Maharashtra Education Society's

Abasaheb Garware College

(Autonomous)

(Affiliated to Savitribai Phule Pune University)

Two Year M.Sc. Degree Program in Physics

(Faculty of Science and Technology)

Syllabi under NEP-2020

Level 6.0 (Physics)

To be implemented from Academic Year 2023-2024

Title of the Course: M.Sc. (Physics)

Preamble

MES Abasaheb Garware College, Pune affiliated to Savitribai Phule Pune University is awarded academic autonomy by the University Grants Commission (UGC), New Delhi and Savitribai Phule Pune University (SPPU), Pune in 2021.

National Education Policy (NEP) – 2020 will be implemented for UG and PG programs from academic year 2023-24 as per the guidelines of UGC. The post graduate programme in Physics is of two years with two semesters every year. In the proposed structure, due consideration is given to Core and Elective Courses (Department specific - Physics), along with Research Methodology (RM) Course and Field Project (FP). In NEP-2020, more emphasis is given on Research Project (RP) to inculcate the research attitude among students. Continuous assessment is an integral part of the NEP system which will facilitate systematic and thorough learning towards better understanding of the subject. This syllabus is planned to improve the students' understanding of fundamental concepts of Physics along with practical skill required to achieve excellence in recent advances of Physics and its applications to society. This course shall motivate students for higher studies in Physics and build-up successful career in various branches of science and technology.

Program Outcomes

1. To train students to qualify national and international level tests like GRE, NET, JEST, GATE etc. successfully and thereby motivate for higher studies.
2. To familiarize the application of materials solutions to enhance or radically improve existing and future technology.
3. To motivate students to improve the skills like conceptual problem-solving ability, proficiency in advanced mathematics, proficiency in theoretical or experimental project design, expertise in employing computer software, proficiency in communication through writing, oral presentations and thereby developing analytical abilities to address real world problems.
4. To foster scientific bent of mind and attitude relevant to science such as concern for efficiency, accuracy and precision, objectivity, integrity, enquiry, effective communication, ethical responsibilities, Initiative and Inventiveness.
5. To assist the students in acquiring basic knowledge in the specialized thrust areas such as Materials Science and Nanotechnology.
6. To inculcate the scientific attitude among students and thereby helping them to take up the global challenges to become as competitive physicists / researchers in diverse areas of theoretical and experimental physics.
7. To train students in skills related to research, education, industry, and market.

Eligibility for **M.Sc. Physics:** **B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics**

Total credits to be completed to award the M.Sc. degree: 88

Credit distribution structure for Two Years / One Year PG Degree Programme

Level/ Degree	Semester	Course Type	Course Code	Course Name	Credit	No. of Hrs to be engaged
6.0 PG Diploma (After 3 Year Degree)	I	Major Core	PHY-501-MJ	Mathematical Methods in Physics	4	60
			PHY-502-MJ	Classical Mechanics	4	60
			PHY-503-MJ	Atoms and Molecules - I	2	30
			PHY-504-MJP	Physics Lab-I	4	120
		Major Elective	PHY-511-MJ	Electronics	4	60
		Research Methodology	PHY-541-RM	Research Methodology	4	60
	II	Major Core	PHY-551-MJ	Electrodynamics	4	60
			PHY-552-MJ	Quantum Mechanics	4	60
			PHY-553-MJ	Atoms and Molecules - II	2	30
			PHY-554-MJP	Physics Lab-II	4	120
		Major Elective	PHY-561-MJ	Physics of Thin Films	4	60
		Field Project/OJT	PHY-581-OJT	On Job Training	4	120
6.5 PG Degree (After 1 Year Diploma / 4 Year UG)	III	Major Core	PHY-601-MJ	Statistical Mechanics	4	60
			PHY-602-MJ	Solid State Physics	4	60
			PHY-603-MJ	Experimental Techniques in Physics – I	2	60
			PHY-604-MJP	Physics Lab - III	4	120
		Major Elective	PHY-611-MJ	Materials Science - I	4	60
		Research Project	PHY-631-RP	Research Project	4	120
	IV	Major Core	PHY-651-MJ	Nuclear Physics	4	60
			PHY-652-MJ	Experimental Techniques in Physics – II	4	60
			PHY-653-MJ	Physics of Nanomaterials	4	60
		Major Elective	PHY-661-MJ	Materials Science - II	4	60
		Research Project	PHY-681-RP	Research Project	6	180

Extra Credits Courses are as follows:

Level	Semester	Course Code	Mandatory Add-On Credit Course	Credits
6.0	I	EC-501-CS	Cyber Security -I	1
		EC-502-HR	Human Rights - I	1
	II	EC-551-CS	Cyber Security -II	1
		EC-552-HR	Human Rights - II	1
6.5	III	EC-601-CS	Cyber Security -III	1
		EC-602-SD	Skill Development - I	1
		EC-603-IC	Introduction to Indian Constitution	2
	IV	EC-651-CS	Cyber Security -IV	1
		EC-652-SD	Skill Development - II	1
			Total Credits	**10**

MAJOR

SEMESTER - I

Course Code and Title: PHY-501-MJ Mathematical Methods in Physics

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Demonstrate complex variables (which contain real and imaginary parts), matrices, linear transformations, eigenvalues, eigen vectors.
2. Use Laplace transforms methods to solve differential equations in Instrumentation.
3. Solve differential equations like Legendre, Bessel and Hermite in physical sciences.
4. Solve transfer functions in Instrumentation using Laplace transforms.
5. Apply Fourier transforms in Mechanics.

Module 1: Complex Analysis **15 Hrs**

Complex number, Complex function (polynomial, Exponential, Trigonometric complex function, Logarithm), Limit and Continuity, differentiation, Analytical function, Cauchy-Riemann condition, Line integrals, Cauchy integral formula, Derivative of analytical functions, Power Series, Taylor's theorem, Laurent's theorem, Calculus of residues

Module 2: Linear Vector Space and Matrix Algebra **15 Hrs**

Revision on Vector space: Vectors (dependent and independent), Vector space, Hilbert space, Dimension of vector space, Matrix representation, Various types of matrices, Similarity transformation, Eigen values and Eigen vectors, Inner product, Orthogonality, Introduction only to Gramm-Schmidt orthogonalization procedure, Self-adjoint and unitary transformation, Eigen values and Eigen vectors of Hermitian and Unitary transformation, Cayley-Hamiltonian theorem, Diagonalization,

Module 3: Special Functions **15 Hrs**

Bessel function, Legendre, Hermite, and Laguerre functions – Generating function, Recurrence relations and their differential equations, Orthogonality properties, Bessel's function of first kind, Spherical Bessel function, Associated Legendre function, Spherical harmonics, Standard methods of solving first order differential equations, Wronskian, Methods for finding the complementary function, Rules to find particular integral

Module 4: Fourier Series and Integral Transforms **15 Hrs**

Fourier series: Definition, Dirichlet's Condition, Convergence, Fourier Integral and Fourier transform, Convolution theorem, Parseval's identity, Application to the solution of

differential equations, Laplace transform and its properties, Fourier transform and Laplace transform of Dirac Delta function

Reference Books

1. Complex Variables and Application: J.W. Brown, R.V. Churchill, Tata McGraw Hill Education
2. Complex Variables: Seymour Lipschutz, Tata McGraw Hill Education
3. Mathematics for Physical Sciences: Mary Boas, John Wiley and Sons
4. Mathematical Methods in Physics: B.D. Gupta, Vikas Publishing House Pvt Ltd.
5. Mathematical Methods in Physics: Satya Prakash, Sultan Chand and Sons.
6. Linear Algebra: Seymour Lipschutz, Tata McGraw-Hill Education
7. Mathematical Method for Physicists: G.B. Arfken and H.J. Weber, Academic Press, NY
8. Methods of Theoretical Physics: P.M. Morse and H. Feshbach, McGraw Hill Publications

Course Code and Title: PHY-502-MJ Classical Mechanics

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Solve the equations of motion using Lagrangian and Hamiltonian formulation.
2. Understand the fundamental equations of motion, conservation principles involving momentum, angular momentum and energy.
3. Solve the central force problems by studying rigid body mechanics and Poisson Brackets.
4. Solve the problems of generating function, canonical transformation.

Module 1: Analytical Dynamics (Lagrangian and Hamiltonian Dynamics) 15 Hrs

Disadvantage of Newtonian mechanics, Principle of virtual work, D'Alembert's Principle, Types of constraints, Generalized co-ordinates, Degrees of freedom, Variational principle and its applications to problems like shortest distance, brachistochrone, geodesics etc. Lagrangian and Hamiltonian equations of motion - derivation using Hamilton's principle of least action and their applications to various problems, Hamiltonian for a charged particle, Properties of kinetic energy function, Time-dependence of total energy (theorem on total energy), Symmetry and conservation laws (energy and momentum), Gauge function for Lagrangian, Invariance under Galilean transformation

Module 2: Canonical Transformations and Poisson Brackets 15 Hrs

Canonical transformations and their applications, Canonical transformations of the free particle Hamiltonian, Liouville's theorem, Poisson Brackets, Jacobi-Poisson theorem on Poisson Brackets, Invariance of Poisson brackets under canonical transformations

Module 3: Central Forces and Non-inertial Frames of Reference 15 Hrs

Lagrangian formulation of motion under central force, Kepler problem, Inverse square law and orbital equation, Stability of orbits, Motion of satellites, Rotating frames of reference, Coriolis force, banking of rivers, Foucault's pendulum and tides

Module 4: Rigid Body Dynamics and Small Oscillations 15 Hrs

Moment of inertia tensor, Euler angles, Angular momentum and torque in Euler's angle, Euler equation of motion for rigid body motion, Symmetric top, General theory of small oscillations, Lagrangian for small oscillations, Secular equation and eigen value equation, System of coupled oscillators, Normal modes and normal coordinates, Vibrations of linear triatomic molecule

Reference Books

1. Classical Mechanics: H. Goldstein, C. Poole and J. Safko, Addison-Wesley
2. Classical Mechanics: N.C. Rana and P.S. Joag, Tata McGraw-Hill Education
3. Classical Mechanics: J.R. Taylor, University Science Books
4. Classical Mechanics: P.V. Panat, Narosa Publishing House
5. Classical Mechanics: Y.R. Waghmare, Prentice-Hall of India

Course Code and Title: PHY-503-MJ Atoms and Molecules - I

Level: 6.0 **Difficulty:** 500

Credits: 02 **Theory Credits:** 02 **Practical Credits:** 00

Total Contact Hrs: 30 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Differentiate different atomic systems, different coupling schemes and their interactions with magnetic and electric fields.
2. Apply the techniques of microwave and infrared spectroscopy to explain the structure of molecules.
3. Study of atomic effect such as Zeeman effect and Stark effect.

Module 1: Atoms **15 Hrs**

Structure of atoms, Electronic angular momentum, Many electron atoms, Revision of quantum numbers, exclusion principle, electron configuration, Hund's rule; origin of spectral lines, selection rules, one electron spectra, Coupling schemes, two electron spectra, fine structure and hyperfine structure, Inclusion of nuclear spin, The Hartree Theory, Results of Hartree theory, X-ray line; Atoms in Electromagnetic field: Zeeman effect- Normal and Anomalous, Paschen- Back effect, Stark effect (weak field)

Module 2: Molecules **15 Hrs**

Bonding mechanism in molecules, Molecular orbital methods, Valence band method, Molecular Spectra – Rotational and vibrational spectra for diatomic molecules, Electronics spectra of diatomic molecules, Born Oppenheimer approximation, vibration course structure, vibrational analysis of band system, Frank – Condon principle, Dissociation energy and dissociation products, rotational fine structure of electronic vibration transitions, The Fortrat diagram, Predissociation

Reference Books

1. Fundamentals of Molecular Spectroscopy: Collin N. Banwell and Elaine M. McCash, McGraw Hill Publication
2. Molecular Structure and Spectroscopy: G. Aruldhas, Eastern Economy Edition
3. Quantum Physics: Robert Eisberg and Robert Resnik, Wiley India Publication
4. Introduction to Quantum Mechanics: Y.S. Waghmare, S. Chand and Co. (Revised Edition)

Course Code and Title: PHY-504-MJP Physics Laboratory-I

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 00 **Practical Credits:** 04

Total Contact Hrs: 120 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Understand the behaviour of electronic components and design of bias circuits for diodes, transistors, op-amps etc.
2. Designing concepts of logic gates and digital circuits.
3. Select and test proper instruments to evaluate performance of electronic circuit.
4. Utilize DMM and CRO like measuring instruments.

Student has to perform Any **10 Experiments**

1. Diode Pump Staircase generator using UJT
2. Voltage Control Oscillator using IC-566
3. Function generator using IC -8038
4. Optocoupler using OPAMPs and IC MCT-2E
5. Constant current Source using OP-AMP
6. DAC (Digital to Analogue Converter) using R-2R and Binary ladder
7. Active filters using OP-AMP / IC- 8038(L-P, H-P. Notch type)
8. Study of Multiplexer and Demultiplexer
9. Precision rectifier
10. Design, built and test oscillator – LC oscillator
11. 8-bit ADC
12. OPAMP: logarithmic amplifier
13. Voltage to Frequency / Frequency to voltage converter using OP-AMP

Reference Books

1. Signetic Linear Data Manual: Vol 1 and 2
2. Power Supplies: B.S. Sonde, Mc Graw Hill Education
3. Operational Amplifier: G.B. Clayton, Newnes
4. OP-AMPS and Linear Integrated Circuits: R.A. Gaikwad, Prentice Hall
5. Data Converters: B.S. Sonde, Tata Mc-Graw Hill Publication. Co. Ltd.
6. Pulse, Digital and Switching Circuits: J. Millman,H. Taub, Tata Mc-Graw Hill

7. Electronic Integrated Circuits and Systems: F.C. Fitchen Van, Nostrand Reinhold Company
8. Digital Principles and Applications: D. Leach and A.P. Malvino, Tata Mc-Graw Hill Pub. Co. Ltd., New Delhi
9. Experiments in Electronics: S.V. Subramanian, McMillan India Ltd.

MAJOR ELECTIVE

Course Code and Title: PHY-511-MJ Electronics

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Acquire knowledge of power electronics, various ICs, semiconductor devices and its application.
2. Develop logic circuits for various applications in real life.
3. Gain knowledge and evaluate the Boolean expressions, combinational logic circuits and simplifications using Karnaugh maps.
4. Analyse the operation of multiplexers, adders and subtractors.
5. Understand the working of rectifiers, A/D and D/A converters.

Module 1: Semiconductor Devices and its Applications **15 Hrs**

Thyristors: Introduction, Characteristics, Two-transistor model of thyristor, Types: phase control and fast switching, DIAC and TRIAC: Construction, working, characteristics and applications as fan regulator; DC-DC converter and Switching mode regulators: Buck, boost, buck-boost, cuk regulators

Module 2: Special Function ICs and their Applications **15 Hrs**

Operational Amplifier: Function generator using two OPAMPS with variable controls, Precision rectifiers (Half wave and Full wave), Diode Pump Staircase generator using UJT, Optocoupler using OPAMPs and IC MCT-2E, Constant current source using OP-AMP, Active filters using OP-AMP, Multiplexer and Demultiplexer, OPAMP as logarithmic amplifier, Voltage to Frequency converter using OP-AMP, Voltage Controlled Oscillator (IC566): Block diagram and working

Module 3: Digital Logic Circuits I: Combinational Logic **15 Hrs**

Review of Boolean identities and its use to minimize Boolean expressions. Use of Karnaugh Map to design 4-variable logic circuits like BCD to 7-segment decoder, Binary-to-Gray and Gray-to-Binary code converter; Digital Logic Circuits II: Model selection, state transition diagram, State synthesis table, design equation and circuit diagram, Moore model, Mealy model

Module 4: Data Converters **15 Hrs**

Digital to Analog converters: Binary weighted and R-2R ladder type with practical circuit (Using Input switches, Level amplifiers, Control gates and Buffer amplifier); Analog to Digital

converters: Single slope, Dual slope, Flash (Simultaneous) type, Counter ramp type, Continuous type and Successive approximation type

Reference Books

1. Power Electronics Circuits, Devices and Applications: Muhammad H. Rashid, Pearson Publication
2. Electronic Devices and Circuits - An Introduction: Allen Mottershead, Prentice Hall of India Publication
3. Solid State Electronic Devices: Ben G. Streetman, Pearson Publication
4. Operational Amplifiers: G.B. Clayton, Newnes Publications
5. Linear Integrated Circuits: D. Roy Choudhury, New Age International Publication
6. Design with OPAMPS and Analog Integrated Circuits: Sergio Franco, Tata McGraw Hill Publication
7. Digital Electronics: R.P. Jain, McGraw Hill Publication
8. Digital Principles and Applications: D.P. Leach and A.P. Malvino, McGraw Hill Publication
9. Digital Electronics - An Introduction to Theory and Practice: W.H. Gothmann, Eastern Economy Edition

MINOR

Course Code and Title: PHY-541-RM Research Methodology

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Understand various postulates of research problems.
2. Design research problem.
3. Write a thesis and know modern statistical methods.
4. Carry out research problem individually in a perfect scientific method.

Module 1: Meaning of Research - Function of Research

Meaning of Research - Function of Research – Characteristics of Research – Steps involved in Research – Research in Pure and Applied Sciences - Inter Disciplinary Research

Factors which hinder Research – Significance of Research - Research and scientific methods – Research Process– Criteria of good Research – Problems encountered by Researchers – Literature review.

Module 2: Identification of Research Problem

Selecting the Research problem – Necessity of defining the problem – Goals and Criteria for identifying problems for research.

Perception of Research problem – Techniques involved in defining the problem –Source of problems – Personal consideration.

Module 3: Research Design

Formulation of Research design – Need for Research design – Features of a gooddesign – Important concepts related to Research design.

Different research designs – Basic principles of experimental designs – Computerand internet in designs.

Module 4: Interpretation and Report Writing

Meaning and Technique of interpretation – Precautions in interpretation – Significance of report writing – Different steps in writing a report – Layout of a Researchreport.

Types of report – Mechanics of writing a research report – Precautions for writinga research report – Conclusion.

Reference Books

1. A Hand Book of Methodology of Research, Rajammall, P. Devadoss and K. Kulandaivel, RMM Vidyalaya Press
2. Research Methodology Methods and Techniques, C.R. Kothari, New Age International Publishers
3. Thesis and Assignment Writing, J. Anderson, Wiley Eastern Ltd.
4. Research Methodology, Mukul Gupta and Deepa Gupta, PHI Learning Private Ltd., New Delhi
5. Fundamentals of Mathematical Statistics, S.C. Gupta and V.K. Kapoor, Sultan Chand and Sons, New Delhi
6. Statistical Methods, G.W. Snedecor and W.G. Cochrans, Lowa State University Press

SEMESTER – II

MAJOR CORE

Course Code and Title: PHY-551-MJ Electrodynamics

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Differentiate between static and dynamic systems.
2. Use Maxwell's equations in analysing the nature of electromagnetic time varying fields.
3. Describe the nature of electromagnetic wave and its propagation through different media and interfaces involved in different situations.
4. Acquire the knowledge of laws of reflection, refraction, boundary conditions and its applications in antireflection coatings.

Module 1: Multipole Expansions and Time Varying Fields 15 Hrs

Multipole expansions for a localized charge distribution in free space, linear quadrapole potential and field, static electric and magnetic fields in material media, boundary conditions, Time dependent fields, Faraday's law for stationary and moving media, Maxwell's displacement current, differential and integral forms of Maxwell's equations, Maxwell's equations for moving medium

Module 2: Energy, Force, Momentum Relations and Electromagnetic Wave Equations 15 Hrs

Energy relations in quasi-stationary current systems, Magnetic interaction between two current loops, Energy stored in electric and magnetic fields, Poynting's theorem, General expression for electromagnetic energy, Electromagnetic wave equations, Electromagnetic plane waves in stationary medium, Reflection and refraction of electromagnetic waves at plane boundaries (Oblique incidence), Electromagnetic waves in conducting medium, Skin effect and skin depth

Module 3: Inhomogeneous Wave Equations 15 Hrs

Inhomogeneous wave equations, Lorentz's and Coulomb's gauges, Gauge transformations, Wave equations in terms of electromagnetic potentials, d'Alembertian operator, Hertz potential and its use in computation of radiation fields, Gauge invariance, Wave guide, Lienard-wiechert potential, Retarded time

Module 4: Relativistic Mechanics and Covariance 15 Hrs

Experimental basis for special theory of relativity (Michelson – Morley experiment), Lorentz transformations, Relativistic velocity addition, Minkowski's space time diagram, Four-vector

potential, electromagnetic field tensor, Lorentz force on a charged particle, Invariance of Maxwell's equations

Reference Books

1. Introduction to Electrodynamics: David J. Griffith, Prentice Hall of India, New Delhi
2. Introduction to Electrodynamics: A.Z. Capri and P.V. Panat, Narosa Publishing House
3. Classical Electricity and Magnetism: W.K.H. Panofsky and M. Phillips, Addison Wesley
4. Foundations of Electromagnetic Theory: Reitz and Milford, World Student Series
5. Classical Electrodynamics: J.D. Jackson, John Wiley
6. Electromagnetic Theory and Electrodynamics: Satya Prakash, Kedar Nath and Co., Meerut
7. Special Theory of Relativity: Robert Resnick, Wiley India Pvt. Ltd.
8. Electromagnetics: B.B. Laud, Willey Eastern
9. Matrices and Tensors in Physics: A.W. Joshi, New Age International
10. Electrodynamics: S.L. Gupta, S.P. Singh, V. Kumar, Pragati Prakashan
11. Classical Electromagnetism: H.C. Verma, Bharati Bhavan Publishers

Course Code and Title: PHY-552-MJ Quantum Mechanics

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Differentiate between classical and quantum mechanical theory and approach.
2. Learn various techniques to solve time dependent and time independent Schrodinger equations using different coordinate systems.
3. Well versed in linear vector space, operators, bra and ket notation.
4. Study of theory of angular momentum and spin matrices, orbital angular momentum and Clebsch-Gordan Coefficient
5. Study various approximation methods utilized in Quantum mechanics.

Module 1: General Formalism of Quantum Mechanics **15 Hrs**

Inadequacy of classical Physics, Photo-electric effect, Compton effect and scattering, wave packets and uncertainty relations, Schrodinger wave equation, probability interpretation and applications, Simple one-dimensional problems wells, barriers and harmonic oscillator (One dimension); Postulates of Quantum Mechanics; Representation of states and dynamical variables, observables, self-adjoint operators, eigen functions and eigen values, degeneracy, Time evaluation of state, Dirac delta function, Completeness and closure property, Physical interpretation of eigen values, eigen functions and expansion coefficients, eigen values and eigen functions of momentum operator

Module 2: Representation of States – Dirac notation **15 Hrs**

Hilbert space, Dirac's bra and ket notation, dynamical variables and linear operators, projection operators, unit operator, unitary operator, matrix representation of an operator, change of basis, unitary transformation, Equation of motion in quantum mechanics, Eigen values and eigen functions of simple harmonic oscillator by operator method

Module 3: Angular Momentum **15 Hrs**

Commutation relations of angular momentum operators, Eigen values and eigen functions of L^2 and Lz operators, ladder operators L_+ and L_-, Pauli theory of spins (Pauli's matrices), matrix representation of J in |jm> basis. Addition of angular momenta, Computation of Clebsch-Gordon coefficients in simple cases (J_1=1/2, J_2=1/2)

Module 4: Approximation Methods **15 Hrs**

Time-independent Perturbation theory: Non degenerate, Zeeman effect, Time dependent Perturbation theory: Transition amplitude 1st and 2^{nd} order, Fermi's golden rule, Harmonic

perturbation, Introduction to WKB approximation, Variational method; Basic principles and applications to particle in box, SHO

Reference Books

1. A Text-book of Quantum Mechanics: P.M. Mathews and K. Venkatesan, McGraw-Hill Publishing Co.
2. Quantum Mechanics: A. Ghatak and S. Lokanathan, MacMillan Publisher
3. Introduction to Quantum Mechanics: Y.S. Waghmare, S. Chand and Co. (Revised Edition)
4. Quantum Mechanics: L.I. Schiff, McGraw-Hill, New York
5. Modern Quantum Mechanics: J. J. Sakurai, Cambridge University Press
6. Quantum Physics: R. Eisberg and R. Resnick, Wiley Publication
7. Introduction to Quantum Mechanics: David J. Griffiths, Cambridge India
8. Introductory Quantum Mechanics: W. Greiner, Springer Publication
9. Introductory Quantum Mechanics: Li Boff, Pearson Education Ltd.
10. Quantum Mechanics – Concepts and Applications: Nouredine Zettili, A John Wiley and Sons Ltd.
11. Principles of Quantum Mechanics: R. Shankar, Plenum Publishing Corporation

Course Code and Title: PHY-553-MJ Atoms and Molecules - II

Level: 6.0 **Difficulty:** 500

Credits: 02 **Theory Credits:** 02 **Practical Credits:** 00

Total Contact Hrs: 30 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

Course Outcomes: After completion of the course, students would be able to:

1. Familiar with various spectroscopic techniques like ESR, NMR and its applications.
2. Apply the principle of Raman, FTIR spectroscopy and its applications in the different field of science & Technology.

Module 1: Spectroscopic Techniques **15 Hrs**

Microwave Spectroscopy: microwave spectrometer, information derived from rotational spectra and analysis of microwave absorption by H_2O; Infrared spectroscopy: IR spectrophotometer and instrumentation, sample handling techniques, FTIR spectroscopy and analysis of HCl spectrum, Applications; Raman spectroscopy: Theory of Raman scattering, Rotational Raman spectra, Mutual exclusion, Raman spectrometer, sample handling techniques, Fourier transform Raman spectrometer, Structure determination using IR and Raman spectroscopy (diamond), Applications

Module 2: Resonance spectroscopy **15 Hrs**

ESR - Principles of ESR, ESR spectrometer, total Hamiltonian, hyperfine structure, ESR spectra of free radicals in solution NMR-Magnetic properties of nucleus, resonance condition, NMR instrumentation, relaxation process, chemical shift, applications of NMR

Reference Books

1. Fundamentals of Molecular Spectroscopy: Collin N. Banwell and Elaine M. McCash, McGraw Hill Publication
2. Molecular Structure and Spectroscopy: G. Aruldhas, Eastern Economy Edition
3. Quantum Physics: Robert Eisberg and Robert Resnik, Wiley India Publication
4. Introduction to Quantum Mechanics: Y.S. Waghmare, S. Chand and Co. (Revised Edition)

Course Code and Title: PHY-554-MJP Physics Laboratory-II

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 00 **Practical Credits:** 04

Total Contact Hrs: 120 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Analyse new physical problems and develop skills of laboratory techniques to find the appropriate solution, interpret the results and a meaningful prediction for the future development of Physics.
2. Learn various experimental methods thereby developing analytical abilities.
3. Acquire the skills related to research and industry- academia.

Student has to perform any **10 Experiments**

1. Transition temperature of Dielectric material:
   a) To determine the capacitance C of the dielectric material as a function of temperature
   b) Hence calculate the transition temperature of dielectric material
2. Michelson's Interferometer: To determine the wavelength of He-Ne LASER by using Michelson's Interferometer apparatus.
3. Specific Heat of Solids: To determine the specific heat of graphite at three different temperatures
4. Frank-Hertz experiment: To study the discrete energy levels using Frank-Hertz experiment
5. G.M. counter: Characteristics of GM tube and Counting statistics
6. G.M. counter: Determination of dead time of GM tube by double source method and determination of end point energy of β-ray source
7. Thermionic emission: To determine work function of Tungsten filament
8.. Four Probe method: Temperature variation and Band gap of Ge-semiconductor
9. Ionic Conductivity of NaCl
10. Zeeman Effect
11. Stefan's constant – Black Body Radiation
12. To study absorption spectra of Iodine molecule and to determine its dissociation Energy using spectrometer

Reference Books

1. Solid State Laboratory Manual in Physics: Department of Physics, University of Pune, Pune-7, 1977
2. Experimental Physics: B.L. Worsnop and H.T. Flint, Asia Publishing House
3. Molecular Structure and Spectroscopy: G. Aruldhas, Prentice-Hall of India Pvt. Ltd., New Delhi
4. Solid State Physics: S.P. Pillai, New Age International Publisher
5. Practical Physics: D.R. Behekar, S.T. Seman, V.M. Gokhale, P.G. Kale, Kitab Mahal Publication
6. Introduction to Experimental Nuclear Physics: R.M. Singru, Wiley Eastern Pvt. Ltd., New Delhi.

MAJOR ELECTIVE

Course Code and Title: PHY-561-MJ Physics of Thin Films

Level: 6.0 **Difficulty:** 500

Credits: 04 **Theory Credits:** 04 **Practical Credits:** 00

Total Contact Hrs: 60 Hrs

Prerequisite for the Course: B.Sc. in Physics/Nanoscience and Nanotechnology/ Electronics/ Mathematics/ Chemistry Or Engineering in Mechanical/ Metallurgy/ Electrical/ Electronics

Course Learning Outcomes: After completion of the course, students would be able to

1. Study basics of vacuum techniques and growth mechanism of thin films.
2. Get knowledge about various deposition and thickness measurement techniques of thin films and thereby developing skills required for industry and/or research.
3. Produce invention by studying properties and applications of thin films.

Module 1: Introduction to Thin Films **15 Hrs**

Overview of vacuum techniques, Comparison of thin and thick films, Theory of growth of thin films: Nucleation, condensation, Capillarity model, Atomistic model, comparison of models, various stages of film growth, Aspects of physical structure of film growth, Crystallite size, surface roughness, density of thin films

Module 2: Deposition Techniques and Measurement of Thickness **15 Hrs**

Physical Vapour Deposition, Chemical Vapour Deposition, Molecular Beam Epitaxy, Sputtering, Spray pyrolysis, Dip coating and Spin coating, Electron –beam deposition, Pulsed Laser Ablation. Tolansky technique, Talystep (styles) method, Quartz crystal microbalance, Stress measurement by optical method, Gravimetric method

Module 3: Properties of Thin Films **15 Hrs**

Electrical Properties: Source of Resistivity in Metallic conductors, Influence of thickness on the resistivity of thin films, Hall Effect and Magneto-resistance in thin films, Fuch-Sondhemir theory, TCR and its effects, Mechanical properties: Adhesion and its measurement with mechanical and nucleation methods, stress measurement by optical method, Optical properties: Absorption and transmission

Module 4: Applications of Thin Films **15 Hrs**

Junction devices (Metal semiconductor junction) Solar cells, ICs, Optical coatings, Thin film sensors (gas and humidity), Anti-reflection coatings – inhomogeneous, homogeneous and multi-layer films, infrared antireflection coating

Reference Books

1. Hand book of Thin Film Technology: Edited by L. I. Maissel and R. Glang, Tata McGraw Hill
2. Thin Film Phenomena: K.L. Chopra, Tata Mc Graw Hill
3. Material Science of Thin Films: M. Ohring, Academic Press

4. Thin Film Process: Edited by J.L. Vossen and W. Kern, Academic Press
5. Vacuum Technology by A. Roth, North Holland