Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5

Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code: 23ScPhyP311 **Course Name: Quantum Mechanics -II**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**
Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:
- Mathematical Methods in Physics (23ScPhyP111)
- Quantum Mechanics- I (23ScPhyP113)

Course Objectives:
- To Study Approximation methods in detail
- To learn the Scattering Theory and Symmetry in Quantum Mechanics
- To apply the theory into relevant numerical examples and solve them.

Course Outcomes:
On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Recall basic quantum mechanics.	1
CO 2	Explain different approximation methods on the basis of course content.	2
CO 3	Apply quantum mechanics to understand behaviour of particle in various quantum conditions	3
CO 4	Analyse the various phenomenon through quantum mechanics	4
CO 5	Determine the appropriate method to understand various quantum related phenomena	5
CO 6	Generate a theoretical aptitude for understanding course content	6

Course Contents

Module 1	**Approximation Methods I**	15 lectures
	Revision and Problem Solving: • Time-independent Perturbation theory: Non-degenerate states • Schrodinger, Heisenberg and Interaction picture. • Heisenberg's matrix mechanics for harmonic oscillators. • Time-dependent Perturbation theory, Fermi's golden rule, Harmonic perturbation • Approximation Methods: Time-independent Perturbation theory: Degenerate states Applications of Time-independent Perturbation theory - Anharmonic Oscillator. Time dependent Perturbation theory: Transition amplitude, 1st and 2nd order, Adiabatic and Sudden Approximations Dipole approximation, Einstein coefficient for spontaneous emission. • Experiential Learning/ Problem Solving	
Module 2	**Approximation Methods II**	15 lectures
	• Variational method: Basic principles and application to Helium atom • WKB approximation: General formalism, Bound states for potential wells – with no rigid walls, with one rigid wall, with two rigid walls. • Bohr’s quantization condition, application to Tunneling-Alpha Decay, Field Emission • Experiential Learning/ Problem Solving	
Module 3	**Module 3: Theory of Scattering**	15 lectures
	• Collisions in 3-D and scattering: Laboratory and CM reference frames; scattering amplitude, differential scattering cross section and total scattering cross section • Method of partial waves; Phase shift, Resonance Scattering, Ramsauer- Townsend effect, Attractive and Repulsive Potentials • Scattering by a perfectly rigid sphere and by square well potential. Yukawa potential. • The Born approximation, Lippman-Schwinger equation, applications and validity of the Born approximation. • Experiential Learning/ Problem Solving	

Module 4	**Symmetry in Quantum Mechanics and Introduction to Relativistic Quantum Mechanics**	15 lectures
	• Symmetry in Quantum Mechanics: • Identical particles: symmetric and antisymmetric wave functions, spin angular momentum, Slater determinants, Spin - Statistics Connection • Wigner-Eckert theorem and its applications. • Experiential Learning/ Problem Solving	

References:

1) Introduction to Quantum Mechanics by by David J. Griffiths
2) A Text-book of Quantum Mechanics by P. M. Mathews and K. Venkatesan.
3) Quantum mechanics by A. Ghatak and S. Lokanathan
4) Quantum Mechanics by L.I. Schiff
5) Modern Quantum mechanics by J. J. Sakurai
6) Quantum Physics by R. Eisberg and R. Resnick
7) Shankar R. Principles of Quantum Mechanics, IInd Edition (Plenum, 1994)
8) Introductory Quantum mechanics by Granier, Springer Publication.
9) Introductory Quantum Mechanics, Li Boff, 4th Edition, Pearson Education Ltd
10) Quantum Mechanics by Nouredine Zettili, A John Wiley and Sons, Ltd., Publication
11) Advanced Quantum mechanics by J. J. Sakurai

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Second Year of M.Sc. Physics
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Course Code: 23ScPhyP312 **Course Name : Solid State Physics**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA : 50 Marks **End-Sem : 50 Marks**

Prerequisite Courses:

- Solid state physics course at graduation level
- Mathematical physics course (23ScPhyP111)

Course Objectives:

- To understand different properties to the solid based on the structural aspects
- To study various properties of solids like electrical and magnetic properties

Course Outcomes:

On completion of the course, student will be able to

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Recall the basics of solid state physics related to the course	1
CO 2	Interpret the mathematical formulation in terms of solid state concepts.	2
CO 3	Apply the laws to various combinations of parameters and study different applications/ cases.	3
CO 4	Examine the behaviour of the solids under different conditions.	4
CO 5	Collaborate the properties of solids with mathematics used in describing the interaction of components.	5
CO 6	Mind-map the relation between the structure of solid and its properties.	6

Course Content:

Module 1	**Band Theory of Solids**	15 lectures
	• Nearly free electron model, DC and AC electrical conductivity of metals • Bloch theorem (with proof) • Kronig-Penney model • Motion of electron in 1 D, effective mass • Tight binding approximation, Zone schemes, • Distinction between metals, semiconductors and insulators	
Module 2	**Magnetic Properties of solids**	15 lectures
	• Theory of Diamagnetism using classical approach • Classical and quantum theory of paramagnetism, • Pauli paramagnetism • Hund's Rule and Magnetic properties of rare earth and iron group ions • Field splitting and quenching of orbital angular momentum • Ferromagnetism: Weiss theory, Curie point, Exchange integral • Ferromagnetic domains, Anisotropy energy, Bloch wall • Antiferromagnetism: Neel temperature • Ferrimagnetism: Curie temperature, susceptibility of ferrimagnets	
Module 3	**Electric Properties of solids**	15 lectures
	• Electric Polarization, Macroscopic and local electric field • Dielectric Constant and Polarizability, Classical Theory of Electronic Polarizability, • Debye Relaxation, Clausius – Mossotti relation, Ferroelectricity, • Structural phase transitions, ferroelectric crystals, • Dielectric behaviour in $BaTiO_3$, Piezoelectricity	
Module 4	**Superconductivity**	15 lectures
	• Properties of Superconductors: Meissner effect, Heat capacity, Energy gap, Isotope effect; • Type I and II superconductors; Superconductor as perfect diamagnet, • Thermodynamics of superconductivity; London equation and London penetration depth; • BCS theory: Electron-Electron interaction via Phonon, Cooper Pair, Bose-Einstein Condensate • High temperature superconductor e.g. $YBa_2Cu_3O_7$. Qualitative discussion of Josephson superconductor tunnelling	

References:

1. Introduction to solid states Physics - Charles, Kittel 7th Edition
2. Solid States Physics - S.O. Pillai (latest edition)
3. Elementary Solid State Physics by Ali Omar (Addison-Wesley Publishing Company)
4. Solid State Physics by M. A. Wahab (Narosa Publishing House)
5. Problem in Solid State Physics – S.O. Pillai

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Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code: 23ScPhyP313 **Course Name: Experimental Techniques in Physics**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:

- Atomic and Molecular Physics (23ScPhyP213)
- Solid state Physics at Graduate level
- Optics and Spectroscopy at Graduate level
- Electromagnetism at Graduate level

Course objective:

- To study the vacuum techniques, pumps and measuring devices
- To study the Structural and Morphological characterization techniques
- To study various Spectroscopic techniques

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Blooms Cognitive level
CO 1	Recall the concepts of pressure, kinetic gas theory	1
CO 2	Compare and Classify various vacuum systems and characterization techniques.	2
CO 3	Identify the suitable vacuum systems and working of characterization techniques.	3
CO 4	Examine the importance of the spectroscopic and microscopic techniques for material investigations.	4
CO 5	Understand the working of vacuum systems selection and characterization techniques.	5
CO 6	Design of appropriate vacuum techniques and characterization techniques for synthesis and analysis of nanostructures	6

Course Contents:

Module 1	Vacuum Physics	10 Lectures
	• Vacuum: concept, importance and applications • Kinetic theory of gasses, average velocity of gas and mean free path, impingement rate of molecules. • Vacuum ranges (Low to High vacuum and Ultra High Vacuum) • Pumping speed, Pump-down time	
Module 2	**Vacuum pumps and Pressure Gauges Spectroscopic Analysis**	**15 Lectures**
	Principle, Construction and working of Vacuum Pumps: • Rotary Pump, Diffusion Pump, Cryogenic Pump, Getter method and Pump • Titanium Sublimation Pump (TSP), Sputter Ion Pump (SIP) Principle, Construction and working of Vacuum Gauges: • Pirani Gauge, Penning Gauge, Hot cathode ionization Gauge (triode type), Bayard Alpert • Leak detection	
Module 3	**Structural and Morphological characterization techniques**	**15 Lectures**
	• Electron-matter interaction • **Electron spectroscopy**: Principle, Instrumentation and working 1. Scanning Electron Microscopy (SEM) and FESEM (comparison of both techniques) 2. Transmission Electron Spectroscopy (TEM) 3. Selected Area Electron Diffraction (SAED) • **Probe Microscopy**: Principle, Instrumentation and working 1. Scanning Tunnelling Microscopy (STM) 2. Atomic Force Microscopy (AFM) • **Magnetic characterization techniques**: Principle, Instrumentation and working 1. Vibrating Sample Magnetometer (VSM), Hysteresis loop and its analysis 2. Superconducting Quantum Interference Device (SQUID) Technique • Thermal Gravimetric Analysis (TGA)	
Module 4	**Spectroscopic Analysis**	**20 lectures**
	• Electron-matter interaction • Principle, instrumentation and working of Infra Red Spectroscopy (IR), Fourier Transform IR (FTIR) Ultraviolet – Visible (UV-VIS) Spectroscopy, Diffused Reflectance Spectroscopy (DRS), X-Ray Absorption Spectroscopy (XPS), Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR)	

References :

- Vacuum Physics and Techniques, T.A. Delchar, Chapman and Hall.
- Vacuum Technology, A. Roth (North Holland, Elsevier Science B.V. 1990)
- HandBook of Thin Film, Maissel and Glang
- Fundamentals of Molecular Spectroscopy, C. N. Banwell, E.M. McCash (McGraw Hill)
- Principles and Applications of Thermal Analysis, Paul Gabbott, Blackwell Publishing
- Molecular Structure And Spectroscopy, Aruldas, Prentice Hall India
- Elements of X Ray Diffraction, B. D. Cullity, S. R. Stock, Pearson Publication
- Nanotechnology: Principles and Practices, S. K. Kulkarni, Springer.

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Second Year of M.Sc. Physics
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Course Code: 23ScPhyP314 **Course Name: Lab Course in Computational Physics**

Teaching Scheme: PR: 4 Hours/Week **Credit: 02**

Examination Scheme: CIA: 25 Marks **End-Sem: 25 Marks**

Prerequisite Courses:

- Basic Algorithm in programming at graduate level
- Mathematical Methods in Physics (23ScPhyP111)
- Computational Physics at graduate level

Course Objectives:

- To apply the theory studied to practise.
- To learn implementation of the problems of Physics.

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Define different terms in python	1
CO 2	Understand loops to solve a problem	2
CO 3	Utilize Python library to solve problems related to classical mechanics and quantum mechanics	3
CO 4	Examine how Python functions and operators are used.	4
CO 5	Evaluate various problems of physics and simulate them.	5
CO 6	Develop a computer program to handle physics problems	6

Course Contents

	List of Experiments	
	1. Legendre polynomials using the standard recurrence relation functions. (Use forward recursion.) 2. Bessel functions of the first kind using the standard recurrence relation. (Use backward recursion) 3. Interpolation: Interpolate the value of a function at a point. Use Lagrange interpolation method. 4. Rotation of matrix: Rotate the elements of a n x n matrix in clockwise/ anticlockwise direction and display the matrices 5. Inverse of a matrix: Find the inverse of a "n x n" matrix and display both matrices. 6. Graphics: Write a program and display the Miller planes in the cubic lattice. Display the FCC, BCC and simple cubic lattice on the computer screen. 7. Find out the motion of a charged particle in a uniform magnetic field. The equation of motion of a particle with charge 'q' and mass 'm' in a uniform magnetic field B using the Modified Euler Method. 8. Circuit analysis using Kirchhoff's Laws. Write the relations for currents through various branches of a Wheatstone's bridge. Find the current using Gauss elimination method. 9. Write the differential equation for charging /discharging of a capacitor C through a resistance 'R'. Solve this equation using Euler method and display your result in tabular as well as graphical form. 10. Write a program to graphically display eigen functions and probability density curves for a particle in one dimensional rigid box. 11. Write the one – dimensional time independent Schrodinger's equation. Solve it using Runge – Kutta method for three different Harmonic Oscillator Potential. 12. Perform the Fourier analysis for (1) Full wave rectifier (2) Square wave Generator 13. Use the Modified Euler Method to solve the differential equation for the displacement z of a freely falling body as a function of time t, from a given height $z = z_0$ at $t = 0$.compare with known analytical results. Add a term due to buoyancy of air on the motion of a spherical body. 14. Consider the motion of a point mass under the influence of a	

harmonic restoring force F= - k x. The kinetic energy of the mass as m(dx/dt)² and potential energy is kx².Such that the total energy E=T+V is a constant throughout the motion. Solve the differential equation with the help of Runge-Kutta Method.

15. The energy levels for a quantum particle in a three-dimensional rectangular box of dimensions $\{L_1, L_2, \text{and } L_3\}$ are given by

$$E_{n_1 n_2 n_3} = \frac{\hbar^2 \pi^2}{2m}\left[\frac{n_1^2}{L_1^2} + \frac{n_2^2}{L_2^2} + \frac{n_3^2}{L_3^2}\right]$$

where the n's are integers greater than or equal to one. Write a program that will calculate, and list in order of increasing energy, the values of the n's for the 10 lowest different energy levels, given a box for which $L_2 = 2L_1$ and $L_3 = 4L_1$.

16. Trapezoidal and Simpson rule: Evaluate a given function f(x) using Trapezoidal and Simpson rule to correct up to given accuracy by successively halving the step size and compare the results.

a. $\int_0^{\pi/2} \cos x\,dx$ b. $\int_1^3 \frac{1}{x^2}\,dx$

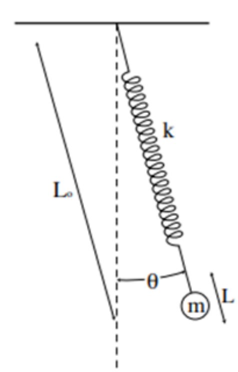
17. Determine the values of unknown variables from the given system of linear equations.

18. A ball is thrown upwards with initial velocity v_o = 5m/s and an initial height y_o = 3 m. Write a Python program to plot y(t), from t = 0 until the ball hits the ground.

19. A mass m is suspended from a spring of spring constant k. The mass is displaced from equilibrium by an initial distance y_o, and then released. Write a Python program to plot y(t) for some reasonable set of parameters.

20. Write a program that plots the motion of a mass oscillating at the end of a spring. The force on the mass should be given by F= − mg + kx.

21. A mass m is attached to a spring with spring constant k, which is attached to a support point as shown in the figure. The length of the resulting pendulum at any given time is the spring: rest length x_o plus the stretch (or compression) x, and the angle of the pendulum with respect to the vertical is θ. This is an example of a coupled oscillator system: the "pendulum" oscillations in θ interact with the "spring" oscillations in x, producing a complex mix of both. The differential equations for this system are given by



$$\ddot{L} = (L_0 + L)\,\dot{\theta}^2 - \frac{k}{m}L + g\cos\theta$$

$$\ddot{\theta} = -\frac{1}{L0+L}\left[g\sin\theta + 2\,\dot{L}\dot{\theta}\right]$$

Write a program that plots the motion of the mass for some initial $\theta \neq 0$.

22. The number of radioactive atoms that decay in a given time period is proportional to the number of atoms in the sample:

$$\frac{dN}{dt} = -\lambda N$$

Write a program that uses Euler's method to plot N(t). Also plot the exact solution, N(t) = No for comparison.

23. Write a program for a random-walk model of diffusion in a 2D environment.

Reference Books:

1. Introductory Methods of Numerical Analysis, S. S. Sastry, Prentice Hall of India Pvt. Ltd. (1990).
2. Computational Physics, R. C. Verma, P. K. Ahluwalia and K. C. Sharma, New Age International Publishers (1999).
3. Computational Physics Problem Solving with Python, Wiley-VCH
4. Scientific Computing in Python, Abhijit Kar, Techno world
5. Effective computation in Physics, Anthony Scopatz and Kathyn D. Huff, O'Reilly
6. An Introduction to Computational Physics, T. Pang, Cambridge Uni. Press. (1997).
7. Introduction to Computer Science Using Python: A Computational Problem-Solving Focus by Charles Dierbach
8. Python Distilled, David M. Beazley, Pearson

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Second Year of M.Sc.
(2023 Course under NEP 2020)

Course Code : 23ScPhyP321 Course Name: Physics of Thin Films

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**
Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:

- Courses related to material science at graduation level
- Atomic and Molecular Physics
- Materials Science

Course Objectives:

- To Study theories of thin film growth
- To Study different deposition techniques of thin films
- To study different applications of thin films

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Blooms Cognitive Level
CO 1	Recall the basic concepts from Atomic-Molecular Physics and solid state physics.	1
CO 2	Compare different Thin Film deposition techniques.	2
CO 3	Implement the basic knowledge of material science to understand various concepts of thin films.	3
CO 4	Correlate concepts of thin films with its applications.	4
CO 5	Review different properties of thin films.	5
CO 6	Adapt the knowledge to apply the different theories like Fuch-Sondheimer theory to different films.	6

Course Contents:

Module 1	Introduction & Mechanism of Thin Film Formation	15 lectures
	● Comparison of thin and thick films ● Theories of growth of thin films: Capillary model, Atomistic model ● Nucleation, Condensation ● Modes of thin film growth ● various stages of thin film growth ● Some Aspects of the Physical Structure of Films- Crystallite Size, Surface Roughness, Density of Thin Films ● Thin Film substrates	
Module 2	**Methods of Thin Film Deposition**	**15 lectures**
	● Physical vapour deposition ● Chemical vapour deposition ● Molecular beam Epitaxy ● Sputtering ● Spray Pyrolysis ● Electrochemical deposition ● Dip coating ● Spin coating ● Photolithography ● Electron- beam deposition, ● Pulsed laser ablation ● SILAR method	
Module 3	**Thickness measurement and Properties of Thin Films**	**15 lectures**
	Thickness measurement ● Optical methods ● Mechanical methods ● Quartz crystal microbalance ● Gravimetric method **Properties of Thin Films** ● Electrical properties ● Mechanical properties ● Optical properties	

Module 4	Applications of Thin Films	15 lectures
	• Resistors • Capacitors • Junction devices • Thin Film Transistor (TFT) • Thin Film storage devices • Thin Film sensors • Thin Film solar cells	

Reference Books:

1. Hand book of Thin Film Technology: Maissel and Glang, (Mc Graw Hill)
2. Thin Film Phenomena: K. L. Chopra, (Mc Graw Hill)
3. Material Science of Thin Films: M. Ohring, (Academic Press)
4. Thin Film Process: J. L. Vossen and Kern, (Academic Press)
5. Vacuum Technology (2nd revised edition), A. Roth, (North Holland)

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Second Year of M.Sc. Physics

(2023 Course under NEP 2020)

Course Code: 23ScPhyP352 **Course Name: Research Project-I**

Teaching Scheme: RP: 8 Hours/Week **Credit: 04**

Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:

- Basics of research Methodology
- Courses related to material science at graduation level

Course Objectives:

- Develop proficiency in research methodologies
- Identify and define research questions
- Collect and analyze data, Interpret and present research findings
- Develop problem-solving and critical thinking skills
- Reflect on and evaluate research outcomes

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Blooms Cognitive Level
CO 1	Recall key concepts, theories, and methodologies relevant to the research topic.	1
CO 2	Explain the significance of the research question and its relevance to the broader field of study. Interpret and summarize complex research findings and methodologies in a clear and comprehensible manner.	2
CO 3	Apply appropriate research methodologies and techniques to address specific research questions or hypotheses.	3
CO 4	Critically assess the validity, reliability, and limitations of research findings and methodologies	4
CO 5	Synthesize research findings into coherent and compelling arguments, hypotheses, or theories	5
CO 6	Design and develop original research proposals or projects, including research questions, methodologies, and data	6

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Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code : 23ScPhyP411 Course Name : Electrodynamics - II

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA : 50 Marks **End-Sem : 50 Marks**

Prerequisite Courses:

- Electrodynamics-I (23ScPhyP211)
- Mathematical Methods in Physics at Graduate level

Course Objective:

- To study and understand Maxwell's Equations in Electrodynamics
- To study the Electromagnetic waves, potentials and field radiations
- To introduce the Special Theory of relativity.

After Successful completion of this course students will able to:

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Recall the laws of electrodynamics	1
CO 2	Explain classical electrodynamics on the basis of course contents.	2
CO 3	Apply laws in Electrodynamics for real life situations	3
CO 4	Analyse the interrelation between Electricity and Magnetism	4
CO 5	Determine the appropriate method for analysis of Electrodynamics problems.	5
CO 6	Create a Theoretical aptitude for understanding the course content	6

Course Contents:

Module 1	Electrodynamics	15 lectures
	• Electromotive force and electromagnetic induction • Maxwell's equations • Conservation laws : Charge and Energy, Poynting's theorem, Momentum	
Module 2	**Electromagnetic waves**	**15 lectures**
	• Waves in one Dimension • Electromagnetic waves in vacuum • Electromagnetic waves in Matter (Absorption and Dispersion) • Guided Waves	
Module 3	**Potentials, Field and Radiation**	**15 lectures**
	• Scalar and Vector Potential • Gauge Transformation • Coulomb's and Lorentz's Gauge • Lienard-Wiechert potential • Dipole radiation • Radiation reactions	
Module 4	**Relativity**	**15 lectures**
	• Special theory of relativity: Einstein's postulate, Lorentz transformation, Space time structure • Proper time and proper velocity • Relativistic Mechanics: Energy and momentum • Magnetism as relativistic Phenomenon, • Field transform, Tensors	

References:

1. Introduction to Electrodynamics, (3rd Edition) by David J. Griffith, Prentice-Hall of India, New Delhi
2. Introduction to Electrodynamics, by A.Z. Capri and P.V. Panat, Narosa Publishing House
3. Classical Electricity and Magnetism, by Panofsky and Phillips, Addison Wesley
4. Foundations of Electromagnetic Theory by Reitz and Milford, World Student Series Edition
5. Classical Electrodynamics, by J.D. Jackson, 3rd Edition John Wiley
6. Electromagnetic Theory and Electrodynamics, by Satya Prakash, Kedar Nath and Co., Meerut
7. Electromagnetics by B.B. Laud, Wiley Eastern
8. Electrodynamics by Kumar Gupta and Singh

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Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code: 23ScPhyP412 **Course Name: Nuclear Physics**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA: 50 Marks **End-Sem : 50 Marks**

Prerequisite Courses:

- Atomic and molecular physics
- Introductory nuclear physics

Course Objectives:

- To impart knowledge about basic nuclear physics properties and nuclear models for understanding of related reaction dynamics.
- To impart the knowledge of fundamental particles, fundamental interactions with the concept of particle antiparticle

Course Outcomes:

On completion of the course, student will be able to

CO No	Course Outcomes (COs)	Bloom's Cognitive Level
CO 1	Locating and retrieving the data of nuclear particles	1
CO 2	Summarizing the models required to infer the structure of a nucleus	2
CO 3	Examining the scattering of elementary particles	3
CO 4	Linking quantum mechanics to the nuclear particles	4
CO 5	Reviewing the detectors and validating its importance	5
CO 6	Solving nuclear reactions and understanding nuclear models	6

Course Contents

Module 1	General Properties and Concepts of Nuclei	15 Lectures
	• Nuclear Mass & Binding Energy, Systematics of Nuclear Binding Energy, Measurement of Charge Radius- Electron Scattering expt. • Concept of Mass Spectrograph, Nuclear spin, Magnetic Dipole Moments & Electric Quadrupole Moments of Nuclei, Radioactivity • Alpha Decay: Velocity of Alpha Particles, Disintegration Energy, Range-Energy Relationship, Geiger- Nuttal Law • Beta Decay: Conditions for Spontaneous Emission of β- & β+ Particles, Selection Rules, Origin of Beta Spectrum- Neutrino Hypothesis • Gamma Decay: Decay Scheme of ^{137}Cs & ^{60}Co Nuclei, Internal Conversion, Internal Pair Creation. • Experiential Learning/ Problem Solving	
Module 2	**Radiation Detectors and Nuclear Models**	**15 Lectures**
	• Detectors: NaI (Tl) Scintillation Detector, Si(Li) and Ge(Li) Detectors, High Purity Germanium Detector, Bubble Chamber, Cloud Chamber, Spark Chamber • Nuclear Models: Shell Model- Square Well Potential, Harmonic Oscillator Potential, Spin-Orbit Coupling, Liquid drop model (Semi-empirical formula), Predictions of the Shell Model, Achievements & Failures of shell Model, Fermi Gas Model, Collective Model. • Experiential Learning/ Problem Solving	
Module 3	**Reaction Dynamics, Nuclear Reactors and Accelerators**	**15 Lecture**
	• Reaction Dynamics: Types of Nuclear Reactions, Conservation Laws in Nuclear Reactions, Q of Nuclear Reaction • Compound Nucleus Hypothesis, Reactors: Fission Chain • Reaction, Four Factor Formula, Multiplication Factor • General Properties and Concepts of Nuclear Reactors, Reactor Materials, Types of Reactors, Different Types of Reactors Developed in India • Accelerators: Van de Graff, Microtron, Electron & Proton Synchrotron, Pelletron, Cyclotron. • Experiential Learning/ Problem Solving	

Module 4	Nuclear Interactions and Particle Physics	15 Lectures
	• Nuclear Interactions: Low Energy Neutron-Proton Scattering, Scattering Length, • Spin Dependence of n-p Interaction, Proton-Proton and Neutron-Neutron Scattering at Low Energies. • Particle Physics: Classification of Elementary Particles, Mass Spectra and Decays of Elementary Particles- Leptons & Hadrons • Quantum Numbers (including Gellmann-Nishijima formula), Conservation Laws, Introduction to Quarks, Higgs Boson • C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics. • Experiential Learning/ Problem Solving	

Reference Books:

1) Introductory Nuclear Physics , K.S.Krane, 1988, Wiley, India.
2) Concepts of Nuclear Physics , B.L.Cohen , Tata McGraw Hill.
3) Nuclear Physics, I.Kaplan, 1989, 2nd Edition, Narosa, New Delhi.
4) Atomic and Nuclear Physics, S.N.Ghoshal, S.Chand.
5) Nuclei and Particles, E.Segre,
6) Nuclear Physics, D.C.Tayal, , Himalaya Publishing House.
8) Radiation Detection and Measurement , G.F.Knoll, 3rd edition, Wiley India.
9) Nuclear Radiation Detectors, S.S.Kapoor and V.S.Ramamurthy , Wiley Eastern Limited.

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Second Year of M.Sc.
(2023 Course under NEP 2020)

Course Code: 23ScPhyP413 Course Name: Physics of Nanomaterials

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**
Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:
- Solid state Physics (23ScPhyP212)
- Material science (23ScPhyP221)

Course Objectives:
- To study Basics of nanomaterials.
- To study methods for synthesis of nanomaterials.
- To study different applications of nanomaterials.

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Define the different types of nanomaterials.	1
CO 2	Compare 0D, 1D, 2D and 3D nanomaterials.	2
CO 3	Determine the methods required to synthesize different types of nanomaterials.	3
CO 4	Explain the principles of various characterization techniques.	4
CO 5	Predict the properties of different sized nanomaterials.	5
CO 6	Write the applications of nanomaterials.	6

Course Contents

Module 1	Introduction to nanotechnology	10 lectures
	• Effect of reduction of dimension, Quantum size effect • Density of states for zero, One, two- and three-dimensional box • Introduction to nano-sized materials. Bottom up and top down approaches. • Types of nanomaterials • Properties of Nanomaterials: Mechanical, Thermal, Electrical, Optical & Magnetic Properties	
Module 2	**Physical and Chemical methods for synthesis of Nanomaterials**	**20 lectures**
	• Surface energy, Sintering, Nucleation, Growth Mechanism of nanoparticles, Ostwald ripening and Agglomeration • Electrostatic and Steric Stabilization • Growth of nuclei controlled by diffusion and surface processes. • High energy ball milling method • Chemical Vapor Deposition • Physical Vapor Deposition • Sputter deposition, • Wet chemical method (colloidal route) • Electrochemical deposition, • Langmuir-Blodgett method • Sol-gel method • Hydrothermal method	
Module 3	**Characterization- Interpretation and Analysis**	**15 lectures**
	Interpretation of • Scanning Electron Microscopy (SEM) • Transmission Electron Microscopy (TEM) • Vibrational Sample Microscopy (VSM) • Scanning Tunneling Electron Microscopy (STEM) • Atomic Force Microscopy (AFM) • X-Ray Diffraction (XRD) • UV-Vis spectroscopy • Raman spectroscopy • X Ray Photoelectron Spectroscopy (XPS) • Fourier Transform Infrared (FTIR) spectroscopy	

Unit 4	Applications of Nanomaterials and Special Nanomaterials	15 lectures
	● **Special Nanomaterials:** Fullerene, Graphene, carbon nanotubes, Porous silicon, Aerogels, Core shell nanoparticles and Quantum dots ● **Applications:** Nanoelectronics, Energy, Quantum dot and Quantum well devices, Nanosensors, Medical, Biological, Automobiles, Space, Defence, Environmental remediation, Applications of nanomaterials in detection of pathogens in food.	

Reference Books :

1) Nanotechnology: Principles & Practices. Sulbha K. Kulkarni, Capital Pub.

2) Nanostructures & Nanomaterials Synthesis, Properties & Applications. Guohong Cao, Imperials college Press London.

3) Introduction to Nanotechnology. C.P. Poole Jr. & F. J.Owens, Wiley Student Ed.

4) Nano: The Essentials. T. Pradeep, McGraw Hill Education.

5) Nanomaterials: Synthesis, Properties & Applications. Edited by A.S. Edelstein & R.C. Commorata. Institute of Physics Publishing, Bristol & Philadelphia

6) Introductory Nanoscience: Physical and Chemical Concepts. Masaru Kuno (Garland Science)

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Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code: 23ScPhyP421 **Course Name: Advanced Computational Physics**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA: 50 Marks **End-Sem : 50 Marks**

Prerequisite Courses:
- Mathematical Methods in Physics (23ScPhyP111)
- Lab Course on Computational Physics (23ScPhyP314)

Course Objectives:
- Learning basic methods, tools, and techniques of computational physics.
- Developing practical computational problem-solving skills.

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Blooms Cognitive level
CO 1	Relate different mathematical methods to solve problems in physics .	1
CO 2	Understand the concepts/ equations involved in various areas of Physics like Electrodynamics, Quantum Mechanics, Classical Mechanics, Solid State Physics etc.	2
CO 3	Apply the methods to various situations and determine solutions of the problems.	3
CO 4	Analyzing different numerical integration methods	4
CO 5	Evaluate solutions of differential equations	5
CO 6	Compile program for any physics problem	6

Course Contents:

Module 1	Interpolation and Curve Fitting	15 lectures
	● Interpolation and Curve Fitting ● Finite difference operators, Differences of a polynomial ● Interpolation with equal intervals - Newton's interpolation formula, Gauss's interpolation formulae, Bessel's formula, Stirling's formula, Everett's formula, ● Interpolation with unequal intervals – Lagrange's interpolation formula, Newton's divided difference formula. ● Basic ideas of Spline interpolation. Curve fitting –method of group averages, least squares method.	
Module 2	**Numerical differentiation and Integration**	**15 lectures**
	● Numerical differentiation - derivatives using difference formulae, ● Differentiation using Lagrange's polynomial and divided difference polynomial. ● Numerical integration : Newton – Cotes quadrature formula ● Trapezoidal rule, Simpson's rule, Romberg's method, Gaussian quadrature method ● Numerical double integration. ● Elementary ideas of Monte Carlo evaluation of integrals.	
Module 3	**Solution of Algebraic and Transcendental Equations**	**15 lectures**
	● Solution of algebraic and transcendental equations: Bisection method, Regula-Falsi method ● Iteration method, Newton-Raphson method, Secant method, Convergence of solutions ● Solution of system of linear equations: Method of determinants, Matrix inversion method, Gauss elimination method ● Gauss – Jordan method, LU factorization, Jacobi method, Gauss – Seidel method.	
Module 4	**Solution of Differential Equations**	**15 lectures**
	● Solution of ordinary differential equations: Initial value problems -Taylor's series method, Picard's method. ● Euler's method, Modified Euler's method, Runge Kutta method, ● Boundary value problems – Finite difference method ● Elementary ideas of solution of partial differential equations – Solution of Laplace equation using Finite difference approximation. ● Numerical error analysis	

References:

1. Computational Physics An Introduction - Vesely
2. Introductory methods of numerical analysis – S S Sastry
3. Numerical methods for Mathematics, Science and Engineering – John H Mathews
4. Introductory Computational Physics – Klein and Godunov
5. A first Course in Computational Physics - Paul and Javier
6. An Introduction to Computational Physics – Tao Pang

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Second Year of M.Sc. Physics
(2023 Course under NEP 2020)

Course Code: 23ScPhyP422 **Course Name: Energy Studies**

Teaching Scheme: TH: 4 Hours/Week **Credit: 04**

Examination Scheme: CIA: 50 Marks **End-Sem: 50 Marks**

Prerequisite Courses:

- Material Science (23ScPhyP221)
- Electromagnetism course at Undergraduate level

Course Objectives:

- Introduce various conventional and non-conventional energy sources and their global significance.
- Explore hydrogen and geothermal energy technologies and their applications.
- Understand electrochemical energy storage systems including batteries, supercapacitors, and fuel cells.
- Analyze battery design, thermal management, and recycling strategies for electric vehicles.

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Bloom's Cognitive level
CO 1	Identify and classify different energy sources and their impact on global energy demand.	1
CO 2	Explain the principles and technologies behind hydrogen and geothermal energy systems.	2
CO 3	Apply knowledge of electrochemical systems to evaluate battery and supercapacitor performance.	3
CO 4	Analyze the design and thermal management strategies for battery systems in electric vehicles.	4
CO 5	Evaluate the sustainability and efficiency of energy storage systems in various applications.	5
CO 6	Design integrated energy storage solutions using hybrid systems for future energy applications.	6

Course Contents

Module 1	**Introduction to energy sources and storage systems**	15 lectures
	● Various types of energy sources: Energy sources and overall energy demand, ● Availability of energy sources, Energy consumption in various sectors and its changing pattern, projected energy demands. ● Energy sources: Coal, Oil, Natural gas, Nuclear power, Hydro-electricity, Solar and other renewable sources, ● Depletion of energy sources and impact of exponential rise in energy consumption on economics of India and on international relations. ● Scope of energy storage, Needs and opportunities in energy storage, Energy storage in the power and transportation sectors. ● Importance of energy storage systems in electric vehicles, Current electric vehicle market.	
Module 2	**Hydrogen and Geothermal Energy**	15 lectures
	● Hydrogen Fuel: Importance of Hydrogen as a future fuel, Sources of Hydrogen, Fuel of vehicles. ● Hydrogen production: Production of Hydrogen by various methods, Direct electrolysis of water, Direct thermal decomposition of water, Biological and biochemical methods of hydrogen production. ● Hydrogen storage: Gaseous, Cryogenic and Metal hydride. Utilization of hydrogen: Fuel cell– Principle, construction and applications. ● Geothermal energy: Geothermal energy as a renewable source of energy, Origin of geothermal resources, Types of geothermal resources, ● Basics of a geothermal electric power plant, Geothermal heat pump, Heating and cooling using a heat pump, Benefits of geothermal heat pumps, ● Global status of power generation from geothermal resources, Identification of geothermal resources in India	
Module 3	**Electrochemical energy storage systems**	15 lectures

	● (a) Batteries: Working principle of battery, Primary and secondary (flow) batteries, Battery performance evaluation methods, Major battery chemistries and their voltages- Li-ion battery, Metal hydride battery and lead-acid battery. ● (b) Supercapacitors: Working principle of supercapacitor, Types of supercapacitors, Cycling and performance characteristics, Difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors ● (c) Fuel cell: Operational principle of a fuel cell, Types of fuel cells, Hybrid fuel cell-battery systems, Hybrid fuel cell-supercapacitor systems.	
Module 4	**Battery design for vehicles**	15 lectures
	● Mechanical Design and Packaging of Battery Packs for Electric Vehicles, ● Advanced Battery-Assisted Quick Charger for Electric Vehicles, Charging Optimization Methods for Lithium-Ion Batteries, ● Thermal run-away for battery systems, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries from Electric Vehicles.	

References:

1. Non-Conventional Energy Sources: G. D. Rai, Khanna Publishers (2011)
2. Renewable Energy Sources and Emerging Technologies: D. P. Kothari, K. C. Singal, and Rakesh Ranjan, Prentice Hall of India Pvt. Ltd. (2008)
3. Renewable Energy Sources and Conversion Technology: N. K. Bansal, M. Kleeman, and S. N. Srinivas, Tata Energy Research Institute (TERI), New Delhi (1996)
4. Lithium-Ion Batteries: Basics and Applications edited by Reiner Korthauer, Springer-Verlag GmbH Germany (2018) ;
5. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience,
6. Energy Storage - Technologies and Applications by Ahmed Faheem Zobaa, InTech.
7. Handbook of battery materials by C. Daniel, J. O. Besenhard, Wiley VCH .
8. Electric & Hybrid Vehicles by G. Pistoia, Elsevier B. V.
9. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub.
10. Energy Storage: Fundamentals, Materials and Applications, by Huggins R. A., Springer

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Second Year of M.Sc. Physics

(2023 Course under NEP 2020)

Course Code: 23ScPhyP452 Course Name: Research Project - II

Teaching Scheme: RP: 12 Hours/Week **Credit: 06**

Examination Scheme: CIA : 75 Marks **End-Sem : 75 Marks**

Prerequisite Courses:

- Basics of research Methodology
- Courses related to material science at graduation level

Course Objectives:

- Develop proficiency in research methodologies
- Identify and define research questions
- Collect and analyze data, Interpret and present research findings
- Develop problem-solving and critical thinking skills
- Reflect on and evaluate research outcomes

Course Outcomes:

On completion of the course, student will be able to–

CO No	Course Outcomes (COs)	Blooms Cognitive Level
CO 1	Recall key concepts, theories, and methodologies relevant to the research topic.	1
CO 2	Explain the significance of the research question and its relevance to the broader field of study. Interpret and summarize complex research findings and methodologies in a clear and comprehensible manner.	2
CO 3	Apply appropriate research methodologies and techniques to address specific research questions or hypotheses.	3
CO 4	Critically assess the validity, reliability, and limitations of research findings and methodologies	4
CO 5	Synthesize research findings into coherent and compelling arguments, hypotheses, or theories	5
CO 6	Design and develop original research proposals or projects, including research questions, methodologies, and data collection instruments.	6