stage amplifiers of a given gain and cut-off frequencies.
8. To study the characteristics of an operational amplifier.
9. To study the addition, integration, and differentiation properties of an operational amplifier.
10. Use of differential amplifier and operational amplifiers in linear circuits.
11. To study the series and parallel LCR circuits.
12. Design of simple logic gates using transistors.
13. To study analog to digital (A/D) and digital to analog (D/A) conversion.
14. To design and study a digital 555 timer.
15. Pulse generator experiments.
16. To design and study a digital counter.

PHM412- OPTICAL TECHNIQUES AND INSTRUMENTATION

4-Credits (2-0-4)

Course objective: Aim of the course is to expose the students to various applications of optical metrology using the principles of wave optics. The course also aims to provide Hands-on experience of interferometric and diffraction-based experiments for thorough understanding of the subject.

Course outcome: After successful completion of the course the student is expected to gain the necessary knowledge of optical techniques and instrumentation as well as the working of optical devices used in diverse fields of science and technology.

Double beam Interferometry: Interference in a plane parallel plate and in a plate of varying thickness, Fizeau fringes, Michelson, Mach-Zehnder, Wavefront-shearing, Twyman-Green, Sagnac Interferometers, Phase Estimation for Surface Profiling, Detection of Gravitational waves.

Multiple beam Interferometry: Visibility and Intensity distribution, Fabry-Perot Interferometer and Fabry-Perot etalon, resolving power and finesse; Nonreflecting and Highly reflecting films, Interference filters, Broad-band reflectors, band-pass filters, dichroic beam splitters and cold mirrors. Scanning Fabry-Perot Interferometer - central spot scanning, Microscopic Surface Form and Roughness detection, Holographic interferometry, Laser vibrometry, Laser Doppler imaging.

Theory of concave grating, Grating spectrographs, resolution and dispersive power of spectrographs, monochromators. Spectrometers, Spectrophotometers - types and applications; Adaptive optics - Wavefront sensor, Guided star systems, MEMS and Deformable mirror and wavefront corrections, actuators.

Experiments:

1. Construction of various interferometers on optical breadboard using He-Ne Laser, Argon ion Laser and Laser diodes and analyze their performance.
2. Construction of an optical 4f system, image addition and subtraction, filtering at Fourier plane.
3. Interferometric methods for surface testing and profiling.
4. Recording and reconstruction of holograms.

Texts/References

1. Ajay Ghatak, **"Optics",** McGraw Hill (2019).
2. P Hariharan, **Basics of interferometry**, Academic press, (2006).
3. E. Hecht and A R Ganesan, **"Optics"**, Pearson Education (2008).
4. R. S. Sirohi, **"Wave optics and applications"**, Orient Longman, (2001).
5. R.K Tyson, **"Principles of Adaptive optics"**, CRC Press (2010).
6. P.K Rastogi, **"Optical measurement techniques and applications"**, Artech House (1997).

SEMESTER III

PHM501-ATOMIC AND MOLECULAR PHYSICS

4-Credits (4-0-0)

Course objective: This course gives understanding of Atomic and Molecular Physics to the students. This contains theoretical topics like H atom spectra, j-j and L-S coupling, Zeeman effect, Stark effect, Molecular spectra, photoluminescence, and other characterizations like ESR, NMR, FTIR and Raman. These observations/phenomenon on single and multi-electrons atoms will be understood based on quantum physics principles.

Course outcome: The students will have advanced knowledge of the origin of atomic and molecular spectra. Study of LS and j-j coupling will develop the analytical and thinking ability of students. The study of Fine structure and the Hyperfine structure will provide the understanding of origin of spectral lines. Study of Zeeman effect and Stark effect shows how atoms interact with electromagnetic field and give rise to spectra. Study of other characterization techniques like ESR, NMR, FTIR, Raman etc. will develop analytical approach in students.

Contents: Overview of Bohr-Sommerfeld theory of H-atom, quantum mechanics of H-atom, magnetic dipole moment (Bohr magneton) and Vector atom model. Quantum states of an electron in an atom, electron spin, Stern-Gerlach experiment, spectra of H, He, and alkali metals, relativistic corrections for energy levels of hydrogen, two electron atom, j-j and L-S coupling, Zeeman effect, Paschen-Back and Stark effects, X-ray spectra, spectral line width and intensities, Molecular symmetry, electronic, rotational and vibrational energy levels in molecules, Franck-Condon principle and selection rules, Fluorescence, Phosphorescence, and Photoluminescence, bond dissociation energies, molecular orbitals and models, ESR, NMR, FTIR, Surface Enhanced Raman Spectroscopy (SERS), Mössbauer Spectroscopy, Spectroscopic Instrumentation.

Text/References

1. H. E. White, **"Introduction to Atomic Spectra",** McGraw-Hill **(1934)**
2. C. N. Banwell and E. McCash, **"Fundamentals of Molecular Spectroscopy",** McGraw-Hill (**1994**)
3. J. M. Hollas, **"Basic Atomic and Molecular Spectroscopy",** Royal Society of Chemistry (**2002**)
4. V. K. Jain, **"Introduction to Atomic & Molecular Spectroscopy",** Narosa Publishing House (**2011**)
5. G. Aruldhas**, "Molecular Structure and Spectroscopy",** PHI Learning Pvt. Ltd. **(2004).**
6. Raj Kumar, **"Atomic and Molecular Spectra: Laser",** Kedar Nath Ram Nath, Meerut, UP.

PHM503- INTRODUCTION TO NANOPHYSICS

2-Credits (2-0-0)

Course objective: The objective of this course is to teach the students about the fundamental and quantum physics of various nanosystems through proper physical and mathematical basis of quantum mechanics for different nanosystems.

Course outcome: The students gain enriched knowledge on the properties of materials at the nanoscale before the synthesis, characterization, and implementation of these materials for various device applications.

Contents: Quantum confined systems, Quantum size effect, Quantum wells, Quantum wires, Quantum dots, Artificial atoms, Electronic structure and Density of states, Metal nanoclusters, Magic numbers, Semiconductor nanocrystals, Quasiparticles and excitons, Excitons in semiconductor nanocrystals, Carrier transport in nanostructures: Coulomb Blockade effect, Scattering and tunneling, Single electron transistor, Defects and impurities, Deep level and surface defects, Ab-initio methods, Chemical reactivity of nanoparticles, Properties of nanomaterials and scaling laws, Electrical, mechanical, dielectric, optical and magnetic properties.

Texts/References

1. "Introduction to Nanotechnology", Charles P. Poole, Frank J. Owens, Wiley India Edition (2010).
2. Richard Booker and Earl Boysen **"Nanotechnology"** Wiley (2005).
3. C. Delerue and M. Lanoo, **"Nanostructures-Theory and Modelling**", Springer (2004).
4. T. Pradeep, **"Nano: The Essentials"** Tata McGraw-Hill (2007).
5. Thomas Varghese, K. M. Balakrishna, **"Nanotechnology**", Atlantic Pub. (2012).

PHM505-PHYSICS LABORATORY-III

4-Credits (0-0-8)

This will be a 4-credit course with 8-contact hours where students will perform the following experiments. The minimum number of experiments will be decided by the department.

1. Characteristic study of, (i) Light Emitting Diode (LED), (ii) Semiconductor Laser, and (iii) Photodetector.
2. To construct a Michelson Interferometer (with Laser) and measure the coherence path length.
3. To study the operation of a Erbium-doped fiber amplifier.
4. To study, (i) numerical aperture, (ii) the propagation loss, (iii) the bending loss of an optical fiber.
5. To study the properties of a optical fiber and learn wavelength-division multiplexing.
6. Birefringence measurement with (i) Rayleigh scattering technique, (ii) Prism coupling technique.
7. To learn the cutting and preparing of an optical fiber and to study its coupling efficiency.
8. To study signal transmission through an optical fiber.
9. To study the Atomic spectra of Hydrogen, Helium, and Hg doublet sources.
10. Deposition of nanostructured thin films/nanoparticles for different deposition parameters by using the thermal evaporation technique and Measurement of the thickness of the deposited thin films of different thicknesses by profilometer.
11. Deposition of nanostructured thin films/nanoparticles by the technique of spin coating for different deposition parameters.
12. Study of electrical properties of thin films: (i) Electrical resistivity, (ii) carrier concentration, (iii) mobility; by electrical and Hall measurements set up in Van der Pauw geometry.
13. Study of the optical properties of the thin films: (i) Transmittance, (ii) Reflectance, (iii) Optical band gap, (iv) Refractive index; by using UV-Vis spectrophotometer and ellipsometery.
14. Indexing of the given X-ray diffraction data for a material and estimation of lattice structure and other crystallographic parameters (Analysis only).

PHM507-COMPUTATIONAL PHYSICS

4-Credits (3-0-2)

Course objective: This course is intended to introduction of Numerical Methods, for obtaining approximate representative numerical results of the problems.
The course would impart training in solving the problems in the field of Applied Mathematics, Theoretical Physics and Engineering which requires computing of numerical results using certain raw data.

Computational errors - generation and propagation, convergence analysis; Roots of algebraic & transcendental Equations: Bisection method, Newton-Raphson method; Interpolation: Newton's forward and backward difference methods, La Grange's and Divided difference methods, Numerical Differentiation; Numerical Integration: Trapezoidal method, Simpson's 1/3 rule, Gaussian quadrature; System of linear equations, L-U decomposition, Solution with direct and iterative methods, Tridiagonal systems solutions, Matrix Eigenvalue Problems: Householder's method, Ordinary differential equations: Picard's method, Initial value problems: Euler method, Runge-Kutta methods, Predictor-Corrector method, Solution of simultaneous and higher order ODEs; boundary value problems: Finite difference method; Partial Differential Equations: Types, Solution of heat, diffusion, diffusion-convection, wave, Laplace and Poisson equations, solution and case study of PDEs for relevant physical systems.

Students will apply the computational methods in problems arising from various branches of physics using MATLAB.

Texts/References

1. M. K. Jain, S. R. K. Iyenger, R. K. Jain, **"Numerical Methods for Scientific and Engineering Computation"**, New age international publishers **(2003).**
2. E. Balagurusamy, **"Numerical Methods",** McGraw-Hill (**2000**).
3. G. H. Golub and C. F. Van Loan, **"Matrix Computations",** Johns Hopkins University Press **(1996).**
4. C. F. Gerald and P. O. Wheatley, **"Applied Numerical Analysis"**, Addison Wesley Pub. Co (**1980**).

Discipline Specific Elective-I

PHM511-CHARACTERIZATION OF SOLID-STATE MATERIALS

3-Credits (3-0-0)

Course objective: The course familiarizes students with various type of functional materials, their properties, and applications in various devices. It offers a detailed understanding of various research instruments, their working principles and instrument user instructions. The course also expertise students for analysis of data acquired from various material characterization instruments.
Course outcome: The students acquire experience working in industrial or research lab settings as a part of a team, through the learning of various characterization technique theoretically in this course.

Solid State Materials: Crystalline and amorphous solids, Elemental and Compound semiconductors, metal oxide semiconductors, organic semiconductors, insulators, superconductors, ceramics, magnetic materials, Bulk, thin films and nanostructures, smart materials.
Characterization Techniques: Crystallography, X-Ray Diffraction Techniques, Small angle X-Ray scattering, Electron diffraction, Neutron Diffraction, Low energy electron diffraction (LEED) and Reflection high energy electron diffraction (RHEED), X-Ray absorption spectroscopy (XAS), X-Ray Fluorescence (XRF) spectroscopy, scanning probe microscopy (AFM and STM), Electron optics, Electron Microscopy- Transmission and Scanning Electron Microscopy (TEM, SEM), X-ray photoelectron spectroscopy (XPS), Electrical characterization: Vander Pauw method, Hall measurements at low and high temperatures, Electrical

conductivity and trapping parameter measurement in semiconductors and insulators, Optical characterization: UV-Visible spectroscopy, Spectroscopic ellipsometry (for determination of optical constants), photoluminescence (PL), compositional analysis employing Auger Electron spectroscopy (AES), Magnetic characterization: Vibrating Sample magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), Thermal analysis (DTA/TGA), Nanoindentation.

Texts/References

1. R. P. Prasankumar (Editor), A. J. Taylor (Editor), **"Optical Techniques for Solid-State Materials Characterization"**, CRC Press (**2011**).
2. B. D. Cullity, S.R. Stock, "Elements of X-Ray Diffraction", Prentice Hall (2001).
3. J. F. Watts, J. Wolstenholme, **"An Introduction to Surface Analysis by XPS and AES",** Wiley (**2003**).
4. P. J Goodhew, J. Humphreys, R. Beanland, **"Electron Microscopy and Analysis",** Taylor & Francis (**2000).**

PHM513-SEMICONDUCTOR PHYSICS AND DEVICES

3-Credits (3-0-0)

Course objective: This course aims theoretical study of semiconductor physics, fabrication techniques of solid-state devices and their characteristics. This course includes topics on charge carriers and their transport, fabrication of P-N junction diodes and its characteristics, band structure and its engineering, junctions, quantum theory of semiconductors and semiconductor optoelectronic devices.

Course outcome: The students will be able to explain the basic properties of semiconductors including the band gap, charge carrier concentration, doping and charge carrier injection/excitation. The students will also understand the working, design and applications of various semiconducting devices including doping and p-n junctions. They will be able to describe the working and design considerations for the various optoelectronic devices like photodetectors, solar-cells, LEDs and Lasers. Quizzes and the Exams will be conducted to gauge the understanding of these major concepts of this course.

Contents: Bonding Forces and Energy Bands in Solids, Charge Carriers in Semiconductors, Carrier Concentrations, Drift of Carriers in Electric and Magnetic Fields, Excess carriers in Semiconductors, Fabrication of P-N Junctions, Forward and Reverse Biased Junctions, Reverse-Bias Breakdown, Transient and A-C Conditions, Band Structure Engineering, Metal-Semiconductor Junctions, Semiconductor Hetero-junctions, Photodiode, LED, Semiconductor Laser, Solar Cells, Physics of Bipolar Devices, Hot Electron Devices, Fundamentals of MOS and Field effect Devices, Review of Quantum theory of Semiconductors, Electrons and Holes in Quantum-Wells, Wires and Dots, Resonant Tunnel Diode.
Semiconductor Optoelectronics: Interactions of photons with semiconductors, semiconductor-based photon sources, light emitting diodes (LEDs), semiconductor-laser amplifiers, semiconductor injection lasers, semiconductor-based absorbers, photodetectors (visible, infrared & THz), photoconductors, photodiodes, avalanche photodiodes, responsivity, dark current, photocurrent and noise in photodetectors, solar cells.

Texts/References

1. Rolf Enderlein, Norman J Horing, **"Fundamentals of Semiconductor Physics and Devices"**, World Scientific (**1997**).
2. Ben Garland Streetman, Sanjay Kumar Banerjee, **"Solid State Electronic Devices"**, Pearson Prentice Hall **(2006).**
3. S. M. Sze, **"Semiconductor Devices: Physics and Technology"**, 2nd Ed., John Wiley & Sons **(1969).**
4. M.S.Tyagi, **"Introduction to semiconductor, materials and devices",** John Wiley & Sons **(2008).**

PHM515-ASTROPHYSICS-I

3-Credits (3-0-0)

Course objective: The primary objective of this course is to give the students basic knowledge of astronomical scales and coordinate system and understand the various astrophysical processes, such as, stellar structure formation, evolution, and different type of stars system.

Course outcome: Students will be able to

- Understand the basic parameters used in modern Astronomy.
- Explain the structure and energy generation in the stars.
- Explain the various process involved in the evolution of the stars.
- Describe the variable stars and their photometry.
- Apply the Period-Luminosity relationship of Cepheids variable for distance measurement.

Astronomical parameters: Celestial Sphere, Horizon, Equatorial, Ecliptic and Galactic Systems of Coordinates, Conversion from one system of co-ordinates to another, Stellar Parallax, Magnitude Scale- Apparent and absolute magnitude, distance modulus. Determination of mass, luminosity, radius, temperature and distance of a star, Colour Index, Color indices and Bolometric correction, The classification of Stellar Spectra, H-R Diagram**,** mass-luminosity relation.

Stellar Structure and Evolution: Virial Theorem, Formation of Stars, Hydrostatic Equilibrium, Integral Theorems on pressure, density and temperature, Homologous Transformations, Polytropic gas spheres – Lane Emden Equation and its solution, Energy generation in stars, P-P and C-N cycles, Radiative and Convection transport of energy, Equations of stellar structure and their solution, Evolution of stars of different masses, pre- and post-main-sequence evolution Fate of massive stars, Supernovae Type I and Type II, Degenerate electron and neutron gases, White dwarfs – mass limit, mass-radius relation, Neutron stars and black holes

Variable Stars: Photometry of variable stars, differential photometry, extinction coefficients, Classes of variable stars, Period-Mean density relationship, Classical Cepheids as distance indicators, pulsation Mechanisms.

Texts/References

1. **"Astrophysics for Physicists",** Arnab Rai Choudhury, Cambridge University Press (2010).
2. Hansen, Carl J., Steven D. Kawaler, and Virginia Trimble, **Stellar Interiors: Physical Principles, Structure and Evolution,** New York, NY: Springer (2004).
3. **"An Introduction to Modern Astrophysics and Cosmology (Second Edition)"**, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co. (2006).
4. **"Introductory Astronomy and Astrophysics (Fourth Edition)"**, M. Zeilik and S. A. Gregory.
5. Saunders College Publishing, 1998, **"Fundamental of Astronomy (Fifth Edition)"**, H. Karttunen et al. Springer (2007).

6. **"The Physical Universe: An Introduction to Astronomy"**, Frank Shu, University Science Books.

PHM517-NONLINEAR DYNAMICS AND CHAOS

3-Credits (3-0-0)

About the Course: Dynamics and nonlinear systems concern the study of things which change over time. This includes, for example, the study of chaos and bifurcations using analytical, numerical, and experimental methods. Applications include nonlinear vibrations (MEMS, lasers), celestial mechanics (including planetary rings and rotations of celestial bodies), biodynamics (including interaction of populations of fireflies, flight of insects, and human walking) and control (including satellite dynamics and manufacturing processes).

Course objective: Main objective of this course is to introduce discrete and continuous nonlinear dynamical systems and analysis of such systems fo r the stability of equilibrium points (local as well as global), their local bifurcations and related normal forms, chaotic and other complex dynamics exhibited by them. There will be problem sets that will require use of computer.

Course outcome: After completing this course students will be able to:

- Analyze the behavior of dynamical systems (e.g. find periodic orbits and assess their stability, draw phase portraits, etc.) expressed as either a discrete-time mapping or a continuous-time flow,
- Apply the techniques of nonlinear dynamics to physical processes drawn from a variety of scientific and engineering disciplines,
- Analyze changes (i.e. bifurcations) to dynamical systems as system parameters are varied,
- Analyze various chaotic applications in real-life systems, say engineering and biomedical applications, control and synchronize them as per requirement,

Contents: Course Introduction and Overview, One Dimensional Systems, Overdamped Bead on a Rotating Hoop, Model of an Insect Outbreak, Two Dimensional Linear Systems, Two Dimensional Nonlinear Systems: Fixed Points, Conservative Systems, Index Theory and Introduction to Limit Cycles, Testing for Closed Orbits, Van der Pol Oscillator, Averaging Theory for Weakly Nonlinear Oscillators, Bifurcations in Two Dimensional Systems, Hopf Bifurcations in Aeroelastic Instabilities and Chemical Oscillators, Global Bifurcations of Cycles, Chaotic Waterwheel, Waterwheel Equations and Lorenz Equations, Chaos in the Lorenz Equations, Strange Attractor for the Lorenz Equations, One Dimensional Maps, Universal Aspects of Period Doubling, Feigenbaum's Renormalization Analysis of Period Doubling, Renormalization: Function Space and a Hands-on Calculation, Fractals and the Geometry of Strange Attractors, Henon Map, Using Chaos to Send Secret Messages.

PH519-MINOR PROJECT

4-Credits

This will be a 4-credit course where students will prepare a written project report (in a specified format) to be submitted in the school and to be presented to the seminar committee.

1. The objective of the minor project may be summarized as: (i) To prepare the student for deep and detailed exploration of a selected topic of interest, (ii) To prepare the student for collecting relevant data through literature survey from array of available resources e.g. published books, monograms, scientific journals, online/web material, scientific magazines etc., (iii) To prepare the student for presenting a scientific topic, subject to the scientific community in a professional way, (iv) To cultivate the habit of discussing, sharing and communicating the ideas with the scientific community, (v) To identify the problems from literature survey and generate their ideas for research to be carried out in the major project that should be beneficial for the society.
2. Student must interact on day-to-day basis with the project advisor and should report his/her progress regularly.

SEMESTER-IV

Discipline Specific Elective-II

PHM502-LASER PHYSICS

3-Credits (3-0-0)

Course objective: The aim of this course is to provide students with a basic understanding of laser operation, laser characteristics and performance of various laser systems for CW and pulsed operation and applications.

Course outcome: Students are expected to understand the basics of laser operation and learn the essential design requirements of 3-level and 4-level laser systems. Students will be able to design stable optical laser cavities and predict performance, including lasing threshold, single-frequency versus multi-mode operation and pulsed operation including Fourier-limited pulse durations.

Contents: Interaction of radiation with matter, spontaneous and stimulated emission, Einstein coefficients, optical amplification and population inversion, line-shape functions, homogeneous and inhomogeneous broadening, Threshold condition; CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around threshold; Output coupling of laser power. Optical resonators; Cavity modes; Mode selection; Pulsed operation of laser: Q-switching and Mode locking: Experimental techniques;

Different laser systems: Nd:YAG/Nd:Glass Lasers, Tunable Ti-Sapphire Laser, Alexandrite Laser, Fiber Lasers, He-Ne Laser, Argon-ion Laser, He-Cd Laser, Excimer Lasers, Carbon dioxide Laser, Copper Vapor Laser, Free-electron Laser, Short Pulsed Lasers, Laser applications in medicine and surgery, spectroscopy, optical communications, metrology and LIDAR and holography.

Texts/References

1. K. Thyagrajan and A Ghatak, **"Lasers: Fundamentals and Applications",** Springer (**2010**)
2. W. T. Silfvast, "**Laser Fundamentals**", Cambridge University Press (2004)
3. O. Svelto, D. C. Hanna, **"Principle of Lasers"**, Springer **(1998)**
4. K. F. Renk, **"Basics of Laser Physics"**, Springer **(2012)**
5. B. B. Laud, **"Lasers and Non-Linear Optics",** Wiley **(1991).**

PHM 504 - ADVANCED NUCLEAR AND PARTICLE PHYSICS

3-Credits (3-0-0)

Course objective: To impart knowledge about advanced nuclear physics properties and the subsequent research areas.

Course outcome: Students will have achieved the ability to:

- Solve the nuclear physics problems using advanced quantum mechanics solutions.
- Explain the different types of nuclear reactors.
- Perform the research experiments using several techniques.
- Apply the nuclear physics in various medical as well as other industrial fields.
- Explain the advanced particle physics and the associated problems.

General properties of nuclei: Basic properties of the nucleus and nuclear radiations.
Quantum mechanical treatment: Quantum mechanical calculations of deuteron bound-state wave function and energy, n-p scattering cross section, transition probability per unit time and barrier transmission probability.
Nuclear Reactors: Basic principle, classification, constituent parts, (Heterogeneous reactor, Swimming pool reactor, Breeder reactor), Solid state detectors- Si (Li), Ge (Li), HPGe detectors, neutron detectors.
Experimental techniques: charged particle, neutron and gamma ray spectroscopy, methods for charge and mass identification, TOF mass spectrometer, detector array, multiplicity, angular distribution and correlation, methods for life time measurements, measurement of magnetic and quadrupole moment (g-factor), Dosimetry, Cerenkov radiations, nuclear power plants.
Applications of Research in nuclear physics: Radioisotopes and applications in industry and nuclear medicine (cancer treatment), Super-heavy element (SHE) production, exotic halo nuclei and applications in astrophysics.
Particle physics: Review of elementary particles, CPT theorem, Feynman graphs and applications, The Standard Model, Quantum Chromo Dynamics (QCD).

Texts/References

1. B. Cohen, **"Concepts of Nuclear Physics",** Tata McGraw Hill (**2008**).
2. K. S. Krane, **"Introductory Nuclear Physics"**, John Wiley & Sons (**1988**).
3. Walter E. Meyerhof, **"Elements of Nuclear Physics"** New York, McGraw-Hill, (1967).
4. A.E. Waltar, and A.B. Reynolds, **"Fast Breeder Reactors"**, Pergamon Press, New York (1981).
5. I. Kaplan, **"Nuclear Physics",** Addison Wesley Pub. Co. (**1955**).
6. James H. Rust, **"Nuclear Power Plant Engineering",** Haralson Publishing Company, P.O. Box 20366, Atlanta, Georgia 30325 (1979).
7. G.F. Knoll, **"Radiation Detection and Measurement",** John Wiley & Sons, Inc. 3rd edition (2000).
8. D. C. Tayal, **"Nuclear Physics"**, Himalaya Publishing House (2012).

PHM506-NANOSCIENCE AND NANOTECHNOLOGY

3-Credits (3-0-0)
Course objective: The main goal of this subject is to provide fundamental concepts of nanoscience and basic understanding of various fabrication and characterization techniques of nanostructured materials.
Course outcome: The students gain enriched knowledge on the properties of materials at the nanoscale and can synthesize and implement these materials for various technological applications.

Contents: Nanoscale Physics: Introduction to different nanosystems and their realization, Quantum size-effects, characteristic scale for quantum phenomena, quantum wells, quantum wires, and quantum dots, nano-clusters and nano-crystals, density of states for low-dimensional structures, Coulomb blockade, magic numbers, optical properties of nanosystems, excitons and plasmons, photo-luminescence, absorption spectra, Localized Surface Plasmons, Nanofabrication Techniques, top-down and bottom-up approaches, Chemical Techniques: Sol-Gel, spray pyrolysis, nucleation and growth of nanostructures and nanodimentional thin films, atomistic and kinetic models of nucleation, Physical Techniques: physical vapor deposition (PVD), chemical vapor deposition (CVD), dc, rf, reactive and magnetron sputtering, pulsed laser deposition (PLD), molecular beam epitaxy (MBE), Lithographic techniques, Technologically important nanostructures: Buckminster fullerene, Carbon nanotubes, Graphene and Magnetic Nanostructures, Applications of nanomaterials in Biology, Environment, and Energy.

Texts/References

1. C. P. Poole**, "Introduction to Nanotechnology**", Wiley-IEEE (2003).
2. T. Pradeep, **"Nano: The Essentials**", McGraw-Hill (2007).
3. H.S. Nalva (editor), "**Handbook of Nanostructured Materials and Nanotechnology"**, Academic Press (1999).
4. S. K. Kulkarni, **"Nano Technology Principles and Practices**", Capital Publishing Company (2006).
5. Silvana Fiorito, **"Carbon Nanotubes**", Pan Stanford Publishing (2007).
6. Richard Booker and Earl Boysen, **"Nanotechlongy**", Wiley (2005).
7. M. Ohring, **"Materials Science of Thin Films**", Academic Press (2012).

PHM508-SOFT ELECTRONIC MATERIALS AND DEVICES

3-Credits (3-0-0)
Course objective: This course aims theoretical study of soft electronic materials used for fabrication of optoelectronic devices. The fabrication techniques of devices and their characteristics will be studies. This course includes material studies of soft materials like organic semiconductors (small molecules, polymers), perovskite materials, and their optical (absorption, luminescence. Optical constants) and transport properties. This course will cover all the steps of fabrication technique (like patterning, thin film formation, encapsulation etc.) of light emitting diodes and photovoltaic devices (solar cell, photodetectors, sensors) and their characteristics.
Course outcome: The students will be able to explain the basic properties of organic semiconductors including the band gap, refractive index, luminescence properties. The students will also understand the working, design and applications of various soft electronic material-based devices including organic light emitting diode (OLED), Organic solar cell, Perovskite solar cell etc. They will be able to understand the design considerations for the various optoelectronic devices for higher efficiency. Quizzes and the Exams will be conducted to gauge the understanding of these major concepts of this course.

Contents: Difference between Inorganic and Organic semiconductors, Small molecules and Polymers, Optical Properties of few small molecules and polymers: concept of highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) levels, Absorption spectra, photoluminescence spectra, photoluminescence excitation spectra, Jablonski diagram.

Thin Films: Growth behavior, luminescent properties, spectroscopic ellipsometry and optical constants, routes of degradation and environmental stability of soft organic thin films.

Devices: Transparent conducting oxides (TCOs) for device application. Optical and electronic properties (absorption, resistivity, workfunction) of indium tin oxide (ITO).

Orgainc Solar Cells (OSC) structures and characteristics (efficiency, fill factor) concept of donor and acceptor layers, sandwich, bulk hetrojunction and dye sensitized solar cell.

Organic light emitting diodes (OLED) structure: Hole injecting, hole transporting, hole blocking, light emitting and electron transporting layers, fabrication of OLED and its characteristics, CIE coordinates, White light sources.

Design and fabrication of device: Patterning of ITO, its surface treatment, evaporation and coating processes, encapsulation, major challenges in device fabrication, optical outcoupling and approaches, Commercialization issues for solar cell and display devices: Efficiency, life time, size, weight and cost. Resolution, brightness, colour Gamut, aspect ratio, contrast ratio, power consumption.

Texts/References

1. H. G. Tompkins, **"A User's guide to Ellipsometry"**, Academic Press (**1993**).
2. R. M. A. Azzam and N. M. Bashara, **"Ellipsometry and Polarized Light"**, Elsevier (**1988**).
3. W. Brutting, **"Physics of Organic Semiconductors"**, Wiley-VCH (**2005**).

Discipline Specific Elective III

PHM510-THIN FILM TECHNOLOGY AND VACUUM SCIENCE

3-Credits (3-0-0)

Course objective: The course familiarizes students with various type vacuum systems and their parts such as pumps, gauges, and other important parts. Other objective of the course is to teach students about the working principle and instrumentation of various thin film synthesis techniques. Students also learn about the properties of thin films for different applications.

Course outcome: The students acquire detailed knowledge and experience for working in industrial or research lab where vacuum based thin film deposition techniques are used for device fabrication.

Contents: Pressure and Vacuum: Behavior of gases, gas transport phenomenon, viscous, molecular and transition flow regimes, measurement of pressure, pressure gauges, residual gas analyses, Vacuum: Need in research and industry, gas throughput, production of vacuum, mechanical pumps, rotary pump, diffusion pump, Getter and ion pumps, cryopumps, turbo-molecular pump, principles of low, high, and ultra-high vacuum, production and measurement systems, materials for vacuum systems, design aspects of vacuum systems for different applications, leak detection, Thin Film Deposition: Thin film nucleation and growth, atomistic and kinetic models of nucleation, physical vapor deposition (PVD), chemical vapor deposition (CVD), plasmas, discharges and arcs, dc, rf, reactive and magnetron sputtering, pulsed laser deposition (PLD), epitaxy, molecular beam epitaxy (MBE), Chemical Techiques: Sol-Gel, spray pyrolysis, mechanical, Characterization of thin film and surfaces: structural, chemical, electrical, optical characterization, mechanical properties of thin films, metallic, semiconducting, insulating thin films, multilayered thin films, applications of thin films.

Texts/References

1. M. Ohring, **"Materials Science of Thin Films"**, Academic Press (**2012**).
2. K. L. Chopra, **"Thin Film Phenomena"**, Mc Graw-Hill (**1969**).
3. Eishabini-Riad, F. D. Barlow, **"Thin Film Technology Handbook"**, McGraw-Hill (**1998**).
4. D. M. Hoffman, B. Singh, J. H. Thomas, **"Handbook of Vacuum Science & Technology"**, Academic Press (**1998**).
5. J. M. Lafferty (Ed.), **"Foundations of Vacuum Science & Technology"**, Wiley (**1998**).

PHM512- NANOPHOTONICS AND NANOPLASMONICS

3-Credits (3-0-0)

Electromagnetics of Metals: Maxwell's Equations and EM Wave Propagation, Dielectric Function (Lorentz Drude Model and Beyond), Real Metals and Interband Transitions, dispersion, optical properties of nano materials, light propagation in nanostructures, photonic crystal, photonic bandgap engineering, photonic crystal fiber, **Surface Plasmon Polaritons (SPP):** SPP at a Single Interface, Multilayer Systems, Energy Confinement, Excitation of SPPs at Planar Interfaces through Prism and Grating Coupling, **Localized Surface Plasmons:** Localized vs. Propagating Plasmons, Mie Theory, Coupling Between Localized Plasmons, Void Plasmons and Metallic Nanoshells, **Surface Enhanced Raman Spectroscopy (SERS):** SERS Fundamentals, SERS Geometries, Enhancement of Fluorescence and Nonlinear Processes, **Applications:** Plasmonics based chemical and biosensors, Plasmonic Solar cells, Plasmonic Photodetectors, Plasmon Based Cancer Therapy, Overview of Silicon Plasmonics, fabrication aspects of nanophotonic devices.

Texts/References

1. Z. Zalevsky, **"Integrated Nanophotonic Devices"**, Elsevier Science (**2010**)
2. S. V. Gaponenko, **"Introduction to Nanophotonics"**, Cambridge University Press (**2010**)
3. S. Maier, **"Plasmonics Fundamentals and Applications"**, Springer (**2007**).
4. Michael Quinten, **"Optical Properties of Nanoparticle Systems"**, Wiley-VCH Verlag GmbH & Co. KGaA **(2011).**
5. H. Reather, **"Surface Plasmons on Rough and Smooth Surfaces and on Gratings"**, Springer (**1985**).

PHM514-OPTICAL FIBER COMMUNICATIONS

3-Credits (3-0-0)

Course objective: The aim of the course is to provide students with the design and operating principles of modern optical communication systems and networks. The course will provide fundamental knowledge of (i) optical fibers, types, losses, propagation modes, distortion, materials; (ii) types of sources used, (iii) receivers used., (iv) transmission link and system design.

Course outcome: After completing this course the students should be able to thoroughly understand the principle of optical fiber communications including fundamentals of fiber optics, sources, and receivers. Understand the different kind of losses, signal distortion in optical wave guides and other signal degradation factors. They will also be able to design fiber optics transmission link.

Contents: Fundamental concepts of data communication, Overview of optical fiber communication system; Step-index and graded-index optical fibers, Wave propagation in step-index fiber, Fiber modes, dispersions in single-mode fiber: Group-velocity, material, waveguide, polarization mode dispersions, dispersion induced limitations; Fiber losses: Attenuation coefficient, material absorption, scattering and bending losses; Fiber materials, Fiber fabrication methods; Photonic crystal fibers; Fiber cables and connectors.
Optical sources : Light emitting diodes (LED), Laser diodes (structure, quantum efficiency, modulation); Source-to-fiber coupling concepts, lensing schemes; Fiber-to fiber coupling and related losses, Fiber splicing ; Optical detectors: Detector responsivity, P-I-N and avalanche photodiodes, photodetector noise, response time, receiver sensitivity, Eye diagrams, BER measurements.
Case study of an optical fiber point-to-point digital link design: System considerations, Link-power budget, Rise-time budget, Transmission distance; Power penalties and error control; Concepts of Distribution networks and Local Area Networks, Wavelength-division multiplexing (WDM) concepts and components.

Texts/References

1. G. Keiser, **"Optical Fiber Communications", Ed. 4.** Tata-Mc-Graw-Hill (2010).
2. J. M. Senior, **"Optical Fiber communications",** Ed.3, Prentice-Hall (2009).
3. A. W. Snyder and J. Love, **"Optical Waveguide Theory"**, Springer (**2010**).
4. G. P. Agrawal, **"Fiber-Optic Communication Systems"**, Ed 3, John Wiley & Sons (2011).
5. A. Ghatak and K. Thyagrajan, **"Introduction to Fiber Optics",** Cambridge University Press (**1998**).

PHM516-ASTROPHYSICS-II
3-Credits (3-0-0)
Course objective: The primary objective of this course is to give the students basic knowledge of binary stars system, galaxies, and Modern Astronomy. Students will also learn about the basic model of Modern cosmology and early Universe.
Course outcome: Students will be able to

- Explain the various processes involved in the system of binary stars.
- Describe the different types of galaxy system and their distributions.
- Explain the origin and applications of 21-cm Hydrogen line in astronomy.
- Describe the basic principle of cosmology and Hubble's flow.
- Examine the thermal history of Universe and current cosmological problems.

Binary Stars and Galaxies: Interacting Binary Systems, Accretion Disks, X-ray Sources, Classification of Binary Stars, Mass determination, Mass Transfer in Binary Systems, Classification of galaxies, Elliptical Galaxies, spiral galaxies, Milky way galaxy, Galaxy Clusters, Galactic rotation curve, Evidence of dark matter, Galactic Stellar Distributions and Populations, Oort Constants, Oort Limit, Globular Clusters.
Overview of Modern Astronomy: 21-cm hydrogen line, cosmic radio sources, quasars, pulsars, gravitational lensing, gamma ray bursters. Sources of Gravitational Waves
Cosmology and the early Universe: Cosmological principle, Robertson- Walker metric. Redshift of galaxies and Hubble's law. Magnitude-red shift relation, Hubble's constant, and deceleration parameter. Friedmann equations and standard models. Closed, flat and open universes. Age of the universe, critical density. Galaxy clusters and problem of missing mass or missing light, dark matter. Thermal history of early universe, helium formation, decoupling of matter and radiation, microwave background radiation. Cosmological constant and the late time acceleration

Texts/References

1. **"An Introduction to Modern Astrophysics and Cosmology (Second Edition)"**, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co., 2006.
2. **"Introductory Astronomy and Astrophysics (Fourth Edition)"**, M. Zeilik and S. A. Greg.
3. **"The Physical Universe: An Introduction to Astronomy"**, Frank Shu, University Science Books.
4. Saunders College Publishing, 1998 **"Fundamental of Astronomy (Fifth Edition)"**, H. Karttunen et al. Springer, 2007.
5. **"Introduction to Cosmology"**, by J. V. Narlikar (Cambridge University Press, 2002).
6. **"Cosmology"** by Steven Weinberg (Oxford University, 2008).
7. **"Modern Cosmology"** by Scott Dodelson, Academic Press; 1 edition (March 27, 2003).
8. **"The early Universe"** by Kolb and Turner.

PHM518-MAJOR PROJECT
20-Credits

This will be a 20-credit course where students will prepare a written project report (in a specified format) to be submitted in the school (or GBU Library) and to be presented to the seminar committee.

1. The objective of the project may be summarized as: (i) To prepare the student for deep and detailed exploration of a s elected topic of interest, (ii) To prepare the student for col lecting relevant data through array of available resources e.g. published books, monograms, scientific journals, onli ne/web material, scientific magazines etc., (iii) To prepare the student for presenting a scientific topic, subject to the s cientific community in a professional way, (iv) To cultivat e the habit of discussing, sharing and communicating the i deas with the scientific community, (v) Final completion o f a project based on experimental/simulation/theory/fabric ation or characterization etc. (vi) To promote the students to write research papers based on the outcome of the proje ct and present the results in national/international conferen ces.
2. Student must interact on day-to-day basis with the project advisor and should report his/her progress regularly.