M.Sc. Year IV (Semester-VII)

Sr. No.	Course Code	Course Name	L	T	P	Credits	Theory	Tutorial	Practical	Total Marks
			Teaching Scheme (Hours)				Examination Scheme			
1	PH 401	Computational Physics	3	1	0	4	100	25	0	125
2	PH 403	Particle Physics	3	1	0	4	100	25	0	125
3	PH 405	Quantum Mechanics-II	3	1	0	4	100	25	0	125
4	PH 4AA	Core Elective – I	3	0	0	3	100	0	0	100
5	PH 4BB	Core Elective – II	3	0	0	3	100	0	0	100
6	PH 407	Experimental Techniques-V (computational physics, particle physics, quantum mechanics & general physics)	0	0	8	4	0	0	200	200
7	PH 409	Mini Project-III	0	0	4	2	0	0	100	100
		Total	**15**	**3**	**12**	**24**	**500**	**75**	**300**	**875**
		Total Contact Hours	**30**							
		Total Credits	**24**							

Core Electives-I — Examination Scheme

Sr. No.	Course Code	Course Name	L (hours)	T (hours)	P (hours)	Credits	Theory	Tutorial	Practical	Total Marks
1	PH 421	Green's Function and Partial Differential Equations	3	0	0	3	100	0	0	100
2	PH 423	Remote Sensing	3	0	0	3	100	0	0	100
3	PH 425	Nanoscience and Nanotechnology	3	0	0	3	100	0	0	100

Core Electives-II — Examination Scheme

Sr. No.	Course Code	Course Name	L (hours)	T (hours)	P (hours)	Credits	Theory	Tutorial	Practical	Total Marks
1	PH 441	Material Science	3	0	0	3	100	0	0	100
2	PH 443	Density Functional Theory	3	0	0	3	100	0	0	100

M.Sc. Year IV (Semester-VIII)										
			Teaching Scheme (Hours)				Examination Scheme			
Sr. No.	**Course Code**	**Course Name**	**L**	**T**	**P**	**Credits**	**Theory**	**Tutorial**	**Practical**	**Total Marks**
1	PH 402	Statistical Mechanics	3	1	0	4	100	25	0	125
2	PH 404	Condensed Matter Physics	3	1	0	4	100	25	0	125
3	PH 406	Electronics & Optical Communication	3	1	0	4	100	25	0	125
4	PH 4CC	Core Elective – III	3	0	0	3	100	0	0	100
5	PH 4DD	Core Elective – IV	3	0	0	3	100	0	0	100
6	PH 408	Experimental Techniques-VI (statistical mechanics, condensed matter physics, electronics, optical communication & general physics)	0	0	8	4	0	0	200	200
7	PH 412	Dissertation Preliminaries	0	0	4	2	0	0	100	100
		Total	**15**	**3**	**12**	**24**	**500**	**75**	**300**	**875**
		Total Contact Hours	**30**							
		Total Credits	**24**							

Core Electives-III

Examination Scheme										
Sr. No.	**Course Code**	**Course Name**	**L (hours)**	**T(hours)**	**P(hours)**	**Credits**	**Theory**	**Tutorial**	**Practical**	**Total Marks**
1	PH 422	Global Navigation Satellite System Elementary Excitations in Solids	3	0	0	3	100	0	0	100
2	PH 424	Thin Films and Vacuum Technology	3	0	0	3	100	0	0	100
3	PH 426	Quantum Field Theory	3	0	0	3	100	0	0	100

Core Electives-IV

Examination Scheme										
Sr. No.	**Course Code**	**Course Name**	**L (hours)**	**T(hours)**	**P(hours)**	**Credits**	**Theory**	**Tutorial**	**Practical**	**Total Marks**
1	PH 442	Many-Body Physics and Relativistic Quantum Mechanics	3	0	0	3	100	0	0	100
2	PH 444	Microprocessor	3	0	0	3	100	0	0	100
3	PH 446	Advanced Crystallography	3	0	0	3	100	0	0	100

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 401: Computational Physics	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand and apply the numerical methods
CO2	solve the problems involving partial differential equations numerically
CO3	interpret the concept of Fourier series, Fourier integral and extend it to conclude the Fourier transform and its applications
CO4	understand the strategy of Monte-Carlo methods by making use of random numbers
CO5	apply the Monte-Carlo methods for quantum mechanical systems
CO6	analyze various physics problems by applying numerical techniques

Syllabus	
REVIEW OF NUMERICAL METHODS	**(10 Hours)**
Errors & approximation, Algebraic and transcendental equations, System of linear equations, Least square curve fitting, Finite differences and difference operators, Newton’s & Lagrange’s Interpolation, Numerical integration, Numerical solution of ordinary differential equations, Numerov’s method, Shooting method	
NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	**(05 Hours)**
Introduction, Wave equation, Laplace’s and Poisson’s equations, Heat diffusion equation	
FOURIER ANALYSIS AND FOURIER TRANSFORM	**(10 Hours)**
Fourier series of a periodic function, Examples. Half-range expansions, Fourier cosine and sine integral, , The Fourier transform, FFT, DFT	
MONTE-CARLO METHODS	**(05 Hours)**
Introduction, Random numbers, Multiplicative congruential algorithm, Applet of random number, Buffon’s needle experiment, Monte-Carlo integrations, Particle in a box, Radio-active decay, Random walk, Examples	
QUANTUM MONTE-CARLO METHODS	**(04 Hours)**
Introduction, Variational Monte-Carlo method (VMC), Metropolis algorithm, VMC for quantum mechanical systems – Harmonic oscillator	
NUMERICAL TECHNIQUES FOR PHYSICS PROBLEMS- EXAMPLES	**(08 Hours)**
Power spectrum of a driven pendulum under damping, The Legendre polynomials generator, Random number generator, π value calculation, Random walk, Heat distribution problem, RMS current by numeric integration	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Kreyszig, E., Advanced Engineering Mathematics 10^{th} edition Wiley 2018
2. Arfken, G. B. and Weber, H. J., Mathematical Methods for Physicists, Academic Press. 2005
3. Chapra, S. G. and Canale, R. P., Numerical methods for Engineers, McGraw Hill 2006
4. Giordano, N. J. and Nakanishi, H., Computational Physics, Pearson-Prentice-Hall 2005
5. Joel Franklin,Computational Methods for Physics, Cambridge India 2015

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 403 : Particle Physics	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	classify the principle and operation of various accelerators and detectors
CO2	understand the fundamentals of particle interactions and decay laws
CO3	interpret the concepts of relativistic kinematics and Feynman calculations
CO4	examine the symmetries associated with conservation laws and properties of quarks
CO5	analyze the bound states of hydrogen atom structure and its association with particle physics and inspect the historical background of neutrino experiments, double beta decay and neutrino oscillations

Syllabus	
PARTICLE ACCELERATORS AND DETECTORS	**(05 Hours)**
Electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators, gas-filled counters, scintillation detectors, semiconductor detectors.	
REVIEW OF PARTICLE PHYSICS	**(06 Hours)**
Historical Introduction, Classification and Natural Units, Feynman Diagrams for the fundamental interactions, decays and conservation laws	
RELATIVISTIC KINEMATICS	**(02 Hours)**
Lorentz transformations, Four Vectors, Energy and momentum, Collisions.	
SYMMETRIES AND QUARKS	**(04 Hours)**
Symmetries, Groups, Conservation laws, Spin and Angular Momentum, Addition of angular momentum, Flavour symmetries, Parity, Charge conjugation, CP Violation, Time reversal and the CPT Theorem. Mesons, Baryons hadron masses and colour factor.	
BOUND STATES	**(04 Hours)**
The Schrodinger equation for the central potential, Hydrogen atom, Fine structure, Lamb shift, Hyperfine structure, Positronium, quarkonium, Light quark mesons, Baryon masses and magnetic moment.	
FEYNMAN CALCULATION	**(05 Hours)**
Life time and cross section, Golden Rule, The Feynman rules for toy theory, lifetime scattering, Higher order diagrams.	
BIRTH OF NEUTRINO AND IMPORTANT HISTORICAL EXPERIMENTS	**(06 Hours)**
The birth of neutrino, Neutrino Detection, Solar Neutrino Detection, Parity violation, helicity measurement, differentiation of □□ and □e, Discovery of Weak Neutral currents and Weak gauge bosons, Observation of neutrinos from SN 1987A, Number of neutrino flavors from width of Z	

boson.	
DOUBLE BETA DECAY AND NEUTRINO OSCILLATIONS	**(10 Hours)**
Introduction to double beta decay, double electron capture, decay rates, possibility of neutrinoless double beta decay and measurement of neutrino mass, Nuclear structure effects on matrix elements, Two - neutrino mixing, General formalism of neutrino oscillations, CP and T violation in neutrino oscillations, Neutrino oscillations in matter.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Introduction to High Energy Physics -- D. H. Perkins, Addison Wesley (1982)
2. Quarks and Leptons: An Introductory Course in Modern Particle Physics -- F. Halzen and A. D. Martin, John Wiley & Sons (1983)
3. The ideas of Particle Physics: An introduction for Scientists -- G. D. Coughlan, J. E. Dodd and B. M. Gripaios, Cambridge University Press (1984).
4. Griffiths, David. Introduction to elementary particles. John Wiley & Sons, 2008.
5. Neutrino Physics -- Kai Zuber, Series in High Energy Physics, Cosmology and Gravitation, Taylor and Francis Group (2004).

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 405 : Quantum Mechanics-II	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	interpret the fundamental phenomena associated with time-independent and time-dependent perturbation theories
CO2	examine the principles of symmetry related to identical particles
CO3	interpret the characteristics of scattering phenomena
CO4	understand the Feynman formalism and path integrals for propagators
CO5	analyze the adiabatic approximations, berry phase, Aharonov–Bohm effect and Hartree-Fock approximation

Syllabus	
TIME-INDEPENDENT PERTURBATION THEORY	**(06 Hours)**
Non-degenerate Case, The Degenerate Case, Hydrogen like Atoms: Fine Structure and the Zeeman Effect, Variational Methods, WKB approximations.	
TIME-DEPENDENT PERTURBATION THEORY	**(06 Hours)**
The Interaction Picture, Time-Dependent Perturbation Theory, Fermi's Golden rule, Applications to Interactions with the Classical Radiation Field, Energy Shift and Decay Width.	
IDENTICAL PARTICLES	**(06 Hours)**
Permutation Symmetry, Symmetrization Postulate, Two-Electron System, The Helium Atom, Permutation Symmetry and Young Tableaux, Spins and Statistics, Slatter determinant.	
SCATTERING THEORY	**(14 Hours)**
Green's Functions, The Lippmann-Schwinger Equation, The Born Approximation, Optical Theorem, Eikonal Approximation, Scattering matrix, Free-Particle States: Plane Waves Versus Spherical Waves, Method of Partial Waves, Low-Energy Scattering and the Bound States, Resonance Scattering, Identical Particles and Scattering, Symmetry Considerations in Scattering, Time-Dependent Formulation of Scattering, Inelastic Electron-Atom Scattering, Coulomb Scattering.	
PATH INTEGRALS	**(06 Hours)**
The Dirac picture, propagators, transition amplitude and propagators, sum over paths, Feynman formalism, equivalence to Schrodinger equation, solving for some potentials.	
SPECIAL TOPICS	**(04 Hours)**
Adiabatic approximations, Berry Phase, Aharonov–Bohm effect, Hartree-Fock approximation.	
	(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Sakurai, Jun John, and Jim Napolitano. Modern quantum mechanics. Vol. 185. Harlow: Pearson, 2014.
2. Zettili, Nouredine. Quantum mechanics: concepts and applications. Wiley (2003)
3. Shankar, Ramamurti. Principles of quantum mechanics. Springer Science & Business Media, 2012.
4. Griffiths, David J., and Darrell F. Schroeter. Introduction to quantum mechanics. Cambridge University Press, 2018.
5. Mathews P.M., and Venkateshan K.,A Text book of Quantum Mechanics; McGraw Hill Education; 2 edition (1 July 2017)

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 421:Green's Function and Partial Differential Equations	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	identify the correlation between the Green's function and Ordinary differential equations
CO2	apply the methods for solving Green's functions
CO3	understand the mathematical modeling for partial differential equations
CO4	examine the characteristics of diffusion equation
CO5	analyze the equations of Laplace, Poisson, wave phenomena and linear transport theory

Syllabus	
GREEN'S FUNCTIONS AND ORDINARY DIFFERENTIAL EQUATIONS	**(04 Hours)**
The Dirac-Delta functions and its properties, Definition of Green's function, initial value problem, superposition integral, the boundary value problem.	
METHODS OF SOLVING FOR GREEN'S FUNCTIONS	**(05 Hours)**
Eigenvalue expansions, Combining green's functions, Fourier transform method, retarded and advanced greens functions, applications to sample ODEs.	
MODELING USING PARTIAL DIFFERENTIAL EQUATIONS	**(04 Hours)**
Mathematical Modeling, Partial differential equations and their types, well-posed problem, linear and non-linear PDEs, order of PDEs.	
DIFFUSION EQUATION	**(07 Hours)**
Introduction, conduction of heat, well-posed problem, separation of variables solution, the Cauchy problem, Fourier Series solution, Green's function for the Diffusion equation, Applications to Finance.	
LAPLACE AND POISSON'S EQUATION	**(07 Hours)**
Introduction, Harmonic functions, well-posed problem and uniqueness, properties of the solutions, solution of the Poisson's equation for some mass distributions, green's function for Laplace equation.	
LINEAR TRANSPORT EQUATION	**(05 Hours)**
Introduction, formulation of the problem and modelling, well-posed problem, stability calculations, integral solution, Green's function for the transport equation, applications.	
WAVE EQUATION	**(10 Hours)**
Concepts related to waves, group velocity and dispersion relations, finite speed of information transfer, waves on a string, 1-D wave equation, initial and boundary value problems, separation of variables, d'Alembert equation, the linear and non-linear case, the Cauchy problem, Green's Function for the wave equation	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Salsa, S., 2016. Partial differential equations in action: from modeling to theory (Vol. 99). Springer.
2. Duffy, D.G., 2015. Green's functions with applications. Chapman and Hall/CRC.
3. Farlow, S.J., 1993. Partial differential equations for scientists and engineers. Courier Corporation.
4. Kreyszig, E., Stroud, K. and Stephenson, G., 2008. Advanced engineering mathematics. Integration.
5. G. F. Roach, Green's Functions Cambridge University Press; 2 edition (27 May 1982)

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 423: Remote Sensing	**3**	**0**	**0**	**0**

Course Outcomes **In the end of the semester students will able to:**	
CO1	recall & understand the concepts of remote sensing
CO2	analyze how physical processes are studied, understood and utilized for furthering our understanding of the interaction of radiation with matter in connection with remote sensing
CO3	apply the concepts of photogrammetry and remote sensing to different problems
CO4	evaluate the applications to various problems related to remote sensing

Syllabus	
CONCEPTS AND FOUNDATIONS OF REMOTE SENSING	**(06 Hours)**
Energy sources and Radiation principles, Energy interactions in the atmosphere, energy interactions with earth surface features, Data acquisition and Interpretations, Reference data, The Global Positioning System An ideal remote sensing system, Characteristics of real remote sensing system.	
ELEMENTS OF PHOTOGRAPHIC SYSTEMS	**(06 Hours)**
Early history of Aerial photography, Basic negative to positive photographic sequence, Film exposure, Film density and characteristic curves, structure & Spectral sensitivity of black and white, color and color infrared films, film resolution, Aerial cameras, filters, electronic imaging, multiband imaging.	
REMOTE SENSING SYSTEMS AND SENSORS	**(06 Hours)**
Satellite borne systems, direct remote sensing, indirect remote sensing.	
IMAGE PROCESSING FUNDAMENTALS	**(06 Hours)**
Introduction, Image rectification and restoration, Image enhancement, contrast manipulation, spatial feature manipulation, image classification, different classification schemes, Classification accuracy assessment, Image transmission and compression	
EVOLUTION OF INTERNATIONAL REMOTE SENSING	**(06 Hours)**
Radars and other international satellite systems	
INDIAN REMOTE SENSING PROGRAMME	**(06 Hours)**
Development of IRS sytem and its components, role and importance of remote sensing.	
APPLICATIONS OF REMOTE SENSING	**(06 Hours)**
Applications in (i) agriculture, (ii) Forestry, (iii) vegetation, and (iv) oceanography	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Campbell J. B., Introduction to Remote Sensing, Taylor and Francis 1996
2. Kumar M., Remote Sensing, NCERT 2001
3. Lilesand T. M. & Keifer R. W., Remote Sensing and Image interpretation, John Wiley & Sons 2002
4. Joseph G., Fundamentals of Remote Sensing, University Press 2004
5. Wolf P. R., Elements of Photography, McGraw Hill 1974

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 425 : Nanoscience and Nanotechnology	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	giving outline of fundamental of nanoscience and nanotechnology
CO2	classify different synthesis method for nanomaterials
CO3	explain different types of nanomaterials
CO4	examine nanomaterias under different characterization techniques
CO5	interprete the properties of different types of the nanomaterials
CO6	discuss the application of the nanoscience and nanotechnology

Syllabus	
INTRODUCTION	**(04 Hours)**
Nanoscale Science and Technology-Implications for Physics, Chemistry, Biology and Engineering; Classifications of nanostructured materials, nanoparticles; 3 quantum dots, nanowires, ultra-thin films-multilayered materials. Length Scales involved and effect on properties: Mechanical, Electronic, Optical, Magnetic and Thermal properties. Introduction to properties and motivation for study (qualitative only).	
SYNTHESIS METHODS	**(10 Hours)**
Bottom-up Synthesis-Top-down Approach: Precipitation, Mechanical Milling, Colloidal routes, Self-assembly, Vapour phase deposition, MOCVD, Sputtering, Evaporation, Molecular Beam Epitaxy, Atomic Layer Epitaxy, MOMBE.	
NANOMATERIAL	**(10 Hours)**
The Science of Nano - What is Nanobiotechnology, Introduction to Nanostructures : Carbon Nanotubes (CNT), Graphenes, Fullerenes, Nano Peapods, Quantum Dots and Semiconductor Nanoparticles Metal-based Nanostructures (Iron Oxide Nanoparticles) Nanowires Polymer-based Nanostructures including dendrimers, Introduction to metal based nanostructures, Protein-based Nanostructures: Nanomotors: Bacterial (E. coli) and Mammalian (Myosin family) Nanobiosensors: Science of Self-assembly - From Natural to Artificial Structures Nanoparticles in Biological Labelling and Cellular Imaging	
CHARACTERIZATION TECHNIQUES	**(08 Hours)**
X-ray diffraction technique, Scanning Electron Microscopy - environmental techniques, Transmission Electron Microscopy including high-resolution imaging, Surface Analysis techniques- AFM, SPM, STM, XPS, , Small-angle X-ray and neutron scattering, Optical and Vibration Spectroscopy, Particle size analyzer	
PROPERTIES	**(06 Hours)**

Metal Nanoclustures, Semiconducting nanoparticles , Rare Gas and Molecular Clusters	
APPLICATIONS	**(06 Hours)**
Microelectromechanical Systems (MEMSs), Nanoelectromechanical Systems (NEMSs), catalysis, biomedical applications	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Nanotechnology: Importance and Application by M.H. Fulekar, IK International, 2010.
2. Nanosystem Characterization Tools In The Life Sciences By Challa Kumar. Wiley-VCH, 2006.
3. Handbook of Nanofabrication. Edited By Gary Wiederrcht. Elsevier, 2010.
4. Introduction to Nanoscience by Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, Anil K. Rao. CRC Press, 2008.
5. Nanostructures & Nanomaterials: Synthesis, Properties, and Applications by Guozhong Cao, Imperial College Press, London, 2004.

Additional books:

6. Carbon Nanotechnology by Liming Dai.
7. Introduction To Nanotechnology, Charles P. Poole, Jr. Frank J. Owens, John Wiley & Sons, 2003

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 441: Material Science	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand the phenomena associated with crystal growth
CO2	identify the characteristics of phase equilibrium and nucleation with the help of diagram
CO3	classify various growth methods for materials synthesis
CO4	interpret the characterization techniques for assessing material properties
CO5	analyze the fabrication methods for nanomaterials preparation and its applications for semiconductor devices

Syllabus	
INTRODUTION TO CRYSTAL GROWTH	**(06 Hours)**
Materials and civilization, structure properties performance, classification of materials, states of matter, theory of liquids, transition between states of matter, energetics of transitions, structure of solids, crystallization, three dimensional bonding, interatomic distances, generalization based on bonding, formation of amorphous solids, metallic glasses, colloidal state of matter, gels, emulsions, liquid crystals, plasma state of matter, advanced materials, composite materials, modern materials needs, Polymeric materials, Organic Semiconductors, Ceramics.	
PHASE EQUILIBRIUM AND NUCLEATION	**(08 Hours)**
Phase diagrams, definition and basic concepts, Gibb's phase rule, one component and two component phase diagrams, properties of phases in materials, crystalline and non-crystalline phases, practical aspects of phase diagram, non-equilibrium in phase diagrams, iron carbon alloy, Phase deformation in materials, nucleation, growth of nuclei, solidification of alloys, common phase transformations in solid materials	
GROWTH TECHNIQUES	**(08 Hours)**
Crystal Growth from Melt, Solution, Vapour, Hydrothermal synthesis etc., Epitaxial Techniques, Liquid Phase Epitaxy, Vapour Phase Epitaxy, Metal Organic Chemical Vapour Deposition (MOCVD), Molecular Beam Epitaxy (CBE), Atomic Layer Epitaxy (ALE)	
MATERIAL PROPERTIES AND CHARACTERIZATION	**(08 Hours)**
Points defects in solids, lattice vacancies, colour centres produced by irradiation with x-rays, methods of characterizations, single crystal technique, Fourier computational methods, techniques and applications of neutron diffraction, comparison of neutron and X-ray diffraction, Elastic and plastic behaviour of materials, viscous and viscoelastic deformation, character of plastic flow, deformation of crystalline materials, plastic deformation, creep fracture, fatigue, hardness, Magnetic properties, types of magnetic materials, applications, Optical properties of metals and non-metals, optical materials, luminescence excitation and emersion, decay mechanisms, thallium	

activated alkali halides, electroluminescence.	
NANOMATERIALS	**(06 Hours)**
Introduction to nanomaterials, Fabrication of nanomaterials, Properties of materials at nano-scale, The era of new nanostructures of Carbon, Carbon Nano Tubes, Characterization of nanostructures, SPM, STM, AFM, SEM, TEM.	
MATERIALS DESIGN FOR SEMICONDUCTOR DEVICES	**(06 Hours)**
Semiconductor optoelectronic properties, III-V materials selection, semiconductor device structure for laser diodes, light emitting diodes (LED's), Photo cathodes, Microwave field-effect transistor.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Callister W. D., Materials Science and Engineering, Wiley 1997
2. Hertyman P., Crystal Growth, Elsevier, 1973
3. Guy A. G., Essentials of materials science, McGraw Hill 1976
4. Pemplin B. R., Crystal Growth, Pergamon Press 1980
5. Vanvleck L. H., Elements of Materials Science and Engineering, Addison Wesley 1999

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VII	L	T	P	C
PH 443: Density Functional Theory	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand the Thomas-Fermi energy and minimum energy principle
CO2	identify the exchange and correlation energy by using Hartree-Fock Method
CO3	interpret the Hohenberg-Kohn theorem and Kohn-Sham equations using variational principle
CO4	analyze the approximations for exchange correlation energies and their applications
CO5	apply time dependent density functional theory to excited states problems

Syllabus	
BACKGROUND	**(10 Hours)**
Thomas-Fermi Theory, Electron Density, Potential Relation, Minimum Energy Principle and Chemical Potential, Exchange energy from Fermi hole	
EXCHANGE AND CORRELATION ENERGY	**(05 Hours)**
Hartree-Fock Method, Exchange energy in atoms, Correlations in Thomas Fermi Framework	
HOHENBERG-KOHN THEOREM	**(05 Hours)**
Hohenberg-Kohn Theorem, V-Representability, derivative discontinuity, Spin Polarized systems, Density Matrix Functional.	
KOHN-SHAM EQUATIONS AND VARIATIONAL PRINCIPLE	**(10 Hours)**
Basic Kohn-Sham equations, Variational principle and self-consistent equations, Extension to magnetic and multi-component systems	
EXCHANGE CORRELATION ENERGIES	**(05 Hours)**
Approximations for exchange correlation energies and their application to atoms, molecules and solids.	
TIME DEPENDENT DENSITY FUNCTIONAL THEORY	**(07 Hours)**
Relativistic and time dependent density functional theory and its application to excited states problems.	
	(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Parr, R. G. & Yang, W. Density-Functional Theory of Atoms and Molecules. (Oxford University Press, USA, 1994).
2. Koch, W. & Holthausen, M. C. A Chemist's Guide to Density Functional Theory. (John Wiley & Sons, 2015).
3. R. E. Nalewajski, Density Functional Theory (Relativistic & Time Dependent), Springer Verlag, 1996.
4. R. M. Martin, Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004.
5. C. Fiolhais, F. Nogueira, M. Marques (eds.), A Primer in Density Functional Theory, Springer-Verlag, 2003

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 402: Statistical Mechanics	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	identify the relevance between statistics and thermodynamics
CO2	interpret the properties of microcanonical, canonical and grand canonical ensembles
CO3	examine the quantum statistics and density matrix for various systems
CO4	classify the consequences associated with Bose-Einstein and Fermi-Dirac statistics
CO5	analyze the Ising model and its solution
CO6	understand the Einstein-Smoluchowski theory and Fokker-Planck and master equations

Syllabus	
THE STATISTICAL BASIS OF THERMODYNAMICS	**(09 Hours)**
The connection between statistics and thermodynamics; Concept of microstates phase space and its connection to Entropy; Classical Ideal Gas and the Maxwell Boltzmann Distribution, Entropy of mixing and Gibbs Paradox	
ELEMENTS OF ENSEMBLE THEORY	**(08 Hours)**
Liouville's Theorem, Microcanonical Ensemble, Canonical Ensemble and Partition Function calculation for various systems; Energy fluctuations in the Canonical Ensemble; Grand Canonical Ensemble; Number Density and Energy Fluctuations in the Grand Canonical ensemble	
FORMULATION OF QUANTUM STATISTICS	**(12 Hours)**
Quantum Statistics and calculation of the Density matrix for various systems; Indistinguishability of Particles, Symmetric and Anti - Symmetric wave functions and calculation of the Bose-Einstein and Fermi-Dirac Distribution for a quantum Ideal Gas; Thermodynamic behaviour of an Ideal Bose Gas, Black-Body radiation and other applications of Bose-Einstein statistics; Thermodynamic behaviour of an ideal Fermi gas and various applications of Fermi-Dirac statistics such as Pauli paramagnetism and calculation of Chandrasekhar limit in White Dwarf stars; Cluster expansion techniques for interacting systems.	
THE ISING MODEL	**(05 Hours)**
Introduction to basic ideas of phase transitions via the Ising model and Van der Waals gas, the exact solution of the Ising model in 1D.	
NONEQUILIBRIUM STATISTICAL PHYSICS	**(08 Hours)**
Boltzmann's Equation, H-Theorem, Description of Einstein-Smoluchowski theory of Brownian motion as a stochastic process; Basic ideas behind the Fokker-Planck and Master equations with simple examples.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Reif, Frederick. Fundamentals of statistical and thermal physics. Waveland Press, 2009.
2. Kardar, Mehran. Statistical physics of particles. Cambridge University Press, 2007.
3. Pathria, R. K., Statistical Mechanics. [Sl]. (1996).
4. Huang, Kerson., Statistical Mechanics, John Wiley & Sons. New York(1963).
5. B. B. Laud, Fundamentals of Statistical Mechanics New Age International Private Limited January 2012.

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 404: Condensed Matter Physics	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	interpret the basic concepts of lattice vibrations and properties of crystal structure
CO2	interpret the phase transitions during the growth process
CO3	classify the liquid crystals and its applications
CO4	compare different types of colloids and their formations
CO5	understand the magnetism phenomena and its applications
CO6	summarize the origin of nanoscience and overview of current industrial applications

Syllabus	
OVERVIEW	**(05 Hours)**
Crystal physics, Lattice vibration and thermal properties, Electronic properties, Dielectrics, Magnetism.	
PHASE TRANSITIONS	**(08 Hours)**
Review of critical phenomena through percolation. Phase transition in softmatter. Equilibrium phase diagrams, Kinetics of phase separation, Growth processes, Liquid-Solid transition, freezing and melting	
LIQUID CRYSTALS	**(08 Hours)**
Types of liquid crystals, Characterization and identification of liquid crystal phases, Orientational order, elastic properties, Phase transition in liquid crystals, Applications. Granular Materials through sandpile model and self-organized criticality.	
COLLOIDS	**(08 Hours)**
Types of Colloids, Characterization of Colloids, Charge and steric Stabilization, Kinetic properties, Forms of colloids: Sols, Gels, Clays, Foams, Emulsions, Electrorheological and Magneto-rheological fluids.	
MAGNETISM	**(07Hours)**
Review of magnetism, Circular and helical order. Consequences of broken symmetry, phase transition, Landau's theory, rigidity, excitation, magnons, domains and domain walls, magnetic hysteresis, pinning effects. Magneto resistance, giant magneto resistance, NMR, technological aspects of magnetic materials	
INTRODUCTION TO NANOSCIENCE	**(07 Hours)**
The nanoscale dimension and paradigm, Definitions, history and current Practice, Overview of current industry applications, Nanoscale science and engineering principles.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. C. Kittel, Quantum Theory of Solids, John Wiley 1987
2. R. A. L. Jones, Soft Condensed Matter Oxford 2002
3. S. Blundell, Magnetism in Condensed Matter, Oxford 2001
4. M. Tinkham, Introduction to SuperconductivityMcGraw-Hill, New York 1996
5. P. W. Anderson Basic Notions of Condensed Matter Physics Addison Wesley 1997

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 406: Electronic and Optical Communication	**3**	**1**	**0**	**4**

Course Outcomes **In the end of the semester students will able to:**	
CO1	apply the Fourier analysis to waveform spectra
CO2	classify various types of noises in communication
CO3	examine the properties of amplitude and frequency modulation
CO4	interpret the characteristics of digital communication
CO5	understand the phenomena of light transmission in optical fiber and associated attenuation losses
CO6	analyze the components of optical communication system

Syllabus	
WAVEFORM SPECTRA	**(06 Hours)**
Various waveforms, Fourier series for periodic waveform, Fourier coefficients, Spectrum for the trigonometric Fourier series, Exponential Fourier series, Energy Signals and Fourier transform, FFT, Inverse FFT, Power Signal, Band-width.	
NOISE	**(04 Hours)**
Thermal noise, Shot noise, Partition noise, Flicker noise, Burst noise, Avalanche noise, Transistor noise, Signal to noise ratio, Noise factor, Noise temperature.	
MODULATION	**(10Hours)**
Review of amplitude modulation, Introduction to frequency modulation, Sinusoidal FM, Non-sinusoidal modulation, Deviation ratio, Modulation index for sinusoidal FM, Phase modulation, Equivalence between PM and FM, Digital phase modulation, Angle modulation circuits, Pulse amplitude modulation, Pulse code modulation, Pulse frequency modulation, Pulse time modulation, Pulse position modulation, Pulse width modulation.	
DIGITAL COMMUNICATION	**(10 Hours)**
Synchronisation, Asynchronous transmission, Bit error in baseband transmission, Matched filter, Bit-timing recovery, Digital carrier systems.	
LIGHT TRANSMISSION IN OPTICAL FIBER	**(06 Hours)**
Principle of light transmission in optical fiber, Numerical aperture, Losses in optical fiber, Dispersion, Types of optical fiber, fiber modes, attenuation, Signal distortion.	
OPTICAL COMMUNICATION SYSTEMS	**(06 Hours)**
Optical sources, Optical Power launching and coupling, Fiber splicing, Connectors, Optical amplifiers, Optical detectors.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Lathi B. P., Communication systems, Wiley Eastern Ltd 1992
2. Roddy D. and Coolen J., Electronic communications, Prentice Hall 2002
3. Keiser G., Optical fiber communications, McGraw-Hill 2000
4. Haykin S., Communication systems, Wiley India 2006
5. Selvarajan A., Kar S., and Srinivas T., Optical fiber communications : Principles and systems, Tata McGraw-Hill 2006

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 422: Global Navigation Satellite System	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand the fundamentals of navigation systems
CO2	identify the segments of GNSS
CO3	analyze the characteristics of satellite signals
CO4	identify the components of receiving systems
CO5	apply the GNSS in surveying, location based services and aircraft landing

Syllabus	
INTRODUCTION AND OVERVIEW	**(02 Hours)**
FUNDAMENTALS OF NAVIGATION SYSTEM	**(10 Hours)**
Concept of Ranging using Time of Arrival, Reference coordinate system, fundamentals of satellite orbits, positioning	
DIFFERENT SATELLITE NAVIGATIONAL SYSTEMS	**(06 Hours)**
GPS, Galileo, IRNSS, Beidou etc.	
GNSS SEGMENTS	**(06 Hours)**
Control Segment, Space segment, User segment	
SATELLITE SIGNAL CHARACTERISTICS	**(06 Hours)**
Frequency and modulation, tracking loops, filters, formation of pseudorange, signal acquisition, processing	
RECEIVING SYSTEMS	**(06 Hours)**
Single frequency receivers, Dual frequency receivers, position accuracy, dilution of precision, Ne frequencies added	
APPLICATIONS OF GNSS	**(06 Hours)**
surveying, location based services, aircraft landing, others	
	(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Kaplan E.D. (ed) Understanding GPS: Principles and applications Artech House
2. Rabbany Ahmed Introduction to GPS: The Global Positioning System Artech House 2006
3. Guochang Xu GPS: Theory, Algorithms and Applications Springer 2007
4. Bradford W. Parkiwson (Ed.), James J. Jr. Spilker (ed.) James J. Spilker per enge (contributor) Global positioning system : Theory and applications (American Inst. Of Aeronautics & Astronaulid 1996
5. James Bao Yen Tsui Fundamentals of Global Positioning system Receivers John Wiley & Sons 2005

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 424: Thin Films and Vacuum Technology	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	evaluate and use models for nucleating and growth of thin films.
CO2	understand the general principles and techniques of thin film deposition.
CO3	apply important laws of physics which govern how a vacuum system works
CO4	account for which components are used in a vacuum system, their construction, function and use.
CO5	discuss typical thin film applications.

Syllabus	
INTRODUCTION TO SURFACE PHYSICS	**(06 Hours)**
Thermodynamic Potentials and the Dividing Surface, Surface Tension and Surface Energy, Surface Stress and Surface Energy, Surface Diffusion and the Boltzmann Distribution. Chemical Potential and Driving Force, Thermodynamics of Vapor Pressure.	
GROWTH OF THIN FILMS	**(08 Hours)**
Vacuum and Kinetic Theory of Gasses, Pressure and Molecular Velocity, The Molecular Density, Collision Frequency, The Mean Free Path, Gas Flow Regimes: viscous, turbulent and molecular flow, Collisions with Surfaces, Kinetics of Crystal Growth, Diffusion, Nucleation Barriers in Classical and Atomistic Models, Growth Modes: Island Growth, Clustering, Coalescence and Ripening, Monolayer Formation Times.	
THIN FILM DEPOSITION TECHNIQUES	**(08 Hours)**
Physical vapor deposition, thermal deposition, Electron beam deposition, Sputtering, Spin-coating, Sol-Gel technique, Epitaxy, Molecular beam epitaxy, Chemical vapor deposition	
INTRODUCTION TO VACUUM TECHNOLOGY	**(06 Hours)**
Fundamental Vacuum Concepts, System Volumes, Leak Rates and Pumping Speeds, Cryopump, The Idea of Conductance, Measurement of System Pressure, Surface Preparation and Cleaning Procedures for Vacuum Systems.	
VACUUM SYSTEM OPERATION	**(06 Hours)**
Types of Vacuum Pumps, Rotary pump, Diffusion pump, TMP, Oil free pumps, Chambers, Tube and Flange Sizes, Valves, Choice of Materials, Pressure Measurement and Gas Composition, Pressure Measurement Gauges, Ultra high vacuum.	
THIN FILM CHARACTERIZATION AND APPLICATIONS	**(08 Hours)**
Properties of thin films, optical properties, electrical properties, magnetic properties, mechanical properties, Introduction to Thin film characterization techniques: Imaging Techniques, Structural	

Techniques, Optical Techniques, Electrical / Magnetic Techniques, Mechanical Techniques, Applications of thin films.

(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Smith D. L., Thin-Film deposition : Principle and practice, McGraw Hill 1995
2. Milton Ohring, Materials Science of Thin Films, 2nd Edition, Academic Press, 2001
3. Goswami A., Thin film fundamentals, New Age International 2007
4. Smith D. L., Thin-film deposition: principles and practice, McGraw Hill 1995
5. Seshan K., Handbook of thin-film deposition processes and techniques: principles, methods, equipment and applications, William Andrew, 2002

Additional Books:

6. Weissler G. L., Vacuum physics and technology, Academic Press, 1979

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 426: Quantum Field Theory	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	Understand the elements of classical field theories
CO2	Identify the second quantization using many-body systems
CO3	Analyze the quantum field theory with the help of scalar fields, fermionic fields and gauge fields
CO4	Interpret the Parity, Charge and Time symmetry for various fields
CO5	Analyze the interfacing peripherals and applications
CO6	Examine the divergence in Feyman diagrams and renormalization

Syllabus	
ELEMENTS OF CLASSICAL FIELD THEORIES	**(03 Hours)**
Lagrangian formulation; Lorentz invariance; symmetries, Noether's theorem and conserved currents	
THE METHOD OF SECOND QUANTIZATION	**(03 Hours)**
Discussing the basic framework for the formulation of many-body quantum systems.	
QUANTUM FIELD THEORY WITH SCALAR FIELDS	**(07 Hours)**
Free scalar fields, Klein-Gordon equation, canonical quantization, propagators, Interacting scalar fields Wick's theorem, Feynman rules.	
QUANTUM FIELD THEORY WITH FERMIONIC FIELDS	**(08 Hours)**
Gauge symmetries, quantum electrodynamics (QED), canonical quantization, working with Feynman diagrams, studying QED processes	
QUANTUM FIELD THEORY WITH GAUGE FIELDS	**(08 Hours)**
Gauge symmetries, quantum electrodynamics (QED), canonical quantization, working with Feynman diagrams, studying QED processes.	
P, T AND C SYMMETRIES	**(05 Hours)**
Parity, Charge and Time symmetry for various fields, CP symmetry, CPT symmetry.	
ADVANCED TOPICS	**(08 Hours)**
Introduction to path integral quantization, divergences in Feynman diagrams, renormalization.	
(Total Contact Time: 42 Hours)	

BOOKS RECOMMENDED:

1. Peskin, M.E., 2018. An introduction to quantum field theory. CRC press.
2. Zee, A., 2010. Quantum field theory in a nutshell (Vol. 7). Princeton university press.
3. Srednicki, M., 2007. Quantum field theory. Cambridge University Press.
4. Lancaster, T. and Blundell, S.J., 2014. Quantum field theory for the gifted amateur. OUP Oxford.
5. Lahiri, A. and Pal, P.B., 2005. A first book of quantum field theory. CRC Press

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 442: Many-Body Physics and Relativistic Quantum Mechanics	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand the second quantization theories for the system of identical particles
CO2	identify the characteristics of spin half Fermions and Bosons
CO3	interpret the relativistic wave equations
CO4	analyze the Lorentz transformation and covariance of the Dirac equation
CO5	classify the solutions to the relativistic equations
CO6	inspect the symmetries of the Dirac equation and conservation laws

Syllabus	
SECOND QUANTIZATION	**(06 Hours)**
System of identical particles, permutation symmetry, completely symmetric and antisymmetric states, bosons, fermions, field operators, momentum representation.	
SPIN-½ FERMIONS AND BOSONS	**(10 Hours)**
Non-interacting fermions, ground state energy and theory of electron gas, Hartree-Fock equation of atoms, Free Bosons, Weakly interacting dilute Bose gas.	
RELATIVISTIC WAVE EQUATIONS	**(05 Hours)**
The Klein-Gordon equation, continuity equation, Free solutions of the KG equation, Dirac equation, continuity equation, Dirac matrices, Dirac equation in covariant form, non-relativistic limit.	
LORENTZ TRANSFORMATIONS AND COVARIANCE OF THE DIRAC EQUATION	**(09 Hours)**
Transformation of Spinors, Representation of S, properties of S, properties of Gamma matrices, solution of Dirac equation for a free particle, Spinors with momentum, orthogonality relations and density, projection operators, The Foldy–Wouthuysen Transformation, Transformation for Free Particles.	
SOLUTIONS TO THE RELATIVISTIC EQUATIONS	**(07 Hours)**
Coupling of the equations to electromagnetic potential, solution to KG equation, solution to Dirac equation, Wave Packets and Zitterbewegung, Superposition of Positive Energy States, the General Wave Packet, General Solution of the Free Dirac Equation in the Heisenberg Representation, Potential Steps and the Klein Paradox, The Hole Theory.	
SYMMETRIES OF THE DIRAC EQUATION	**(06 Hours)**
Invariance and Conservation Laws, The General Transformation, Rotations, Translations, Spatial	

Reflection, Charge Conjugation, Time Reversal Invariance of the Dirac Equation.
(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Schwabl, F., 2012. Advanced quantum mechanics. World Publishing Corporation.
2. Bjorken, J.D. and Drell, S.D., 1965. Relativistic quantum mechanics. McGraw-Hill.
3. Negele, J.W., 2018. Quantum many-particle systems. CRC Press.
4. Greiner, W., 1990. Relativistic quantum mechanics (Vol. 3). Berlin: Springer.
5. Sakurai, J.J., 1967. Advanced quantum mechanics. Pearson Education India.

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 444: Microprocessor	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	understand the architecture of microprocessor 8085
CO2	identify the programming techniques and set of instructions
CO3	classify the timing for the execution of input and output instructions
CO4	understand the interrupt structure of 8085
CO5	analyze the interfacing peripherals and applications
CO6	compare the 8085 and 8086 microprocessors

Syllabus	
INTRODUCTION TO MICROPROCESSOR-8085	**(06 Hours)**
Basic 8085 microprocessor architecture and its functional blocks, 8085 microprocessor IC pin outs, Memory and Address, data and control buses, Clock signals, Instruction cycles, Machine cycles, Timing states, Instruction timing diagrams.	
PROGRAMMING 8085 MICROPROCESSOR	**(06 Hours)**
Basic 8085 instruction set, Programming Techniques with Additional Instructions, Counters and Time delays, Stack and Subroutines, Code Conversion, BCD Arithmetic, and 16-Bit Data Operations.	
8085 INTERFACING	**(06 Hours)**
Bus interfacing concepts, Timing for the execution of input and output (I/O) instructions, I/O address decoding, Memory and I/O interfacing, Serial I/O lines of 8085.	
INTERRUPTS	**(08 Hours)**
Interrupt structure of 8085, RST (restart) instructions, vectored interrupt, interrupt process and timing diagram of interrupt instruction execution.	
INTERFACING PERIPHERALS (I/OS) AND APPLICATIONS	**(08 Hours)**
Interfacing Data Converters, Programmable Interface Devices, General- Purpose Programmable Peripheral Devices, Serial I/O and Data Communication, Microprocessor Applications.	
ADVANCE MICROPROCESSORS	**(08 Hours)**
Introduction to Microprocessor-8086, Comparison between 8085 and 8086, Development of x86 series of microprocessors and microcontrollers.	
	(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Gaonkar R. S., Microprocessor architecture, programming and applications: With the 8085/8080A Wiley Eastern 1995
2. Srinath N. K., 8085 Microprocessor programming and interfacing Prentice Hall 2005
3. Uffenbeck J., Microcomputers and microprocessors : The 8080, 8085 and Z-80 programming inferfacing and troubleshooting Prentice Hall 2005
4. Ghosh P. K. and Sridhar P. R., 0000 to 8085: Introduction to Microprocessors for engineers and scientists Prentice Hall 2006
5. Rafiquzzaman M. Microprocessors and Microcomputer-Based System Design CRC Press1995

Fourth year of Five Years Integrated M.Sc.(Physics) M.Sc. – IV, Semester – VIII	L	T	P	C
PH 446 : Advanced Crystallography	**3**	**0**	**0**	**3**

Course Outcomes **In the end of the semester students will able to:**	
CO1	analyze the nucleation process and choose proper growth rate condition for crystal growth
CO2	classify the different experimental crystal growth methods
CO3	examine defects in crystalline materials after growth
CO4	explain in detail experimental method for crystal structure
CO5	determine the crystal structure
CO6	develop the application of crystals in protein crystallizations

Syllabus	
NUCLEATION AND GROWTH RATE	**(04 Hours)**
Nucleation, homogeneous nucleation and heterogeneous nucleation, driving force for crystallization, growth on rough faces, growth on perfect singular faces, growth on imperfect singular faces, transport at growth interface, transport in bulk solids, growth rate of a crystal	
CRYSTAL GROWTH METHODS	**(10 Hours)**
Bridgman and related methods-basic processes, Czochralski and related methods: Kyropoulos growth, Dendrite method, Stepanov method, edge define film fed growth, high pressure methods, hydrothermal growth. Chemical vapour transport technique: introduction, some theoretical aspects-concepts of epitaxy, reaction, transport processes, stability condition, closed systems, open systems for bulk crystals, open systems for thin layers.	
DEFECTS IN CRYSTALLINE MATERIALS	**(08 Hours)**
Defects in crystalline materials – an introduction, concept of slip, dislocations and slip, cross slip, velocity of dislocations, climb, and experimental observations of climb. Stress field of a dislocation-edge and screw, strain energy of a dislocation, forces on dislocations, forces between dislocations, unit dislocation, partial dislocations- the Shockley partial, Frank partial or Sessile dislocation, Lomer-Cottrell sessile dislocation, Intersections of dislocations, movement of dislocation containing elementary jogs, composite jogs.	
EXPERIMENTAL METHOD FOR CRYSTAL STRUCTURE	**(08 Hours)**
Laue Photographs, Powder Photographs, Diffractometer and Spectrometer Measurements	
APPLICATIONS	**(06 Hours)**
Orientation and Quality of Single Crystals, Structure of Polycrystalline Aggregates, Determination of Crystal Structure	
Protein Crystals	**(06 Hours)**

Protein sources, Protein Purification, Principles of Protein Crystallization, Protein crystallization Techniques, Phase Calculations using isomorphism and anomalous dispersion methods, multiple wave length methods, Ramchandran plot, Protein folding, Application of Synchrotron radiation.
(Total Contact Time: 42 Hours)

BOOKS RECOMMENDED:

1. Crystal growth processes by J.C. Brice (Blackie and sons Ltd.)
2. Crystal growth by Santaraghvan and P. Ramasamy (Kru Publishers)
3. Introduction to dislocation by D. Hull (Pergamon press)
4. Elements of X-ray diffraction by B.D. Cullity, S.R.Stock, Prentice Hall, New Jersey
5. Physics of Crystal Growth (Collection Alea-Saclay: Monographs and Texts in Statistical Physics) Alberto Pimpinelli, Jacques Villain, Cambridge University Press (10 December 1998)