Master of Science

in

Physics

Course Structure & Syllabus

Department of Physics & Photonics Science

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

Curriculum Structure for M. Sc. Program

SEMESTER-I

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	18	Core courses
XX-6MN	Programme Core (Lab) Courses	05	Lab courses
Total		**23**	

SEMESTER-II

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	20	Core courses
XX-6MN	Programme Core (Lab) Courses	05	Lab courses
Total		**25**	

SEMESTER-III

Course No.	Course Name	Credits	Course Type
XX-6MN	Programme Core Courses	08	Core courses
XX-7MN	Programme Electives*	08	Elective courses
XX-796	Summer Internship/Industrial Training	01	Experiential Learning Course
XX-798	M.Sc. Dissertation	08	Research Work
Total		**25**	

SEMESTER-IV

Course No.	Course Name	Credits	Course Type
XX-7MN	Programme Electives*	08	Elective courses
XX-70N	Institute Elective (Interdisciplinary)	04	Open Elective
XX-797	Community Connect	01	Community Learning
XX-799	M.Sc. Dissertation	10	Research Work
Total		**23**	

* Programme Electives: Any course listed in scheme as Annexure (List of Electives).

SEMESTER-I

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-611	Programme Core Course	4	0	0	4	4
XX-612	Programme Core Course	4	0	0	4	4
XX-613	Programme Core Course	4	0	0	4	4
XX-614	Programme Core Course	4	0	0	4	4
XX-615	Programme Core Course	2	0	0	2	2
XX-616	Programme Core (Lab) Course	0	0	4	4	2
XX-617	Programme Core (Lab) Course	0	0	4	4	2
XX-618	Programme Core (Lab) Course	0	0	2	2	1
Total		**18**	**0**	**10**	**28**	**23**

SEMESTER-II

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-621	Programme Core Course	4	0	0	4	4
XX-622	Programme Core Course	4	0	0	4	4
XX-623	Programme Core Course	4	0	0	4	4
XX-624	Programme Core Course	4	0	0	4	4
XX-625	Programme Core Course	4	0	0	4	4
XX-626	Programme Core (Lab) Course	0	0	4	4	2
XX-627	Programme Core (Lab) Course	0	0	4	4	2
XX-628	Programme Core (Lab) Course	0	0	2	2	1
Total		**20**	**0**	**10**	**30**	**25**

SEMESTER-III

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-631	Programme Core Course	4	0	0	4	4
XX-632	Programme Core Course	4	0	0	4	4
XX-7MN	Programme Elective-I*	4	0	0	4	4
XX-7MN	Programme Elective-II*	4	0	0	4	4
XX-796	Summer Internship/Industrial Training	0	0	0	0	1
XX-798	M.Sc. Dissertation	-	-	-	-	8
Total		**16**	**0**	**0**	**16**	**25**

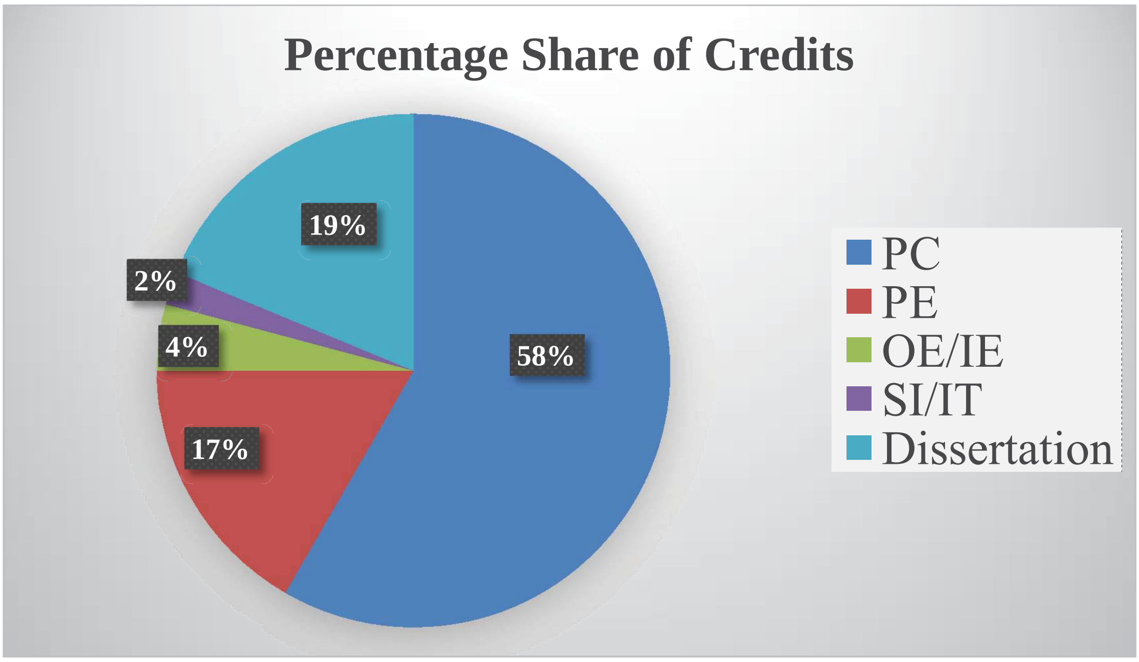
SEMESTER-IV

Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
		L	T	P		
XX-7MN	Programme Elective –III*	4	0	0	4	4
XX -7MN	Programme Elective –IV*	4	0	0	4	4
XX-70N	Open Elective/Institute Elective	4	0	0	4	4
XX-797	Community Connect*	0	0	0	0	1
XX-799	M.Sc. Dissertation	-	-	-	-	10
Total		**12**	**0**	**0**	**12**	**23**

*Programme Electives: Any course listed in scheme as Annexure (List of Electives).

Types of Courses and credits in each Semester

Types of Courses	1st	2nd	3rd	4th	Total Credits
PC	23	25	8	0	56
PE	0	0	8	8	16
OE/IE	0	0	0	4	04
SI/IT	0	0	1	1	02
Dissertation	0	0	8	10	18
Total					**96**



Curriculum for M.Sc. Physics Program
(2 Years) in Consonance with NEP-2020

SEMESTER-I

S. No.	Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
			L	T	P		
1	PH-611	Classical Mechanics	4	0	0	4	4
2	PH-612	Quantum Mechanics - I	4	0	0	4	4
3	PH-613	Mathematical Physics	4	0	0	4	4
4	PH-614	Electrodynamics	4	0	0	4	4
5	PH-615	Indian Knowledge System	2	0	0	2	2
6	PH-616	Electricity and Optics Lab	0	0	4	4	2
7	PH-617	Computational Physics Lab	0	0	4	4	2
8	PH-618	Measurement and Instrumentation Lab	0	0	2	2	1
	Total		**18**	**0**	**10**	**28**	**23**

SEMESTER-II

S. No.	Course No.	Subject	Teaching Schedule			Hours/ Week	Credits
			L	T	P		
1	PH-621	Atomic and Molecular Spectroscopy	4	0	0	4	4
2	PH-622	Quantum Mechanics - II	4	0	0	4	4
3	PH-623	Electronics	4	0	0	4	4
4	PH-624	Solid State Physics	4	0	0	4	4
5	PH-625	Thermodynamics and Statistical Physics	4	0	0	4	4
7	PH-626	Spectroscopy Lab	0	0	4	4	2
8	PH-627	Solid State Physics Lab	0	0	4	4	2
9	PH-628	Electronics Lab	0	0	2	2	1
	Total		**20**	**0**	**10**	**30**	**25**

SEMESTER-III

S.No	Course No.	Subject	Teaching Schedule			Hours/Week	Credits
			L	T	P		
1	PH-631	Particle Physics	4	0	0	4	4
2	PH-632	Nuclear Physics	4	0	0	4	4
3	PH-7MN	Program Elective-I*	4	0	0	4	4
4	PH-7MN	Program Elective-II*	4	0	0	4	4
5	PH-796	Summer Internship/ Industrial Training**	0	0	0	0	1
6	PH-798	M.Sc. Dissertation	-	-	-	-	8
Total			**16**	**0**	**0**	**16**	**25**

* Program Electives are listed in Annexure A.

** Summer Internship/Industrial Training has to be undertaken by the students just after second semester during summer vacation and its evaluation will be done in the third semester.

SEMESTER-IV

S.No.	Course No.	Subject	Teaching Schedule			Hours/ week	Credits
			L	T	P		
1	PH-7MN	Program Elective-III*	4	0	0	4	4
2	PH-7MN	Program Elective-IV*	4	0	0	4	4
3	PH-70N	Institute Elective**	4	0	0	4	4
4	PH-497	Community Connect***	-	-	-	-	1
5	PH-799	M.Sc. Dissertation	-	-	-	-	10
Total			**12**	**0**	**0**	**12**	**23**

** Institute Electives are listed in Annexure A.

Total Credit of the Program = 96

Total Program Core Credit = 56; Total Program Elective Course Credit = 16; Total Institute Elective Course Credit = 04, Industrial Training,/Summer Internship =1, Community Connect =1 M.Sc. Dissertation =18

Annexure A
(List of Program Electives and Institute Electives)

Program Elective-I

Course Code	Subject Name	L-T-P	Credits
PH-711	Experimental Techniques in Physics	4-0-0	4
PH-712	Nuclear Detectors and Accelerator Physics	4-0-0	4
PH-713	Quantum Computation and Information	4-0-0	4

Program Elective-II

Course Code	Subject Name	L-T-P	Credits
PH-714	Optical Fiber Communication	4-0-0	4
PH-715	Polymer & Liquid Crystals	4-0-0	4
PH-716	Optoelectronics	4-0-0	4

Program Elective-III

Course Code	Subject Name	L-T-P	Credits
PH-717	Nano-Structured Materials	4-0-0	4
PH-718	Advanced Solid State Physics	4-0-0	4
PH-719	Plasma Physics	4-0-0	4
PH-720	Astronomy and Astrophysics	4-0-0	4

Program Elective-IV

Course Code	Subject Name	L-T-P	Credits
PH-721	Thin Film Technology	4-0-0	4
PH-722	Quantum Field Theory	4-0-0	4
PH-723	Quantum Optics	4-0-0	4
PH-724	Atmospheric and Space Physics	4-0-0	4

Institute Elective Courses

Course Code	Subject Name	L-T-P	Credits
PH-701	Nuclear Science and Applications	4-0-0	4
PH-702	Nanotechnology	4-0-0	4
PH-703	Properties of Matter	4-0-0	4
PH-704	Quantum Computation	4-0-0	4

Course Name: **Classical Mechanics** Course Code: **PH-611** Course Type: **Core**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To make the students aware of the limitation of Newtonian Mechanics and the alternate formalism of Lagrange and Hamilton. 2. To discuss the problems associated with planetary motion, rigid body dynamics, and coupled oscillators. 3. To introduce the idea of canonical transformation and transition from classical to quantum mechanics through Hamilton-Jacobi theory.
Course Content
Newton's laws of motion, shortcomings of Newtonian Mechanics. Lagrangian Mechanics: Constraints, generalized coordinates, principle of virtual works, D'Alembert's principle, Lagrange's equations of motion for conservative and non-conservative systems, Lagrange's equations from D'Alembert's principle, applications of Lagrangian formulation. Hamiltonian Mechanics: Generalized momenta and cyclic coordinates, Hamilton's principle and the Lagrange's equations, Hamilton's equations of motion, application of Hamiltonian formulation, Routhian. Central force: Two body central force problem, differential equations for orbits, Kepler's laws, virial theorem, scattering in a central force field, Rutherford scattering. Variational principles and principle of least action. Canonical transformations. Poisson and Lagrange brackets, Liouville's theorem, phase space dynamics, stability analysis. Hamilton-Jacobi equation and transition to quantum mechanics. Coupled oscillators. Dynamics of rigid body. Non-inertial coordinate systems. Symmetry, invariance and Noether's theorem. Basics of special theory of relativity and relativistic mechanics. Four-vectors formulation. Basics of covariant formulation of electrodynamics.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Use the principle of virtual work, Lagrange's and Hamilton's approach to solve mechanical problems. CO2. Relate the central force field problems to the celestial mechanics. CO3. Connect classical and quantum mechanics through the Hamilton-Jacobi theory.
Books and References 1. Classical Mechanics by Goldstein H., Narosa Publishing House, New Delhi. 2. Mechanics by Landau L D and Lifshitz E. M., Pergamon Press, Oxford. 3. The Feynman Lectures on Physics by Feynman, Leighton, and Sands, Pearson. 4. Classical Mechanics by Upadhyaya J. C., Himalaya Publishing House. 5. Classical Mechanics by Rana N. C. and Joag P. S., Tata McGraw-Hill Publishing Co. New Delhi. 6. Classical Mechanics by Aruldhas G., PHI Learning Pvt. Ltd., Delhi. 7. Classical Mechanics by Rao S., Prentice Hall of India, New Delhi.

Course Name: **Quantum Mechanics-I**
Course Code: **PH-612**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To make the students understand where classical mechanics fails and the emergence of quantum mechanics.
2. To demonstrate the extraordinary power of quantum mechanics in dealing with microscopic world.
3. To make the students feel why is quantum mechanics so bizarre although proved to be a supremely successful theory.

Course Content

The wave function, normalization, linear momentum, wave-particle duality, commutators and the Heisenberg's uncertainty principle. Wave-function in coordinate and momentum representations. Schrodinger equation and its applications in one dimension. Tunneling through potential barriers. Mathematical background of quantum mechanics: Hilbert space, observables, eigenvalues and eigenvectors, generalized statistical interpretation, Schwarz's inequality, Schmidt orthonormalisation technique, operators, Dirac's bra and ket notation, linear algebra. Quantum mechanics in three dimensions: The hydrogen atom, orbital and spin angular momenta, addition of angular momenta, Clebsch-Gordan coefficients. Stern-Gerlach experiment. Identical particles, Pauli's exclusion principle and quantum statistical mechanics.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1. Study physical systems by solving the Schrodinger equation.
CO2. Extract quantitative information about microphysical world.
CO3. Appreciate the mathematical rigour and brilliance of quantum mechanics.

Books and References

1. Introduction to Quantum Mechanics by Griffiths, D. J., Pearson India Education service Pvt. Ltd.
2. Quantum Mechanics Concepts and Applications by Zettili N., John Wiley and Sons, Ltd. Publication.
3. The Feynman Lectures on Physics by Feynman, Leighton, and Sands, Pearson.
4. The Principles of Quantum Mechanics by Dirac P. A. M., Oxford Science Publications.
5. Principles of Quantum Mechanics by Shankar R., Plenum-New York.
6. Quantum Mechanics: Theory and Applications by Ghatak A. and Lokanathan S., Kluwer Academic Publishers.

Course Name: **Mathematical Physics**
Course Code: **PH-613**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To bring the mathematical clarity about the physical laws of nature and to enhance the necessary mathematical skills.
2. To use it in solving problems in classical and quantum mechanics, electrodynamics and other fields of theoretical Physics.
3. To overcome the common fear for mathematical rigour by making the students realize how beautifully nature works simply on a mathematical framework.

Course Content

Complex analysis: Analytic function, Cauchy-Riemann conditions, harmonic function, Cauchy's integral theorem, Cauchy's integral formula, Taylor's series, Laurent's series, singularity, pole, residue, Cauchy's residue theorem, contour integration. Special functions: Power series solutions to differential equations, Frobenius method, Legendre, Bessel, Hermite, Laguerre polynomials. Fourier series. Integral transformation: Laplace and Fourier transformations. Gamma and beta functions. Elementary probability theory, binomial, Poisson, and normal distributions. Central limit theorem. Green's function. Tensor analysis. Elementary group theory.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Appreciate the use various mathematical tools, like, complex analysis, integral transformation, tensor analysis, Green's function in solving real-life problems.
CO2. Solve higher order linear ordinary differential equations with constant coefficients.
CO3. Apply their mathematical understanding to analyze complex engineering problems.

Books and References

1. Mathematical Methods for Physicists by Arfken G., Academic Press, San Diego, U.S.A.
2. Mathematical Methods for Physicists and Engineers by Harvil and Pipes, Tata McGraw Hill Publishing Company, New Delhi.
3. Advanced Engineering Mathematics by Kreyszig E., John Wiley & Sons, New York.
4. Mathematical Physics by Dass H.K., S. Chand and Company Lmd, New Delhi.
5. Matrices and Tensors in Physics by Joshi A.W., New Age International Publishers, New Delhi.
6. Elements of Group Theory for Physicists by Joshi A.W., New Age International Publishers, New Delhi.

Course Name: **Electrodynamics**
Course Code: **PH-614**
Course Type: **Core**

Contact Hours/Week: **4L** | Course Credits: **04**

Course Objectives

1. To impart knowledge about the Electric field, Magnetic field, and Electromagnetic theory.
2. To show the unification of three grand branches of physics which were dealt separately by the physicists before Maxwell, viz., electricity, magnetism, and optics, and to demonstrate why the unification of physical theories is a holy grail in physics
3. To introduce the fundamental concepts relevant to energy transfer, reflection, refraction of electromagnetic waves across the interface.

Course Content

Electrostatics: Work and Energy in electrostatics, Poisson and Laplace equations, Earnshaw's theorem, Boundary conditions and Uniqueness theorem, Multipole expansion, Method of electrostatic images. Magnetostatics: Magnetic scalar and vector potentials, magnetic field vector and Boundary conditions, Maxwell's modification of Ampere's law. Time Varying Fields: Continuity equation, Maxwell's equations, wave equation in free space. Poynting theorem and Poynting vector, Electromagnetic scalar and vector potential, Gauge transformations; Lorentz invariance of Maxwell's equations. Electromagnetic Waves: Plane waves in non-conducting and conducting media, skin depth, polarization-linear and circular polarization, Reflection and refraction of electromagnetic waves across a dielectric interface at a plane surface between dielectrics. Total internal reflection, Polarization by reflection, Reflection from the surface of a metal. Electromagnetic Radiation: Radiation from moving charges and dipoles, Retarded Potentials, Lienard-Wiechert Potentials, Transmission lines and waveguides. Dispersion relation in plasma.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1. Gain understanding of Maxwell's equations & electromagnetic boundary conditions.
CO2. Understanding the phenomenon of reflection, refraction and polarization.
CO3. Distinguish between a good metal and a good dielectric.
CO4. Grasp idea of electromagnetic wave propagation through space and wave guides.

Books and References

1. Introduction to Electrodynamics by Griffiths D. J., Pearson Education Pvt. Ltd., New Delhi.
2. Classical Electrodynamics by Jackson J. D., John Wiley & Sons Pvt. Ltd., New York.
3. Classical Electromagnetic Radiation by Marian J. B. and Heald M. A., Academic Press, New Delhi.
4. Classical Electrodynamics by Puri S. P. Tata McGraw-Hill Publishing Company, New Delhi.
5. Electromagnetic Waves and Radiating Systems by Jordon E. C. and Balmain K. G., Prentice Hall of India, New Delhi.
6. Elements of Electromagnetics by Matthew N. O. Sadiku Oxford University Press.

Course Name: **Indian Knowledge System** Course Code: **PH-615** Course Type: **Core**
Contact Hours/Week: **2L**   Course Credits: **02**
Course Objectives 1. To create awareness among the students about the history and culture of our land. 2. Ushering new areas of research in the field of Indian knowledge system. 3. To explore the scientific and rational facets of traditional Indian knowledge.
Course Content
Bhāratīya Civilization and Philosophy: Genesis of the land, Antiquity of civilization, Traditional Knowledge System, The Vedas, Main Schools of Indian Philosophy, Ancient Education System: Takṣaśilā University and Nālandā University, Knowledge Export from Bhārata. Science, Astronomy, and Mathematics: Concept of Matter, Life and Universe, Gravity, Velocity of Light, Aeronautics, Vedic Cosmology and Modern Concepts, Sun, Earth, Moon, and Eclipses, Concepts of Zero and Pi, Number System, Vedic Mathematics. Engineering, Technology, and Architecture: Pre-Harappan and Sindhu Valley Civilization, Juices, Dyes, Paints and Cements, Glass and Pottery, Metallurgy, Engineering and Technology in Vedic and Post-Vedic ages, Marine Technology. Life, Environment, and Health: Life Science in Plants, Anatomy, Physiology, Agriculture, Ecology and Environment, Āyurveda, Integrated Approach to Healthcare, Medicine, Microbiology, Surgery, and Yoga.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Promote the youths to explore the various fields of research associated with Indian knowledge system. CO2. Relate the ancient Indian education to the various aspects of the modern scientific approach. CO3. Add career, professional and business opportunities in this field.
Books and References 1. Histrory of Science in India Volume-1, Part-I, Part-II, Volume VIII, by Sibaji Raha, et al. National Academy of Sciences, India and The Ramkrishan Mission Institute of Culture, Kolkata (2014). 2. Pride of India- A Glimpse of India's Scientific Heritage edited by Pradeep Kohle et al. Samskrit Bharati (2006). 3. Vedic Physics by Keshav Dev Verma, Motilal Banarsidass Publishers (2012). 4. Textbook on The Knowledge System of Bhārata by Bhag Chand Chauhan, 5. India's Glorious Scientific Tradition by Suresh Soni, Ocean Books Pvt. Ltd. (2010).

Course Name: **Electricity and Optics Lab** Course Code: **PH-616**
Contact Hours/Week: **4P**   Course Credits: **02**
Course Objectives 1. To make students aware of instrument handling. 2. To make students learn experimental skills. 3. Make students capable to work in groups.
List of Experiments* 1. To find the wavelength of light by Newton's ring method. 2. To find the wavelength of light using the Diffraction grating. 3. To find the refractive index of the material of the prism using a spectrometer. 4. Variation of the magnetic field along the axis of a current carrying coil and hence find the radius of the coil. 5. To estimate the resistivity of semiconductor crystal by four probe method. 6. Realization of hysteresis loop of magnetic material. 7. To study the interference pattern using Michelson interferometer and estimate wavelength of light. 8. To study the polarization of light and find a Brewster's angle. 9. To study the interference phenomenon using a Fresnel Biprism setup. 10. To study the optical fiber parameter. * New experiments may be added as per requirement. ***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*
Course Outcomes Upon successful completion of the course, the students will be able to CO1. To realize the behavior of light. CO2. To study magnetic phenomenon in solids. CO3. Study of optical fiber parameter. CO4. Design apparatus for electrical study. CO5. Understand various physical phenomenons.

Course Name: **Computational Physics Lab** Course Code: **PH-617**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

1. To illustrate the importance of numerical solutions to many real life physics problems where analytical solutions are impossible to obtain.
2. To make the students feel the ever-growing importance of programming and simulation in various branches of modern physics
3. To correlate computer programming, mathematics and physics.

List of Experiments

1. Use of programming languages, like, FORTRAN, C, C++, PYTHON, and commercial numerical tools, like, MATHEMATICA and MATLAB, to perform basic mathematical calculations, e.g., matrix operations, sum of a given series etc.
2. To read data from an input file and write the output in a file.
3. To plot graphs in two and three dimensions using softwares.
4. To find the roots of an equation by iteration, bisection, regula falsi, and Newton-Raphson methods.
5. To interpolate and extrapolate a given data set.
6. To perform least square curve fitting into linear equation and polynomials.
7. To perform numerical differentiation.
8. To perform numerical integration.
9. To study the motion of a particle in the central force field and plot the output for visualization.
10. To study the motion of a projectile using simulation and plot the output for visualization.
11. To find numerical solutions to the equation of motion of a simple harmonic oscillator and plot the outputs for visualization both classically and quantum mechanically.
13. To solve the Schrodinger equations for a particle for some simple potentials, e.g., infinite and finite square well potentials, Dirac-delta potential, and for the free particles.
14. To solve Laplace’s and Poisson’s equations in the context of electrodynamics.

***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Learn the use of programming languages, mathematical, simulation as well as plotting tools.
CO2. Design algorithm to a given physical problem.
CO3. Solve problems using computers.
CO4. Analyze physical problems from obtained output.

Course Name: **Measurement and Instrumentation Lab** Course Code: **PH-618**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

1. To make students aware of instrument handling.
2. To make students learn experimental.
3. Make students capable to work in groups.

List of Experiments

1. To study the thermal expansion phenomenon using a dilatometer.
2. To measure I-V characteristics of a p-n junction diode and extract its parameters.
3. To measure C-V characteristics of a p-n junction diode and extract its parameters.
4. To calibrate a thermocouple for temperature measurement.
5. To use the gauges to measure low pressure/ vacuum level.
6. To Study LDR Characteristics.
7. Measurement of speed using photoelectric pickup.
8. Measurement of linear displacement using L.V.D.T.
9. To study the temperature transducer.
10. To study optocoupler trainer.

***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Realize theoretical concepts using experiments.
CO2. Enhance experimental skills.
CO3. Study various properties of solids.
CO4. Understand various physical phenomena.

Course Name: **Atomic and Molecular Spectroscopy** Course Code: **PH-621** Course Type: **Core**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the fundamentals of atomic and molecular Physics of the systems. 2. To introduce about how to describe the structure of atoms and molecules on the basis of quantum mechanics. 3. To introduce about the Physics of spectra of alkali elements, two-electron systems, various coupling schemes, diatomic molecules, their electronic states, vibrations and rotations, their spectra and a brief discussion of polyatomic molecules. 4. To introduce about the behavior of atoms in external electric and magnetic fields. 5. To introduce about the fundamentals of Raman spectroscopy and its application for the structure determination of molecules.
Course Content
Quantum States of One Electron Atom: Atomic orbitals -Hydrogen spectrum – The Pauli Exclusion Principal – Ritz combination principle, Spectra of alkali elements, Spin – orbit interaction; Larmor's theorem and the fine structure in alkali spectra – Equivalent and non-equivalent electrons-penetrating and non-penetrating orbits, quantum defect and screening parameter, selection rules and intensity rules, breadth of the spectrum-Doppler effect, Natural breadth, external effects. Two Electron Systems: General characteristics of the energy levels of alkaline earth elements; selection rules and intensity rules, Interaction energy in LS or Russell-Saunder's coupling and JJ-coupling, LS-coupling, Hyper fine structure (qualitative) Normal and Anomalous Zeeman effect, Paschen Back effect, Stark effect, Lande's g-factor in LS coupling. Molecular Structure: Types of molecules - Diatomic linear symmetric top, asymmetric top and spherical top molecules, Types of molecular energy states and molecular spectra, Born Oppenheimer approximation-Rotational Spectra, Spectra of diatomic molecules as a rigid rotator-Energy levels and spectra, diatomic molecules as a non rigid rotor. Vibrational Spectra: Vibrational energy of a diatomic molecule as a simple harmonic oscillator – Energy levels and spectrum, Vibrating molecule as an-harmonic oscillator– Morse potential energy curve - Molecules as vibrating rotator Vibration spectrum of diatomic molecule – PQR branches IR spectrometer (qualitative). Raman Spectroscopy: Raman effect - Quantum theory, Pure rotational spectra of diatomic molecules – Vibration rotation Raman spectrum of diatomic molecules – Experimental set up for Raman spectroscopy – Application of IR and Raman spectroscopy in the structure determination of simple molecules, Franck Condon principle.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Describe the atomic spectra of one and two valance electron atoms. CO2. Explain the change in behavior of atoms in external applied electric and magnetic field. CO3. Explain rotational, vibrational, electronic and Raman spectra of molecules. CO4. Apply these concepts to understand the structure of molecules.
Books and References 1. Introduction to Atomic Spectra by H.E. White, Tata Mcgraw Hill. 2. Fundamentals of molecular spectroscopy by C.B. Banwell & E. M. McCash, Tata Mcgraw Hill. 3. Spectroscopy Vol. I, II & III by Walker & Straughen, Springer. 4. Introduction to Molecular spectroscopy by G.M. Barrow, Tata Mcgraw Hill.

Course Name: **Quantum Mechanics-II**
Course Code: **PH-622**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To apply the theoretical knowledge of the quantum mechanics acquired by the students in the first semester course solve real life physics problems.
2. To study the structure of molecules and atomic systems and to know how electromagnetic radiation interacts with these systems.
3. To enable the students to extract the structure of matter from the scattering of particles.

Course Content

Time-independent perturbation theory. The variational principle. WKB approximation. Time-dependent perturbation theory and Fermi's golden rule, selection rules. Quantum scattering theory: Scattering amplitude, differential and total cross-section, phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Semi-classical theory of radiation. Concept of measurement in quantum mechanics and Bell's theorem. Basics of quantum computation: Qubits, Bloch sphere representation of a qubit, quantum logic gates.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Realize how our notion of reality which are perceived by doing some sort of measurements on various physical observables are completely defied by quantum mechanics.

CO2. Get the taste of paradigm shift from the domain of non-relativistic quantum mechanics to the domain of evolving quantum field theories till date.

CO3. Learn the fundamental of the quantum computing.

Books and References

1. Modern Quantum Mechanics, J. J. Sakurai, Pearson India Education Pvt. Ltd
2. Introduction to Quantum Mechanics by Griffiths, D. J., Pearson India Education Pvt. Ltd.
3. Quantum Mechanics by Schiff L. I., McGraw Hill Book.
4. Quantum Mechanics by Merzbacher E., John Wiley & Sons.
5. Quantum Mechanics: Concepts and Applications by Zettili N., John Wiley and Sons, Ltd. Publication.
6. The Feynman Lectures on Physics by Feynman, Leighton, and Sands, Pearson.
7. The Principles of Quantum Mechanics by Dirac P. A. M., Oxford Science Publications.
8. A First Book of Quantum Field Theory by Lahiri A. and Pal P. B., Alpha Science International Ltd.
9. Quantum Computer Science: An Introduction by N. David Mermin, Cambridge University Press.

Course Name: **Electronics** Course Code: **PH-623** Course Type: **Core**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the basic semiconductor devices, operational amplifier and communication systems. 2. To introduce the fundamental concepts relevant to homo, hetro-junctions, electronic circuits, and different modulation techniques used in communication. 3. To enable the students to understand the factors that required for the operation as well as control of electronic, optoelectronic devices.
Course Content
Semiconductor Devices: Diodes, Junctions, Transistors, Field effect devices, homo- and hetro-junctions devices, device structure, device characteristics, frequency dependences and applications. Optoelectronic Devices: LEDs, Diodes Lasers, Photodetectors and Solar Cells, Electronic Circuits: Differential amplifier, Operational amplifier OP-AMP as inverting, Non-inverting, Scalar, Summer, Integrator, Differentiator, Schmitt trigger and Logarithmic amplifier, Digital techniques and applications as resistors, counters, comparators and similar circuits. Convertors and Vibrators: A/D and D/A convertors, applications. Transducers. Microprocessors and microcontroller basics. Multivibrators (Bistable, Monostable, Astable), Modulation Techniques: Basic concepts of communication systems, Need for modulation, Information in communication system, Coding, Types of Pulse modulation, Pulse width modulation (PWM), Pulse position Modulation (PPM), Principle of Pulse code modulation (PCM).
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify and Characterize semiconductors, diodes, transistors and operational amplifiers. CO2. Bias the transistors and FETs for amplifier applications. CO3. Design op-amp circuits to perform arithmetic operations. CO4. Design simple analog circuits. CO5. Understand fundamental principles of communication system.
Books and References 1. Physics of Semiconductor Devices, S. M. Sze, WILEY INDIA 2. Semiconductor Physics and Devices- Basic Principles, Donald A Neamen 4th Edition Mc Graw Hill Publication 3. Op-amp and linear Integrated Circuits, Ramakant Gayakwad, Pearson Publication Fundamental of electrical circuits, Charles K. Alexander and Matthew N.O. Sadiku, Tata McGraw Hill Publication

Course Name: **Solid State Physics**
Course Code: **PH-624**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To impart knowledge about the solid state of the materials.
2. To introduce the fundamental concepts relevant to crystal structure, phonon gas and the electron gas in solids.
3. To enable the students to understand the factors that affect thermal, electrical behavior of solids.

Course Content

Overview of Crystal structure, Reciprocal lattice, Diffraction conditions, Brillouin zones, Atomic scattering factor and structure factor; types of crystal binding, cohesive energy of ionic crystals, covalent and metallic bonding, hydrogen bonding. Lattice vibrations (monoatomic and diatomic lattice), elastic waves, density of states of a continuous medium (1D, 2D, 3D), quantization of elastic waves, phonon momentum. Phonon heat capacity, Debye and Einstein theory of specific heat, Lattice Thermal Conductivity and Umklapp Processes, Semiconductors: Direct and Indirect Absorption Processes, Equations of motion, effective mass, intrinsic carrier concentration, impurity conductivity, Cyclotron resonance and Magnetoresistance in semiconductors. Lattice vacancies, diffusion, colour centers, F-centers, Schottky and Frenkel defects, dislocations (edge and screw), Burger vector, slip, planar (stacking) faults; grain boundaries, elastic and thermal properties, analysis of stress strain relations, elastic compliance and stiffness constant. Free electron theory (Lorentz Drude model) and its failure, Hall Effect, Sommerfield theory, electrical conductivity, Fermi-Dirac distribution function, Fermi energy. Introduction to dia, para and ferromagnetism, Superconductivity, critical field and temperature, Meissner effect, isotope effect, Type-1 and Type-II superconductors, vortex state, BCS theory, origin of energy gap

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts of crystallography, different theories of heat and electric conduction.

CO2. Describe problems like basic crystals, dependence of heat capacity and thermal conductivity with temperature, Fermi surfaces in description of electric and magnetic properties of solids.

CO3. Apply principles to determine crystal structure, thermal behavior of solids, magnetic and electric behavior of solids.

CO4. Assess the results obtained by solving above problems.

Books and References

1. Introduction to Solid State Physics by Kittle C., John Wiley & Son.
2. Solid State Physics by Dekker A. J. , Macmillan India Ltd., New Delhi.
3. Introduction to Solids by Azaroff L. V., Tata McGraw-Hill, New Delhi.
4. Solid State Physics by Ashcroft N. W. and Mermin N. D., Thomson Asia Pte. Ltd.
5. Elementary Solid State Physics by Ali Omar, Addison Wesley Publishing Company.
6. Solid State Physics, M.A. Wahab, Narosa Publication

Course Name: **Thermodynamics and Statistical Physics** Course Code: **PH-625** Course Type: **Core**
Contact Hours/Week: **4L**   Course Credits: **04**
Course Objectives 1. To impart knowledge about the fundamentals of thermodynamics and statistical mechanics. 2. To introduce the fundamental concepts relevant to thermodynamic potentials, probability, classical and quantum statistics. 3. To enable the students to understand the statistical basis of thermodynamics and its applications to magnetism, black body radiation and phase transition.
Course Content
Thermodynamics: Macroscopic and microscopic coordinates, Extensive and intensive variables, Thermal equilibrium, The laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell's relations, Chemical Potential, TdS and energy equations. Probability and Kinetic theory: The macroscopic and microscopic states, Postulate of equal a priori probability, Probability densities, connection between statistics and thermodynamics, classical ideal gas, Gibbs' paradox, Phase space densities; Liouville's theorem and its consequences, The Boltzmann equation; transport phenomena. Classical Statistical Mechanics: Postulates; Microcanonical, canonical, and grand canonical ensembles, partition functions, fluctuation of energy and density, Equipartition and virial theorems, Ideal gas in canonical and grand canonical ensemble. Quantum Statistical Mechanics: Quantum-mechanical ensemble theory, Introduction to density matrix and its applications, Microcanonical ensemble of ideal Bose, Statistics of the occupation numbers, Statistical mechanics of Bosons, Fermions, Bose-Einstein condensation, Blackbody radiation and Planck's law of radiation, Magnetic behavior of an ideal Fermi gas, Diamagnetism, Paramagnetism. Phase Transition and critical phenomenon: First and second order phase transitions, Ising model, Critical phenomena, Landau theory of phase transitions.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify the link between statistics and thermodynamics, classical and quantum statistics and its applications. CO2. Describe problems like ideal gas, transport phenomenon, critical phenomenon and black body radiation. CO3. Apply principles to explain Gibbs'paradox, magnetism and phase transitions. CO4. Assess the results obtained by solving above problems.
Books and References 1. Heat and Thermodynamics by Zemansky M. W. and Dittman R., Mc Graw Hill Co., NewYork. 2. Statistical Mechanics by Patharia R.K, Pergamon, Oxford. 3. Statistical Mechanics by Huang K., Wiley Eastern, New Delhi. 4. Elementary Statistical Physics by Kittel C., Wiley Eastern, New Delhi. 5. Statistical Mechanics by Agarwal B.K. and Eisner M, Wiley Eastern, New Delhi. 6. Introduction to Modern Statistical Mechanics by Chandler D., Oxford University Press, New Delhi.

Course Name: **Spectroscopy Lab** Course Code: **PH-626**	
Contact Hours/ Week: **4P**	Course Credits: **02**

Course Objectives

1. To make students aware of instrument handling.
2. To make students learn experimental skills.
3. Make students capable to work in groups.

List of Experiments

1. NMR spectroscopy of selected materials.
2. To measure Landau's g-factor using electron spin resonance.
3. Optical absorption spectra of materials, estimation of (direct / indirect) band-gap.
4. To verify the existence of discrete atomic energy levels and determine the minimum excitation energy of argon using Frank Hertz apparatus.
5. To determine electronic charge to mass ratio by Millikan's oil drop method.
6. To find ionization potential of mercury.
7. Raman spectrometer: Stokes and anti-Stokes lines.
8. Rydberg constant: Hydrogen spectrum – different series.
9. To study the Zeeman effect.
10. To determine the dielectric constant of solid.
11. New experiments will be incorporated time to time.

***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. To study the spectroscopic behavior of materials.
CO2. Understand nature of atomic energy levels.
CO3. To study dielectric properties.
CO4. Understand various physical phenomena.

Course Name: **Solid State Physics Lab** Course Code: **PH-627**
Contact Hours/Week: **4P** Course Credits: **04**
Course Objectives 1. To make students aware of instrument handling. 2. To make students learn experimental skills. 3. Make students capable to work in groups.
List of Experiments 1. Curie temperature of a ferrite: Inductance technique. 2. Magnetic susceptibility measurement using Quincke's Method. 3. Electrical conductivity by two and four probe method of semi conducting crystals. 4. Band gap studies of LEDs using Newton's ring method. 5. Hall effect: estimation of carrier concentration, Hall voltage and carrier mobility. 6. X-ray diffraction: estimation of crystallographic parameters. 7. Resistivity determination of irregular sample using Van der Pauw method 8. To study thermoluminescence of F-centre in alkali halides 9. Study of magnetoresistance in a given sample 10. Study of phase diagram of Pb-Sn system 11. Hysteresis study of iron-core ***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*
Course Outcomes Upon successful completion of the course, the students will be able to CO1. To realize the behavior of magnetic materials CO2. To study magnetic phenomena in solid. CO3. Study of solid properties. CO4. Understand various physical phenomena.

Course Name: **Electronics Lab**
Course Code: **PH-628**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives
1. To make students learn performing experiments
2. To make students learn to the concepts of digital electronics.
3. Make students capable to work in groups to solve common problems

List of Experiments
1. To verify logic gates
2. To study the characteristics of NAND gate and its use as universal gate.
3. To study the characteristics of NOR gate and its use as universal gate
4. To study the phase relationship between waveforms using Lissajous figures.
5. To study different waveforms using the oscilloscope
6. To study the inverter operation using operational amplifier.
7. To study the differentiator circuit using operational amplifier.
8. To study the Integrator circuit using operational amplifier.
9. To study the half adder and full adder circuits using NAND gate.
10. To design and verify gain and frequency response of inverting amplifier using IC-741.
11. To design and verify gain and frequency response of the non-inverting amplifier using IC-741.
12. To design and verify gain and frequency response of the differentiator circuit using IC-741.

***The concerned course coordinator will prepare the actual list of experiments/problems at the start of the semester based on above generic list.*

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1. Realize theoretical concepts using experiments.
CO2. Enhance experimental skills.
CO3. Study various properties of solids.
CO4. Understand various physical phenomena.

Course Name: **Particle Physics**
Course Code: **PH-631**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To show the students about the swashbuckling theoretical as well as experimental developments in the avenue of particle physics in just a span of last few decades.
2. To introduce the fundamental concepts related to interactions and fields in particle physics, and the relation between symmetries and conservation laws.
3. To have an idea how drastically different and weird the subatomic universe is.

Course Content

Introduction and Overview: Historical development, Particle classification: Bosons, Fermions, Particles and Antiparticles, Quarks and Leptons; Basic ideas about the interactions and fields in Particle Physics, Types of interactions: Electromagnetic, Weak, Strong and Gravitational, Natural Units, Overview Relativistic Quantum Mechanics, Invariance Principles and Conservation laws: Conservation of electric charge, Baryon number, Lepton number, Continuous symmetry transformations: translation and rotation; Parity, Pion parity, Charge Conjugation, Strangeness and Isospin, Gell-Mann Nishijima scheme and Quark Model, G-parity, Time reversal invariance, ı 0−ı 0 doublet, CP violation, CPT theorem. Electromagnetic Interactions: Form factors of nucleons. Parton model and Deep inelastic scattering structure functions, Cross Section and Decay Rates. Quantum Chromo dynamics, Asymptotic freedom, confinement hypothesis. Classification of hadrons by flavor symmetry: SU(2) and SU(3) multiplets of Mesons and Baryons. The Baryon Octet and Decuplet, Pseudoscalar mesons and Vector mesons. Weak interactions and Gauge invariance: Classification of weak processes, Fermi theory of β-decay, Parity non conservation in β-decay, two component theory of neutrino and determination of helicity, V-A interaction, Cabibbo's theory, Gauge Principle, Local and Global gauge transformations, Abelian and non-Abelian gauge fields, Standard Model (SM) and Grand Unification.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1. Identify different mechanisms in the field of high energy Physics.
CO2. Describe problems with different types of particle interactions and fields involved.
CO3. Apply the concepts and principles/laws to describe the particle decay mechanism.

Books and References

1. Quarks and Leptons: An Introductory Course in Modern Particle Physics by Halzen F. and Martin A. D., John Wiley and Sons.
2. Introduction to Elementary Particles by Griffiths D. J., Wiley-VCH Verlag, GmbH & Co.
3. Introduction to High Energy Physics by Perkins D. H., Cambridge University Press.
4. Particle Physics by Martin and Shaw, Wiley.
5. Introduction to Particle Physics by Khanna M. P., Prentice Hall India.

Course Name: **Nuclear Physics**
Course Code: **PH-632**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives
1. To impart knowledge about the Nuclear Physics.
2. To introduce the fundamental concepts of Nuclear theory involving nuclear models.
3. To enable the students to understand the Nuclear forces and different nuclear models used to investigate nuclei and nuclear properties.

Course Content

Nuclear Properties: Introduction, constituents of nucleus and their intrinsic properties, angular momentum, magnetic moment and electric quadrupole moment of nucleus, wave mechanical properties of nucleus, nuclear forces. Nuclear Interactions; Two nucleon system, deuteron problem, binding energy, nuclear potential well, p-p and p-n scattering experiments at low energy, meson theory of nuclear force, e.g. Bartlett, Heisenberg, Majorana forces and potentials, exchange forces and tensor forces, effective range theory-spin dependence of nuclear force, Charge independence and charge symmetry of nuclear forces-Isospin formalism, Yukawa interaction. Nuclear Models: Liquid drop model, Bohr-Wheeler theory of fission, Experimental evidence for shell effects, Shell Model, Spin-Orbit coupling, Magic numbers, Applications of Shell model like Angular momenta and parities of nuclear ground states, Quantitative discussion and estimates of transition rates, magnetic moments and Schmidt lines, Collective model-nuclear vibration spectra and rotational spectra, Nuclear Decay: Beta decay, beta spectrum. Angular momentum and parity selection rules, Comparative half-lives, Allowed and forbidden transitions, selection rules. Detection and properties of neutrino, Gamma decay, Multipole transitions in nuclei, Internal conversion, Nuclear isomerism. Nuclear Reaction: Conservation laws, energetics of nuclear reaction, Direct and compound nuclear reaction mechanism, Compound nuclear-scattering matrix, Reciprocity theorem, Breit Wigner one level formula, Resonance scattering.

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1. Identify different concepts of nuclear properties, different models of nuclear forces.
CO2. Describe problems related nuclear modeling and nuclear reactions.
CO3. Apply principles to determine the basic properties of various nuclear systems and different nuclear reaction mechanisms.
CO4. Assess the results obtained by solving problem related to basic nuclear properties and nuclear reaction mechanism.

Books and References

1. Nuclear Structure by Bohr A. and Mottelson B.R., Benjamin Readings.
2. Introductory Nuclear Physics by Krane K. S., Wiley Estern, New York.
3. Nuclear Physics by Roy R.R. & Nigam B.P., New Age International, New Delhi.
4. Nuclear Physics by Irving Kaplan, Addison Wesley, New Delhi.
5. Theory of Nuclear Structure by Pal M. K., East West Press Pvt. Ltd., New Delhi.
6. Nuclear Physics: Experimental and Theory by Hans H.S., New Age International, New Delhi,

Course Name: **Experimental Techniques in Physics**
Course Code: **PH-711**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** | Course Credits: **04**

Course Objectives

1. To impart knowledge about the experimental techniques used in Physics.
2. To introduce the fundamental concepts of X-ray diffraction and spectroscopy.
3. To enable the students to understand the theory of X-ray diffraction and different spectroscopic techniques.

Course Content

Crystal structure identification and lattice parameter determination, Particle size determination using Bragg's law of X-ray diffraction. Optical Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; Scanning Electron Microscopy; Transmission Electron Microscopy; Low Energy Electron Diffraction; Reflection High Energy Electron Diffraction; Neutron diffraction; Auger Electron Microscopy; Secondary ion mass spectroscopy; Raman Spectroscopy, X-ray photoelectron spectroscopy. Photoluminescence Spectroscopy, Electron spectroscopy for chemical analysis, FTIR, UV-VIS-NIR spectrophotometry & Ellipsometry Thermal Characterization. Differential scanning calorimeter; Differential Thermal Analyzer. Deep Level Transient Spectroscopy; Thermally Simulated Current; C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers,

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts of X-ray diffraction, neutron diffraction and spectroscopy.

CO2. Describe problems related to the structure of solids, measurement of magnetic properties and other parameters.

CO3. Apply principles to determine crystal structures, microstructure, band gap and specific heat.

CO4. Assess the results obtained by solving problem related crystal structure and energy band determination.

Books and References

1. Instrumentation and Experiment Design in Physics and Engineering by Sayer, M., Mansingh, A., Measurement.
2. Nanoparticles and Nanostructured Films–Preparation, Characterization and Application by J.H. Fendler (Wiley).
3. Elements of X-Ray Diffraction, by B.D. Cullity and S.R. Stock Pearson New International Edition
4. X-Ray Diffraction: A Practical Approach by C. Suryanarayana and M. Grant Norton, Springer-Verlag New York Inc
5. Semiconductor Material and Device Characterization By Dieter K. Schroder, Wiley Publication

Course Name: **Nuclear Detectors and Accelerator Physics** Course Code: **PH-712** Course Type: **Program Elective-I**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the Detection of Nuclear Radiations and their measurements. 2. To introduce the fundamental concepts related to the experimental determination of Nuclear properties 3. To enable the students to understand the Physics of Accelerators of Charged Particles and Neutron Physics
Course Content
Detection of Nuclear Radiations and their measurements: Methods for detection of free charge carriers, Ionization chamber, Proportional counter, Geiger-Muller counter, Semiconductor detectors, Scintillation detector, Cheremkov detector, Wilson cloud chamber, Bubble chamber, Nuclear emulsion techniques. Determination of Nuclear Properties: Nuclear mass measurement, Ion optics, Production and detection of positive ions, Dempster's mass spectrometer, Aston's and Bainbridge's mass spectrograph, Double focusing mass spectroscope. Measurement of nuclear spin and magnetic moment: Nuclear spin from Zeeman effect of hyper fine lines, Nuclear spin and statistics from molecular spectra, Atomic beam method of nuclear magnetic moment determination, Accelerators of Charged Particles: Classification and performance characteristics of accelerators, Ion sources, Electrostatics accelerators, Cockroft – Walton generator, Cyclotron, Synchro-cyclotron, Betatron, Electron and proton synchrotron, Linear accelerator. Neutrons and Neutron Physics: Classification and properties of neutron, Sources of neutron, Neutron detectors; Slow neutron detection through nuclear reactions and induced radioactivity, Fast neutron detection.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts of detection of various types of Nuclear Radiations. CO2. Apply principles to understand and experimental determination of nuclear properties CO3. Assess the results obtained by solving problem related to nuclear radiation physics.
Books and References 1.Nuclear Radiation Physics by Lapp R. E. and Andrews H. L., Prentice Hall, New Delhi. 2. Radiation Detection and Measurement, 4th Edition Hardcover by GF Knoll, John Wiley & Sons Inc 3. Mass spectroscopy by Mc Dowell C. A., McGraw Hill Book Company, New Delhi. 4. Experimental Nuclear Physics by Segre E., John Wiley and Sons. 5. Particle Accelerators by Livingstone M.S. and Blewett J. P., McGraw Hill Book Co. 6. Nuclear Radiation Detectors by Kapoor S S and Ramamurthy V. S., Wiley Eastern, New Delhi. 7. Principles of Nuclear Reactor Engineering by Glasstone S. Mc Millan Co. London. 8. Nuclear Physics by Ghoshal S. N., S Chand and Co., New Delhi.

Course Name: **Quantum Computation and Information**
Course Code: **PH-713**
Course Type: **Program Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To explain the students how modern day science is becoming more and more interdisciplinary since this course is indeed an admixture of physics, computer science, information theory and mathematics.
2. This eventually will spread their interests to diverse fields of science and engineering.
3. To train our students in this immensely enticing field which is full of unimaginable technical prospects, quite potentially capable of changing human life forever in an unprecedented way.

Course Content

Introduction to Quantum Computation: Quantum bits (qubits), Bloch sphere presentation of a qubit, multiple qubits. Background Mathematics and Physics: Hilbert space, Probabilities and measurements, entanglement, density operators and correlation, basics of quantum mechanics, measurements in bases other than computational basis. Quantum Circuits: single qubit gates, multiple qubit gates, design of quantum circuits. Quantum Algorithms: Classical computation on quantum computers, relationship between quantum and classical complexity classes, Deutsch's algorithm, Deutsch's-Jozsa algorithm, Shor factorization, Grover search. Noise and error correction: Graph states and codes, Quantum error correction, fault-tolerant computation. Introductory quantum information theory and cryptography: Comparison between classical and quantum information theories, Bell states, quantum teleportation, quantum cryptography, no cloning theorem.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Develop sophisticated applications based on quantum computing.

CO2. Discern the extraordinary technical superiority of quantum computation and information over its classical counterparts.

CO3. Explore grand lucrative possibilities of controlling AI with the theory of quantum computation and information.

Books and References

1. Quantum Computation and Quantum Information by Nielsen M. A., Cambridge University Press.
2. Principles of Quantum Computation and Information by Benenti G., Casati G. and Strini G., Vol. I: Basic Concepts, Vol II: Basic Tools and Special Topics World Scientific.
3. Principles of Quantum Computation and Information by Benenti G. and Casati G., World Scientific.

Course Name: **Optical Fiber Communication** Course Code: **PH-714** Course Type: **Program Elective-II**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about Optical fiber Communication. 2. To introduce the fundamental concepts of optical fiber communication. 3. To enable the students to understand the optical fiber network and optical fiber communication.
Course Content
Fiber Optics: Total internal reflection, step index and graded index fibers, Guided Modes of a step-index fiber, graded index fibers, single-mode fibers. Optical Fibers: Attenuation in optical fibers, Dispersion, Bit rate and bandwidth, splicing and splicing loss, Pulse dispersion, Dispersion compensation, Fiber materials, fiber fabrication methods, fiber characterization, optical amplifiers. Modes in planar optical waveguides: TE and TM modes, Modes in channel waveguides. Light sources, couplers and detector; Basic principles of LEDs and LDs, modulation characteristics and drive circuits block diagram and circuit of a transmitter. Concept of light detection, photo-diodes, power relationship and bandwidth, responsively and quantum efficiency of a photodetector, p-i-n photodiode, metal-semiconductor-metal photodetectors, Some integrated Optical devices: Prism Coupling, optical switching and wavelength filtering etc. Optical fiber sensors; basic principles and applications.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts of propagation of signals through waveguide. CO2. Describe problems related to attenuation and dispersion in optical fibres. CO3. Apply principles to understand optical fibre communication system. CO4. Assess the results obtained by solving problems related to the propagation of optical signal.
Books and References 1. Optical Electronics by A.K. Ghatak and K. Thyagarajan, Cambridge University Press. 2. Introduction to Fiber Optics by A.K. and K. Thyagarajan, Cambridge University Press. 3. Optical Fiber Communications by G. Keiser, McGraw-Hill, Inc. New Delhi. 4. Photonics by A. Yariv and P. Yeh, Oxford University Press.

Course Name: **Polymer & Liquid Crystals** Course Code: **PH-715** Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

1. To impart knowledge about Polymers and liquid crystals.
2. To introduce the fundamental concepts of polymers and liquid crystals.
3. To enable the students to understand different concepts related to polymers and liquid crystals.

Course Content

Polymer, Introduction, monomer, degree of polymerizations, chemistry of polymers, polymer synthesis and polymer structure, polymers classification's, polymer morphology, thermal properties, multicomponent polymeric materials, applications. Liquid Crystals, Classification of liquid crystals: Thermotropic and lyotropic, Nematic, Smectic, cholestric, Ferroelectric liquid crystals (LCs), Blue phase LCs, molecular structure of LCs, structure-property relationship of thermotropic liquid crystals. Molecular and mean field theory, Birefringence phenomena, polarizing microscopy, texture identifications and defects, Electric & Magnetic effects, Optical properties of liquid crystals. Liquid crystal composites: polymer and nano-materials dispersed liquid crystal composites, polymer liquid crystals, molecular dynamics between LCs and Dopants. Liquid crystal applications, present and future displays, manufacturing of LCDs, twisted nematic, super-twisted nematic, LED, IPS based displays and overview of LC in advance field.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts of polymers and liquid crystals.

CO2. Describe problems related to preparation, classification and characterization of polymers and optical crystals.

CO3. Apply principles to determine the basic properties of polymers and liquid crystals.

Books and References

1. Introduction to Liquid crystal Chemistry and Physics by Peter J. Cooling and M. Hird, Taylor and Francis.
2. The Physics of Liquid Crystals by P.G. De. Gennes, Oxford University Press.
3. Liquid Crystals by S. Chandrasekhar, Cambridge University Press.
4. Liquid Crystal fundamental by S. Singh, D. A. Dunmur, World Scientific.
5. Handbook of Polymer Science and Technology by M. H. Ferry, CBS, Vol. 2.
6. Polymer Science by Gowarikar, Johan wiley and Sons.
7. Principles of Polymer Science by Bahadur and Sastry, Narosa Publishing House.

Course Name: **Optoelectronics** Course Code: **PH-716** Course Type: **Program Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

1. To impart knowledge about opto-electronics.
2. To introduce the fundamental concepts of optoelectronics including, optical fiber network and fiber communication.
3. To enable the students to understand different aspects of optoelectronics, including fiber network, light sources and detectors.

Course Content

Dielectric wave guide and optical fibers: Light propagation in homogeneous medium, Snell's law and total internal reflection, Optical fibers, types of optical fibers, Numerical aperture, dispersion in optical fibers, optical bandwidth and bit rate, attenuation, scattering and absorption in optical fibers, Fiber materials and fabrication techniques. Semiconductor Science and Light Sources: Review of energy bands, Fermi level in semiconductors, doping of semiconductors, direct and indirect band gap semiconductors, effective mass, Fermi level, classification of semiconductors into element, binary, ternary and quaternary compounds, conduction mechanisms, amorphous semiconductors. Junction Devices: P-N junction, potential barrier and barrier width, forward and reverse saturation current junction capacitance, contact potential explanation based on band structure, M-S contact and its properties, photodiodes, photovoltaic devices and solar cell materials. Display devices and photo detectors: Luminescence from quantum well, photo luminescence and phosphorescence, phototransistors electro luminescence process, LEDs their structures and choice of materials, Plasma displays, photon devices and their characteristics, solar cells. Emission and absorption of radiation, population inversion, pumping, doped laser, gas laser, semiconductor laser, liquid dye laser, laser modes and holography.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts of optoelectronics.
CO2. Describe problems related optical network, optical communication, light sources and detectors.
CO3. Apply principles to determine parameters of optical fiber, fiber network, optical sources, detectors and display devices.
CO4. Assess the results obtained by solving problems related to different optoelectronic devices.

Books and References

1. Optical Electronics by A. K. Ghatak & K Thyagarajan, Cambridge University Press.
2. Physics of Semiconductor Devices by S. M.Sze, Wiley, New York.
3. Semiconductors, Opto-electronic Devices by P. Bhattacharya, PHI.
4. Optoelectronics and Photonics- Principles and Devices by S.O. Kasap, Pearson Education Inc.
5. Semiconductor Physics and Devices by S. S. Islam, Oxford University Press.
6. Optoelectronics by J. Wilson & J.F.B.Hawkes, PHI.

Course Name: **Nano-Structured Materials**
Course Code: **PH-717**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To impart knowledge about the nano-structured materials.
2. To introduce the fundamental concepts of synthesis and characterization of nanomaterials.
3. To enable the students to understand various properties at nano scale.
4. To enable the students to understand the Physics at nano-scale.

Course Content

Introduction to nanomaterials: Types of nanomaterials, emergence and challenges in nanotechnology, properties of nanomaterials; nanoparticles, nanowires, nanoclusters, quantum wells, core-shells, nanoshells, self-assembled nanostructures, superlattices, nanocomposites, nanoporous materials, nanofluids and carbon-based nanomaterials; Synthesis of nanostructured materials: Approaches and challenges, characterization techniques of nanomaterials: structural, optical, morphological & thermal characterization. Occurrence, production, purification, properties and applications of fullerene, carbon nanotube, graphene, carbon onion, nanodiamond and films, transition metal dichalcogenides (TMDCs) & oxides, MXenes, Hexagonal Boron Nitride (hBN). Heterostructures: An overview of quantum mechanical concepts related to lowdimensional systems. Heterojunctions, Type-I and Type-II heterostructures, classification of quantum confined systems, electrons and holes in quantum wells, electronic wavefunctions, energy sub-bands and density of electronic states in quantum wells, quantum wires, and quantum dots, effective mass mismatch in heterostructures, coupling between quantum wells, superlattices, electron states - wavefunctions and density of states for superlattices, excitons in bulk & nanostructures, the unit cell for quantum well, for quantum wire and for quantum dot. nanoclusters and nanoparticles: introduction, metal nanoclusters- magic numbers, geometric structures, electronic structure, bulk to nano transition, magnetic clusters; semiconducting nanoparticles; Rare-gas and Molecular clusters. Application of nanomaterials in healthcare, sensors, coatings, catalysis, agriculture, automotives, electronics, photonics, information technology, quantum computing, energy and aerospace sectors.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts to develop nanomaterials for different applications.
CO2. Describe problems related to synthesis and characterization.
CO3. Describe problems related to quantum confinement.
CO4. Apply principles to determine the basic properties of nanoclusters and nanoparticles.

Books and References

1. Nanostructures and Nanomaterials; Synthesis, Properties and Applications by Guozhong Cao Imperial College Press.
2. Introduction to Nanotechnology by Chales P Poole, Frank J Owen, Wiley India.
3. Handbook on Nanotechnology Vol 5 by H S Nalwa, Academic Press.
4. Nano: The Essentials Understanding Nanoscience and Nanotechnology by T Pradeep, McGraw Hill.
5. Nanomaterials- Synthesis, Properties and Applications by Edelstein A. A. and Cammarata R.C., Institute of Physics Publishing, London.
6. Quantum Wells: Physics and Electronics of two-dimensional systems by Shik A. World Scientific.
7. Nanostructured Carbon for advanced Applications by Benedek et al G., Kluwer Academic Publishers.
8. Quantum Wells, Wires, and Dots: Theoretical and Computational Physics by Harrison, P, John Wiley.
9. Quantum Heterostructures: Microelectronics and Optoelectronics by Mitin, V.V, Kochelap, VA and Stroscio, MA Cambridge University Press.

Course Name: **Advanced Solid State Physics**
Course Code: **PH-718**
Course Type: **Program Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To impart knowledge about semiconductors, magnetism and dielectric materials.
2. To introduce the concepts of defects.
3. To enable the students to understand different concepts related to magnetism and defects.

Course Content

Introduction to Magnetism, Magnetic susceptibility, classification of materials, Langevin diamagnetic theory, quantum theory of diamagnetism, classical & quantum theory of Paramagnetism, gyromagnetic ratio, Bohr magneton, Brillouin function, Hund's rule, crystal field splitting, quenching of the orbital angular momentum, paramagnetic susceptibility of conduction electron, atomic origin of magnetism, ferromagnetism in insulator and Curie temperature and Curie Wiess law, molecular field theory, physical origin of molecular filed, antiferromagnetism, Neel temperature, ferrimagnetism, ferromagnetism in metals, ferromagnetic domains, hard and soft directions, magnetic anisotropic energy, magnetization process. Band theory of solids, Fermi surfaces in metals, Reduced zone scheme, Periodic zone scheme, Construction of Fermi surfaces, Nearly free electrons, Electron orbits, hole orbits and open orbits, Calculations of energy bands, Tight binding method, Wigner-Seitz method, Pseudopotential method. Quantization of orbits in a magnetic field, Landau levels, quantum Hall effect (QHE), De Hass- van Alphen effect, Shubnikov-De Hass oscillation. Lifshitz-Kosevich (LK) formula, Onsagaer relation, Landau fan diagram, Determination of different parameters i.e. Berry Phase, Fermi surface area, Fermi momentum, Fermi velocity, Fermi energy, Effective mass, Dingle temperature, Quantum scattering time, mean free path, mobility, carrier concentration, Topological insulator, Edge states. Introduction to dielectric materials, dielectric constant & polarizability, local field, Lorentz relation, Clausius-Mosotti relation, molar polarizability, dipolar, ionic & electronic polarizability, dipolar dispersion, piezoelectricity & ferroelectricity, ferroelectric domains.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify different concepts of magnetism and dielectric properties.
CO2. Describe problems related to characterization of magnetic and dielectric materials.
CO3. Apply principles to determine the basic properties of dfects and dislocations.

Books and References

1. Introduction to Solid State Physics by Kittle C., John Wiley & Son.
2. Solid State Physics by Dekker A. J. , Macmillan India Ltd., New Delhi.
3. Introduction to Solids by Azaroff L. V., Tata McGraw-Hill, New Delhi.
4. Solid State Physics by Ashcroft N. W. and Mermin N. D., Thomson Asia Pte. Ltd.
5. Elementary Solid State Physics by Ali Omar, Addison Wesley Publishing Company.
6. Solid State Physics, M.A. Wahab, Narosa Publication.
7. Physics of Ferromagnetism by Soshin Chikazumi, Oxford University Publication.

Course Name: **Plasma Physics** Course Code: **PH-719** Course Type: **Program Elective-III**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the plasma state. 2. To understand the fundamental concepts of plasma physics. 3. To enable the students to understand various properties of the plasma state.
Course Content
Plasma state, Debye shielding and Plasma frequency, Criteria for plasma state, Plasma production/ Occurrence of plasma, Simple applications of plasma. Single charged particle motions in constant and uniform electromagnetic field, Non-uniform magnetic field, grad – B drift and curvature drift, Magnetic mirror, Adiabatic invariants, Introduction to plasma as fluids, Plasma fluid equations, Adiabatic fluid responses. Waves in plasma, Linearization procedure, Plasma oscillations (Electron waves), Plasma normal modes, Sound wave in a neutral gas, Plasma ion sound waves/acoustic waves, An electromagnetic Plasma waves, Wave properties applications, Upper and lower hybrid waves. Plasma equilibrium stability, Frozen flux theorem, Ponderomotive force, Plasma instabilities and its types. Controlled Fusion, Fusion History, Lawson criteria, Fundamentals of Inertial Magnetic Fusion, Magnetic Confinement method (Magnetic Mirrors), Tokamak.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts to develop plasma applications. CO2. Describe problems related to plasma physics. CO3. Apply principles to describe plasma problems.
Books and References 1. Introduction to Plasma Physics and Controlled Fusion by Chen F. F., Plenum Press, New York. 2. Principle of Plasma Physics by Krall N.A. and Trivelpiece A.W., Tata McGraw- Hill Publishing Company, New Delhi. 3. Fundamental of Plasma Physics by Seshadri S R, Addison-Wesley Pub. Co. 4. Plasma Physics by Dendy R, Cambridge University Press, New York. 5. Introduction to Unmagnetized Plasma by Chanchal Uberoi, Prentice Hall of India Pvt. Ltd., New Delhi.

Course Name: **Astronomy and Astrophysics** Course Code: **PH-720** Course Type: **Program Elective-III**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To understand the fundamental concepts of Solar Physics. 2. To promulgate the interesting astronomical facts and the related scientific theories associated with our universe. 3. To enable the students to understand the various problems of Solar and Astrophysics.
Course Content
Solar physics: Structure of the sun, solar interior, solar atmosphere, sun spots and their properties, solar flare, small & large scale solar structures and their classifications, phases & flare theory, solar cycle, solar magnetic field, solar wind, spatial configuration of magnetic field frozen into the solar wind, termination of solar wind, heliosphere, fluid theory for static as well as expanding isothermal solar atmosphere. Qualitative description of astro-objects (from planets to large scale structures): length, mass and time scales. Radiative Processes: Radiation theory and Larmor formula, different radiative processes. Introduction to cosmology: Evolution of structures in the universe, red shift, and the expansion of our universe, flat rotation curve of galaxies and introduction to dark matter, role of gravity in different astrophysical systems, star formation, stellar evolution, supernovae, H-T diagram, compact stars, milky way galaxy, spiral and elliptical galaxies, active galaxy, black holes. Cosmological models: Big Bang and steady state models.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Learn about the birth, evolution and the probable fate of our universe. CO2. Enhance the learning appetite for planets and their moons, stars, constellations, and other celestial formations. CO3. Realize and appreciate the vastness of the universe which in turn help to set them up the much-needed thoroughfare of scientific philosophy.
Books and References 1. Astrophysics of the Sun by Zirin H., Cambridge University Press, Cambridge. 2. Solar System Astrophysics by Brandt J. C. & Hadge P.W. 3. Guide to the Sun by Kenneth Philips J. H., Cambridge University Press. 4. Astrophysical Concepts by Harwitt M., Springer-Verlag, New York. 5. An Introduction to Modern Astrophysics by Carroll W. & Ostlie D. A., Pearson. 6. The Physics of Astrophysics Vol I & II by Shu F. H., University Science Books.

Course Name: **Thin Film Technology** Course Code: **PH-721** Course Type: **Program Elective-IV**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about thin films. 2. To introduce the fundamental concepts of film deposition. 3. To enable the students to understand various methods of film deposition and their advantages and disadvantages.
Course Content
Nucleation & Growth in thin films, models of nucleation, basic modes of thin film growth, stages of film growth. & mechanisms, amorphous thin films, epitaxy - homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors. Properties and technological applications of thin film. Thermal evaporation techniques of film deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult's law; electron beam evaporation, pulsed laser deposition, ion beam evaporation, glow discharge. Sputtering techniques of film deposition, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Sol-Gel synthesis, drop casting, spin coating and LB techniques. Physical Vapour deposition, Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, laser & plasma enhanced CVD, Chemical Techniques - Spray Pyrolysis, Electrodeposition, Ion plating, reactive evaporation, ion beam assisted deposition.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts of film deposition. CO2. Describe problems related to deposition of thin films and their growth. CO3. Apply principles to determine the effect of different techniques of film deposition and growth.
Books and References 1. The Materials Science of Thin Films by Milton Ohring, Academic Press. 2. Thin Film Phenomena by Kasturi L. Chopra, Mc Graw Hill (New York). 3. Thin – Film Deproperities; Principles and practices by Denald L. Smith, Mc. Grow Hill, Inc. 4. Thin Film Fundamentals by Goswami A., New Age International Publishers. New Delhi. 5. Handbook of Physical Vapor Deposition (PVP) Processions by Donald M. Mattox, Elsevier 6. Physical Vapor Deposition of Thin Film by John E. Mohan, John Wiley & Sons.

Course Name: **Quantum Field Theory** Course Code: **PH-722** Course Type: **Program Elective-IV**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To explain the students the necessity of transitioning from the domain of quantum mechanics to the domain of the quantum field theory in a systematic way. 2. To develop the mathematical framework (that is the quantum field theory) for explaining the dynamics of fundamental particles. 3. To have theoretical understanding of the unification of various interactions.
Course Content
Preliminaries: Creation and annihilation operators, the idea of time and space in relativistic quantum mechanics, natural unit system. A quick overview of classical field theory, second quantization, quantization of scalar fields and Dirac fields. The S-matrix formulation. Transition from Wick expansion to Feynman diagrams: Yukawa interaction, Feynman amplitude and Feynman rules, virtual particles. Cross sections and decay widths calculations. Quantization of the electromagnetic fields and quantum electrodynamics. C, P, and T symmetries and the combination of these symmetries. Introduction to form factors. Renormalization. Symmetries: Concept of symmetry and groups, spontaneous symmetry breaking, Goldstone's theorem, Higgs mechanism. Yang-Mills theory. Electroweak theory. Introduction to Standard Model
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Recognize the importance of a solid and rigorous mathematical framework like the quantum field theory in answering our never-ending queries about the existence of everything in the universe and about the universe itself. CO2. Feel and visualize the horizon of human knowledge. CO3. Implement the knowledge in describing the particle dynamics.
Books and References 1. An Introduction to Quantum Field Theory by Peskin M. E. and Schroeder D. V., Westview Press. 2. Quantum Field Theory by Ryder L. H., Cambridge University Press. 3. Quantum Field Theory by Itzykson C. and Zuber J. B., McGraw-Hill Book Co. 3. The Quantum Theory of Fields Vol I, by Weinberg S., Cambridge University Press. 4. Introduction to The Theory of Quantum Fields by Bogoliubov N. N. and Shirkov D. V., Interscience. 5. A First Book of Quantum Field Theory by Lahiri A. and Pal P. B., Alpha Science International Ltd.

Course Name: **Quantum Optics**
Course Code: **PH-723**
Course Type: **Program Elective-IV**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To impart knowledge about the fundamental concepts of Quantum Optics.
2. To introduce the applications of optical coherence.
3. To enable the students to understand the classical and quantum theories of optical coherence.

Course Content

Quantization of the radiation field, quantum harmonic oscillator, the zero-point energy, the connection between the positive and negative frequency parts of the electric field operator; states of the quantized radiation field - single mode number states, thermal states, phase states, the minimal uncertainty states, the coherent and squeezed coherent states. Various definitions of a coherent state: the minimal uncertainty states, the states with classical motion, the displacement operator eigenstates, the Glauber-Sudarshan P-function, the Q-function and other quasi-probability distribution functions and their use in the semi-classical description of a radiation field, Nonclassical aspects like squeezing and antibunching and examples of nonclassical states and experimental status. Important experiments in Quantum Optics: Photon counting experiments, Intensity-intensity correlation - Hanbury-Brown and Twiss experiment. The concept of an analytic signal, elementary description of stochastic processes, correlation functions and coherence functions, Stationary and ergodic processes, Wiener-Khinchin relations, Young's double slit experiment to discuss the conditions on the classical coherence functions and quantum coherence functions for various orders of coherence, higher-order correlations functions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Identify the introductory background in quantum mechanics.
CO2. Describe thermal states, phase state and squeezed coherent states.
CO3. Apply principles to understand the examples of non-classical states and experimental status.
CO4. Assess the results obtained by solving problem related to quantum optics.

Books and References

1. Optical coherence and quantum optics, by L. Mandel and E. Wolf, Cambridge.
2. Quantum Optics An Introduction by Mark Fox, Oxford University Press.
3. Fundamentals of Quantum Optics and Quantum Information by Peter Lambropoulos, David Petrosyan, Springer-Verlag Berlin Heidelberg.

Course Name: **Atmospheric and Space Physics** Course Code: **PH-724** Course Type: **Program Elective-IV**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the fundamental concepts of Atmospheric and Space Physics. 2. To introduce the applications of Space Physics. 3. To understand problems related to Atmospheric and Space Physics.
Course Content
The Neutral atmosphere, atmospheric nomenclature, the Hydrostatic equation, Geopotential height, expansion and contraction, fundamental forces in the atmosphere, apparent forces, atmospheric composition, solar radiation interaction with the neutral atmosphere, climate change, Momentum equation in rotating coordinates, component equation in spherical coordinates, scale analysis of equation of motion, continuity equation, thermodynamics of dry atmosphere, thermal wind, vertical motion, EM Radiation, fundamentals of EM waves, effects of environment, Antennas- basic considerations, types of antennas. Propagation of waves: ground wave, sky wave, and space wave propagation, troposcatter communication and extra terrestrial communication, The Ionosphere, morphology of ionosphere, the D, E and F-regions, chemistry of the ionosphere, ionospheric parameters, E and F region anomalies and irregularities in the ionosphere, Basic concepts, overview of GPS system, augmentation services, GPS system segment, GPS signal characteristics, GPS errors, multi path effects, GPS performance, satellite navigation system and applications.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify the introductory background in space Physics. CO2. Describe problems related to Atmospheric and Space Physics. CO3. Apply principles to understand Atmospheric and Space Physics.
Books and References 1. An Introduction to Dynamic Meteorology by James R Holton, Academic Press Inc. 2. An atmospheric Science by John E. Oliver & John J. Hindore, Climatology, Pearson Education. 3. Electronic Communication systems by George Kennedy & Bernard Davis, Tata McGraw Hill Co. 4. Introduction to Ionospheric Physics by Henry Rishbeth & Owen K. Garriot, Academic press. 5. Understanding GPS principles and applications by Elliot D. Kaplan and Christopher J. Hegarty, Artech House, Boston.

Course Name: **Nuclear Science and Applications** Course Code: **PH-701** Course Type: **Institute Elective**
Contact Hours/Week: **4L**   Course Credits: **04**
Course Objectives 1. To impart knowledge about the Nuclear Physics. 2. To introduce the fundamental concepts Nuclear theory involving nuclear models 3. To enable the students to understand the Nuclear forces and different nuclear models used to investigate nuclei and nuclear properties.
Course Content
Introduction to the Nucleus and theories of Nuclear Composition, Non-existence of Electron in Nucleus, Classifications of Nuclei, Properties of Nucleus, Wave Mechanical Properties of Nucleus, Binding Energy & Nuclear Stability, Nuclear Forces & their Properties. Nuclear alpha, beta and gamma decay (Basic Idea). Models of Nuclear Structure: Liquid Drop Model, Semi-Empirical Mass Formula and its Applications, Experimental Evidence of Nuclear Magic Numbers. Detectors of Nuclear Radiation: Interaction Between Energetic Particles and Matter, Ionization Chamber, Proportional Counter, Gieger-Muller Counter, Solid-State Detector, Nuclear Emulsions. Radioactivity and Radiation Hazards, Introduction to Radioactivity, Radioactive Series, Successive Transformation and Radioactive Equilibrium, Neutron Sources and types of Neutrons, Mass & Wavelength of Neutrons, Neutron Detection, Nuclear Reactions, Induced Radioactivity, Radio Isotopes, Applications of Radioisotopes, Radioactive Dating, Biological Effects of Nuclear Radiations, Radiation Hazards, Radiation Levels for safety, Radiation Protection Methods, Nuclear Disasters, Nuclear Waste Disposal. Nuclear Reactors: Nuclear Cross section, Theory of Nuclear Fission and Fusion, Source of Stellar Energy, Thermonuclear Reactions, Transuranic Elements, Nuclear Power Reactor Technology, Uranium Enrichment Techniques, Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Fast Breeder Reactor, Fusion Reactor Technology, Lawson Criterion, Plasma Confinement Mechanism, Tokamak, Present Nuclear Energy Status.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts of nuclear properties, different models of nuclear forces. CO2. Describe problems related nuclear modeling and nuclear reactions. CO3. Apply principles to determine the basic properties of various nuclear systems and different nuclear reaction mechanisms. CO4. Assess the results obtained by solving problem related to basic nuclear properties and nuclear reaction mechanism.
Books and References 1 Nuclear Physics by S. N. Ghoshal, S. Chand & Company Ltd. 2. Nuclear Physics: Principles and Applications by John Lilley, Wiley India Pvt Ltd. 3. Introductory Nuclear Physics by Kenneth S. Krane, Wiley India Pvt Ltd. 4. Modern Physics by R. Murugeshan and Kiruthiga Sivaprasath, S. Chand & Company Ltd. 5. Nuclear Physics by Tayal D C, Himalaya Publishing House. 6. Basic Nuclear Physics by Srivastava B.N., Pragati Prakashan, Meerut.

Course Name: **Nanotechnology**
Course Code: **PH-702**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives
1. To impart knowledge about the nano-systems.
2. To introduce the fundamental concepts of atomic level system.
3. To enable the students to understand the Physics at nano scale.

Course Content

Introduction: Nanoscience, nanotechnology, nanostructures, under lying physical principles of nanotechnology, Fundamental physicochemical principles - size dependence properties of nanostructured materials, matter quantum confinement, The importance of nanoscale morphology, Societal aspects of nanotechnology: Health, environment, hype and reality. Synthesis Techniques: Top down and bottom up approaches to produce nanomaterials. Overview of self-assembly, Inert gas condensation, arc discharge, RF plasma, plasma arc technique, ion sputtering, laser ablation, laser pyrolysis, ball milling, molecular beam epitaxy, chemical vapour deposition method and electro deposition. Metal/Semiconductor Nanostructures: Size control of metal nanoparticles and their characterization, study of their properties, optical, electronic, magnetic, surface plasmon band and its applications, role in catalysis, nano-particles, stabilization in sol, glass, and other media, change of bandgap, blue shift, composites, Plasmon resonance and its applications. Carbon Nanostructures: Introduction, Carbon nano-structure, carbon nanotubes, graphene, mechanical, optical and electrical properties & applications, functionalization of carbon nanotubes, reactivity of carbon nanotubes, applications. Tools for characterization of nanomaterials: X-ray diffraction, scanning electron microscopy (SEM) and EDAX analysis, transmission electron microscopy (TEM), a brief historical overview of atomic force microscopy (AFM) and scanning tunneling microscopy (STM), UV-Vis, IR and Raman spectroscopy, Photoluminescence (PL) spectroscopy.

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1. Identify different concepts of Nanoscience, nanotechnology, nanostructures.
CO2. Describe size dependent properties of nano materials.
CO3. Apply principles to determine the basic properties of nanoclusters and nanoparticles using different characterization techniques.

Books and References
1. Nano Materials by Bandyopadhyay A.K. New Age International Publishers, New Delhi
2. Quantum Wells: Physics and Electronics of two-dimensional systems by Shik, A. World Scientific.
3. Introduction to Nanotechnology by Poole, Jr. C.P .and Owens F.J., Wiley India.
4. Nanomaterials- Synthesis, Properties and Applications by Edelstein A. A. and Cammarata R. C., Institute of Physics Publishing, London.
5. Nanostructured Carbon for advanced Applications by Benedek et al G., Kluwer Academic Publishers.
6. Quantum Wells, Wires, and Dots: Theoretical and Computational Physics by Harrison P. John Wiley.
7. Nanotechnology, Innovation and Opportunity by Lynn E. Foster, Pearson Education, New Delhi.

Course Name: **Properties of Matter** Course Code: **PH-703** Course Type: **Institute Elective**
Contact Hours/Week: **4L** Course Credits: **04**
Course Objectives 1. To impart knowledge about the mechanical properties of solids and fluids. 2. To introduce the fundamental concepts related to elasticity and fluid dynamics. 3. To enable students to understand the ultrasonic generation and propagation through media.
Course Content
Elasticity: Stress, strain, Hook's law, Young's modulus, bulk modulus, modulus of rigidity, Poisson's ratio, ratio between elastic constants, torsion of a cylinder, bending beam and cantilevers, cantilever loaded at one end, cantilever supported at two ends and loaded in the middle. Thermal Properties: Conduction, convection and radiation, thermal conductivity, thermal diffusivity, heat flow problems in different structures and media. Piezoelectric Materials: Piezoelectric effect, Magnetostriction effect, Ultrasonics generation, properties and their applications. Shock waves: Introduction, Types of shock waves, Mach number, Generation of shock waves, various types of shock waves, applications of shock waves. Fluid Mechanics: Equation of continuity, equation of motion, viscosity of liquids, dimensions of viscosity, Poieseuille's equation, Stoke's law, Raynold's number.
Course Outcomes Upon successful completion of the course, the students will be able to CO1. Identify different concepts of electricity and fluid mechanics. CO2. Describe problems related to mechanical and thermal properties. CO3. Apply principles to understand different mechanism in fluids.
Books and References 1. Modern Engineering Physics by A.S. Vasudeva, S. Chand & Co. New Delhi. 2. Mechanics and Wave Motion by V.K. Singh, D. Singh and D.P. Singh, I.K. International Publishing House Pvt. Ltd, New Delhi. 3. Mechanics by D. S. Mathur, S. Chand & Company (Pvt.) Ltd, New Delhi.

Course Name: **Quantum Computation**
Course Code: **PH-704**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

1. To explain the students how modern day science is becoming more and more interdisciplinary since this course is indeed an admixture of physics, computer science, information theory and mathematics.
2. This eventually will spread their interests to diverse fields of science and engineering.
3. To train our students in this immensely enticing field full of unimaginable technical prospects, quite potentially capable of changing human life forever in an unprecedented way.

Course Content

Introduction to Quantum Computation: Quantum bits (qubits), Bloch sphere presentation of a qubit, multiple qubits. Background Mathematics and Physics: Hilbert space, Probabilities and measurements, entanglement, density operators and correlation, basics of quantum mechanics, measurements in bases other than computational basis. Quantum Circuits: single qubit gates, multiple qubit gates, design of quantum circuits. Quantum Algorithms: Relationship between quantum and classical complexity classes, Deutsch's algorithm, Deutsch's-Jozsa algorithm, Shor factorization, Grover search. Noise and error correction: Graph states and codes, Quantum error correction, fault-tolerant computation.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1. Develop sophisticated applications based on quantum computing.

CO2. Discern the extraordinary technical superiority of quantum computation and information over its classical counterparts.

CO3. Explore grand lucrative possibilities of controlling AI with the theory of quantum computation and information.

Books and References

1. Quantum Computation and Quantum Information by Nielsen M. A., Cambridge University Press.
2. Principles of Quantum Computation and Information by Benenti G., Casati G. and Strini G., Vol. I: Basic Concepts, Vol II: Basic Tools and Special Topics World Scientific.
3. Principles of Quantum Computation and Information by Benenti G. and Casati G., World Scientific.