M. J. P. Rohilkhand University, Bareilly

Syllabus

of

M.Sc. Physics (Or Fourth & Fifth Year of Higher Education)

Under National Education Policy- 2020

(To be effective from session 2022-23)

Designed & Approved by:

The Board of Studies in Physics, M. J. P. Rohilkhand University, Bareilly

1.	Dr. A. P. Singh, Hindu College, Moradabad	Convener
2.	Dr. Sanjeev Srivastava, Government P. G. College, Bisalpur (Pilibhit)	Member
3.	Dr. Seema Teotia, Government Raza P. G. College, Rampur	Member
4.	Dr. Sundar Singh, Bareilly College, Bareilly	Member
5.	Dr. Anil Kumar, Gandhi Smarak Degree College, Surjannagar (Moradabad)	Member
6.	Dr. Neeraj Rathore, Bareilly College, Bareilly	Member
7.	Dr. H. K. Malik, I.I.T., Delhi	External Expert
8.	Dr. Praveen Singh, I.V.R.I., Bareilly	External Expert

SEMESTER-WISE TITLES AND CODES OF THE PAPERS

Ist Year – Semester I

Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper I	PCT 101	Mathematical Physics	4	Core	100
Paper II	PCT 102	Classical Mechanics	4	Core	100
Paper III	PCT 103	Quantum Mechanics I	4	Core	100
Paper IV	PCT 104	Electronic Devices	4	Core	100
Paper V	PCP 105	Practical- General Lab	4	Core	100
Paper VI	PEM 106	Minor Subject- Computer Programming C & MATLAB	4	Elective	100
	PRP 207	Research Project/Internship in any institution, lab or industry (*To be continued and final report to be submitted at the end of Semester II*)	-	Project	-
		Total Credits Semester-I	**24**		

Ist Year – Semester II

Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper I	PCT 201	Atomic & Molecular Spectroscopy	4	Core	100
Paper II	PCT 202	Statistical Mechanics	4	Core	100
Paper III	PCT 203	Solid State Physics	4	Core	100
Paper IV	PCT 204	Physics of Nanoscale Materials	4	Core	100
Paper V	PCP 205	Practical- General Lab	4	Core	100
Paper VI	PRP 207	Research Project/Internship in any institution, lab or industry (*To be continued from Semester I)*	8	Project	100
		Total Credits Semester II	**28**		

IInd Year- Semester III

Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper I	PCT 301	Nuclear Physics I	4	Core	100
Paper II	PCT 302	Electromagnetic Theory	4	Core	100
Paper III	PST 303 (A) **Or** PST 303 (B)	PST 303 (A)-Electronics I: Analog Communication Systems **Or** PST 303 (B)- Condensed Matter Physics I (First paper of each specialization)	4	Specialization	100
Paper IV (Optional Paper)	PET 304 (A) **Or** PET 304 (B) **Or** PET 304 (C)	PET 304 (A)- Advanced Solid State Physics **Or** PET 304 (B)- Lasers & Fibre Optics **Or** PET 304 (C)- Atmospheric Physics & Space Science	4	Elective	100
Paper V	PCP 305	PCP 305 (A)- Practical- Specialization (Electronics) **Or** PCP 305 (B)- Practical- Specialization (Condensed Matter Physics)	4	Specialization	100
Paper VI	PRP 306	Master Dissertation (*To be continued and final report to*	-	Dissertation	-

		be submitted at the end of Semester IV)			
		Total Credits Semester-III	**20**		

IInd Year- Semester IV

Paper No.	Paper Code	Title of Paper	Credits	Type	Marks
Paper I	PCT 401	Quantum Mechanics II	4	Core	100
Paper II	PCT 402	Nuclear Physics II	4	Core	100
Paper III	PST 403 (A) **Or** PST 403 (B)	PST 403 (A) - Electronics II: Digital Electronics and Microprocessors **Or** PST 403 (B)- Condensed Matter Physics II (Second paper of each specialization)	4	Specialization	100
Paper IV (Optional Paper)	PET 404 (A) **Or** PET 404 (B) **Or** PET 404 (C)	PET 404 (A)- Classical Electrodynamics & Plasmas **Or** PET 404 (B)- Modern Communication Electronics **Or** PET 404 (C)- Materials Science and Energy Devices	4	Elective	100
Paper V	PCP 405	PCP 405 (A)- Practical- Specialization (Electronics) **Or** PCP 405 (B)- Practical- Specialization (Condensed Matter Physics)	4	Specialization	100
Paper VI	PRP 306	Master Dissertation *(To be continued from Semester III)*	8	Dissertation	100
		Total Credits Semester-IV	**28**		

General Guidelines:

1. Paper III of Semester III & IV will be of specialization, so papers of the same specialization have to be chosen in both semesters.
2. Paper IV of Semester III & IV will be an optional paper, so only one of the three options given therein has to be chosen in each semester.
3. During the course of each semester, students have to perform at least 6 experiments in the laboratory as per the availability of experiments in the particular college. In the end-semester exam, students have to perform 2 experiments in each semester out of the list of experiments given therein.
4. Each paper will be of 100 (= 25+75) marks. In each paper, there will be 25 marks for continuous internal evaluation (CIE) in terms of Attendance/class interaction/assignments/quiz/tests etc and rest of the 75 marks will be for the end-semester exam.
5. Suggestive no. of periods of 40-minute duration:
    a) Total lectures per paper per semester = 45
    b) Lectures per paper per week = 4
    c) Practical periods per week = 24
    d) Periods for Project/Dissertation per week = 06.

M.Sc. Ist Year

Semester I

Paper I: Mathematical Physics (PCT 101)

Course Objectives:

- To understand the important mathematical methods and tools in physics
- To provide basic skills required for the application of mathematical methods in physics
- To develop understanding of mathematical methods for the analysis of theories and concepts in physics
- To develop among students' essential knowledge about the application of such methods in their respective research fields

Learning Outcomes:

- After completing this course, students will acquire wide knowledge about analytic functions, several theorems about complex functions, singularities, residues, contour integration and their applications in physics and engineering
- After completion of the course, students will be well equipped in the use of several special functions, polynomials and differential equations in different branches of physics and engineering
- Students will learn to make use of Fourier series and transforms for obtaining solution of different physical problems
- After completing the course, students will acquire sufficient level of understanding about probability and statistical distributions and their role in data analysis
- After the completion of the course, students will have significant understanding about tensors and their role in understanding physical concepts.

Total Lectures: 45

Unit I: Complex Variables (10 Lectures**)**

Analytic functions, The Cauchy-Riemann equations, Cauchy's Integral Theorem, Cauchy's Integral formula for a function and its derivatives, Taylor & Laurent series, Singularities of a function, Zeros and Poles, Cauchy's Residue Theorem, Contour integration of simple functions.

Unit II: Special Functions, Polynomials & Differential Equations (13 Lectures**)**

Legendre, Bessel, Hermite, and Laguerre differential equations- Solution and orthonormal properties.

Linear ordinary differential equations of first and second order, Partial differential equations (Laplace, Wave and Heat equations in two and three dimensions), Green's function method of solving inhomogeneous boundary value problems.

Unit III: Fourier Series, Fourier and Laplace Transforms (10 Lectures**)**

Fourier series, Fourier series of even and odd functions, Half-range expansion, Arbitrary period, Fourier integral and its complex form, Fourier transforms, Fourier sine and cosine transforms, Application of Fourier series and transformation, Wavelet transforms and applications, Laplace transforms.

Unit IV: Probability statistics and Elementary Tensor Analysis (12 Lectures**)**

Elementary probability theory, random variables, Binomial, Poissson and Normal distributions, Central limit theorem, Hypothesis testing and Data analysis in statistics.

Coordinate transformations; Contravariant and Covariant vectors; Contravariant, Covariant and Mixed tensors; Symmetric and skew-symmetric tensors; Fundamental operations with tensors; Metric tensor, Conjugate tensor and associated tensors; Examples of tensors in Physics.

Text and Reference Books

1. Mathematical Physics: B.S. Rajpoot
2. Mathematical Physics: H. K. Das
3. Complex Variables: Schaum's Outline Series
4. Mathematical Methods for Physicists: George B. Arfken, Hans J. Weber, Frank E. Harris
5. Applied Mathematics for Engineers & Physicists: Louis A. Pipes & Lawrence R. Harvill
6. Advanced Engineering Mathematics: Erwin Kreyszig
7. Mathematical Physics: Satya Prakash

Paper II: Classical Mechanics (PCT 102)

Course Objectives:

- To study central force motions and scattering in different frames of reference
- To study the mechanics of dynamical systems using Lagrange's equations of motion for both conservative and non-conservative forces
- To understand and apply the variational principle for solving mechanical problems using calculus of variations
- To develop understanding of cyclic coordinates and conservation of corresponding momentum
- To study Hamilton's principle and establish its relation to Lagrangian formulation and apply it to the solution of some standard mechanical problems
- To develop understanding of canonical transformations and Poisson brackets
- To study the Hamilton-Jacobi technique of solving mechanical problems and develop understanding of rigid body dynamics and also of small oscillations.

Learning Outcomes:

- After the successful completion of the present classical mechanics course students will be able to clearly understand the power of Lagrangian and Hamiltonian formulations for solving dynamical problems and to point out the strengths and weakness of each of these formulations
- Students will be able to apply variational principle for obtaining the solution of dynamical problems
- A clear understanding will be developed regarding the canonical transformations and Poisson brackets
- Students will achieve sufficient level of knowledge about Hamilton-Jacobi method of solving dynamical problems
- Understanding of Moment of Inertia tensor for rigid bodies and also of small oscillations and normal modes will also be achieved.

Total Lectures: 45

Unit I: Central Force Motions and Lagrange's Equations (10 Lectures**)**
Central force motions, Two-body collisions- Scattering in laboratory and centre of mass frames, D'Alembert's principle, generalized coordinates and generalized force, Derivation of Lagrange's equations, Velocity-dependent potentials and the dissipation function, Applications of Lagrange's equations- Single particle in space, Simple pendulum with rigid support, Atwood's machine, Bead sliding on rotating wire (time-dependent constraint).

Unit II: Variational Principles and Lagrange's Equations (13 Lectures**)**
Hamilton's principle, Some techniques of the calculus of variations: shortest distance between two points in a plane, Minimum surface of revolution and The Brachistochrone problem. Derivation of Lagrange's equations from Hamilton's principle, Advantages of variational principle formulation, Canonical or Conjugate momentum, Cyclic coordinates and conservation of conjugate momentum.

Unit III: Canonical Transformations and Poisson Brackets (10 Lectures**)**
Hamilton's equations and applications to standard problems, Canonical transformations- Generating function, conditions for canonical transformations and applications to problems, Poisson Brackets and their properties, Invariance of Poisson Bracket under canonical transformation, Symmetry invariance and Noether's theorem.

Unit IV: Hamilton-Jacobi Formulation, Rigid Body Dynamics, and Small Oscillations (12 Lectures)
Hamilton-Jacobi Equations, Hamilton's Principal and Characteristic function, Applications to the problem of Projectile and One-dimensional Harmonic Oscillator.

Rigid Body Dynamics: Inertia tensor and Moment of Inertia, Euler's equations of motion, Torque-free motion of a rigid body, Motion of heavy symmetrical Top.

Theory of small oscillations, normal modes.

Text and Reference Books

1. Classical Mechanics: Herbert Goldstein, Charles P. Poole, John Safko
2. Classical Mechanics: N. C. Rana and P. S. Jog
3. Classical Mechanics: B. D. Gupta and Satya Prakash
4. Classical Mechanics: S. L. Gupta, V. Kumar, H. V. Sharma, Pragati Prakashan Meerut

5. Classical Mechanics: J. C. Upadhyaya, Himalaya Publishing House
6. Classical Mechanics of Particles and Rigid Bodies: Kiran C. Gupta
7. Mechanics: A Sommerfield
8. Introduction to Dynamics: Percival and D. Richards

Paper III: Quantum Mechanics I (PCT 103)

Course Objectives:

- To study the fundamental quantum mechanical concepts and apply Schroedinger equation to the case of spherically symmetric potentials
- To develop operator formalism in quantum mechanics and study various operators in the matrix form
- To understand the different components of angular momentum operators and their commutation rules and addition of orbital and spin angular momenta
- To study approximation methods in quantum mechanics for solving those quantum mechanical problems which cannot be solved exactly.

Learning outcomes:

After successfully completing this course, students will be able

- To understand the role played by the wave function in the description of a quantum system
- To develop understanding of time-independent Schroedinger equation and its solution for spherically symmetric potentials e.g., Hydrogen atom problem leading to eigenvalues and eigenfunctions
- To differentiate between different kinds of operators used in quantum mechanics and the concept of commuting operators representing quantities that can be measured simultaneously
- To develop theory of angular momenta, their commutation rules and the way orbital and spin angular momenta add to produce resultant angular momentum
- To understand various approximation techniques such as time independent perturbation theory, Variational method, and W. K. B. method to find approximate solutions of quantum mechanical problems which are not exactly solvable.

Total Lectures: 45

Unit I: Fundamental Concepts of Quantum Mechanics (10 Lectures**)**

Postulates of Quantum Mechanics, Wave function in Coordinate & Momentum Representation, Momentum eigenfunctions, Box normalization, Schroedinger Equation for Spherically Symmetric Potentials, Degeneracy, Hydrogen Atom- Radial equation, Eigenvalues and Eigenfunctions.

Unit II: Operator Formalism (10 Lectures**)**

Linear operators, Hermitian operators, Unitary operators and Unitary Transformations, Matrix representation of operators, Diagonalization of Matrices, Parity operator, Simultaneous measurement and Commuting operators.

Unit III: Theory of Angular Momentum (10 Lectures**)**

Angular momentum operators and their commutation relations, Ladder operators, Introduction to Dirac's Bra and Ket notation, Matrices for J^2, J_z, J_x, J_y, J_+, & J_- ; Addition of Orbital and Spin angular momenta: Clebsch- Gordon Coefficients, Spin angular Momentum, Spin wave functions, Stern-Gerlach experiment.

Unit IV: Quantum Dynamics and Approximation Methods (15 Lectures**)**

Time-independent perturbation theory- non degenerate and degenerate cases; Applications to Harmonic oscillator, Ground state of Helium atom, Zeeman effect without electron spin, First order & Second order Stark effect in Hydrogen.

The Variational Method- application to ground state & excited states of He atom, Electron interaction energy, Variation of parameter.

W.K.B. Method and its application to alpha decay problem, Identical particles and exchange degeneracy, Symmetric and Antisymmetric wave functions.

Text and Reference Books

1. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016
2. Quantum Mechanics: S. Gasiorowicz
3. Principles of Quantum Mechanics: Ajoy Ghatak and Lokanathan

4. Principles of Quantum Mechanics: I. S. Tyagi, Pearson Publications
5. Quantum Mechanics: L. I. Schiff
6. Quantum Mechanics: Concepts and Applications – Nouredine Zettili
7. Advanced Quantum Mechanics: Satya Prakash, Kedar Nath Ram Nath

Paper IV: Electronic Devices (PCT 104)

Course Objectives:

- To study various special purpose diodes and their applications in rectification, amplification, and oscillation producing circuits
- To study JFET & MOSFET amplifiers and certain other applications of these devices
- To develop understanding of fundamentals of operational amplifiers (Op-amps)
- To acquire a deep understanding of various applications of Op-amps.

Learning Outcomes:

After successfully completing this course in electronics, students will be able

- To understand clearly the working and applications of LED, Tunnel, Varactor, Solar cells, LCD and Schottky diodes, and SCR etc
- To develop thorough understanding of construction, working principles, and applications of JFET and MOSFET amplifiers and their relative merit and demerit as compared to BJTs
- To have fundamental knowledge about the construction and working of differential amplifiers and its successor operational amplifier along with a comparison between ideal and practical op-amp in terms of its electrical parameters. It will also provide clear understanding of open-loop and closed loop operations of op-amp
- To develop a clear understanding about the versatility of op-amp in terms of its applications.

Total Lectures: 45

Unit I: Special Diodes & Optoelectronic Devices (10 Lectures**)**

Varactor diode; Schottky diode; Tunnel diode; Liquid crystal diode (LCD); Light emitting diode (LED)- Construction, working, generation of light and external quantum efficiency, high frequency limit, effect of surface and indirect recombination current in LED; Solar cell- Construction, working, Open circuit voltage, short circuit current & fill factor, Photodetectors, Semiconductor controlled rectifier (SCR), Diac, Triac.

Unit II: FET Amplifiers (12 Lectures**)**

Junction Field-Effect Transistor (JFET): Construction, Working, JFET parameters, Biasing (Source bias, Voltage divider bias, Self-bias), amplifier configurations (Common source & Common drain amplifier), Applications.

Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET):

Depletion Type MOSFET– Construction, Working, Biasing (Gate bias, Self-bias, Voltage divider bias, Zero-bias), amplifier configurations (Common source and Common drain amplifier), Applications. **Enhancement Type MOSFET-** Construction, Working, Biasing (Gate bias, Drain-feedback bias, Voltage Divider bias), amplifier configurations (Common source and Common drain amplifier), Applications.

Unit III: Introduction to Operational Amplifiers (10 Lectures**)**

Differential amplifier and its circuit configurations, Dual-input balanced output differential amplifier, DC & AC analysis of differential amplifier, Common mode and differential mode signals, Common-mode rejection ratio (CMRR). Block diagram of Operational amplifier (Op-Amp), Op-Amp electrical parameters, Characteristics of Op-amp: Ideal and practical, Equivalent circuit of Op-amp, Ideal Voltage transfer curve.

Unit IV: Applications of Operational Amplifier (13 Lectures**)**

Inverting & Non-inverting amplifiers, Open-loop configuration of Op-amp, Op-Amp with negative feedback (Closed loop operation), Feedback configurations, Op-amp as non-inverting amplifier, special cases of non-inverting amplifier, Op-amp as Inverting amplifier, special cases of inverting amplifier, Difference amplifier (or subtractor), Comparators, Schmitt trigger, Voltage Controlled Oscillator

(VCO), Op-amp integrator & differentiator, Frequency response of internally compensated and non-compensated Op-amp, Closed-loop frequency response.

Text and Reference Books:

1. Electronic Devices and Circuits: Sundar Singh & Sanjeev Tyagi, Pragati Prakashan, Meerut
2. Solid State Electronic Devices: Ben G. Streetman & Sanjay Banerjee
3. Physics of Semiconductor Devices: S. M. Sze, Kwok Kwok Ng & Yiming Li
4. Electronic Principles: Albert Paul Malvino & David J Bates
5. Electronic Devices and Circuit Theory: R. L. Boylestad and L. Nashelsky
6. Integrated Electronics: J. Millman and C. C. Halkias
7. Principles of Electronics: V. K. Mehta

Suggestive Digital Platforms / Web Link

1. MIT Open Learning – Massachusetts Institute of Technology, https://openlearning.mit.edu/
2. National Programme on Technology Enhanced Learning (NPTEL), https://www.youtube.com/user/nptelhrd
3. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
4. Swayam Prabha – DTH Channel, https://www.swayamprabha.gov.in/index.php/program/current_he/8

Paper V: Practical- General Lab (PHP 105)

1. Verification of Network Theorems (Thevenin, Norton, Superposition)
2. To study various transistor biasing methods
3. To determine Hybrid parameters of a transistor
4. To plot FET Characteristics and determine drain resistance and transconductance
5. Study of Regulated Power Supply
6. Determination of Planck's Constant using a Photocell
7. Determination of e/m by Magnetron method
8. Determination of e/m by Helical method
9. To determine reverse saturation current, material constant and band gap of PN Junction
10. To study the V-I characteristics of DIAC/TRIAC.

Paper VI (Minor Elective)
Computer Programming- C & MATLAB (PEM 106)

Course Objectives:

- To introduce students with the basics of C programming language
- To acquaint students with how to express various functions, variables, matrices etc in C
- To develop understanding of different kinds of loops and operators
- To Introduce students with MATLAB and its use in mathematical computing.

Learning Outcomes:

After successfully completing this course, students will -

- Acquire sufficient knowledge about C language
- Learn basics of programming in C language
- Be familiar with the computational tool MATLAB
- Learn graphics and programming in MATLAB.

Total Lectures: 45

Unit I: Programming in C (22 Lectures)

Character set, Constants, Variables and Keywords, C Instructions, Type Declaration Instruction, Arithmetic Instruction, Integer and Float Conversions, Type Conversion in Assignments, Hierarchy of Operations, Associativity of Operators, Control Instructions in C, Decision Control Structure, IF, IF-ELSE, Nested IF-ELSE, forms of IF, Logical operator, Loop Control Structure, WHILE Loop, FOR Loop, Nesting of Loops, BREAK Statement, CONTINUE Statement, DO-WHILE Loop, Case Control

Structure, SWITCH, GOTO, Functions & amp; Pointers, Arrays, Two and three-dimensional Array, Puppetting On Strings, Standard Library String Functions, Structures, Array of Structures.

Unit II: Introduction to MATLAB (23 Lectures)

MATLAB Basics- Variables, Numbers, Operators, Expressions, Input and Output, Vectors, Arrays-Matrices, **MATLAB Functions:** Built-in Functions, User defined functions, **Graphics with MATLAB:** Files and File Management-Import/Export, Basic 2D, 3D, plots, Graphic handling, **Programming with MATLAB:** Conditional Statements, Loops, MATLAB Programs- Programming and Debugging, Applications of MATLAB Programming, **Mathematical Computing with MATLAB:** Algebraic equations, Basic Symbolic Calculus and Differential equations, Numerical Techniques and Transforms.

Text and Reference Books:

1. Let Us C: Fifth Edition, Y. P. Kanetkar
2. A Guide to MATLAB- For Beginners and Experienced Users: Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg, Cambridge University Press
3. Essentials of MATLAB Programming: 2nd Edition, Stephen J. Chapman, Engage Learning
4. MATLAB Demystified: David McMahon, The McGraw-Hill Companies
5. Engineering Computation with MATLAB: 2nd Edition, David M. Smith, Pearson Education, Inc.

Semester II

Paper I: Atomic & Molecular Spectroscopy (PCT 201)

Course Objectives:

The primary objective of this course is to allow students to make a study of physics of atoms and molecules in terms of emission and absorption of radiations by them. Specifically, this course is aimed at

- Developing an understanding of fine structure of spectral lines in Hydrogen as obtained due to the consideration of relativistic effects and spin-orbit interaction
- Providing the knowledge about coupling schemes of orbital and spin angular momenta of electrons in the atoms
- Qualitative as well as quantitative discussion on Zeeman, Paschen-Back, Stark, and Back-Goudsmit effects and causes of width of spectral lines
- Qualitative as well as quantitative discussion on Pure rotational, Vibrational-rotational, and Raman spectra of molecules through models of rigid-rotator, non-rigid rotator, harmonic oscillator, anharmonic oscillator through the use of classical and quantum theories
- Studying electronic transitions between energy levels of molecules giving rise to electronic spectra. The discussion will include both coarse as well as fine structure of electronic bands

Learning Outcomes:

On successfully completing this course, the student will be able

- To understand the fine structure of hydrogen spectral lines and its explanation on the basis of spin-orbit interaction
- To understand how orbital and spin angular momentum of an electron in an atom add together to form the total angular momentum of one electron atom or how total angular momenta so obtained add vectorially to provide total angular momentum of the many-electron atoms
- To interpret causes and types of width of spectral lines
- Gain significant understanding of rotational, vibrational, Raman, and electronic spectra of molecules.

Total Lectures: 45

Atomic Spectra

Unit I: (10 Lectures**)**

Relativistic correction for energy levels of Hydrogen, Spin-orbit interaction and fine structure, Lamb-shift, Spectra of alkali atoms, LS & jj couplings, Normal and Anomalous Zeeman effect.

Unit II: (10 Lectures**)**

Paschen-Back effect, Hyperfine structure and isotopic shift, Examples of hyperfine structure, Back & Goudsmit effect, Weak field and strong field Stark effect in Hydrogen.

Natural width, Doppler width, Collision and pressure induced width of spectral lines; Width due to Stark effect.

Molecular Spectra

Unit III: (15 Lectures**)**

Observed molecular spectra and their representation by empirical formulae- Different energy states of molecules, Spectra in the visible and ultraviolet regions, Spectra in the infrared region, Microwave spectra, Raman spectra.

Interpretation of the principal features of Infrared and Raman spectra by means of the models of the Rigid-rotator and of the Harmonic oscillator, Interpretation of the fine structure of Infrared and Raman spectra by means of the models of Anharmonic oscillator, non-rigid rotator, Vibrating rotator and Symmetric top. Intensities in rotation-vibration spectra.

Unit IV: Electronic Spectra (10 Lectures**)**

Electronic energy & total energy of molecules, Vibrational structure of Electronic Transitions, Rotational structure of electronic bands, Intensity distribution in the Vibrational structure, Frank-Condon Principle.

Text and Reference Books:

1. Introduction to Atomic Spectra: H. E. White
2. Spectra of Diatomic Molecules: G. Herzberg
3. Molecular Spectroscopy: J. M. Brown
4. Fundamentals of Molecular Spectroscopy: C. N. Banwell
5. Introduction to Molecular Spectroscopy: G. M. Barrow
6. Atomic & Molecular Spectra: Laser - Raj Kumar

Paper II: Statistical Mechanics (PCT 202)

Course Objectives:

- To develop fundamental concepts such as macrostates and microstates, quantum states, phase space and thermodynamic probability etc
- To develop theory of ensembles and their role in the description of many particle systems under different set of constant parameters
- To study the importance of partition function and its use in the calculation of several important thermodynamic quantities
- To study interacting systems and application of Bose-Einstein Statistics and Fermi-Dirac statistics to analyse ideal Bose gas and Fermi-Dirac gas
- To study different kinds of fluctuations including density and energy fluctuations
- To learn the theoretical aspect of order-disorder phase transitions, random walk and Brownian motion etc.

Course Outcomes:

The successful completion of this course will make a student able

- To understand the concept of Phase space and to differentiate between macroscopic and microscopic quantities of a statistical system
- To develop a clear understanding of the importance of ensembles in statistical physics. The student will also acquire sufficient knowledge about the application of ensembles to some standard statistical problems
- To differentiate between identical distinguishable and identical indistinguishable particles and between symmetric and antisymmetric wave functions.
- To interpret the thermodynamic behaviour of ideal Bose gas and ideal Fermi gas
- To understand the continuous and discontinuous phase transitions, the property of superfluidity, and the phenomena of diffusion and Brownian motion.

Total Lectures: 45

Unit I: Foundation of Statistical Physics (10 Lectures**)**

Phase space of a classical system, macroscopic & microscopic states, accessible & inaccessible states, quantum states and the phase space, Postulate of equal a priori probability, Thermodynamic probability of a macrostate, calculation of number of microstates in the phase space of (i) a free particle, and (ii) one-dimensional harmonic oscillator.

Unit II: Ensembles (15 Lectures**)**

Microcanonical ensemble and its application to one-dimensional harmonic oscillator, definition of partition function.

Canonical ensemble- Partition function, free energy and its connection with thermodynamic quantities, energy fluctuations, application to the system of harmonic oscillators, magnetization of spin-half systems.
Grand canonical ensemble- Equilibrium between a system and particle-energy reservoir, grand partition function, chemical potential, application to a system of independent and localized particles, density and energy fluctuations.

Unit III: Interacting Systems (10 Lectures**)**

Identical particles, symmetric & antisymmetric wave functions, partition function for bosons and fermions; Ideal Bose gas- thermodynamic behaviour, Bose-Einstein condensation; black-body radiation and Planck’s law; Ideal Fermi gas- thermodynamic behaviour, magnetic behaviour- Pauli Paramagnetism; Landau theory of diamagnetism.

Unit IV: Phase Transitions & Fluctuations (10 Lectures**)**

Phases of matter, Thermodynamic potential, First-order phase transitions, Continuous phase transitions, Ising model-mean field theory, Order parameter, Landau theory, Superfluidity, Diffusion equation, Random walk and Brownian motion.

Text and reference Books:

1. Statistical Mechanics: R. K. Pathria
2. Statistical Mechanics: F. Reif
3. Statistical Mechanics: K. Huang
4. Statistical Physics: Landau and Lifshitz
5. Statistical Physics: F. Mandl
6. Relativity and Statistical Physics: Sundar Singh, Jai Prakash Nath & Co, Meerut

Paper lII: Solid State Physics (PCT 203)

Course Objectives:

- To study free electron theory and other concepts related to electrical and thermal conductivity of metals
- To develop an understanding of band theory of solids and effects associated with it
- To make a study of elastic constants and propagation of elastic waves in crystals
- To study magnetic properties of solids

Learning Outcomes: Successful completion of this course-

- Will allow students to acquire knowledge about electrical and thermal conductivity of metals and different theories explaining their variation
- Will provide students significant understanding of band theory of solids, Fermi surfaces in metals & their determination
- Will develop an understanding about elastic constants of crystals and the propagation of elastic waves in crystals particularly in cubic crystals
- Will transfer sufficient knowledge about properties of Paramagnetism, diamagnetism, and ferromagnetism in materials and theories associated with them.

Total Lectures: 45

Unit l: Free Electron Theory and Transport Properties (10 Lectures**)**

Free electron gas in three dimensions; Drude-Lorentz theory of electrical & thermal conductivity; Sommerfeld theory of electrical conductivity; Mattheissen’s rule; Umklapp scattering; Wiedmann-Franz law.

Unit ll: Band Theory of Solids and Fermi Surfaces (10 Lectures**)**

Wave functions in a periodic lattice and Bloch theorem; Kronig-Penny model; Distinction between metal, semiconductor and insulator; Fermi surfaces and metals; Experimental methods in Fermi surface determination: de Haas-Van Alphen effect.

Unit lll: Elastic Constants of Crystals and Elastic Waves (10 Lectures**)**

Elastic stress, strain and dilation; Elastic compliance and stiffness constants; Elastic energy density; Elastic stiffness constants of cubic crystals.
Elastic waves in cubic crystals- waves in (100), (110) and (111) directions. Measurement of elastic moduli of solids by acoustical methods; Ultrasound in solids.

Unit lV: Magnetism (15 Lectures**)**
Types of magnetism; Qualitative discussion of diamagnetism;
Paramagnetism: Origin of permanent magnetic moment, Quantum theory of Paramagnetism;
Ferromagnetism: Weiss theory of spontaneous magnetisation, Temperature dependence of spontaneous magnetisation, Quantisation of spin waves- Magnons, Bloch $T^{3/2}$ Law, Weiss theory of Hysteresis-Ferromagnetic domains and Bloch wall;
Molecular field theory of Antiferromagnetism and ferrimagnetism.

Text and Reference Books:

1. Introduction to Solid State Physics: Charles Kittel, Wiley India Pvt. Ltd.
2. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016
3. Solid State Physics: N. W. Ashcroft and N. D. Mermin
4. Solid State Physics: R. L. Singhal & P. A. Alvi, Kedar Nath Ram Nath
5. Solid State Physics: S. O. Pillai, New Age International Publishers
6. Fundamentals of Solid State Physics: B.S. Saxena, R.C. Gupta, P N. Saxena, J.N. Mandal, Pragati Prakashan Meerut
7. Solid State Physics: M. A. Wahab
8. Introduction to Solids: Azaroff
9. Principles of the Theory of Solids: J. M. Ziman, CUP-Vikas Students

Suggestive Digital Platforms / Web Link

1. MIT Open Learning – Massachusetts Institute of Technology, https://openlearning.mit.edu/
2. National Programme on Technology Enhanced Learning (NPTEL), https://www.youtube.com/user/nptelhrd
3. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
4. Swayam Prabha – DTH Channel, https://www.swayamprabha.gov.in/index.php/program/current_he/8

Paper IV: Physics of Nanoscale Materials (PCT 204)

Course Objectives:

- To learn fundamental concepts in nanoscience and nanotechnology
- To understand the effect of quantum confinement on energy eigenvalues and eigenfunctions of electrons in lower dimensional materials
- To develop an understanding of density of states for bulk, quantum well, quantum wire, and quantum dots
- To study about synthesis of nanomaterials through several physical and chemical methods
- To study about methods and techniques for the determination of particle size and band gap of a material
- To study about characterization techniques such as SEM, TEM, STM, AFM etc
- To develop an understanding of carbon nanotubes (CNTs) and some other allotropes of carbon.

Learning Outcomes:
Successful completion of this course will allow students-

- To have sufficient knowledge about the basics of nanoscience
- To acquire significant understanding of quantum confinement and its effects in quantum wells, wires and dots
- To interpret the meaning of density of states in lower dimensional materials and to learn its quantitative variation with energy and dimension of the crystal
- To acquire knowledge about the synthesis of nanomaterials through physical and chemical methods
- To characterize nanomaterials in terms of particle size, energy band gap, composition, emission and absorption of radiation etc
- To have significant knowledge about Fullerenes, CNTs and graphene etc.

Total Lectures: 45

Unit I: Fundamental Concepts in Nanoscience (10 Lectures**)**
Introduction to nanoscience & nanotechnology, Size dependence of properties, Moore's law, Surface energy and Melting point depression of nanoparticles, Qualitative idea of Free electron theory and band

theory of solids, Concept of effective mass, Localized particles, Donors, Acceptors and Deep traps, Exciton- Frenkel & Mott-Wannier.

Unit II: Quantum confinement and Density of states (10 Lectures**)**

Quantum confinement, Quantum size effect, Lower-dimensional structures- 0D,1D,2D,3D nanostructures, Quantum well, Quantum wire, Quantum dot, Application of Schroedinger equation to well, wire, dot- eigenvalues, eigen functions & applications.

Density of states- Definition, Calculation of density of states for Bulk material, quantum well, quantum wire, and quantum dot- Variation of density of states with energy and dimensions of crystal.

Unit III: Synthesis of Nanomaterials (10 Lectures**)**

Top-down & Bottom-up approaches; **Physical methods:** Ball-milling, Physical Vapour Deposition (PVD)- Thermal evaporation, E-beam evaporation, Sputtering deposition, and Pulsed Laser Deposition (PLD), Molecular Beam Epitaxy.

Chemical methods: Chemical Vapour Deposition (CVD), Metal-Organic Chemical Vapour Deposition (MOCVD), Sol-Gel, Spray-pyrolysis, Solvothermal Synthesis, Hydrothermal Synthesis.

Unit IV: Characterization Techniques and Carbon Nanotubes (15 Lectures**)**

Particle size and Band gap determination: Determination of particle size using XRD, Scherrer's formula, increase in width of XRD peaks of nanoparticles, shift in absorption spectra peak of nanoparticles, energy band gap determination from shift in absorption peaks, shift in Photoluminescence (PL) peaks.

Electron Microscopy Techniques: Scanning electron microscope (SEM), Transmission electron microscope (TEM), Scanning-tunnelling electron microscope (STM), Atomic force microscope (AFM).

Nanotechnology in Carbon Materials: Fullerenes, Carbon nanotubes (CNTs), Single Wall & Multi Wall CNTs-Synthesis, Structure, Properties and Applications, Elementary idea about Graphene.

Text and Reference Books:

1. Nanoscience and Nanotechnology: Sundar Singh, Pragati Prakashan, Meerut
2. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016
3. Introduction to Nanotechnology: Charles P. Poole, Jr. Frank J. Owens
4. Quantum Wells, Wires and Dots: Paul Harrison
5. Quantum Dot Heterostructures: D. Bimberg, M. Grundman, N. N. Ledentsov
6. Carbon Nanotechnology: Liming Dai
7. Nanostructured Materials and Nanotechnology: Hari Singh Nalwa

Paper V

Practical- General Lab (PCP 205)

1. To plot B-H Curve and determine coercivity and retentivity of the material
2. To determine velocity of ultrasonic waves (in kerosene oil) by Ultrasonic Interferometer
3. Study of Op Amp Characteristics
4. To study Laser (Diffraction/Two slit/ Grating)
5. Michelson Interferometer- Determination of Wavelength
6. To verify Fresnel Formulae
7. Biprism- Determination of Wavelength
8. To study Hall effect in metals and semiconductors
9. Synthesis of nanoparticles through sol-gel process
10. P-N Junction Diode- Clipping and Clamping Circuits

M. Sc. II Year
Semester III
Paper I: Nuclear Physics- I (PCT 301)

Course Objectives:

- To study basic properties of nuclei
- To study Alpha decay, Beta decay, and Gamma decay of nuclei and also transition rules and other effects associated with these decays
- To study theory of nuclear reactions
- To understand the mechanism of nuclear fission and fusion.

Course Outcomes: After successfully completing this course, students-

- Will acquire knowledge about fundamental properties of nuclei and their variation
- Will be able to understand the mechanism of Alpha decay of nucleus
- Will develop an understanding of Beta decay of nucleus, the neutrino concept, and associated parity violation in this mode of decay
- Will learn how nuclei can decay through the emission of Gamma rays. They will also acquaint themselves with Mossbauer Effect and its applications
- Will understand how conservation laws are involved in nuclear reactions and will also be able to interpret the meaning and importance of Q-value of nuclear reactions.

Total Lectures: 45

Unit- I (10 Lectures**)**

Basic nuclear properties; Size, Shape, Charge distribution, Theories of nuclear Composition, Binding energy of nucleus, Semi-empirical Binding Energy formula and its applications, nuclear size determination using scattering of fast electrons, nuclear Spin and Parity, magnetic moment of nuclei, Electric dipole moment and quadrupole moment of nuclei.

Unit- II (12 Lectures**)**

Alpha decay, Gamow theory of Alpha decay, Alpha ray spectrum, Geiger-Nuttall law, Beta- decay, Fermi's theory of beta decay, Beta ray spectra, Beta ray selection rules, Allowed and forbidden transitions, Fermi and Gamow Teller Transition, Parity violation in beta-decay, Detection of neutrino.

Unit- III (10 Lectures**)**

Gamma emission, Recoil energy, Internal-conversion, Internal Pair creation and Pair Annihilation, Determination of Gamma ray energy, Gamma ray Selection rules, nuclear isomerism, Mossbauer Effect and its applications.

Unit- IV (13 Lectures**)**

Nuclear reactions, Conservation laws, The Q-Value of nuclear reaction, Relation between Q-value and Threshold energy, Direct reactions, Pick up and Stripping reactions, Indirect reactions, Compound nucleus, Bohr theory of Compound nucleus, Resonance phenomenon, Breit-Wigner single level formula, nuclear fission, Bohr-Wheeler theory of nuclear fission, Condition of Spontaneous Fission, Controlled chain reaction, nuclear reactors, Nuclear Fusion.

Text and Reference Books:

1. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016
2. Nuclear Physics: Krane K.S., Wiley India Pvt. Ltd., (2008)
3. Nuclear physics principles and applications: Lilley J. S., John Wiley & Sons Ltd.
4. Concepts of Nuclear Physics: Bernard Cohen
5. Atomic and Nuclear Physic: S N. Ghoshal, Vol. II., 2000
6. Nuclear Physics: R. R. Roy and B. P. Nigam, Wiley-Eastern Ltd. 1983
7. Introduction to Nuclear Physics: Wong, PHI
8. Nuclear Physics: D. C. Tayal
9. Basic Nuclear Physics and Cosmic Rays: B. N. Srivastava

Paper II: Electromagnetic Theory (PCT 302)

Course Objectives:

- To introduce the basic mathematical concepts related to electromagnetic vector fields.
- To impart knowledge on the concepts of electrostatics, electric potential, energy density and their applications.
- To impart knowledge on the concepts of magnetostatics, magnetic flux density, scalar and vector potential and its applications.
- To impart knowledge on the concepts of Faraday's law, induced emf and Maxwell's equations.
- To impart knowledge on the concepts of Concepts of electromagnetic waves and Transmission lines.

Learning Outcomes:

- Understand the basic mathematical concepts related to electromagnetic vector fields. .
- Apply the principles of electrostatics to the solutions of problems relating to electric field and electric potential, boundary conditions and electric energy density.
- Apply the principles of magnetostatics to the solutions of problems relating to magnetic field and magnetic potential, boundary conditions and magnetic energy density.
- Understand the concepts related to Faraday's law, induced emf and Maxwell's equations.
- Apply Maxwell's equations to solutions of problems relating to transmission lines and uniform plane wave propagation.

Total Lectures: 45

Unit- I: Maxwell's Equations (10 Lectures**)**

Maxwell's Equations in vacuum and matter, Maxwell's correction to Ampere's law for non-steady currents and concept of Displacement current, Boundary conditions for electromagnetic fields, Poynting's theorem, Conservation of energy and momentum for a system of charged particles and electromagnetic field.

Unit- II: Electromagnetic Potentials and Gauge Transformations (12 Lectures**)**

Vector and scalar potentials, Maxwell's Equations in terms of Electromagnetic Potentials, Electromagnetic wave equation, Non-uniqueness of Electromagnetic Potentials and Concept of Gauge. Gauge Transformations: Coulomb and Lorenz Gauge, Transformation Properties of Electromagnetic Fields and Sources under Rotation, Spatial Inversion and Time-Reversal.

Unit- III: Reflection, Refraction and Polarization of Electromagnetic Waves (13 Lectures**)**

Propagation of Electromagnetic Plane Waves in Vacuum, Non-conducting Medium, Conducting Medium and Plasma, Reflection, Refraction and Polarization of Electromagnetic Waves, Fresnel Formulae, Total internal reflection and critical angle, Frequency Dispersion Characteristics of Dielectrics and Conductors; Normal and Anomalous Dispersion, Kramer Kronig Relations.

Unit- IV: Wave Guides (10 Lectures**)**

Basic concept of waveguide, Propagation of Electromagnetic Waves in Rectangular Waveguides, TE and TM Modes, Cut off frequency, Energy Flow and Attenuation. Modal Analysis of guided modes in a cylindrical waveguide, Cavity resonator, Radiation due to electric and magnetic dipoles.

Text and Reference Books:

1. Introduction to Electrodynamics: David J. Griffiths, Prentice-Hall of India, New Delhi
2. Classical Electrodynamics: John David Jackson, Wiley India
3. Theory and Problems of Electromagnetics: Joseph A. Edminster, Tata Mc Graw Hill
4. Electricity and Magnetism: E.M. Purcell, Berkeley Physics Course, Vol II, McGraw- Hill
5. Foundations of Electromagnetic Theory: J. R. Reitz, F. J. Milford and R. W. Christy, Pearson
6. Electricity and Magnetism: K. K. Tiwari
7. Electromagnetic Theory and Electrodynamics: Satya Prakash.
8. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016

Paper III (A)

Electronics I: Analog Communication Systems (PST 303 (A))

Course Objectives:

The fundamental objectives of this course are: -

- To enable students to understand the basic concepts of analog communication systems.
- To interpret and analyze the characteristics of the main components of communication electronics.
- To introduce the various types of transmission lines and antennas and to discuss the losses associated.
- To give thorough understanding about impedance transformation and matching.
- To be able to design the simplest devices and transmitting and receiving systems of radiofrequency series.
- To impart in depth knowledge of different types of analog communication systems and different modulation techniques used in these systems.

Learning Outcomes:

On completion, the student will be able to: -

- Analyze analog communication signals in time domain and frequency domain.
- Distinguish between different analog modulation techniques.
- Analog signal generation techniques.
- Discuss the fundamental concepts of wave propagation in Transmission Lines and Antennas.
- Analyze the line parameters and various losses in transmission lines.
- Apply smith chart for line parameter and impedance calculations.

Total Lectures: 45

Unit 1: Signal Communication (10 Lectures**)**

EM wave propagation- transmission lines, line equation, coaxial cable, Propagation of ground wave, space wave and Sky wave, Characteristic impedance, reflection coefficient, Standing wave ratio (SWR) and measurement of impedance in various media, Introduction to Fiber optics and wireless communication.

Unit 2: Transmission Line & Antenna (13 Lectures**)**

Fundamental of Transmission lines, Different types of Transmission lines, Primary line constants, phase velocity and line wavelength, Characteristic impedance, Propagation Coefficient, Phase and group velocities, Standing waves, Lossless line at radio frequencies, Voltage standing wave ratio (VSWR), Slotted line measurements at radio frequencies, Transmission lines as circuit elements, Linear dipole antennas, Antenna array techniques, Systems and characterization antenna matching and basic antenna types, Radar-principle, operation and applications.

Unit 3: Amplitude Modulation Systems (12 Lectures**)**

Principles of Amplitude Modulation; AM envelope and Equation of AM wave, Modulation index and Percent Modulation, Frequency Spectrum and Bandwidth, AM Power Distribution, AM by Multiple Sine waves, Transmission efficiency, Double Side-Band Suppressed Carrier (DSB-SC), AM Modulator Circuits; Low-level AM Modulator, Medium Power AM Modulator.

Unit 4: Frequency Modulation Systems (10 Lectures**)**

Theory of Frequency and Phase Modulation, Relationship between phase and frequency modulation, Mathematical Representation of FM, Phase and frequency deviation, Spectrum of an FM signal, Sinusoidal modulation, Bandwidth of a sinusoidally modulated FM signal, Generation of FM signal, Direct and Indirect Methods.

Text and Reference Books:

1. Electronic Devices and Circuits: Sundar Singh & Sanjeev Tyagi, Pragati Prakashan, Meerut
2. Electronic Communication Systems: George Kennedy and Bernard Davis, 4th edition
3. Principles of Communication Systems: H. Taub and Donald L. Schilling
4. Electronic Communications: Dennis Roddy and John Coolen
5. Electronic Communication Systems-Fundamentals Through Advanced: Wayne Tomasi, 4th edition
6. Communication Systems: Simon Haykin, John Wiley & Sons, Inc.
7. Electronic Communications: Dennis Roddy & John Coolen, Pearson Education

Paper III (B)
Condensed Matter Physics I (PST 303 (B))

Course Objectives:

- To study about crystal types, symmetry elements and X-ray diffraction in crystals
- To make a study of free electron gas, interacting electron gas, diffraction of electrons from surface, and about thermionic emission and associated effects
- To develop an understanding of transport properties of solids and semiconductors, particularly to study about Quantum Hall effect (QHE) and conduction mechanism in semiconductors
- To study about dielectric properties of solids.

Learning Outcomes: After successfully completing this course, students-

- Will acquire knowledge about symmetry elements in the crystals and the different types of lattices
- Will understand about the tight-binding approximation, Hartree-Fock approximation, and diffraction of electrons from surfaces
- Will be able to understand about very important and research-oriented topics such as QHE, IQHE, and FQHE
- Will learn about dielectric polarization and the properties of ferroelectricity and antiferroelectricity.

Total Lectures: 45

Unit l: Crystallography (11 Lectures)

Crystal structure: Primitive and Non-Primitive unit cells, Wigner-Seitz cell;

Symmetry Elements in crystals: Point group and Space group, Rotation axes, Reflection plane, Inversion centre, Rotation-Inversion axes, Screw axis, Glide plane;

Types of Bravais lattices; Tetrahedral and Octahedral interstitial sites; Closed packed Structure; Diamond Structure, Zinc Blende Structure, Wurtzite Structure; Spinel Structure.

Bragg's diffraction of X-Ray, Electrons and Neutrons for Determination of crystal structure.

Unit ll: Electron States in Solids and Surface Physics (12 Lectures)

Determination of electron States: Nearly free electron approximation; Tight binding approximation; Cellular method; Pseudo-Potentials methods;

Interacting electron gas: Hartree and Hartree-Fock approximation; Landau's quasi-particle theory-Fermi liquid;

Surface and Substrate; Elementary idea of surface Crystallography: Lattice, Mesh, Substrate net and surface net, Reciprocal net points & Rods; Electron diffraction from surface- Low Energy Electron Diffraction (LEED) & Reflective High Energy Electron Diffraction (RHEED);

Surface Electronic Structure: Work function, Thermionic emission, Surface states, Tangential Surface transport.

Unit lll: Transport Properties of Solids and Semiconductors (12 lectures)

Boltzmann Transport Equation; Resistivity of Metals and Semiconductors; Quantum Hall effect-Integral Quantised Hall Effect (IQHE) and Magnetoresistance; Fractional Quantised Hall Effect (FQHE);

Semiconductors: General Properties and Band Structure; Direct & Indirect band gap; Carrier statistics in Intrinsic Semiconductors; Electrical conductivity; Impurities; Carrier statistics in Extrinsic Semiconductors; Mechanism of current conduction in semiconductors; Drift and diffusion currents, Mobility of current carriers; Hall effect.

Unit lV: Dielectric Properties of Solids (10 Lectures)

Macroscopic concept of Polarization; Dielectrics: Local field at an atom; Clausius-Mossotti relation; Dipolar, Ionic & Electronic polarizability; Dielectric Constant;

Ferroelectricity: Curie Temperature; Dielectric behaviour above Curie temperature; Spontaneous polarization below Curie temperature; Ferroelectric Hysteresis;

Antiferroelectricity; Piezoelectricity, Pyroelectric effect, Applications of piezoelectricity and pyroelectricity.

Text and Reference Books

1. Introduction to Solid State Physics: Charles Kittel, Wiley India Pvt. Ltd.
2. Engineering Physics: H. K. Malik, McGraw Hill, 2^{nd} Ed., 2016
3. Solid State Physics: N.W. Ashcroft and N.D. Mermin, Cengage learning
4. Principles of the Theory of Solids: J.M. Ziman, CUP- Vikas Students' Edition
5. Solid State Physics: S.O. Pillai, New Age International Publishers
6. Solid State Physics: R. L. Singhal & P. A. Alvi, Kedar Nath Ram Nath
7. Elements of Solid State Physics: J. P. Srivastava, Prentice Hall of India
8. Fundamentals of Solid State Physics: B.S. Saxena, R.C. Gupta, P N. Saxena, J.N. Mandal, Pragati Prakashan
9. Solid State Physics: A. J. Dekker, Macmillan India Limited
10. Condensed Matter Physics: M. Marder, John Wiley & Sons
11. Principles of Condensed Matter Physics: P. M. Chaikin and T. C. Lubensky, Cambridge University Press
12. Crystal Structure Analysis: Buerger, John Wiley & Sons.

<u>Suggestive Digital Platforms / Web Link</u>

1. 'MIT Open Learning – Massachusetts Institute of Technology, https://openlearning.mit.edu/
2. National Programme on Technology Enhanced Learning (NPTEL), https://www.youtube.com/user/nptelhrd
3. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
4. Swayam Prabha – DTH Channel, https://www.swayamprabha.gov.in/index.php/program/current_he/8

Paper IV (A)
Advanced Solid State Physics (PET 304 (A))

Course Objectives:

- To study about various crystal defects and imperfections in solids
- To study about superconducting effects and theories to explain them
- To develop an understanding of NMR and ESR
- To make a study about disorders in alloys and liquid crystals

Learning Outcomes: After successfully completing this course, students-

- Will understand about various types of defects occurring in crystals and also their effect on conductivity of the solid
- Will acquire knowledge about superconductivity and its associated effects and also certain applications of superconductivity
- Will understand the importance of experimental techniques of NMR and ESR
- Will develop an understanding of the concept of order-disorder in alloys and liquid crystals.

Total Lectures: 45

Unit l: Crystal Defects (10 Lectures)

Point defects: Impurities, Vacancies and Interstitials; Schottky and Frenkel defects; Concentration of Schottky & Frenkel defects as function of temperature; Diffusion through Solids and Ionic Conductivity; Colours of Crystals – Experimental facts about F-center and F-band Spectra, de Boer model of F-center; Other colour centers like F_A-center, V-center, R-center & M-center (only qualitative discussion).
Line defects or Dislocations: Edge dislocation, Screw dislocation, Burgers vector.

Unit II: Superconductivity (13 Lectures)

Persistent currents; Effect of magnetic field on Superconductivity; Meissner effect; Type I & Type II Superconductors; Entropy and Heat capacity; Energy gap; Microwave and Infrared properties; Isotope effect; Thermodynamics of superconducting transition- Rutger's formula; Electrodynamics of superconducting transition- London equations; Coherence length; BCS theory; High Tc Superconductors; Superconducting Tunneling- D.C. and A.C. Josephson effects, SQUIDs.

Unit lll: Magnetic Resonance (12 lectures)

Nuclear Magnetic Resonance (NMR): Equations of motion; longitudinal and transverse relaxation times; Line width; Experimental method; Some applications- Determination of nuclear magnetic moments, structural studies, diffusion in solids;
Nuclear Quadrupole Resonance (NQR); Ferromagnetic Resonance (FMR);
Electron Spin Resonance (ESR): Nature of the phenomenon, experimental study, Few applications.

Unit lV: Disorder in Alloys and Liquid Crystals (10 Lectures)

Translational symmetry in Alloys; Substitutional solid solutions: Hume-Rothery rules; Order-Disorder Transformation in alloys: long-range and short -range order; Elementary theory of order: long-range order parameter and short-range order parameter; Phase diagrams of a binary system: Liquidus and Solidus curves and Eutectics.
Liquid Crystals: Formation of liquid crystals; Melting point and Transparency Temperature; Mesomorphic phase; Types of Mesophase- Smectic, Nematic and Cholesteric mesophases; Properties and applications of liquid crystals.

Text and Reference Books:

1. Introduction to Solid State Physics: Charles Kittel, Wiley India Pvt. Ltd.
2. Solid State Physics: N.W. Ashcroft and N.D. Mermin, Cengage Learning
3. Principles of the Theory of Solids: J. M. Ziman, CUP- Vikas Students' Edition
4. Solid State Physics: S.O. Pillai, New Age International Publishers
5. Solid State Physics: R. L. Singhal, Kedar Nath Ram Nath Publications
6. Elements of Solid State Physics: J. P. Srivastava, Prentice Hall of India
7. Fundamentals of Solid State Physics: B.S. Saxena, R.C. Gupta, P N. Saxena, J.N. Mandal, Pragati Prakashan Meerut
8. Solid State Physics: A. J. Dekker, Macmillan India Limited.
9. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016

Suggestive Digital Platforms / Web Link

5. MIT Open Learning – Massachusetts Institute of Technology, https://openlearning.mit.edu/
6. National Programme on Technology Enhanced Learning (NPTEL), https://www.youtube.com/user/nptelhrd
7. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
8. Swayam Prabha – DTH Channel, https://www.swayamprabha.gov.in/index.php/program/current_he/8

Paper IV (B)

Lasers & Fibre Optics (PET 304 (B))

Course Objectives:

- To study about various dynamic processes involved in the laser emission
- To acquire knowledge about important components of Laser systems such as laser amplifier and resonator
- To make a comparative study of different types of lasers such as solid-state laser, Gas laser, semiconductor laser, Dye laser etc.
- To study about safety concerns of lasers and also about applications of lasers in different fields such as medical, military, industrial etc.
- To develop understanding of optical fibres, their types and characteristics. To acquire knowledge about dispersion and attenuation in single-mode fibres.
- To have a basic understanding of optical fibre cables.

Learning Outcomes:

After successful completion of this course, students

- Will be able to understand the dynamics of lasing action in lasers

- Will acquire sufficient level of understanding about working principle of various types of lasers and their relative merits and demerits
- Will get knowledge about applications of lasers in different fields
- Will be able to form a solid background in optical fibre communication and to understand relative merits of single-mode fibres over other types of fibres
- Will have an understanding of degradation effects e.g., dispersion and attenuation in single-mode fibres.

Total Lectures: 45

Unit I: Basic Principles of lasers (10 Lectures**)**
Laser rate equation for three and four level systems; Dynamics of Laser Process: Switching, Mode locking, Mode pulling, Lamb dip, Hole burning; Energy levels and radiating properties of molecules, liquids and solids.

Unit II: Different Laser Systems (12 Lectures**)**
Laser amplifier; laser resonators; Techniques of laser excitation; Different laser systems: Ruby laser, He-Ne laser, Nd:Yag laser, Co_2 laser, Semiconductor injection laser, Dye lasers, Excimer lasers.

Unit III: Applications of Lasers (10 Lectures**)**
Material processing; Laser communication; Holography; Military applications; Medical applications; Industrial applications; Laser hazards and laser safety; Infrared optical devices; Laser cooling; Trapping.

Unit IV: Optical Fibre communication (13 Lectures**)**
Key elements of optical fibre systems; Optical fibre structure; Waveguiding and fabrication of optical fibres; Optical fibre modes and configurations; Graded index fibre structure; Single-mode fibres (SMFs) and Multimode fibres (MMFs); Limitations of MMFs; Characteristics of SMFs; Dispersion and Attenuation in SMFs; Fibre-optic cables.

Text and Reference Books:

1. Laser-Matter Interaction for Radiation & Energy: H. K. Malik, CRC Press (Taylor & Francis), Ist Ed., 2021
2. Lasers, Theory and Applications: K. Thyagarajan and A. K. Ghatak
3. Lasers and Non-linear Optics: B. B. Laud
4. Laser Physics: P. W. Milonni and J. H. Eberly
5. Principles of Laser: O. Swelto
6. Lasers: A. E. Siegman
7. Fibre Optics and Optoelectronics: R. P. Khare
8. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016

Paper IV (C)

Atmospheric Physics & Space Science (PET 304 (C))

Course Objectives:

- To study about the composition and dynamics of the lower atmosphere of the earth and to study variations in atmospheric conditions
- To develop an understanding of the Ionosphere and the magnetosphere and certain effects occurring there
- To acquaint the students with the Sun and effects associated with it
- To make a study about solar winds, solar flares etc.

Learning Outcomes: After successfully completing this course students will be able –

- To understand about the effects occurring in the lower atmosphere and also the consequences of Ozone hole
- To get sufficient information on the Ionosphere and Magnetosphere
- To know what is occurring inside the Sun and also about different regions in its interior
- To develop a significant level of understanding about the solar flares, coronal mass ejections etc.

Total Lectures: 45

Unit I (10 Lectures)
Lower atmosphere: Composition, constituents, dynamics; Diurnal and seasonal variations of Temperature, Pressure and Humidity; Ozone hole and its impact on climate.

Unit II (10 Lectures**)**

Ionosphere and Magnetosphere: Structure and formation, Density profile of upper atmosphere; Storm-substorm phenomena.

Unit III (13 Lectures**)**

Structure of the sun: Solar interior, solar atmosphere, photosphere, chromosphere, corona; Sunspots and their properties, solar rotation, Babcock model of sunspot formation.

Unit IV (12 Lectures**)**

Solar cycle and solar activity: Solar wind, Solar Flares, Coronal Mass Ejections (CMEs); Heliosphere and solar magnetic field; Space weather: causes and consequences.

Text and Reference Books

1. Meteorology: Understanding the Atmosphere: Steven A. Ackerman and John A. Knox
2. An Introduction to Meteorology: S. Petterssen, McGraw-Hill Book Company, USA
3. Elements of Space Physics: R. P. Singhal, Prentice Hall of India, New Delhi
4. Guide to the Sun: Kenneth J. H. Philips, Cambridge University Press
5. Astrophysics of the Sun: Harold Zirin, Cambridge University Press, U. K.

Paper V (A)
Practical- Electronics Specialization (PCP 305 (A))

1. To study Modulation & Demodulation
2. To study Transmission lines
3. 555 Timer as monostable multivibrator
4. Designing of Phase-shift Oscillator
5. To design an ‘Asymmetric Astable Multivibrator’ using 555 Timer IC
6. To design a ‘Symmetric Astable Multivibrator’ using 555 Timer IC
7. To study G. M. Counter
8. Study of Flip-flops
9. To design, fabricate and test +5V DC Power supply
10. To design a “Differentiator circuit” using 741 IC
11. To design an “Integrator circuit” using 741 IC

Paper V (B)
Practical- Condensed Matter I Specialisation (PCP 305 (B))

1. To study Bragg’s Law
2. To study Hall effect in metals
3. To study Hall effect in semiconductors
4. To study Electron Spin Resonance (ESR)
5. Determination of Lande g-factor using ESR Spectrometer
6. To study Nuclear Magnetic Resonance (NMR)
7. Measurement of resistivity using four-probe method
8. Determination of energy gap of semiconductors using four-probe method
9. Measurement of magnetic susceptibility
10. Measurement of dielectric constant

Semester IV

Paper I: Quantum Mechanics- II (PCT 401)

Course Objectives:

- To study about the time-dependent perturbation theory and other approximation methods in quantum mechanics
- To develop an understanding of quantum theory of scattering for various perturbing potentials
- To study about the method of partial waves in understanding the scattering phenomenon
- To study about identical particles, their wave functions and scattering effects involving such particles
- To develop an understanding of Klein-Gordon and Dirac approaches for solving problems in relativistic quantum mechanics.

Learning Outcomes:

Successful completion of this course will provide students-

- Sufficient knowledge about time-dependent perturbation theory and other approximation methods and their effects on atomic systems
- Thorough understanding of scattering of particles and its analysis through several methods for various scattering potentials
- Significant understanding about identical particles and the phenomena associated with these particles
- A comparative knowledge about two important approaches of solving problems in relativistic quantum mechanics viz. Klein-Gordon and Dirac.

Total Lectures: 45

Unit I: Time –Dependent Perturbation Theory (10 Lectures**)**
Time Dependent Perturbation theory and its Applications to Constant Perturbation, Transition probability, Fermi's Golden Rule, Harmonic Perturbation, Sudden and Adiabatic Approximations, Semi-Classical theory of radiation, Electric dipole Approximation, Selection rules.
Unit II: Quantum Theory of Scattering (12 Lectures**)**
Non-relativistic scattering theory, differential and total scattering cross section, Born- approximation method with examples of scattering by Screened Coulomb Potential, Gaussian Potential, Exponential Potential, Square well and Yukawa potentials. Partial wave analysis Method, Optical theorem, Dependency of Phase shift on Potential.
Unit III: Identical Particles and Spin (10 Lectures**)**
Identical Particles, Exchange Operator, Symmetric and Asymmetric wave functions, Construction of wave function for a system of particles, Pauli Exclusion Principle, Slater Determinant, Spin-statistics connection, Spin wave function for a system of two spin half particles, Distribution of bosons and Fermions in different potential wells/boxes. Scattering of two identical particles, Pauli- spin matrices.
Unit IV: Relativistic Wave Equation in Quantum Mechanics (13 Lectures**)**
Klein-Gordon equation for relativistic free particle, Expression of particle probability density and current density. Reduction of K.G. equation for charge particle in electromagnetic field to non-relativistic Schrödinger equation. Dirac relativistic equation for free particle, Properties of Dirac matrices, Expressions of Probability and Current densities, Plane wave solution of Dirac equation for free particle, Negative Energy states, Existence of electron spin, spin and magnetic moment of the electron.
Text and Reference Books:

1. Principles of Quantum Mechanics: Ajoy Ghatak and Lokanathan
2. Principles of Quantum Mechanics: I. S. Tyagi, Pearson Publications
3. Quantum Mechanics: L. I. Schiff
4. Quantum Mechanics: Concepts and Applications: Nouredine Zettili
5. Advanced Quantum Mechanics: Satya Prakash
6. Principles of Quantum Mechanics: R Shanker
7. Quantum Mechanics: Tannoudji
8. Modern Quantum Mechanics: J. J. Sakurai (Addison-Wessley, 1993)
9. Quantum Mechanics: E Merzbacher
10. Introduction to Quantum Mechanics: Griffiths
11. Relativistic Quantum Fields, Vol. I: J.D. Bjorken and S.D. Drell (McGraw-Hill, 1964)
12. Relativistic Quantum Fields, Vol.II: J.D. Bjorken and S.D. Drell (McGraw-Hill, 1978)

Paper II: NUCLEAR PHYSICS- II (PCT 402)

Course Objectives:
- To study about nuclear two-body problem (deuteron problem) and to study about properties of nuclear forces
- To study various aspects of different nuclear models
- To study about elementary particles and conservation laws associated with them
- To study the Quark hypothesis and other related concepts.

Learning Outcomes: After successfully completing this course, students-
- Will develop understanding of deuteron system and various properties of nuclear forces

- Will be able to interpret the conclusions arising out of liquid drop model, shell model, and collective model of nucleus
- Will acquire knowledge about four fundamental interactions and elementary particles and conservation laws for them
- Will develop an understanding about the Quark model, different types of quarks and their interactions etc.

Total Lectures: 45

Unit- I (12 Lectures**)**
Nuclear two-body problem, Simple theory of deuteron problem, Nature of the nuclear force, Form of nucleon-nucleon potential, Low energy n-p scattering, Low energy p-p scattering, Existence of two nucleon bound system, scattering length and effective range theory, scattering of neutron from hydrogen molecule, Charge symmetry and charge independence of nuclear forces, Meson theory of nuclear forces.

Unit- II (12 Lectures**)**
Liquid drop model, Magic numbers and evidence of shell structure, Extreme single particle shell model, Predictions of spin, parity and magnetic moment of nuclei, Collective model, Rotational and Vibrational spectra of nuclei, Fermi degenerate gas model.

Unit- III (11 Lectures**)**
Four fundamental interactions, Elementary particles and their classifications, Elementary particles and their quantum numbers (charge, spin, lepton number, baryon number, isospin, strangeness, parity, time reversal, charge conjugation, CP violation) CPT theorem, Gellmann-Nishijima formula.

Unit- IV (10 Lectures**)**
Eight-fold way, Quarks hypothesis, Quarks name and their quantum numbers, Quark structure of Hadrons, color of Quarks, Evidence of quarks, Quark-Quark interaction, Application of symmetry arguments to particle reactions, Gluon, Relativistic Kinematics.

Text and Reference Books:

1. Nuclear Physics: D. C. Tayal
2. Introduction to Nuclear and Particle physics: A. Das and T. Ferbel.
3. Quarks and Leptons: Halzen and Martin, John Willey and Sons
4. Unitary symmetry and Elementary Particles: D. B. Lichtenberg.
5. Symmetry Principles in Particle Physics: Emmerson.
6. Introduction to High Energy Physics: Donald H. Perkins, University of Oxford.
7. Nuclear Physics: S. N. Ghoshal, First edition, S. Chand Publication.
8. Nuclear & Particle Physics: An Introduction: B. Martin (Willey, 2006)
9. Introduction to Elementary Particles: D. Griffiths (Academic Press, 2nd Ed. 2008
10. Engineering Physics: H. K. Malik, McGraw Hill, 2nd Ed., 2016

Paper III (A)

Electronics II: Digital Electronics and Microprocessors (PST 403(A))

Course Objectives:

- To study logic gates for parity generation and checking and study K-map and its role in digital design
- To study different binary codes and code convertors
- To study different logic families- DTL, TTL, ECL, MOS, and CMOS
- To design the arithmetic logic circuits and storage data systems: flip-flop, registers. Counters and converters.
- To learn about the basic and advanced knowledge of microprocessors and interfacing.

Learning outcomes:

At the completion of the course students will be able to:

- To learn about CMOS technology, ICs designing for digital circuit operations.
- To learn the actual role of transistors for making ICs and data storage systems.
- After studying and practical learning of logic families, gates, and circuits, the students can get the job in microelectronic component industries, telecommunication industries for designing circuits and their functions.
- To learn how to design microprocessor 8085 and basic traffic light controllers.

Total Lectures: 45

Unit 1: Binary Codes & Code Convertors (10 Lectures**)**
Exclusive-OR & Exclusive NOR gates and their use in parity generation and checking, Sum of Products (SOP) and Product of Sums (POS) methods, Karnaugh map (K-map), pairs, quads and octets, K-map simplifications, Don't care conditions, Product of Sums simplifications, Min-terms and Max-terms, Binary codes- BCD, Excess-3, Gray code, ASCII code. Code converter- BCD-to-binary, BCD-to-Excess-3, BCD-to-Gray, BCD to Seven segment Decoder/Driver, Binary-to-BCD, Binary-to-Gray, Gray-to-binary, Gray-to-BCD code.
Unit 2: Logic Families (11 Lectures**)**
Digital logic families- Classification and their Characteristics (RTL, DTL, TTL, ECL, MOSFET, CMOS); RTL NAND gate & RTL Inverter; DTL NAND gate & DTL NOR gate; Transistor- Transistor Logic (TTL)- active pull up & passive pull up circuits; TTL NOR gate; Tri-State Logic (TSL); Positive and Negative Logic; Emitter Coupled Logic; MOSFET Logic-MOSFET Inverter, MOSFET NOR and NAND gates; Complementary MOS (CMOS)- CMOS inverter, CMOS NOR and NAND gates, Advantages/Disadvantages of CMOS.
Unit 3: Sequential Circuits (14 Lectures**)**
Flip-Flops: SR Flip-Flop- NOR and NAND gate latch, Clocked RS Flip-Flop, SR Flip-Flop with Preset and Clear inputs; D Flip-Flop (D Latch), Edge-triggered D Flip-Flop; JK Flip-Flop, Race-around condition in JK Flip-Flop, Master-Slave JK Flip-Flop; T Flip-Flop; Excitation table of Flip-Flops; Interconversion between different Flip-Flops.
Registers: Definition, Types of Registers- Serial-in-serial out (SISO), Serial-in-parallel out (SIPO), Parallel-in-serial out (PISO), Parallel-in parallel out (PIPO).
Counters: Asynchronous and Synchronous counters, Mod-3, Mod-5, Decade counter, Ripple counter, Up-Down Counter, Shift counters.
Digital-to-Analog and Analog-to-Digital Converters.
Unit 4: Data- Processing Circuits, Microprocessors and Interfacing (10 Lectures**)**
Data Processing circuits: Multiplexers (MUX) and Demultiplexers (DEMUX); Decoders & Encoders.

Microprocessor- 8085, microprocessors architecture, interfacing devices, BUS timing, Microprocessor based traffic light controller, Waveform generation and frequency measurement, Basic terms and ideas of memory.

Text and Reference Books

1. Electronics Devices and Circuits: Sundar Singh & Sanjeev Tyagi, Pragati Prakashan, Meerut
2. Electronic Device and Circuit: R. Boylestad and L. Nashelsky
3. Analysis and Design of Digital Integrated Circuit: Hodges, Jackson and Saleh
4. Digital Principles and Implementation: A.P. Malvino and D.P. Leach
5. Digital Principles and Applications: D.P. Leach & A.P. Malvino
6. Analog and Digital Electronics: Sundar Singh & Sanjeev Tyagi
7. Fundamentals of Microprocessors and Microcomputers: B. Ram
8. Microprocessor, Architecture, Programming and Application: R.S. Gaonkar
9. Introduction to Microprocessor: A.P. Mathur
10. Microprocessor and Interfacing: D.V. Hall.

Paper III (B)
Condensed Matter Physics II (PST 403 (B))

Course Outcomes:
- To study imperfections in crystals
- To study optical properties in solids
- To study thin films and surface topography
- To learn use of SEM, TEM, STEM, AFM for the characterization of materials
- To make study of disorder systems and glasses

Learning Outcomes: After successfully completing this course, students
- Will learn about various types of imperfections in crystals particularly point, line and planar defects and dislocations
- Will develop an understanding of the optical properties of solids particularly photoconductivity and photoluminescence, electroluminescence. They will also learn about excitons.

- Will learn about the thin film preparation through various methods and also their characterization through electron microscopic methods
- Will develop an understanding of disorder systems and glasses and their properties.

Total Lectures: 45

Unit l: Imperfections in Crystals (11 Lectures)

Point Imperfections: Frenkel and Schottky defects; Colour centres;

Shear strength of single crystals – Elastic deformation of solids; Plastic deformation of crystals: Slip planes and Twinning;

Line Imperfections or Dislocations: Edge dislocation and Screw dislocation; Burgers vector; Elastic energy of dislocation; Dislocation multiplication- Frank and Read source; Effect of dislocations on crystal growth- Whiskers;

Planar defects: Stacking defect; Grain boundaries; Low-angle grain boundaries or Tilt boundaries; Twin boundaries.

Unit ll: Optical properties of Solids (12 Lectures)

Plasma Optics- Dielectric function of a crystal and dispersion relation for electromagnetic waves; Plasmons; Optical reflectance; Excitons: Tightly bound (Frenkel) exciton; Weakly bound (Mott-Wannier) exciton; Exciton condensation into Electron-Hole drops (EHD);

Photoconductivity: Simple model of a photoconductor; Influence of Traps; Space Charge effects;

Photoluminescence: Excitation and Emission; Decay mechanisms; Thallium-activated alkali halide Phosphors; Sulphide Phosphors;

Electroluminescence.

Unit lll: Thin Films and Surface Topography (11 Lectures)

Thin film preparation methods: Physical deposition techniques- Evaporation techniques (Vacuum thermal evaporation, Electron beam evaporation, Laser beam evaporation, Molecular beam epitaxy); Sputtering techniques (DC Sputtering and RF Sputtering). Chemical deposition techniques- Sol-gel technique, Chemical bath deposition, Spray Pyrolysis technique, Electroplating technique and Chemical Vapour deposition (CVD).

Study of surface topography by multiple beam interferometry; Determination of film thickness (Fizeau and FECO method); Surface morphology using Electron Microscopy- SEM, TEM, STM and AFM.

Unit lV: Disorder Systems and Glasses (11 Lectures)

Disorder in Condensed Matter; Substitutional, Positional and Topological disorder; Hume-Rothery rules; Order-disorder Transformation: Long-range and Short-range order; Elementary theory of order: long-range order parameter and short-range order parameter; Phase diagrams of a binary system: Liquidus and Solidus curves and Eutectics.

Functional and Structural description of Glasses and Liquids; Electronic Structure of Amorphous Solids; Localized and Extended Electron States; Mobility Edges; Glass formation; Types of glasses and glass transition; Viscosity and Hopping Rate.

Text and Reference Books

1. Nanoscience and Nanotechnology: Sundar Singh, Pragati Prakashan, Meerut
2. Charles Kittel, “Introduction to Solid State Physics”, Wiley India Pvt. Ltd.
3. N.W. Ashcroft and N.D. Mermin, “Solid State Physics”, Cengage learning.
4. J.M. Ziman, “Principles of the Theory of Solids”, CUP- Vikas Students’ Edition.
5. S.O. Pillai, “Solid State Physics”, New Age International Publishers.
6. R. L. Singhal, “Solid State Physics”, Kedar Nath Ram Nath.
7. J. P. Srivastava, “Elements of Solid State Physics”, Prentice Hall of India.

8. B.S. Saxena, R.C. Gupta, P N. Saxena, J.N. Mandal, “Fundamentals of Solid State Physics”, Pragati Prakashan.
9. A. J. Dekker, “Solid State Physics”, Macmillan India Limited.
10. M. Marder, “Condensed Matter Physics”, John Wiley & Sons,
11. P.M. Chaikin and T.C. Lubensky, “Principles of Condensed Matter Physics”, Cambridge University Press
12. Buerger, “Crystal Structure Analysis”, John Wiley & Sons,
13. K. L. Chopra, “Physics of Thin Films”
14. Tolansky, “Multiple beam interferometry”

Suggestive Digital Platforms / Web Link

1. MIT Open Learning – Massachusetts Institute of Technology, https://openlearning.mit.edu/
2. National Programme on Technology Enhanced Learning (NPTEL), https://www.youtube.com/user/nptelhrd
3. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
4. Swayam Prabha – DTH Channel, https://www.swayamprabha.gov.in/index.php/program/current_he/8

Optional Paper

Paper IV (A)

Classical Electrodynamics & Plasmas (PET 404 (A))

Course Objectives:

- To evaluate fields and forces in Electrodynamics and Magneto dynamics using basic scientific method
- To provide concepts of relativistic electrodynamics and its applications in branches of Physical Sciences
- To provide a new concept of plasma physics.

Learning Outcomes:

- Achieve an understanding of Maxwell's equations, gauge transformations, Coulomb and Lorentz gauge, mathematical properties of the spacetime in special relativity, matrix representation of Lorentz transformation
- Review potentials due to a moving charge, Lienard Wiechert potentials, power radiated Larmor’s formula and its relativistic generalization
- To learn Plasma physics, Debye shielding phenomenon etc.

Total Lectures: 45

Unit- I (12 Lectures**)**
Homogeneous and inhomogeneous (Poincare) Lorentz groups, Pseudo-Euclidean space time, Space time rotations, rapidity, Proper, improper, orthochronous, antichronous Lorentz groups, Light cone and Matrix representation of Lorentz transformations, Space like, time like and light like Four-vectors, orthogonality, Four-tensors, four- velocity, four-momentum, four-acceleration, Minkowski force.

Unit- II (11 Lectures)
Covariant form of continuity equation, 2-Form electromagnetic field-strength tensor, dual field-strength tensor, Covariant formulation of Maxwell’s field equations with gauge invariance, Lorentz force equation in covariant form, Transformation of electromagnetic fields as tensor components, Proca Lagrangian with Photon mass, Canonical approach to electrodynamics, Lagrangian and Hamiltonian formulation for a relativistic charged particle in external electromagnetic field, Canonical and Symmetric Stress Tensors, Solution of the wave equation in covariant form.

Unit- III (12 Lectures**)**
Retarded and advanced potentials, Lienard-Wiechert potentials for a moving point charge, Fields produced by a charge in uniform and accelerated motion, Radiation from an accelerated charge, Radiated power, Larmor’s formula and its relativistic generalization, Thomson scattering of radiation, Thomson cross section.

Unit- IV (10 Lectures**)**
Elementary concepts of plasma, derivation of moment equations from Boltzmann’s equation. Plasma oscillations, Debye shielding, Plasma confinement, Electron waves, Ion waves, Ordinary waves, Extraordinary waves.

Text and Reference Books:

1. Electromagnetic Theory and Electrodynamics: Satya Prakash
2. Laser-Matter Interaction for Radiation & Energy: H. K. Malik, CRC Press (Taylor & Francis), Ist Ed., 2021
3. Classical Electrodynamics: John David Jackson (Wiley India)
4. Introduction to Electrodynamics: David J. Griffiths (Prentice-Hall of India, New Delhi)
5. An Introduction to Relativity: J. V. Narlikar (Cambridge Univ Press)
6. Introducing Einstein's Relativity: Ray D'Inverno (Clarendon Press, Oxford)
7. Electromagnetic Field Theory for Engineers and Physicists: G. Lehner (Springer)
8. Modern Electrodynamics: A. Zangwill (Cambridge University Press)
9. Introduction to Plasma Physics and Controlled Fusion: Francis F. Chen
10. Plasma Physics: S.N. Sen
11. Foundations of Electromagnetic Theory: J.R. Reitz, F. J. Milford and R. W. Christy.

Paper IV (B)
Modern Communication Electronics (PET 404(B))

Course Objectives:

The fundamental objectives of this course are: -

- To enable students to understand the basic concepts of circuits found in analog communication systems.
- To impart in depth knowledge of different devices used in microwave electronics
- To interpret and analyze the characteristics of the main components of different radars.
- To be able to design the simplest devices and transmitting and receiving systems of radiofrequency series.
- To introduce the various types of modulation and demodulation used in analog signal transmission.
- To give a thorough understanding about satellite communication.

Learning Outcomes:

On completion, the student will be able to: -

- Analyze analog communication signals in time domain and frequency domain.
- Distinguish between different analog modulation techniques.
- Understand different devices used in microwave electronics.
- Discuss the fundamental concepts of radars and their applications.
- Analyze the different modulation and demodulation types used in signal transmission.
- Develop understanding about satellite communication and its theory.

Total Lectures: 45

Unit 1: Microwave Electronics (10 Lectures**)**

Microwave characteristics features & applications, waveguides and cavity resonators, two cavity klystron, reflex klystron, semiconductor Gunn diode characteristics, microwave antenna, detection of microwave, dielectric constant measurement, isolator and circulator, PIN diode modulator, directional coupler.

Unit 2: Radar Communication (12 Lectures**)**

Basic radar systems, radar range equation and performance factor, radar cross section, pulsed radar system, duplexer, radar display, Doppler radar, CWIF radar, FMCW radar, moving target indicator (MTI), blind speeds.

Unit 3: Analog Signal Transmission (13 Lectures)

Amplitude, Frequency & Phase modulation, AM, FM, Modulating and Demodulating circuits, AM, FM Receivers functioning (BLOCK diagram) and Characteristics Features, PAM, PWM and PPM modulation and demodulation, Quantization processes, Compounding and Quantization noise, PC M, Differential PCM and Delta Modulation systems, Comparison of PCM and DM, Time division multiplexing.

Unit 4: Satellite Communication (10 Lectures**)**

Principle of Satellite Communication, Satellite frequency allocation and band spectrum, Satellite orbit, trajectory and its stability, Satellite link design, Elements of Digital Satellite Communic ation, Multiple Access technique, Antenna system, Transponder, Satellite Applications.

Text and Reference Books:

1. Hand Book of Electronics: S. L. Gupta & V. Kumar, Pragati Prakashan
2. Modern Electronic Communication: Gary M. Miller, 6th edition
3. Communication System: Simon Haykin
4. Electronics Communication: Roddy and Coolen
5. Microwave and Radar Engineering: M. Kulkarni
6. Digital and Analog Communication Systems: K. San Shanmugam
7. Satellite Communication: Pratt and Bostian
8. Microwave: K.C. Gupta
9. Electronic Communication Systems: George Kennedy & Bernard Davis.

Paper IV (C)
Material Science and Energy Devices (PET 404(C))

Course Objectives:

- To develop an understanding of engineering of materials structure
- To study about advanced engineering materials
- To learn basic concepts involved in photovoltaic energy conversion process
- To acquire skills in materials selection and engineering design for different kinds of solar cells
- To impart knowledge about the fundamentals of hydrogen energy, hydrogen production, storage and transportation
- To study about various fuel cells and materials required for their construction
- To learn fundamental concepts involved in the energy storage in the devices such as supercapacitors and batteries
- To impart in-depth knowledge about important advanced supercapacitors and batteries

Learning Outcomes: This course is a higher skill development course in advanced energy storage and production devices and may directly provide employment to the students. After successful completion of the course, the students -

- Will be able to interpret materials' properties in terms of their microstructure
- Will acquire fundamental knowledge about solar energy conversion process
- Will understand different aspects associated with hydrogen energy and construction of fuel cells and their applications
- Will acquire knowledge of energy storage in supercapacitors and batteries
- Will understand how the advanced supercapacitors and batteries are constructed
- Will learn about the materials' selection and engineering involved in the solar energy systems, hydrogen energy systems, and energy storage systems.

Total Lectures: 45

Unit I: Materials' Classification & Properties (10 Lectures)

Definitions and basic concepts of material science, Advanced engineering materials, Alloys, Dielectrics, Polymers, Composites, Glasses, Ceramics and Biomaterials, Meta materials, Smart materials, Topological insulators, Properties and applications.

Unit II: Materials Aspects of Solar Energy (12 Lectures)

Importance of renewable energy, materials and devices in present technology, Fundamental concepts in photovoltaic energy conversion, Optical properties of solids, p-n junction solar cell, Transport equation, Short-circuit current (I_{SC}) & Open-circuit voltage (V_{OC}), Single crystal silicon & amorphous silicon (a-Si) solar cells, Elementary idea about advanced solar cells- Tandem solar cells, Solid liquid junction solar cells, Dye sensitized solar cells (DSSCs), Quantum dots sensitized solar cells (QDSSCs), Organic solar cells.

Unit III: Hydrogen energy (12 Lectures**)**

Photoelectrolysis and photocatalytic process, Elementary idea about various storage processes, Special features of solid hydrogen materials, New storage modes, Safety affecting factors, Hydrogen sensors, Use of Hydrogen fuel, Use in vehicular transport, Hydrogen for electricity generation, Fuel cells, Various types of fuel cells, Applications of fuel cells.

Unit IV: Supercapacitors and Batteries (11 Lectures**)**

Capacitor principles, properties of capacitors, Electrochemical capacitors, Electrochemical interface, Double-layer capacitors: Li-ion based hybrid supercapacitors, applications of supercapacitors, Properties of batteries, introduction to battery technology, primary batteries, secondary batteries, Li-ion and Ni-ion based advanced batteries, applications of batteries.

Text and Reference Books:

1. Materials Science and Engineering: V. Raghavan
2. Materials Science and Engineering: An Introduction by William D. Callister Jr.
3. Rudiments of Materials Science: S. O. Pillai & Sivakami Pillai
4. Advanced Engineering Materials: Sandra Kalveram
5. Fundamental of Solar Cells Photovoltaic Solar Energy: Fahrenbruch & Bube
6. Solar Cells Devices-Physics: Fonash
7. Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications by Aiping Yu, Victor Chabot, Jiujun Zhang
8. Hydrogen as a Future Energy Carrier: A. Zuttel, A. Borgschulte, and L. Schlapbach
9. Advanced Batteries: Materials Science Aspects by Robert Huggins

Paper V (A)

Practical- Electronics Specialisation (PHP 405 (A))

1. Op-amp differentiator
2. Op-amp integrator
3. Shift Registers
4. Counters
5. ROM
6. RAM
7. A/D Converter
8. D/A Converter
9. Microprocessor 8080/8085
10. To design and test an “Inverting Schmitt Trigger” using 741 IC
11. To design and test a “Non-Inverting Schmitt Trigger” using 741 IC

Paper V (B)

Practical- Condensed Matter II Specialisation (PCP 405 (B))

1. Measurement of magnetoresistance
2. Study of lattice vibration in Mono/Diatomic lattice
3. Determination of lattice constants of a cubic crystal
4. X-Ray Powder Photograph
5. Ferroelectric Phase Transition
6. Lattice Vibration- Electrical Analog
7. UV-Visible Spectrum of CdS Film
8. Determination of carrier concentration using Hall measurement
9. Variation of ultrasonic velocity in metal with temperature using ultrasonic interferometer and analysis of data
10. Variation of ultrasonic velocity in metal/quartz with frequency using ultrasonic interferometer and its analysis.

Evaluation & Assessment Methods

1. Continuous Internal Evaluation (CIE):

There will be continuous internal evaluation of students and they will be awarded marks in each paper by the concerned Professor out of maximum 25 marks.

Suggested Continuous Internal Evaluation Methods:

1. Test/Quiz/Assignment/Seminar - 20 Marks
2. Class Attendance and Interaction – 05 Marks

2. End-Semester Exams: There will be end-semester exam for each paper as per the following pattern:

Question paper pattern for end-semester examination

Time: 3 Hours **M. M. = 75**

Note: Attempt any five questions. All questions carry equal (=15) marks. Questions may have two or more than two parts.

Q. 1 (From Unit I)

Q. 2 (From Unit I)

Q. 3 (From Unit II)

Q. 4 (From Unit II)

Q. 5 (From Unit III)

Q. 6 (From Unit III)

Q. 7 (From Unit IV)

Q. 8 (From Unit IV)