Semester – VII

Mathematical Physics **B0107U1T**

Unit I Complex Analysis: Analytic functions, Cauchy-Riemann equations, Cauchy's theorem, Cauchy's Integral formula, Laurent series, Poles, Residue theorem, Evaluation of integrals.

Unit II Linear Differential Equations: Second order linear differential equations; Regular, regular singular and singular points; series expansion method.

Unit III Special Functions: Bessel, Legendre, Hermite and Laguerre differential equations with properties of their solutions.

Unit IV Integral transforms: Laplace transform, Fourier theorem, Fourier transforms.

Unit V Dirac delta function and Green function: Green function for Laplace operator, Solution of Poisson's equation, Inhomogeneous Wave equation and applications.

Reading List:

1. Mathematical methods for Physicists, George Arfken, Hans Weber and Harris, 4th edition, Academic Press Inc. 1995.
2. Advanced Engineering Mathematics: Erwin Kreyszig
3. Mathematical Physics by H.K. Dass, S. Chand Publications, 5th edition, 2017.
4. Schaum's Outlines Complex Variables by M. R. Spiegel, Mc-G
5. Mathematical Physics by B.S. Rajput
6. Mathematical Physics, AK Ghatak, Trinity Press-Laxmi Publications, 1st Edition, 1995.

Classical Mechanics **B0107U2T**

Unit I Variational Principles and Langrange's Equations: Hamilton's principle, Calculus of variations, Langrange's equations, Conservation Theorems and symmetry properties.

Unit II Hamiltonian formalism: Legendre transformations and the Hamiltonian Equations of Motion, Cyclic coordinates.

Unit III Canonical Transformations: Canonical transformations, Poisson Bracket

Unit IV Hamilton – Jacoby Theory: Hamiltonian Jacoby equations; Hamiltonian Jacoby theory, geometrical optics and wave mechanics

Unit V Small oscillations and normal modes: Small oscillations about a stable equilibrium, Normal modes and their frequencies, Langrangian and Hamiltonian formalism of Classical Fields.

Reading List:

1. Classical Mechanics: H Goldstein
2. Classical Mechanics: J. C. Upadhayay
3. Classical Mechanics: John R. Taylor
4. Classical Mechanics: David J. Morin
5. Classical Mechanics: N C Rana and P S Joag

Electrodynamics and Relativity **B0107U3T**

Unit I Guided electromagnetic waves: Transmission Lines and Wave Guides, Modes in a rectangular wave guide, Cavity resonators.

Unit II Tensor analysis: General coordinate transformation; contravariant, covariant and mixed tensors; metric tensor; raising and lowering of indices; contraction of indices.

Unit III Minkowsky space and Lorentz transformations: Geometry of space-time in Special Relativity; Minkowsky metric; Light cone and principle of causality; Invariance of Minkowsky metric under Lorentz transformations; Lorentz group; Proper, improper and orthochronous transformations; Pseudo-tensors.

Unit IV Covariant formulation of electromagnetism: Charge-current density four-vector; Scalar and Vector potentials; Gauge invariance; Electromagnetic potential four-vector; Electromagnetic field tensor; Lorentz transformation of electric and magnetic fields; Invariants of the electromagnetic field

Unit V Electromagnetic field of a charge moving with constant velocity, Covariant form of Lorentz force law; Dynamics of charged particles in static and uniform electric fields.

Reading List:

1. The Feynman Lectures on Physics, Vol. II: Mainly Electromagnetism and Matter, Richard Feynman, Robert B. Leighton, Matthew Sands (Pearson Education India, 2012)
2. Schaum's Outline of Vector Analysis, Murray R. Spiegel (McGraw-Hill Education)
3. Introduction to Electrodynamics, 4th edition, D. J. Griffiths (Pearson Education India, 2015)
4. A first Course in General Relativity, 2nd edition, Bernard Schutz (Cambridge University Press, 2009)
5. Field and Wave Electromagnetics, 2nd edition, David K. Cheng (Pearson Education India, 2014)

Quantum Mechanics – I **B0107U4T**

Unit I Hilbert Space, Dirac's Bra & Ket Notations, Observables as Operators, Projection operators, Hermiticity of Operators, Orthonormality and Completeness Relation, Matrix representation of Kets, Bras and operators. Wave-functions in Coordinate and Momentum Representations.

Unit II Elementary ideas of Measurement in Quantum Mechanics, Commutators and Heisenberg uncertainty principle, General proof of Uncertainty Principle.

Unit III Time Evolution of the System's state, Schrödinger, Heisenberg and Dirac Representations.

Unit IV Matrix Theory of Harmonic Oscillator, Time Development of Harmonic Oscillator.

Unit V Stern-Gerlach Experiment and Spin, Orbital Angular Momentum, Angular Momentum Algebra, Addition of Angular Momenta, Clebsch-Gordan Coefficients, Explicit Addition of Angular Momentum 1/2 with Angular Momenta 1/2 and 1.

Reading List:

1. Quantum Mechanics: Concept and Applications by Nouredine Zettili
2. Advance Quantum Mechanics by B. S. Rajput
3. Advance Quantum Mechanics by J. J. Sakurai
4. Principles of Quantum Mechanics by P. A. M. Dirac

Minor Elective (value added) course for students of other departments:

Fundamentals of Physics **B0107U8M**

Unit I Historical Development of Physics; Classification of physics in terms of Length scales, Time scales and Energy scales.

Unit II Evolution of universe and formation of stars. Newton's law of Gravitation; Planetary motion and Kepler's laws; Galilean relativity and concept of inertial frames. Einstein's theory of special relativity.

Unit III Failure of classical ideas with examples of blackbody spectrum and Photoelectric effect; Heisenberg's Uncertainty Principle; Wave-particle duality. Double-slit experiment, Stern-Gerlach experiment.

Unit IV Concepts of discrete energy levels and spin. Elementary ideas of Schrodinger's Wave mechanics. Relation between Spin and Statistics

Unit V Bose-Einstein and Fermi-Dirac statistics, and Maxwell-Boltzmann statistics as classical limit. Elementary Particles (classification, quantum numbers) and Fundamental Interactions (classification, range, strength).

Reading List:

1. The Feynman Lectures on Physics vol. I, II & III, Richard Feynman, Robert B. Leighton, Matthew Sands (Pearson Education India, 2012)
2. Remarkable Physics: From Galilio to Yukawa, Ioan James (Cambridge University Press, 2004)
3. University Physics vol. I, II, III, William Moebs, Samuel J. Ling, Jeff Sanny (12^{th} Media Services, 2016)

Semester – VIII

Quantum Mechanics – II **B0108U1T**

Unit I Time-Independent Perturbation Theory and Applications, Variational Method, WKB Method.

Unit II Time-Dependent Perturbation Theory, Constant and Harmonic Perturbation, Transition probabilities, Fermi's Golden Rule.

Unit III Elementary theory of Scattering: Phase shifts, Method of partial waves, Born approximation.

Unit IV Klein Gordon Equation and Free Particle, Solution, Dirac Equation, Dirac Matrices, Covariance of Dirac Equation & Bilinear Covariant.

Unit V Solution for a Free Particle, Negative Energy states and Hole Theory, Spin, Position Operator.

Reading List:

1. Introduction to Quantum Mechanics by D. J. Griffiths
2. Modern Quantum Mechanics by J. J. Sakurai
3. Quantum Mechanics: Concept and Applications by Nouredine Zettili
4. An Introduction to Relativistic Quantum Field Theory by S. S. Schweber
5. Quantum Mechanics, L. I. Schiff, Mc-Graw Hill
6. Relativistic Quantum Mechanics, James D. Bjorken and Sidney D. Drell (Tata McGraw Hill Education, 2013)

Statistical Mechanics **B0108U2T**

Unit I A review of Gibbs ensembles, Partition function for Perfect Gas and ensemble of Harmonic Oscillators, Partition Function for Gases containing Monoatomic, Diatomic and Polyatomic Molecules. Grand partition function,

Unit II Grand potential, FD and BE distribution in Grand Canonical ensemble Degenerate Bose Gas, Momentum Condensation, Liquid He II, Two fluid theory, Superfluidity.

Unit III Degenerate FD Gas, Conduction Electrons in a Metal, Fluctuations, One dimensional Random walk, Gaussian Distribution, Fluctuation in energy in canonical ensemble and concentration in Grand Canonical ensemble.

Unit IV Random processes, Markoff process, Langevin Equation, Correlation functions, Fluctuations Dissipation Theorem, Weiner-Khintchine theorem, Nyquist theorem,

Unit V Conditional probability, Fokker Plank Equation, Brownian motion.

Reading List:

1. Fundamentals of Statistical and Thermal Physics, F. Reif, Levant Kolkata, (2010).
2. Statistical Mechanics, K. Huang, 2nd ed., Wiley India, Delhi, (2009).
3. Statistical Mechanics, R. K. Pathria and P. D. Beale, 3rd Edition, Elsevier, Oxford, (2011).
4. Statistical Physics of Particles, M. Karder, Cambridge University Press, Cambridge, (2007).
5. Statistical Physics, L. D. Landau and E. M. Lifshitz, Part 1, Volume 5, Pergamon Press, New York, (1980).

Solid State Electronics **B0108U3T**

Unit I P-N Junction Diode: Rectifier with LC Filter, Electronic regulator. Bipolar Junction Transistors: h-parameters, inter conversion in different configurations, low frequency transistor amplifier, thermal stability and bias stabilization.

Unit II Field Effect Transistors:Small signal model and dynamic parameters, CS and CD amplifiers. Multistage Amplifiers: BJT at high frequencies, frequency response of gain and phase shift, frequency response of RC coupled amplifier.

Unit III Feedback Amplifiers and Oscillators: Different negative feedback amplifiers, stability and Nychistcriteria , sinusoidal oscillators , phase shift and Wien's bridge oscillators, Crystal oscillator, astable multivibrator.

Unit IV Power and Radio Frequency Amplifier: Large signal amplifier and distortions, push-pull amplifier, single and double tuned amplifiers.

Unit V Modulation: Frequency and phase modulation, frequency modulation Demodulation: Frequency changing and tracking; AGC, AFC, FM detection, amplitude limiter, phase discriminator, ratio detector.

Reading List:

1. Electronic Devices and Circuits by Millman & Halkias.
2. Electronic Fundamentals and Applications by John D. Ryder.
3. Physics of Semiconductor Devices by S. M. Sze.
4. Principles of Electronics by V. K. Mehta.

Atomic & Molecular Physics **B0108U4T**

Unit I Quantum states of an electron in an atom, Spectrum of Hydrogen and Helium atom, fine structure Spectra of Alkali atoms; energy level diagrams, Sharp, Principal, Diffuse and fundamental series.

Unit II Width of spectral lines, X-ray spectroscopy, Spectroscopic terms; LS & JJ couplings, Hyperfine structure

Unit III Zeeman, Paschen Back & Stark effect, Electron spin resonance, Nuclear magnetic resonance, chemical shift

Unit IV Spectra of Diatomic Molecules Rotational Spectra (rigid rotator and non-rigid rotator model) Vibrational Spectra (harmonic and enharmonic model) Molecular Symmetric Top, Vibrating rotator Isotopic shift

Unit V Raman Spectra (Quantum mechanical and classical approach) Electronic Spectra-vibrational structure of band system, fine structure of the band systems. Intensity distribution in band systems

Reading List:

1. Fundamentals of Molecular Spectroscopy, Third Edition, C.N. Banwell & E. M. McCash, McGraw-Hill book company, London, 1972.
2. Molecular Physics, W. Demtroder, Wiley-VCH Verlag GmbH & Co., KGaA, Weinheim, 2005.
3. Atomic and Molecular Spectra, Rajkumar, KNRN Publishing House, Meerut.
4. Atomic Physics, C. J. Foot (OUP Oxford)
5. Introduction to Atomic Spectra, H.E. White.

Semester VII and VIII laboratory courses and experiments

General Lab **B0107U5P/B0108U6P**

1. Concave Grating, Hg Source Arc
2. Optical Properties of Quartz
3. Cornu's fringes
4. Fabry-Perot Interferometer
5. Edser-Butler Fringes
6. Fresnel's Formula
7. Study of Total Internal Reflection
8. Curie Temperature
9. Quincke's Tube method
10. Iodin Absorption Spectra
11. Stefan's Constant
12. Ultrasonic Interferometer – Variation of velocity with temperature
13. Forbidden Energy Gap of semiconductors
14. Laser Intensity diffraction pattern of different objects
15. Fourier Analysis

Electronics Lab **B0107U6P/B0108U5P**

Design and Study of Amplifier

1. Common Emitter Amplifier
2. Common Bas Amplifier
3. Common Collector Amplifier
4. Double Stage Amplifier
5. Comparison of Amplifiers in CB, CE and CC configuration

A. Study of Temperature Variation of Characteristics and Constants

6. BJT Characteristics and Constants
7. Bias-stabilization
8. Band Gap of Si and Ge diodes

B. Study of Power Supply

9. Constant Voltage Power supply
10. Constant Current Power Supply
11. IC Controlled Power Supply

C. Design and Study of an Oscillator

12. Phase-Shift Oscillator
13. Tuned Collector Oscillator
14. Astable multivibrator

E. Study of Device other than BJT

15. Field Effect Transistor
16. Silicon Controlled Rectifier
17. Uni-Junction Transistor

F. Amplitude-Modulation and Demodulation

G. Negative Feedback

H. Study of AM detector

Minor Elective (value added) course for students of other departments:

Frontiers in Physics **B0108U8M**

Unit I Space and Time, Einstein's Special and General Relativity, Unified reality, Does time flow? Strings and all that, The elegant universe, Black holes, neutrinos, gravitational waves, dark matter.

Unit II Basics of Nanotechnology, Application in medicine, Nano-therapy for combating cancer, what is green nanotechnology? Multi-dimensional impact of nanotechnology on health, nanotechnology in warfare, nano art, nano electronics, nano bots.

Unit III The quantum world, Basic idea of probability, concept of continuous and discrete, quantum healing, quantum computation, quantum biology, QUBITS the new buzzword.

Unit IV The Physics of climate change, structure of the atmosphere, composition of the earth's atmosphere, the ozone problem, greenhouse gases, carbon footprints and how to minimize them, factors controlling climate.

Unit V Sustainable development and clean energy, renewable energy sources: solar cells, wind and hydropower; nuclear fusion.

Reading List:

1. Understanding the Universe: From Quarks to the Cosmos, Donald Lincoln (World Scientific Publishing Co Pte. Ltd., 2012)
2. Ripples in Spacetime – Einstein, Gravitational Waves, and the Future of Astronomy, Govert Schilling, Martin Rees (Harvard University Press, 2017)
3. Nanoscience: The Science of the Small in Physics, Engineering, Chemistry, Biology and Medicine, Hans-Eckhardt Schaefer (Springer, 2010)
4. The Quantum World: Quantum Physics for Everyone, Kenneth

W. Ford (Harvard University Press, 2004)

5. Physics and Technology of Sustainable Energy, E. L. Wolf (Oxford University Press, 2018)

Semester – IX

Solid State Physics **B0109U1T**

Unit I Electron band theory: one electron band theories. Plane wave like and localized wave functions. Nearly free electron approximation. Elementary discussion of orthogonalized Plane Wave (OPW) and Pseudo potential methods, Variation of Fermi energy in extrinsic semiconductors, de-Hass-van Alphen effect experiment to investigate Fermi surface.

Unit II Superconductivity: Meissner effect, isotope effect, type I and II superconductors. Cooper pairs. Elementary ideas of BCS theory, Approximate estimate of transition temperature, superconducting energy gap, Measurement of energy gap by infrared absorption and electron tunnelling methods, Elementary ideas about Josephson effect and high Tc superconductors.

Unit III Ionic lattice in presence of infrared field, dielectric constant, L.S.T. relation, LO and TO modes, ordered phases of matter, translational and orientational order, Quasicrystals, conducting polymers.

Unit IV Lattice defects: Frenkel and Schottky defects, colour centres, number of defects (vacancies) in equilibrium, Dislocations, edge and screw Burgers vector.

Unit V Diamagnetism, Langevin diamagnetic equation, Quantum theory of para magnetism rare earth ions and iron group ions. Ferromagnetism, Curie temperature, Heisenberg model, Temperature dependence of saturated magnetization.

Reading List:

1. Introduction to Solid State Physics C. Kittel, 8th Edition, John Wiley & Sons, Inc. New Jersey, USA (2012).
2. Solid State Physics, A. J. Dekker, McMillan India, (2000)
3. Solid State Physics, Neil. W. Ashocroft & N. David Mermin, Holt, Rinehart and Winston, (1976).
4. The Oxford Solid State Basics, Steven H. Simon 1st Edition, Oxford University Press, Oxford, UK, (2013).

Nuclear and Particle Physics **B0109U2T**

Unit I Deuteron, n-n scattering, n-p scattering, p-p scattering, charge symmetry of nuclear forces.

Unit II Shell Model, Extreme Single particle picture and angular momentum, magnetic moment, quadrupole moment of nuclei, Nuclear Isomerism, Collective model (qualitative discussion)

Unit III Compound Nucleus, Breit-Wigner Formula, Direct Interaction, Heavy Ion Reactions, Relativistic Kinematics

Unit IV Fundamental types of Interactions, General Classifications of Elementary Particles, Isospin, Strangeness, Conservation Laws, Symmetries (C, CP, CPT), SU(3) and quark model

Unit V Alpha, beta and gamma decay

Reading List:

1. Nuclear Physics, 2nd edition, V. Devnathan (Narosa, 2011)
2. Introduction to Elementary Particles, 2nd Edition, D. J. Griffiths (Wiley-VCH, 2008)
3. Introductory Nuclear Physics, 3rd edition (An Indian Adaptation), Kenneth S. Krane, (Wiley India Pvt. Ltd., 2022)
4. Introductory Nuclear Physics, 2nd edition, Samuel S.M. Wong, (Wiley India Pvt. Ltd., 2013)
5. Nuclear Physics, D.C. Tayal (Himalaya Publishing House, 2009)

Specialization I: Electronics

Analog and Digital Electronics **B0109U3T**

Unit I Wide band amplifier: Review of BJT at high frequencies. Hybrid piequivalent model, Junction capacitance. Effect of an emitter bypass capacitor on low frequency response. High and low frequency compensations.

Unit II Operational Amplifier: Ideal op-amp. Emitter coupled differential amplifier. CMRR, Slew Rate, Off - set error voltage and current and there balancing circuits. Temperature drifts, measurement of op-amp parameters.

Unit III Linear Analog System: Basic op-amp Applications: Inverter, Scale changer, phase shifter, adder, voltage to current converter, current to voltage converter, voltage follower, analog integration and differentiation, analog compensation, solution of simultaneous and differential equations up to second order, amplitude and time scaling. Active filter, Butterworth filter, active resonant band pass filter.

Unit IV Non-linear Analog System: Sample and hold circuits, Comparators, Zero-crossing Detector, Schmitt Trigger (regenerative comparator), log and antilog amplifiers, log multiplier, wave form generator, Clippers and Clampers.

Unit V Digital Electronics (TTL Based): Review up to combination logic, Flip Flop: SR, JK, Master slave, Registers and counters: Shift Register, ripple counter, up down asynchronous and synchronous counters, ring counter and sequence, generators

Reading List:

1. Integrated Electronics: Analog and Digital Circuits and system by J. Milliman and C. C. Halkias
2. Pulse, Digital and switching waveform by J. Milliman and H. Taub
3. Op-Amps and Linear Integrated Circuits by R. A. Gayakwad
4. Linear Integrated Circuits by D. R. Choudhury and S. B. Jain

Microwaves **B0109U4T**

Unit I Introduction of microwaves, transmission line analysis, transmission line sections in as circuit elements, impedance matching, Smith chart, Coaxial Lines, Waveguides (WG): wave equation, rectangular WG, circular WG, rectangular cavity resonator, cylindrical resonator, re-entrant cavities

Unit II Passive microwave devices: Scattering Matrix, Microwave Hybrid Circuits, Terminations, Attenuators, Phase Shifters, Directional Couplers: Two Hole directional couplers, S-Matrix of a Directional coupler, Hybrid Couplers, Microwave Propagation in ferrites, Faraday Rotation, Isolators, Circulators, S-parameter analysis of all components.

Unit III Vacuum Tube Microwave Generators: Velocity modulation and density modulation, small signal theory of bunching, two cavity klystron amplifier and multiplier, two cavity klystron Oscillator, Reflex klystron: Theory of bunching, optimum power, effect of repeller voltage, electronic admittance, efficiency, electronic tuning.

Unit IV Magnetron: Travelling wave magnetron, modes of oscillations, output power, travelling wave tube: Description, dynamic of electron beam, coupling of beam and slow wave structure, waves in periodic structure, TWT amplifier and BWO, Generation of mm waves.

Unit V Detection of microwaves, measurement of microwaves, measurement of VSWR, frequency, wavelength, microwave power, dielectric properties of materials, magnetic parameters at microwave frequency. Applications of microwaves in material processing.

Reading List:

1. H. A. Atwater, Introduction to Microwave Theory, McGraw Hill Publishing Co. (1962)
2. Samuel Y. Liao, “Microwave Devices and Circuits”, 3rd Ed, Pearson Education.
3. D. C. Dube, “Microwave Devices and Applications”, Narosa Publishing House, New Delhi, 2011
4. R.E Collin, “Foundation for Microwave Engineering “, 2nd Ed., John Wiley India.

Specialization II: Laser and Spectroscopy

Laser Spectroscopy **B0109U5T**

Unit I Light Sources (Arc, Spark, Discharge, Beam Foil etc.), Synchrotron, Laser, Thermal and Direct Photo Detectors, Optical Multichannel Analyzer, Charged Coupled Devices (CCD), Integrated Charged Coupled Devices (ICCD).

Unit II Fixed-frequency and Tuneable lasers, YAG, Argon Ion, Excimer, Dye, Semiconductor Lasers

Unit III Laser Photoacoustic Spectroscopy, Laser Induced Fluorescence (LIF), Laser Optogalvanic Spectroscopy

Unit IV Laser Raman Spectroscopy (CARS, SRS, SERS), Time Resolved Spectroscopy

Unit V Fourier Transform Spectroscopy, Laser Isotope Separation, Medical Applications of Laser.

Reading List:

1. Laser Spectroscopy and Instrumentation, Wolfgang Demtroder, Springer
2. Principles of Lasers, Svelto, Orazio, Fifth edition, Springer
3. Atom, Laser and Spectroscopy, 2nd Edition, Kindle Edition, S. N. Thakur, D. K. Rai
4. Laser and nonlinear optics, B.B. Laud, New Age International Pvt Ltd Publishers.
5. Lasers: Fundamentals and Applications, Thyagarajan, K., Ghatak, Ajoy, Springer
6. Principles of fluorescence spectroscopy by Joseph R. Lakowicz

Electronic Spectra of Diatomic Molecule **B0109U6T**

Unit I Review of electronic spectra of diatomic molecules, Deslander's table, Franck Condom Principle

Unit II Symmetry properties of rotational levels for di-atomic molecule, Intensity of molecular band in electronic spectra. Nuclear spin and Intensity alternation in electronic band structure.

Unit III Classification of Molecular States, Multiplet Structure, Coupling and Uncoupling phenomena, Selection Rules for Electronic Transitions,

Unit IV Building up Principles. Electronic Configuration in diatomic molecule, Molecular Orbital Theory.

Unit V Continuous and diffused spectra, Pre-dissociation, Determination of dissociation energy of O_2, I_2 and N_2 molecules

Reading List:

1. Gerhard Herzberg, Atomic spectra and atomic structure
2. Gerhard Herzberg, Molecular Spectra and Molecular Structure IV. Constants of Diatomic Molecules
3. G. Aruldhas, Molecular Structure and Spectroscopy.
4. C.N. Banwell and E.M. McCash, Fundamentals of Molecular Spectroscopy.
5. W. Demtroder, Molecular Physics.
6. Sune Svanberg, Atomic and Molecular Spectroscopy.

Specialization III: Condensed Matter Physics

Condensed Matter Physics – I **B0109U7T**

Unit I Ewald's method, Lorentz field

Unit II Phonons in perfect-crystals: General theory of lattice dynamics of nonprimitive lattice, normal coordinate description

Unit III Phonon concept, Ionic crystals, Quantization of lattice vibrations, shell model, Inelastic scattering of slow neutrons by crystals for study of phonons. Kramer Kronig relation

Unit IV *Many body Techniques:* The basic Hamiltonian, Hartree and Hartree Fock equation, interacting electron gas, Hartree-Fock Approximation for the electron gas, Exchange hole, Exchange energy, Density Functional Theory, Thomas Fermi approximation, Local Density Approximation (LDA), Generalized gradient approximation (GGA)**.**

Unit V *Classification of materials and their characterization techniques:* X ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), UV-Vis and FTIR Spectroscopy, Thermal Conductivity measurement techniques, Ultrasonic spectroscopy.

Reading List:

1. Quantum Theory of Solids, C. Kittel, 2nd Ed., John Wiley and Sons, USA, 1987.
2. Density Functional Theory, David S. Sholl, Janice A. Steckel, Wiley & Sons (2009).
3. Electronic Structure Calculations for Solids and Molecules, J. Kohanoff, Cambridge University Press.
4. Computational Materials Science: An Introduction, June Gunn Lee, Second Edition, CRC press (2017).
5. Handbook of material Characterization, Surender K. Sharma, Springer (2018).
6. Materials Characterization: Introduction to microscopic and Spectroscopic Methods, Yang Leng, John Wiley & Sons (Asia) Pte Ltd (2008).

Condensed Matter Physics – II **B0109U8T**

Unit I Dielectric constant of ionic crystals. Static polarizability, polarizability in variable field, Placzek's approximation, first order Raman scattering, second-order Raman scattering,

Unit II Elementary ideas of the study of phonons by Raman scattering Plasmons, interaction of electromagnetic waves with phonons and polaritons.

Unit III Excitation in imperfect crystals: Definition of classical Green functions, application to one dimensional harmonic oscillator, principle of causality. Double-time quantum Green functions, correlation functions, spectral density.

Unit IV Static Green function (Fourier transform), application to lattice vibrations and electron energy states.

Unit V Point defect in one-dimensional lattice, localized, gap and resonance modes. Elementary ideas of extension to impurity electron energy states, gap states.

Reading List:

1. Introduction to Solid State Physics: C. Kittel
2. The Green Function in Solid State Physics, J. Mahanti.
3. Dynamical Theory of Crystal Lattice, Max Born and Kun Huang
4. Quantum Theory of Solids, J. Callaway
5. Elementary Solid State Physics, Omar, M.A., Pearson Education,

(1999).
6. Solid State Physics, Ashcroft, N.W. and Mermin, N.D., Cengage Learning, (2008).
7. Solid State Physics: A. J. Dekker
8. Solid State Physics: M.A. Wahab

Semester IX Laboratory Courses

Electronics Lab	**B0109U9P**
Laser and Spectroscopy Lab	**B0109U10P**
Condensed Matter Physics Lab	**B0109U11P**

Semester – X

Experimental Techniques & Control Systems **B0110U1T**

Unit I Data Interpretation and Analysis: precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and non-linear curve fitting, chi-square test.

Unit II Optoelectronic Devices and Detectors: Solar cells, Photo-detector, Transducers (Temperature, Pressure, Vacuum pumps and Gauges)

Unit III Ideal operational amplifier, characteristics and applications; Inverting and non-inverting amplifier, integrator, differentiator, adder and comparator.

Unit IV Analogue v/s digital data: Statement of sampling theorem, A/D converters Flash converters, single slope, double slope and successive approximation converter), D/A converter (R-2R ladder type and weighted resistor type converter).

Unit V Fourier Transforms and lock-in detector, Box car averaging. Microprocessor and microcontroller basics, Instruction set related MOV, MVI and I/O commands. Addressing I/0 devices (Memory mapped & I/0 mapped I/O)

Reading List:
1. Pulse, Digital and switching waveform by J. Milliman and H. Taub
2. Op-Amps and Linear Integrated Circuits by R. A. Gayakwad
3. Electronics: Fundamental and Applications by D. Chattopadhyay and P. C. Rakshit
4. Microprocessor Architecture, programming and applications with 8085 by R. S. Gaonkar

Elective Courses

Elective I: Computational Physics with Python **B0110U2T**

Unit I Introduction to Operating systems, Linux, Python Basics: Interpreter, statements, variables, mathematical operators, loops, functions, libraries and modules, class and object, and simple applications.

Unit II Python libraries: numpy, scipy, matplotlib, pandas; extracting data from datafiles, managing datasets. 2D and 3D plots and graphs

Unit III Programming for Newton-Raphson method, iterative method, Newton's

forward and backward interpolation.

Unit IV Numeric integration and differentiation, Euler's methods, Runge-Kutta methods for ODE, matrix manipulation

Unit V Programming for the motion of real pendulum, Random numbers, Monte-Carlo method, the random walk, Ising model and solution of wave equations, Schrödinger 's equation.

Reading List:

1. Computational Physics with Python, Eric Ayars (California State University, 2013).
2. Computational Physics: Problem Solving with Python, 3rd edition, Rubin H. Landau, Manuel J. Paez, (Wiley-VCH, 2015).
3. Introducing Python: Modern Computing in Simple Packages, B. Lubanovic, (O'Reilly Media, Inc, 2015).
4. A Primer on Scientific Programming with Python, Hans Petter Langtangen (2014).

Elective II: Advanced Electrodynamics and Second Quantization B0110U3T

Unit I Radiation from a Moving Charge: Solution of Inhomogeneous Wave equation, Greens Functions, Lienard-Wiechert Potentials and Field from a moving charge, Larmor's formula and its Relativistic Generalization

Unit II Angular Distribution of Radiation from an Accelerated Charge, Electromagnetic Field and Radiation from an Oscillating Localized Source.

Unit III Radiation Reaction and Self-Force: Radiation Reaction Force from Conservation of Energy, Line Width and Level Shift of an Oscillator.

Unit IV Covariant Lagrangian Formalism, Noether's Theorem, Energy Momentum, Angular Momentum and Spin Tensors, Current Density Four Vector.

Unit V Second Quantization of Scalar field and of Electromagnetic Field in Radiation Gauge and of Dirac Field, Spin of Photons, Simple Problems on Algebra of Annihilation and Creation Operators.

Reading List:

1. Classical Electrodynamics, J. D Jackson, Wiley India.
2. Introduction to Electrodynamics, D. J. Griffths, Pearson, (2014).
3. Introduction to the Principles of Electromagnetism, Walter Hauser, Addison-Wesley Educational Publishers Inc, (1971).
4. Classical Electromagnetic Radiation, M A Heald and J B Marion, Academic Press, NY (1980)
5. Classical Electromagnetic Theory, Jack Vanderlinde, Springer (2007).

Elective III: Group Theory B0110U4T

Unit I Group theory and its application: Abstract definitions: Group, Multiplication Table, Sub-groups, Isomorphism and homomorphism, complexes, Cosets and classes, Indirect-group, Direct product of groups.

Unit II Theory of Representation: Linear vector space, basis, matrix representation of operators, unitary space, Unitary matrices, representation of group, characters, reducible and irreducible representations, Invariant subspaces, Schur's Lemmas

Unit III Orthogonality theorem for irreducible representation and characters Regular representation, occurrence of, an irreducible representation in a reducible representation.

Unit IV Theorem for possible number of irreducible representations of a group. Direct product of representations. Relationship to Quantum mechanics: Symmetry transformations, degeneracy and invariant subspaces, projection operators, transformation of functions.

Unit V Applications to molecular and crystal symmetry, Fundamental point group operations and nomenclature, construction of thirty-two point groups and character tables for their irreducible representations.

Reading List:

1. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
2. 2. Groups and Symmetry, M. A. Armstrong (Springer, 1988).
3. 3. Advanced Method of Mathematical Physics, R. S. Kaushal & D. Parashar (Narosa, 2008).
4. Group Theory and Its Applications to Physical Problems, M. Hamermesh (Dover, 1989).
5. Chemical Applications of Group Theory, F. Albert Cotton (John Wiley, 1988).
6. Mathematical Methods for Physicists, G. Arfken, H. Weber, & F. Harris (Elsevier, 2012).
7. Linear Integral Equations, W. V. Lovitt (Dover, 2005).
8. Introduction to Integral Equations with Applications, A. J. Jerri (Wiley-Interscience, 1999).

Specialization – I: Electronics

Microprocessor **B0110U5T**

Unit I Microprocessor 8085: Hardware description, Programmable Registers, Generation of control signal, Instruction cycle and machine cycle.

Unit II Instruction set, Addressing mode, simple programs, Counters and time Delay, Stack and Subroutines.

Unit III 8085 Interrupts, PIA 8255 Handshaking, via interrupt and polling.

Unit IV Memory organization and mapping, I/O devices Chip select and interfacing in I/O mapped and memory mapped I/O schemes. CMOS devices as RAM and ROM. Memory refresh.

Unit V A to D and D to A converter, IC ADC0809 and DAC08, Pin Out their interfacing with 8085.

Reading List:
1. Microprocessor Architecture, programming and applications with 8085 by R. S. Gaonkar
2. Microprocessor System the 8086 / 8088 Family by Liu and Gibson
3. Microprocessor and Interfacing by D. V. Hall
4. Fundamentals of Microprocessor by B. Ram

Physics of Semiconductor Devices **B0110U6T**

Unit I Semiconductor Physics: Carrier concentration in intrinsic and extrinsic semiconductors, recombination process, current density and continuity equations, decay of photo excited carriers, steady state injunction, transient and steady state diffusion.

Unit II P-n junction diode: Junction and diffusion capacitance, diode equation, break downs, temperature dependence of voltage and current. Varactor diode and parametric conversion and amplification,

Unit III Tunnel diode, V-I characteristics, tunnel diode as an amplifier and as an oscillator.

Unit IV Gunn diode, modes of operation, power and frequency performance. Impact: Static and dynamic characteristic, small signal analysis and negative conductance, power and frequency performance, device design and performance. Schottky effect and Schottky diode.

Unit V BJT: Current voltage relations in active, cut off and saturation regions, microwave transistor, cut off frequency, device geometry and performance.

Reading List:
1. S. M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, Third Edition, Wiley Interscience
2. Donald A. Neamen, An Introduction to Semiconductor Devices, McGraw-Hill, 2006
3. Jasprit Singh, Semiconductor Devices, John Wiley Sons, New York, 2001
4. Michael Shur, Physics of Semiconductor Devices, Pearson India Education Services Pvt. Ltd., Noida, 2019
5. Peter Y. Yu and Manel Cardona, Fundamentals of Semiconductors, Physics and Materials Properties, Springer Heidelberg Dordrecht, London, 2010.
6. P. John Paul, Electronic Devices and Circuits, New Age International (P), Ltd., Publishers, New Delhi, 2017
7. Massimo Rudan, Physics of Semiconductor Devices, Springer New York Heidelberg Dordrecht, London, 2015

Specialization – II: Laser and Spectroscopy

Advanced Atomic Spectroscopy **B0110U7T**

Unit I Lamb – shift in hydrogen spectrum,

Unit II Complex Spectra and their interpretation, nitrogen, oxygen and manganese as examples, Alternation of multiplicities, Inversion of states

Unit III Breit's Scheme for spectral term derivation, Rydberg atoms and Rydberg states

Unit IV Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Inductively Coupled Plasma Mass Spectroscopy (ECP-MS) Photo electron spectroscopy (PES), Auger Electron Spectroscopy (AES), X-Ray Fluorescence Spectroscopy (XRF).

Unit V Limitations of Optical Microscope and Electron Microscope, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Electron Microscopy (STEM), Fluorescence Microscopy.

Reading List:

1. Atomic spectra & atomic structure, Gerhard Hertzberg: Dover publication, New York.
2. Introduction to Infrared and Raman spectroscopy, Norman D Colthup, Lawrence H Daly and Stephen E Wiberley, Academic press, NY.
3. Molecular Spectra and Molecular Structure, Volume. I: Spectra of diatomic molecules by Gerhard Herzberg
4. Molecular structure & spectroscopy, G. Aruldhas; Prentice – Hall of India, New Delhi.
5. Principles of fluorescence spectroscopy by Joseph R. Lakowicz

IR & Raman Spectra of Polyatomic Molecules **B0110U8T**

Unit I Symmetry Elements and Symmetry Operations, Point Groups, Classification of Molecules into Point Groups.

Unit II Rotational vibration spectra of Linear molecule, Selection Rules and Transition of Rigid Rotator, Parallel and Perpendicular bands in linear molecules

Unit III Vibrational Motion, Normal co-ordinates and Normal modes of vibration, Accidental degeneracy, Vibrational Energy, Symmetry Co-ordinates, Symmetries of Normal modes of Vibration of N_2O and CO_2 molecules

Unit IV Pure Rotational Structure in the Raman and Far Infrared Spectra of Linear molecules, Alternation of Intensity. Active and Inactive IR and Raman Fundamentals, Functional Group Analysis.

Unit V Interaction of Rotation and Vibration, Rotation Vibration Spectra of Linear Polyatomic Molecule, Energy levels and Symmetry Properties, Coriolis Interaction, IR and Raman Spectra of Linear Polyatomic Molecule.

Reading List:

1. Herzberg, G, Infrared and Raman Spectra of Polyatomic Molecules.
2. G. Aruldhas, Molecular Structure and Spectroscopy.
3. C.N. Banwell and E.M. McCash, Fundamentals of Molecular Spectroscopy.
4. S. Chandra, Molecular Spectroscopy.

5. Sune Svanberg, Atomic and Molecular Spectroscopy.

Specialization – III: Condensed Matter Physics

Condensed Matter Physics – III **B0110U9T**

Unit I Transport Theory: Phenomenological coefficient L_{ij} and their physical inter reaction. General Boltzmann equation and its linearization Entropy production. Relaxation time solution of Boltzmann equation.

Unit II Electronic contributions of thermal and electrical conductivities and to Peltier, Seeback coefficient for metals and electronic semiconductors. Relationship between electrical and ideas about lattice contribution to thermal conductivity.

Unit III Magnetism: Classical and Semi Classical Theories: Failure to explain large internal fields. Exchange interaction. Ising Model. Bragg William Approximation. Explanation of large external fields. Non-existence of ferromagnetism in two-dimensional Ising Model. Two sub-lattice Model and classical theories of anti-ferromagnetism and ferrimagnetism, Ferrites and garnets.

Unit IV Second Quantized Theory: Ferromagnetic Heisenberg Hamiltonian, Holstein-Primakoff transformations and their application to Heisenberg Hamiltonian for small fractional spin reversal. Ferromagnetic magnons, Magnon heat capacity and saturation magnetization at small temperatures. Antiferromagnetic Hamiltonian and its reduction using Holstein Primakoff transformation, Antiferromagnetic magnons. Zeropoint sub-lattice magnetization.

Unit V The Magnetic Phase Transition: Order parameter, Landau's theory of second order phase Transitions. Fluctuations of the order parameter. Elementary qualitative ideas about critical exponents and scaling.

Reading List:

1. Introduction to Solid State Physics: C. Kittel
2. The Green Function in Solid State Physics, J. Mahanti.
3. Dynamical Theory of Crystal Lattice, Max Born and Kun Huang
4. Quantum Theory of Solids, J. Callaway
5. Elementary Solid State Physics, Omar, M.A., Pearson Education, (1999).
6. Solid State Physics, Ashcroft, N.W. and Mermin, N.D., Cengage Learning, (2008).
7. Solid State Physics: A. J. Dekker
8. Solid State Physics: M.A. Wahab

Condensed Matter Physics – IV **B0110U10T**

Unit I Many Electron Systems: Second quantization for Fermions, field operators, electron density operator, Hamiltonian for two particle interactions in second quantized form: Coulombian interaction and screened Coulombian interaction.

Unit II Linear Response Theory: Dielectric response analysis, dielectric constant for electron gas in self consistent approximation, Lindhard formula, dielectric constant. Dielectric screening of a point charge impurity.

Unit III Electron-Phonon Interaction: Long wavelength limit, deformation potential interaction, Born approximation, deformation potential perturbation Hamiltonian, Normal processes, polaron. Number of phonons accompanying electron.

Unit IV Electron-electron interaction via phonons, Attractive interaction, Cooper pairs, Reduced Hamiltonian for superconducting state. Bogoliubo-Valatin transformation, Diagonal and non-diagonal terms.

Unit V Superconducting ground state energy, nature of ground state, excited states, Temperature dependence of energy gap, Transition temperature, Simple treatment of Meissner effect and flux quantization.

Reading List:

1. Quantum Theory of Solids, C. Kittel, 2nd Ed., John Wiley and Sons, USA, 1987.
2. Quantum Theory of Solid State, Joseph Callaway, Academic Press (1991).
3. Principles of the Theory of Solids", J.M. Ziman

Semester X Laboratory and Dissertation Courses

Electronics Lab	**B0110U11P**
Laser and Spectroscopy Lab	**B0110U12P**
Condensed Matter Physics Lab	**B0110U13P**
PG Dissertation	**B0110U14P**

List of Experiments: Semester – IX & X

Electronics:

1. (a) Mode Analysis of klystron
   (b) Characterization of Directional coupler and Magic T and calibration of Attenuator
2. (a) Measurement of VSWR
   (b) Measurement of complex dielectric constant of material at microwave frequency
   (c) Verification of square law of crystal detector
3. Dielectric constant of a dispersing medium at RF frequencies.
4. ESR
5. Steady state and transient response of wide band amplifier.
6. Characterization of Op-Am: CMRR, Open loop gain bias voltage and bias currents, slew Rate.
7. Characterization of Summer, Integrator and Differentiator
8. Analog computation
9. Active filters
10. Log and Antilog Amplifiers and multiplication
11. A/D and D/A converter
12. Microprocessor
13. Video Amplifier
14. IC familiarization
15. Microstrip line

16. Logicom

Laser and Spectroscopy:

1. Study of Zeeman Effect
2. Study of L.I.F spectra
3. Study of Laser excited spectra
4. Laser induced fluorescence study of chlorophyll.
5. Intensity measurement of spectral lines.
6. Detection of unknown elements by recording emission spectra.
7. LED and Laser Diode Characteristics
8. Fiber Optic UV-Vis Spectrometer for Absorbance of powder, liquid & thin film Samples.
9. Fiber Optic UV-Vis Spectrometer for Reflectance of powder, liquid & thin film Samples.
10. Fiber Optic UV-Vis Spectrometer for Transmission of powder, liquid & thin film Samples.
11. Fiber Optic UV-Vis Spectrometer for Basic Fluorescence of Liquid Samples

Condensed Matter Physics:

1. X-Ray Diffraction
2. Hall Effect
3. Measurement of Energy Gap in Semiconductor Four Probe Method.
4. Hysteresis Characterization of Different Samples.
5. Lattice Dynamics of monoatomic and diatomic lattices.
6. Measurement of Curie Temperature.
7. ESR Experiment.
8. Measurement of tunnelling current through a metal-insulator junction.
9. Thermoluminescence of F-centres.
10. Measurement of energy gap, refractive index, and absorption coefficient of semiconductor by using optical method.