



BHARATHIDASAN UNIVERSITY, TIRUCHIRAPPALLI 620 024.

M.Sc. Physics

CHOICE BASED CREDIT SYSTEM -

LEARNING OUTCOMES BASED CURRICULUM FRAMEWORK (CBCS - LOCF)

(Applicable to the candidates admitted from the academic year 2026 - 2027 onwards)

Sem.	Course	Course Title	Ins. Hrs.	Credit	Exam Hrs.	Marks		Total
						Int.	Ext.	
I	Core Course - 1 (CC - 1)	Mathematical Physics	6	4	3	30	70	100
	Core Course - 2 (CC - 2)	Classical and Relativistic Mechanics	6	4	3	30	70	100
	Core Practical - 1 (CP - 1)	Python Programming for Computational Physics	6	4	3	40	60	100
	Discipline Centric Elective Course - 1 (DCEC - 1)	Any one from the list	5	4	3	30	70	100
	Generic Elective Course - 1 (GEC - 1)	Any one from the list	4	3	3	30	70	100
	Skill Enhancement Course - 1 (SEC - 1)	Computational Physics Using Python	3	2	3	30	70	100
	Value Added Course - 1 (VAC - 1)*	Ethical Practices in Research	-	2*		30	70	100*
	Total		30	21	-	-	-	600
II	Core Course - 3 (CC - 3)	Quantum Mechanics	5	4	3	30	70	100
	Core Course - 4 (CC - 4)	Thermal and Statistical Physics	5	4	3	30	70	100
	Core Practical - 2 (CP - 2)	General Physics and Electronics – I	6	4	3	40	60	100
	Discipline Centric Elective Course - 2 (DCEC - 2)	Any one from the list	5	4	3	30	70	100
	Generic Elective Course - 2 (GEC - 2)	Any one from the list	4	3	3	30	70	100
	Skill Enhancement Course - 2 (SEC - 2)	Machine Learning Techniques in Physics	3	2		30	70	100
	Non-Major Elective Course - 1 (NMEC - 1)	One Course from Outside Department	2	2	3	30	70	100
	Total		30	23	-	-	-	700
Summer Internship / Industrial Activity during the Summer Vacation after 1 st Year								

III	Core Course - 5 (CC - 5)	Electromagnetic Theory	6	4	3	30	70	100
	Core Course - 6 (CC - 6)	Condensed Matter Physics	6	4	3	30	70	100
	Core Practical - 3 (CP - 3)	General Physics and Electronics – II	6	4	2	40	60	100
	Discipline Centric Elective Course - 3 (DCEC - 3)	Any one from the list	5	4	2	30	70	100
	Generic Elective Course - 3 (GEC - 3)	Any one from the list	5	3	3	30	70	100
	Non-Major Elective Course - 2 (NMEC - 2)	One Course from Outside Department	2	2	3	30	70	100
	Internship / Industrial Activity @			2		20	80	100
	Total		30	23	-	-	-	700
IV	Core Course - 7 (CC - 7)	Atomic and Molecular Spectroscopy	6	4	3	30	70	100
	Core Course - 8 (CC - 8)	Classical and Quantum Optics	6	4	3	30	70	100
	Core Course - 9 (CC - 9)	Nuclear and Particle Physics	6	4	3	30	70	100
	Discipline Centric Elective Course - 4 (DCEC - 4)	Any one from the list	4	4	2	30	70	100
	Entrepreneurship / Industry Based Course @	Solar Energy Technologies and Energy Storage Systems	3	3	3	30	70	100
	Project Work @		5	5	-	20	80	100
	Value Added Course - 2 (VAC - 2)*	Intellectual Property Rights in Science and Technology	-	2*	3	30	70	100*
	Total		30	24	-	-	-	600
Grand Total				91				2600

LIST OF DISCIPLINE CENTRIC ELECTIVE COURSE (DCEC)

<i>Discipline Centric Elective Course - 1 (DCEC - 1)</i>	
1.	Advanced Analog and Digital Electronics
2.	Modern Electronic Instrumentation and Sensors
<i>Discipline Centric Elective Course - 2 (DCEC - 2)</i>	
1.	Microprocessor Architectures and Microcontroller Systems
2.	Embedded Systems and Artificial Intelligence
<i>Discipline Centric Elective Course - 3 (DCEC - 3)</i>	
1.	Quantum Computation and Information Processing
2.	Advanced Quantum Mechanics and Applications
<i>Discipline Centric Elective Course - 4 (DCEC - 4)</i>	
1.	Physics of Nanomaterials and Nanotechnology
2.	Crystal Growth and Thin Film Technology

LIST OF NON-MAJOR ELECTIVE COURSE (for other Department Students only)

NON-MAJOR ELECTIVE COURSE – 1 (NME-1)	
1	1. Physics in Everyday Life (or) 2. Energy for Sustainable Living (or) 3. Energy, Environment, and Society (or) 4. Renewable Energy in Daily Life
NON-MAJOR ELECTIVE COURSE – 2 (NME-2)	
2	1. Mobile Phones from Physics Perspective (or) 2. Basics of Communication Technology (or) 3. Introduction to Digital and Wireless Technologies (or) 4. Introduction to Space and Astronomy

LIST OF GENERIC ELECTIVE COURSE (GEC)

<i>Generic Elective Course - 1 (GEC - 1)</i>	
1.	Fundamentals of Biophysics
2.	Medical Physics
3.	Additive Manufacturing
<i>Generic Elective Course - 2 (GEC - 2)</i>	
1.	Clean Energy Technology
2.	Advanced Materials
3.	Polymer and Bio Materials
<i>Generic Elective Course - 3 (GEC - 3)</i>	
1.	Nanofabrication and Characterization Techniques
2.	Plasma Physics and Applications
3.	Materials Synthesis and Characterization

Summary of Curriculum Structure of PG Programmes

Sl. No.	Types of the Course	No. of Courses	Credits for each Course	Total Credits	Marks
1.	Core Course	9	4	36	900
2.	Core Practical	3	4	12	300
3.	Discipline Centric Elective Course	4	4	16	400
4.	Generic Elective Course	3	3	9	300
5.	Skill Enhancement Course	2	2	4	200
6.	Non-Major Elective Courses	2	2	4	200
7.	Internship / Industrial Activity @	1	2	2	100
8.	Entrepreneurship / Industry Based Course @	1	3	3	100
9.	Project @	1	5	5	100
Total		26	-	91	2600
Value Added Courses *		2*	2	4*	200

*	The value added courses credit will not be included in the total CGPA. These courses are extra-credit courses. Instruction hours for these courses is 30 hours								
@	Summer Internship will be carried out during the summer vacation after the First year. Viva Voce will be conducted by the college and Marks shall be sent to the University and the same will be included in the 3rd semester Mark Statement. Summer Internship / Industrial Activity & Project Scheme of Evaluation: <table border="1"> <tr> <td>Description</td><td>Marks</td></tr> <tr> <td>Report</td><td>80</td></tr> <tr> <td>Viva</td><td>20</td></tr> <tr> <td>Total</td><td>100</td></tr> </table>	Description	Marks	Report	80	Viva	20	Total	100
Description	Marks								
Report	80								
Viva	20								
Total	100								

Program Outcome

PO 1 Disciplinary Knowledge: Broad and in-depth knowledge of advanced scientific concepts, principles, and methodologies within the chosen domain. Ability to critically explain, integrate, and apply scientific knowledge to theoretical and practical problems. Opportunities to earn additional credits through specialized and interdisciplinary courses further enhance expertise and broaden disciplinary understanding.

PO 2 Critical Thinking: Field visits, academic interactions, and experiential learning activities will help students develop critical observation, interpretation, and analytical skills. Ability to evaluate and interpret scientific data, formulate hypotheses, and draw logical conclusions. Encourages independent thinking and the ability to assess scientific problems from multiple perspectives.

- PO 3 Analytical Reasoning:** Through classroom discussions, scientific literature reviews, and interactive learning environments, students will strengthen their analytical reasoning abilities. Ability to critically evaluate scientific texts, identify gaps in existing knowledge, formulate research questions, and synthesize new ideas and concepts. Promotes evidence-based reasoning and logical interpretation of scientific information.
- PO 4 Scientific Reasoning:** Strong foundation in scientific methods, experimental design, and data interpretation through laboratory-based courses. Enhances practical knowledge of scientific instrumentation, calibration procedures, laboratory safety, and appropriate research techniques. Ability to conduct scientifically sound experiments and interpret results accurately.
- PO 5 Self-Directed Learning:** Encourages independent and self-directed learning through assignments, field reports, project work, and literature-based studies. Ability to organize, analyze, and present scientific findings in professional formats relevant to academic and industrial settings. Fosters responsibility, time management, and continuous self-improvement in learning.
- PO 6 Reflective Thinking:** Laboratory-intensive core courses will expose students to a broad range of research methodologies and experimental techniques. Ability to reflect on learning experiences, evaluate the effectiveness of scientific approaches, and understand the broader applications of scientific techniques within the discipline.
- PO 7 Problem-Solving Skills:** Ability to develop and apply scientific principles, quantitative reasoning, and mathematical concepts to solve discipline-specific problems. Ability to analyze experimental data, interpret scientific observations, and derive meaningful conclusions. Prepares students to address real-world scientific and societal challenges effectively.
- PO 8 Research-Related Skills:** Internships, dissertation work, and research-oriented projects provide opportunities to design, develop, and execute independent research studies. Students gain hands-on experience in research methodology, experimental techniques, data analysis, scientific writing, and ethical research practices. These experiences strengthen laboratory competence and prepare students for advanced research and professional careers.
- PO 9 Lifelong Learning:** Cultivates a mindset of continuous learning and professional adaptability. Ability to identify gaps in knowledge and skills, adapt to emerging technologies and scientific advancements, and pursue self-directed learning throughout their careers. Encourages lifelong learning that supports academic growth, employability, and professional excellence.

PO 10 Leadership Readiness: Ability to take initiative, work collaboratively, and manage academic and research responsibilities effectively. Through seminars, group projects, internships, and research activities, students develop decision-making, problem-solving, organizational, and interpersonal skills. Ability to lead scientific teams, communicate effectively in professional environments, and contribute responsibly to academic, industrial, and societal development.

Program Specific Outcomes (PSOs)

PSO 1. Mathematical and Classical Dynamics Proficiency

Apply advanced mathematical techniques, including vector calculus, complex analysis, tensors, and group theory, alongside classical mechanics frameworks such as Lagrangian, Hamiltonian, and relativistic mechanics, to formulate and solve complex physical problems.

PSO 2. Quantum and Statistical Modeling

Formulate and analyze quantum mechanical models and operator formalisms, and apply statistical ensembles (microcanonical, canonical, and grand canonical) to understand the microscopic and macroscopic behavior of matter, including phase transitions and quantum degenerate gases.

PSO 3. Electromagnetic and Optical Systems

Evaluate and apply Maxwell's equations and the principles of classical and quantum optics to study electromagnetic wave propagation, waveguides, radiation, photon statistics, and quantum entanglement.

PSO 4. Condensed Matter Physics Expertise

Analyze crystal structures, lattice vibrations, and electron theories to predict and explain the electrical, thermal, magnetic, and dielectric properties of solids, including the mechanisms underlying superconductivity.

PSO 5. Atomic, Molecular, Nuclear, and Particle Physics

Interpret atomic and molecular spectra using quantum models, coupling schemes, and selection rules, while explaining nuclear properties, decay mechanisms, reaction kinematics, and the classification of elementary particles within the Standard Model.

PSO 6. Computational Physics and Machine Learning Application

Design and simulate complex physical systems using Python programming, numerical methods (including Monte Carlo techniques and Runge-Kutta methods), and machine learning algorithms such as regression, neural networks, and deep learning.

PSO 7. Advanced Electronics and Embedded Systems Design

Design and analyze analog and digital circuits, operational amplifiers, microprocessors (8085), microcontrollers (8051, ARM, ESP32), and edge AI systems for instrumentation, sensing, and control applications.

PSO 8. Advanced Experimental and Instrumentation Skills

Execute precision measurements and sophisticated experiments in mechanics, optics, thermodynamics, and solid-state physics using advanced instruments (such as interferometers, spectrometers, and four-probe setups), and analyze experimental data using rigorous statistical methods and error propagation techniques.

PSO 9. Nanotechnology and Materials Science Specialization

Apply synthesis, fabrication, and characterization techniques (including SEM, TEM, XRD, PVD, and CVD) to analyze and design nanomaterials, quantum dots, thin films, and 2D materials for optical, electronic, and spintronic applications.

PSO 10. Interdisciplinary and Applied Physics Integration

Apply core physical principles to emerging and interdisciplinary domains, demonstrating the ability to analyze and solve problems in fields such as biophysics, medical physics, clean energy technologies, plasma physics, and quantum computation.

Year: I

CORE COURSE 1

Semester: I

Code:

**MATHEMATICAL PHYSICS
(Theory)**

Credits: 4

Prerequisite: UG level Physics with Allied Mathematics

Objectives:

1. Recall the fundamental concepts of vector calculus, complex analysis, linear algebra, tensors, and differential equations.
2. Explain the principles of vector integral theorems, Cauchy-Riemann conditions, matrix diagonalization, and Sturm-Liouville theory.
3. Apply residue theorem, Fourier/Laplace transforms, and special functions to solve physical problems.
4. Analyze physical systems using vector calculus, complex integration, eigenvalue problems, and Green's functions.
5. Evaluate the suitability of mathematical models for electromagnetism, quantum mechanics, and wave phenomena.
6. Formulate and solve mathematical models using series solutions, Green's functions, and integral transforms for physical systems.

Unit I: Vector Calculus (14 Hrs – 12 L + 2 T)

Vector and scalar fields - Gradient, divergence, curl and Laplacian - Vector identities - Line, surface and volume integrals - Gauss theorem, Green's theorem and Stoke's theorem with applications - Orthogonal curvilinear coordinates - Gradient, divergence, curl and Laplacian in cylindrical and spherical polar coordinates. **Tutorials:** Problems on vector identities and integral theorems.

Unit II: Complex Analysis (12 Hrs – 12 L + 2 T)

Analytic and harmonic functions - Differentiability and Cauchy-Riemann conditions - Complex integration - Cauchy's integral theorem and integral formula - Residues and singularities - Taylor's and Laurent's series - Zeros and poles - Residue theorem and evaluation of definite integrals - Conformal transformations and mapping applications - Gamma function: definition, properties, relation to Beta function - Applications to definite integrals. **Tutorials:** Problems on Cauchy's theorem, residue theorem, and definite integrals.

Unit III: Matrices and Tensors (15 Hrs – 13 L + 2 T)

Symmetric, anti-symmetric, orthogonal, Hermitian, skew-Hermitian and unitary matrices - Trace of a matrix - Transformation of matrices - Characteristic equation - Eigenvalues and eigenvectors - Cayley-Hamilton theorem - Diagonalization - Definition of tensors - Contravariant, covariant and mixed tensors - Rank of a tensor - Symmetric and antisymmetric tensors - Contraction of tensor - Metric tensor - Raising and lowering indices - Transformation laws. **Tutorials:** Problems on matrix diagonalization, Cayley-Hamilton theorem, and tensor operations.

Unit IV: Integral Transforms (14 Hrs: 12 L + 2 T)

Fourier transform and its inverse - Transform of Gaussian function and Dirac delta function - Fourier transform of derivatives - Cosine and sine transforms - Convolution theorem - Laplace transforms and its inverse - Transforms of derivatives and integrals - Differentiation and integration of transforms - Applications to ordinary differential equations - Introduction to Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) concepts. **Tutorials:** Problems on Fourier and Laplace transforms.

Unit V: Ordinary Differential Equations and Green's Functions (15 Hrs: 13 L + 2 T)

Methods of finding solutions of second order ordinary differential equations - Sturm-Liouville theory - Series solution using Frobenius method - Legendre polynomials: generating function, Rodrigue formula, orthogonality properties, recurrence relations - Hermite polynomials: generating function, orthogonality properties, recurrence relations - Dirac delta function - One dimensional Green's function - Green's function in 2D and 3D (concepts only). **Tutorials:** Problems on series solutions, Legendre and Hermite polynomials, and Green's functions.

Unit VI: Current Contours (Self-Directed Learning Activities for Continuous Internal Assessments Only)

Definition of contour in complex plane - Simple closed contour - Orientation - Contour integrals: definition and basic properties - Cauchy-Goursat theorem - Cauchy's integral formula - Numerical evaluation of contour integrals using computational tools - Applications to real definite integrals - Physical applications: Feynman propagators, Kramers-Kronig relations - Group Theory and Linear Vector Space.

Primary Text Books for Study

1. B. D. Gupta, *Mathematical Physics* (4th edition), Vikas Publishing House, New Delhi, 2009
2. H. K. Dass and Dr. Rama Verma, *Mathematical Physics* (7th edition), S. Chand & Company Pvt. Ltd., New Delhi, 2014.
3. P. K. Chattopadhyay, *Mathematical Physics* (2nd edition), New Age International, New Delhi, 2013.

Reference Books

1. A. W. Joshi, *Matrices and Tensors in Physics* (4th edition), New Age International Pvt. Ltd., India, 2017.
2. Mary L. Boas, *Mathematical Methods in the Physical Sciences* (3rd edition), John Wiley & Sons, 2005
3. G. B. Arfken, H. J. Weber, and F. E. Harris, *Mathematical Methods for Physicists – A Comprehensive Guide* (7th edition), Academic Press, 2013.
4. E. Butkov, *Mathematical Physics*, Addison Wesley, London, 1973.
5. L. A. Pipes and L. R. Harvill, *Applied Mathematics for Engineers and Physicists*, McGraw Hill, Singapore, 1967. – Units IV, V (applications of PDEs and transforms).

Online/Web Resources

1. NPTEL – Selected Topics in Mathematical Physics (Prof. V. Balakrishnan, IIT Madras) - Complete course - <https://nptel.ac.in/courses/115106086>

2. NPTEL – Complex Analysis (Prof. P. A. S. Sree Krishna, IIT Guwahati) - <https://nptel.ac.in/courses/111103070>
3. MIT OCW – Mathematical Methods for Physicists - <https://ocw.mit.edu/courses/18-085-computational-science-and-engineering-i-fall-2008/>
4. Wolfram Alpha – Complex integrals, matrix diagonalization - <https://www.wolframalpha.com>
5. SageMath (Open source) – Practice transforms and PDEs computationally - <https://www.sagemath.org>
6. YouTube: Dr. Trefor Bazett (visual explanations)
7. YouTube: Faculty of Khan (tensors and group theory)

Course Outcomes

On the successful completion of the course, students will be able to:

1. Recall and define the fundamental concepts of vector calculus, complex analysis, matrices, tensors, integral transforms, and differential equations.
2. Explain the principles of vector integral theorems, Cauchy-Riemann conditions, matrix diagonalization, and Sturm-Liouville theory.
3. Apply residue theorem, Fourier/Laplace transforms, and special functions to solve physical problems.
4. Analyze physical systems using vector calculus, complex integration, eigenvalue problems, and Green's functions.
5. Evaluate the suitability of mathematical models for electromagnetism, quantum mechanics, and wave phenomena.
6. Formulate and solve mathematical models using series solutions, Green's functions, and integral transforms for physical systems.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	–	2	–	2	–	2	–
CO2	3	3	2	–	2	2	2	–	2	–
CO3	3	3	3	2	2	2	3	2	2	–
CO4	3	3	3	2	2	2	3	2	2	–
CO5	3	3	3	2	3	3	3	2	3	2
CO6	3	3	3	2	3	3	3	3	3	2

3 = High, **2** = Moderate, **1** = Low

Year: I

CORE COURSE 2

Semester: I

Code:

**CLASSICAL AND RELATIVISTIC
MECHANICS
(Theory)**

Credits: 4

Prerequisite: UG Physics

Objectives

- Recall the foundational principles of Newtonian, Lagrangian, Hamiltonian, and relativistic mechanics governing discrete dynamical systems.
- Explain the physical significance of symmetries, constraints, conservation laws, canonical variables, and relativistic invariance.
- Apply Lagrangian, Hamiltonian, and Hamilton-Jacobi formulations to solve problems involving central forces, rigid bodies, and oscillatory systems.
- Analyze mechanical systems using phase-space trajectories, stability analysis, Poisson brackets, and canonical transformations.
- Evaluate the applicability and limitations of different theoretical frameworks in modeling physical systems.
- Formulate mathematical models for mechanical systems using symmetry principles and conservation laws.

Unit I: Lagrangian Formalism (14 Hours: 12 L + 2 T)

Review of Newtonian mechanics and its limitations - Constraints and generalized coordinates - D'Alembert's principle - Lagrange's equations of motion - Velocity-dependent potentials and dissipation functions - Calculus of variations - Euler-Lagrange equation derivation - Hamilton's variational principle - Symmetries and conservation laws - Cyclic coordinates - Noether's theorem (introduction).

Tutorials: Problems on Lagrange's equations for constrained systems.

Unit II: Central Force Motion and Rigid Body Dynamics (15 Hours: 13 L + 2 T)

Reduction to a one-body problem - Effective potential - Kepler's problem: orbits and Kepler's laws - Rutherford scattering in lab and center-of-mass frames - Kinematics of rigid body motion - Orthogonal transformations - Euler angles - Inertia tensor - Principal axes and moments of inertia - Euler's equations of rigid body motion - Torque-free motion - Heavy symmetric top (qualitative). **Tutorials:** Problems on central force motion, Kepler's problem, Euler angles and inertia tensor.

Unit III: Hamiltonian Formalism and Canonical Transformations (14 Hours – 12 L+ 2 T)

Legendre transformations - Hamiltonian and Hamilton's equations of motion - Canonical transformations - Generating functions - Conditions for canonical transformations - Poisson brackets - Fundamental Poisson bracket relations - Equations of motion in Poisson bracket form - Liouville's theorem and its physical significance - Relation between Poisson brackets and quantum commutation relations - **Tutorials:** Problems on canonical transformations and Poisson brackets.

Unit IV: Hamilton-Jacobi Theory, Small Oscillations, and Dynamical Systems (14 Hours – 12 L + 2 T)

Hamilton-Jacobi equation - Hamilton's principal and characteristic functions - Harmonic oscillator - Separation of variables - Action-angle variables - Application to Kepler problem - Theory of small oscillations - Eigenvalue problem - Frequencies of free vibrations - Normal coordinates - Application to linear triatomic molecules - Forced vibrations and resonance (brief) - Phase-space trajectories - Fixed points and classification (nodes, saddles, spirals, centers) - Linear stability analysis - Limit cycles (concept only). **Tutorials:** Problems on Hamilton-Jacobi equation, phase-space analysis and fixed points.

Unit V: Relativistic Mechanics (14 Hours – 12 L + 2 T)

Minkowski space and 4-vectors - Covariant formulation of special relativity - Relativistic kinematics - Relativistic dynamics (4-momentum, 4-force) - Relativistic collisions: Invariant mass, particle decay, Compton scattering - Relativistic Lagrangian for a free particle - Transition from discrete to continuous systems. **Tutorials:** Problems on relativistic kinematics (decay, Compton scattering)

Unit VI: Current Contours (Self-Directed Learning Activities for Continuous Internal Assessments only)

Liouville's theorem - Numerical integration of equations of motion (Runge-Kutta method) for central force and oscillatory systems - Phase space visualization for pendulum and Duffing oscillator - Stability analysis of fixed points using computational tools - Numerical simulation of relativistic particle motion in electromagnetic fields - Comparison of analytical and numerical solutions.

Primary Text Books

1. N. Rana and P. Joag, Classical Mechanics, McGraw-Hill, New Delhi, 2017.
2. R. G. Takwale and P. S. Puranik, Introduction to Classical Mechanics, McGraw Hill Education, 2017.
3. Kiran C. Gupta, Classical Mechanics of Particles and Rigid Bodies, New Age International, 2018.
4. S. P. Puri, Special Theory of Relativity, Pearson Education India, 2013.
5. A. K. Raychaudhuri, Classical Mechanics: A Course of Lectures, Oxford University Press, 1984.

Books for Reference

1. H. Goldstein, C. P. Poole, and J. Safko, Classical Mechanics (3rd edition), Pearson, New Delhi, 2011.
2. L. D. Landau and E. M. Lifshitz, Mechanics (Course of Theoretical Physics, Vol. 1, 3rd edition), Butterworth-Heinemann.
3. L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields (Course of Theoretical Physics, Vol. 2, 4th edition), Butterworth-Heinemann.
4. John R. Taylor, Classical Mechanics, University Science Books.
5. David Morin, Introduction to Classical Mechanics: With Problems and Solutions, Cambridge University Press, 2008.
6. S. T. Thornton and J. B. Marion, Classical Dynamics of Particles and Systems (5th edition), Cengage Learning, 2006.

7. M. Lakshmanan and S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos, and Patterns, Springer, Chennai, 2003.
8. M. Spiegel, Theory & Problems of Theoretical Mechanics, McGraw-Hill Education, 2017. (Schaum series – solved problems)

Online/Web Resources

1. NPTEL Open Courseware: Classical Mechanics by Prof. V. Balakrishnan (IIT Madras). <https://nptel.ac.in/courses/122106027>
2. Prof. V. Balakrishnan, Topics in Nonlinear Dynamics, IIT Madras – <https://nptel.ac.in/courses/115106059>
3. Prof. David Tong, Classical Dynamics (Lecture Notes), University of Cambridge – <https://www.damtp.cam.ac.uk/user/tong/teaching.html>
4. Prof. Iain Stewart, Classical Mechanics III (8.09), MIT Open Course Ware – <https://ocw.mit.edu/courses/8-09-classical-mechanics-iii-fall-2014/>

Course Outcome

On the successful completion of the course, students will be able to:

1. Recall the fundamental principles and mathematical frameworks of Newtonian, Lagrangian, Hamiltonian, and relativistic mechanics.
2. Explain the physical significance of symmetries, conservation laws, canonical variables, and relativistic invariance in mechanical systems.
3. Apply Lagrangian, Hamiltonian, and Hamilton-Jacobi formulations to solve problems involving central forces, rigid bodies, and oscillatory systems.
4. Analyze dynamical systems using phase-space trajectories, stability analysis, Poisson brackets, and canonical transformations.
5. Evaluate the applicability and limitations of different theoretical frameworks in modeling physical systems.
6. Formulate mathematical models for mechanical systems using symmetry principles and conservation laws.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	1	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	1	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

CORE PRACTICAL 1

Semester: I

Code:

**PYTHON PROGRAMMING FOR
COMPUTATIONAL PHYSICS
(Practical)**

Credits: 4

Prerequisite: UG Physics

Objectives:

- Recall Python programming constructs, NumPy arrays, and Matplotlib plotting functions. K1
- Explain the implementation of numerical methods (curve fitting, root finding, integration, ODE solvers, Monte Carlo) in Python. K2
- Apply Python to write, debug, and execute programs for solving physics problems. K3
- Analyze numerical results for accuracy, convergence, and physical significance. K4
- Evaluate the efficiency and stability of different numerical methods for specific problems. K5
- Design Python programs to simulate physical systems and present results with appropriate visualizations. K6

Experiments

Experiment 1: Python and NumPy Refresher (6 hours)

Topics: Review of Python syntax – Variables, loops, conditionals, functions – NumPy arrays: creation, indexing, slicing, broadcasting – Vectorized operations – Basic input/output.

Programming Task: Write a Python program to compute **factorial**, **Fibonacci series**, and **prime numbers using functions**.

Visualization: None (focus on syntax).

References: PHY 506 S (Unit I)

Experiment 2: Data Visualization with Matplotlib (6 hours)

Topics: Basic plotting (line, scatter, bar, histogram) – Customization (labels, titles, legends, colors) – Subplots – Saving figures.

Programming Task: Plot $\sin(x)$, $\cos(x)$, and $\tan(x)$ on the same figure with different colors and line styles.

Visualization: Required for all subsequent experiments.

References: PHY 506 S (Unit III)

Experiment 3: Curve Fitting – Straight Line Fit (6 hours)

Topics: Method of least squares – Normal equations – Linear regression – Goodness of fit (R^2).

Programming Task: Fit a straight line to given (x, y) data (e.g., Ohm's law: voltage vs. current). Calculate slope, intercept, and R^2 .

Visualization: Scatter plot with fitted line.

References: PHY 506 S (Unit II)

Experiment 4: Curve Fitting – Exponential and Power Law Fits (6 hours)

Topics: Linearization of nonlinear functions – Exponential fit ($y = ae^{(bx)}$) – Power law fit ($y = ax^b$) – Transforming data for linear regression.

Programming Task: Fit exponential decay (radioactive decay data) and power law (period vs. length of pendulum) using linearization.

Visualization: Log-log and semi-log plots.

References: PHY 506 S (Unit II)

Experiment 5: Newton-Raphson Method – Real Roots (6 hours)

Topics: Newton-Raphson algorithm – Derivative calculation – Convergence criteria – Termination conditions.

Programming Task: Find real roots of equations: $x^3 - 2x - 5 = 0$, $x - \cos(x) = 0$.

Visualization: Plot function showing root location.

References: PHY 506 S (Unit III)

Experiment 6: Newton-Raphson Method – Complex Roots (6 hours)

Topics: Extension to complex variables – Complex arithmetic in Python – Finding complex roots of polynomials.

Programming Task: Find complex roots of $x^2 + 1 = 0$ and $x^3 - 1 = 0$.

Visualization: Plot roots on a complex plane.

References: PHY 506 S (Unit III)

Experiment 7: Solution of Simultaneous Equations – Gauss-Jordan Method (6 hours)

Topics: Gauss elimination – Jordan's modification – Matrix inverse using Gauss-Jordan – Pivoting for stability.

Programming Task: Solve system of linear equations (3x3 and 4x4). Find the inverse of a given matrix.

Visualization: None.

References: PHY 506 S (Unit III)

Experiment 8: Numerical Integration – Composite Trapezoidal and Simpson's Rules (6 hours)

Topics: Newton-Cotes formulas – Trapezoidal rule – Simpson's 1/3 rule – Composite rules – Error analysis.

Programming Task: Compute $\int_0^1 4/(1+x^2) dx = \pi$ (using both methods). Compare with analytical result. Compute error as function of step size.

Visualization: Plot convergence (error vs. step size) on log-log scale.

References: PHY 506 S (Unit II)

Experiment 9: Ordinary Differential Equations – Euler and RK4 Methods (6 hours)

Topics: First-order ODEs – Euler method – Fourth-order Runge-Kutta (RK4) method – Comparison of accuracy – Second-order ODEs (reduction to first-order system).

Programming Task: Solve damped harmonic oscillator ($d^2x/dt^2 + b dx/dt + \omega_0^2 x = 0$) using Euler and RK4. Compare with analytical solution.

Visualization: Phase space plots (x vs. v) and position vs. time.

References: PHY 506 S (Unit IV)

Experiment 10: Monte Carlo Methods – Random Numbers and Integration (6 hours)

Topics: Uniform random number generation – Park-Miller method – Tests for randomness (mean, variance, chi-square) – Monte Carlo integration.

Programming Task: Generate random numbers using Park-Miller. Compute mean and variance. Estimate π using the dartboard method.

Visualization: Histogram of random numbers, scatter plot of dartboard hits.

References: PHY 506 S (Unit V)

Experiment 11: Monte Carlo Methods – Radioactive Decay and Hydrogen Atom (6 hours)

Topics: Simulation of stochastic processes – Radioactive decay ($N = N_0 e^{-\lambda t}$) – Sampling from probability distributions – Hydrogen atom electron distribution.

Programming Task: Simulate radioactive decay of N_0 nuclei with half-life T . Sample electron position in hydrogen atom from ψ^2 distribution.

Visualization: Decay curve (N vs. t), electron cloud scatter plot.

References: PHY 506 S (Unit V)

Experiment 12: Symplectic Integration and Schrödinger Equation (6 hours)

Topics: Symplectic integration for conservative systems – Energy conservation – Numerical solution of 1D time-independent Schrödinger equation (Shooting method).

Programming Task: (a) Symplectic Euler vs. standard Euler for harmonic oscillator – compare energy conservation. (b) Solve 1D Schrödinger equation for harmonic oscillator potential to find ground state energy and wavefunction.

Visualization: Energy vs. time (symplectic vs. Euler), wavefunction plots.

References: PHY 506 S (Unit IV) + PHY511C (Quantum Mechanics)

Primary Textbooks

1. Hans Petter Langtangen, A Primer on Scientific Programming with Python (5th Edition), Springer, 2016.
2. Mark Newman, Computational Physics, CreateSpace Independent Publishing, 2012.
3. David J. Pine, Introduction to Python for Science and Engineering, CRC Press, 2019.

Reference Books

1. William H. Press, Numerical Recipes: The Art of Scientific Computing (3rd Edition), Cambridge University Press, 2007.
2. Allen B. Downey, Think Python (2nd Edition), O'Reilly Media, 2015.

Online Resources

NPTEL Courses

1. Scientific Computing Using Python by Prof. Mahendra Verma, IIT Kanpur
<http://www.digimat.in/nptel/courses/video/115104135/115104135.html>

Free Online Resources

1. Google Colab – <https://colab.research.google.com>
2. NumPy Documentation – <https://numpy.org/doc/stable/>
3. Matplotlib Documentation – <https://matplotlib.org/stable/contents.html>
4. Scipy Lecture Notes – <https://scipy-lectures.org/>

YouTube Resources

1. Sentedex – Search “Sentedex Python”
2. Corey Schafer – Search “Corey Schafer Python”
3. Mr. P. Solver – Search “Mr P Solver computational physics”

Course Outcomes

On the successful completion of the course, students will be able to:

1. Recall Python syntax, NumPy array operations, and Matplotlib plotting commands.
2. Explain the algorithm and implementation of numerical methods (Newton-Raphson, Gauss-Jordan, Trapezoidal/Simpson, Euler/RK4, Monte Carlo).
3. Apply Python to implement numerical methods for solving physics problems.
4. Analyze numerical solutions for accuracy by comparing with analytical solutions (where available).
5. Evaluate the convergence and stability of different numerical methods (Euler vs. RK4, Trapezoidal vs. Simpson).
6. Design Python programs to simulate physical systems (harmonic oscillator, radioactive decay, Schrödinger equation) with proper visualization.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	1	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	1	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I	DISCIPLINE CENTRIC ELECTIVE COURSE 1	Semester: I
Code:	1. ADVANCED ANALOG AND DIGITAL ELECTRONICS (Theory)	Credits: 4

Prerequisite: --

Objectives

- Recall the fundamentals of semiconductor devices, IC fabrication, logic gates, and flip-flops.
- Explain the working of tunnel diodes, Gunn diodes, Op-Amps, 555 timers, PLLs, counters, registers, and FSM.
- Apply Op-Amps, 555 timers, PLLs, combinational logic, shift registers, and energy harvesting to design circuits.
- Analyze quantum transport, filter response, PLL lock dynamics, timing diagrams, and propagation delays.
- Evaluate trade-offs in filter design, PAL vs. PLA, phase detectors, state encoding, and nanoelectronic devices.
- Design circuits using Op-Amps, 555 timers, and PLLs for various applications.

Unit I: Semiconductor Devices and IC Fabrication (10 Hrs)

Tunnel diodes: negative resistance characteristics - Gunn effect - SCR, DIAC, TRIAC: construction, V-I characteristics, and triggering methods - UJT principles and relaxation oscillator design - Comparison of power devices for control applications - Monolithic IC fabrication: epitaxial growth, thermal oxidation, photolithography, diffusion, masking, and etching - Fabrication of resistors, capacitors, and transistors on-chip. **Tutorials:** Problems on tunnel diode characteristics and UJT relaxation oscillator design.

Unit II: Operational Amplifiers (12 Hrs)

Ideal vs. practical Op-amp - Offset, bias current, CMRR, slew rate, and noise - Internal compensation techniques - Miller effect and dominant pole - Peak detector and precision rectifiers (half-wave and full-wave) - Active filters: low-pass, high-pass, band-pass (Sallen-Key topology) - Logarithmic and anti-logarithmic amplifiers - Relaxation oscillator using Schmitt trigger - Current-to-voltage and voltage-to-current converters - Trade-offs in active filter design: order vs. roll-off, component sensitivity. **Tutorials:** Problems on peak detector design and active filter design.

Unit III: Timers, PLL, and Combinational Logic (12 Hrs)

555 timer: functional diagram, monostable and astable operation - Frequency division and Frequency Shift Keying (FSK) generator - PLL basic principle: phase detector, VCO, loop filter - Capture range vs. lock range and pull-in time analysis - Analog vs. digital phase detectors (XOR and PFD) - PLL applications: frequency multiplication and division - Evaluation of PLL performance - Logic minimization: K-maps (up to 5 variables) - Multiplexers, demultiplexers, and decoders (BCD to seven-segment). **Tutorials:** Problems on K-map simplification and design using 555 timer and PLL.

Unit IV: Sequential Circuits (14 Hrs)

Programmable Array Logic (PAL) and Programmable Logic Array (PLA) architectures - Comparison of PAL and PLA: flexibility, speed, and cost - JK master-slave flip-flop: race-around condition and edge triggering - Switch contact bounce and debouncing circuits - Universal shift registers: SISO, SIPO, PISO, PIPO - Asynchronous (ripple) counters: timing skew and propagation delay analysis - Synchronous counters: design and modulus changing - Finite State Machine (FSM): Mealy vs. Moore, state encoding trade-offs. **Tutorials:** Problems on FSM design and sequential circuit analysis.

Unit V: Nanoelectronics and Emerging Technologies (12 Hrs)

Ballistic transport and conductance quantization - Memristor: physics and applications (RRAM, neuromorphic computing) - Single-Electron Transistors (SET): Coulomb blockade - Carbon Nanotube FETs (CNTFETs) and graphene transistors - Energy harvesting: piezoelectric, thermoelectric, and photovoltaic principles - Comparison of emerging technologies with CMOS - **Tutorials:** Case study report on one emerging technology.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of Op-Amp based active filters using SPICE/LTspice - Design and simulation of 555 timer in monostable and astable modes - PLL lock range and capture range simulation using Python/Scipy - Simulation of UJT relaxation oscillator waveform - Comparative analysis of PAL vs. PLA using logic minimization tools - Introduction to memristor hysteresis loop simulation.

Primary Textbooks:

1. R. A. Gayakwad, Op-Amps and Linear Integrated Circuits (Pearson, 2021)
2. M. Morris Mano & M. D. Ciletti, Digital Design (Pearson, 2018)
3. S. M. Sze & M. K. Lee, Semiconductor Devices: Physics and Technology (Wiley, 2012)
4. Adel S. Sedra, Kenneth C. (KC) Smith & Adapted by Arun N. Chandorkar, Microelectronic Circuits (Oxford University Press, 2017)

Reference Books:

1. J. Millman, C. Halkias, Integrated Electronics (McGraw Hill, 2017)
2. C. Durkan, Current at the Nanoscale (World Scientific, 2013)
3. R. L. Geiger, P. E. Allen, VLSI Design Techniques (McGraw Hill, 2010)

Online Resources:

1. NPTEL – Digital Electronic Circuits – Prof. Goutam Saha, IIT Kharagpur, <https://www.nptel.ac.in/courses/108105132>
2. NPTEL – Analog Electronic Circuits - Prof. Shanthi Pavan, IITM, IIT Madras, <https://nptel.ac.in/courses/108106188>.
3. James Fiore's "Operational Amplifiers & Linear ICs" (free PDF).
4. LTSpice / QSpice for simulation.

Course Outcome

On the successful completion of the course, students will be able to:

1. Recall the fundamentals of semiconductor devices, IC fabrication, logic gates, and flip-flops.
2. Explain the working principles of tunnel diodes, Gunn diodes, Op-Amps, 555 timers, PLLs, PAL, PLA, and FSM.
3. Apply Op-Amps, 555 timers, PLLs, combinational logic, shift registers, and energy harvesting to design circuits.
4. Analyze negative resistance characteristics, filter response, PLL lock range, timing diagrams, and ballistic transport.
5. Evaluate trade-offs in filter design, PAL vs. PLA, phase detectors, state encoding, and nanoelectronic devices.
6. Design circuits using Op-Amps, 555 timers, and PLLs for various applications.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	1	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I DISCIPLINE CENTRIC ELECTIVE COURSE 1 Semester: I

Code: 2. MODERN ELECTRONIC INSTRUMENTATION Credits: 4
AND SENSORS
(Theory)

Prerequisite: --

Objectives

1. Recall the principles of transducers, sensors, signal conditioning, and data acquisition systems.
2. Explain the working of various sensors and their interfacing with microcontrollers.
3. Apply operational amplifiers in signal conditioning circuits.
4. Analyze sensor characteristics including sensitivity, linearity, resolution, and hysteresis.
5. Evaluate the suitability of different sensors for specific physics experiments.
6. Design a complete data acquisition system using sensors, signal conditioning, and microcontroller.

Unit I: Fundamentals of Instrumentation (12 hours)

Measurement systems and generalized instrumentation system - Static and dynamic characteristics: accuracy, precision, resolution, sensitivity, linearity, hysteresis, drift, repeatability, reproducibility - Range and span - Loading effects - Calibration and standards - Classification of transducers: active vs. passive - Selection criteria for sensors - Signal conditioning: bridge circuits (Wheatstone), amplification (instrumentation amplifier), filtering (low-pass, high-pass), linearization, level shifting - **Tutorials:** Problems on sensor characteristics and Wheatstone bridge design.

Unit II: Analog and Digital Data Acquisition (12 hours)

Operational amplifiers in instrumentation: differential amplifiers, instrumentation amplifier (three Op-amp configuration), precision rectifiers, peak detectors, sample and hold circuits - Sampling theorem, aliasing, anti-aliasing filters - ADC architectures: SAR, dual-slope, flash, delta-sigma - ADC specifications: resolution, conversion time, quantization error - DAC architectures: weighted resistor, R-2R ladder - DAC specifications - Reconstruction filters - Components of a DAQ system: multiplexers, ADC/DAC, buffers, DAQ cards - PC-based data acquisition - Introduction to LabVIEW - Data logging and visualization. **Tutorials:** Problems on ADC resolution and instrumentation amplifier design.

Unit III: Physical and Mechanical Sensors (12 hours)

Thermocouples (types J, K, T) with cold junction compensation - RTDs (PT100) - Thermistors (NTC, PTC) - Semiconductor sensors (LM35, DS18B20) - Infrared sensors - Comparison and selection - Strain gauges: gauge factor, Wheatstone bridge configuration, temperature compensation - Load cells - Piezoresistive, capacitive, and piezoelectric pressure sensors - LVDT - Optical encoders - Hall effect position sensors - Ultrasonic sensors - Accelerometers (piezoelectric, capacitive, MEMS) - Gyroscopes - Applications in vibration monitoring. **Tutorials:** Problems on thermocouple linearization and strain gauge bridge design.

Unit IV: Optical, Magnetic, and Chemical Sensors (12 hours)

Photoconductive cells (LDR) - Photodiodes (PIN, avalanche) - Phototransistors - Photomultiplier tubes (PMT) - Charge-Coupled Devices (CCD) - CMOS sensors - Fiber optic sensors - Hall effect sensors - Magnetoresistive sensors (AMR, GMR, TMR) - Fluxgate magnetometers - SQUID - Electrochemical and MOS gas sensors - Humidity sensors - pH sensors - Biosensors: principle, bioreceptors, transduction - Glucose sensors - MEMS: accelerometers, gyroscopes, pressure sensors - Smart sensors and sensor networks. **Tutorials:** Problems on photodiode responsivity and magnetic sensor selection.

Unit V: Microcontroller Interfacing and Embedded Instrumentation (12 hours)

Introduction to microcontrollers (Arduino, ESP32) - Programming basics - Digital I/O - PWM - Interrupts - Timers and counters - Reading analog sensors using ADC - I²C, SPI, OneWire, and UART protocols - Bluetooth, WiFi (ESP8266/ESP32) for IoT - MQTT protocol - Cloud-based data logging - LabVIEW basics and virtual instruments - DAQ using LabVIEW. **Tutorials:** Problems on sensor interfacing and complete instrumentation system design.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Calibration and characterization of temperature sensors - Data acquisition and logging using LabVIEW or Python - Interfacing of I²C and SPI sensors - Wireless sensor network using ESP32 and MQTT - Simulation of instrumentation amplifier using LTspice - Design of digital thermometer with LCD display.

Primary Textbooks

1. H. S. Kalsi, *Electronic Instrumentation* (4th Edition), Tata McGraw Hill, 2018.
2. D. A. Bell, *Electronic Instrumentation and Measurements* (3rd Edition), Oxford University Press, 2013.
3. R. A. Gayakwad, *Op-Amps and Linear Integrated Circuits*, Pearson, 2021.
4. J. Fraden, *Handbook of Modern Sensors: Physics, Designs, and Applications* (5th Edition), Springer, 2016.
5. A. D. Helfrick and W. D. Cooper, *Modern Electronic Instrumentation and Measurement Techniques* (Pearson, 2015)

Reference Books

1. S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits* (4th Edition), McGraw Hill, 2015.
2. A.D. Helfrick and W. D. Cooper, *Modern Electronic Instrumentation and Measurement Techniques*, Pearson, 2015.
3. R.S. Khandpur, *Handbook of Analytical Instruments* (2nd Edition), McGraw Hill, 2006.
4. C.W. de Silva, *Sensors and Actuators: Engineering System Instrumentation* (2nd Edition), CRC Press, 2015.

Online Resources

1. NPTEL – Electrical Measurement and Electronic Instruments – Prof. Avishek Chatterjee, IIT Kharagpur, <https://nptel.ac.in/courses/108105153>.

2. NPTEL – Semiconductor Devices to Sensors: Principles, Design, and Application – Prof. Mitradip Bhattacharjee, IISER, <https://nptel.ac.in/courses/108106001>.
3. NPTEL – Transducers for Instrumentation – Prof. Ankur Gupta, IIT Delhi, <https://nptel.ac.in/courses/108102191>
4. NPTEL – Industrial Instrumentation– Prof. Alok Barua, IIT Kharagpur, <https://nptel.ac.in/courses/108105064>.
5. Arduino Documentation – <https://docs.arduino.cc>
6. ESP32 Documentation – <https://docs.espressif.com>
7. National Instruments – LabVIEW Fundamentals – <https://www.ni.com/labview>

Course Outcome

1. Recall the principles of transducers, sensors, signal conditioning, ADC/DAC, and data acquisition.
2. Explain the working principles of temperature, pressure, optical, magnetic, chemical, and MEMS sensors.
3. Apply Op-Amps to design instrumentation amplifiers, active filters, and signal conditioning circuits.
4. Analyze sensor performance characteristics including sensitivity, linearity, resolution, and noise.
5. Evaluate the selection criteria for sensors in different physics experiments.
6. Design a microcontroller-based data acquisition system with sensor interfacing and PC communication.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	3	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

GENERIC ELECTIVE COURSE 1

Semester: I

Code:

**1. FUNDAMENTALS OF BIOPHYSICS
(Theory)**

Credits: 3

Prerequisite: --

Objectives

1. Recall the fundamental physical principles governing biological systems at molecular, cellular, and tissue levels.
2. Explain the application of thermodynamics, transport phenomena, and electrostatics to biological processes.
3. Apply physical concepts to analyze membrane potentials, nerve conduction, and muscle contraction.
4. Analyze the interaction of radiation with biological systems and its effects on cells and tissues.
5. Evaluate bioenergetic processes and spectroscopic techniques used in biological research.
6. Design simple models to describe physical behavior of biological systems.

Unit I: Introduction to Biophysics (10 hours)

Biophysics as an interdisciplinary science - Physical principles in biological systems - Length scales in biology (molecular to organismal) - Thermodynamics of living systems: entropy and order, free energy, non-equilibrium steady state - Molecular forces: Van der Waals forces, hydrogen bonding, hydrophobic interactions, electrostatic interactions - Their role in biomolecular structure and function. **Tutorials:** Problems on free energy and entropy in biological systems.

Unit II: Biomolecular Structure and Dynamics (10 hours)

Amino acids and protein structure (primary to quaternary) - DNA and RNA structure (double helix, base pairing) - Physical forces stabilizing biomolecular structures - Folding and unfolding transitions - Lipid bilayer structure and dynamics - Passive and active transport - Diffusion and osmosis - Fick's laws of diffusion - Osmotic pressure and its biological significance. **Tutorials:** Problems on Fick's laws and osmotic pressure.

Unit III: Bioenergetics and Enzyme Kinetics (10 hours)

Energy transformation in living systems - ATP as energy currency - Redox reactions and electron transport chains - Gibbs free energy in biochemical reactions - Coupled reactions - Michaelis-Menten equation - Lineweaver-Burk plot - Enzyme inhibition - Allosteric regulation - Physical basis of enzyme catalysis (transition state theory, activation energy). **Tutorials:** Problems on Michaelis-Menten kinetics and Lineweaver-Burk plots.

Unit IV: Membrane Potentials and Nerve Biophysics (10 hours)

Nernst equation - Donnan equilibrium - Resting membrane potential - Action potential - Hodgkin-Huxley model - Voltage-gated ion channels - Propagation of nerve impulses - Sliding filament theory - Excitation-contraction coupling - Force generation and energetics - Molecular motors (kinesin, dynein, myosin). **Tutorials:** Problems on Nernst potential and action potential simulation.

Unit V: Radiation Biophysics and Spectroscopic Techniques (8 hours)

Ionizing and non-ionizing radiation - Direct and indirect effects - DNA damage and repair - Cell survival curves (target theory) - Linear energy transfer (LET) and relative biological effectiveness (RBE) - UV-Vis absorption spectroscopy - Fluorescence spectroscopy (FRET) - Circular dichroism - NMR spectroscopy in biology - X-ray crystallography (brief) - Introduction to single-molecule techniques. **Tutorials:** Problems on cell survival curves and LET calculations.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of Michaelis-Menten enzyme kinetics - Determination of K_m and V_{max} using Lineweaver-Burk plot - Numerical solution of Hodgkin-Huxley equations - Modeling of diffusion across membranes using Fick's laws - Analysis of protein folding using energy landscape concepts - Simulation of Nernst potential for different ion concentrations - Case study: FRET efficiency calculation.

Primary Textbooks

1. P. Nelson, Biological Physics: Energy, Information, Life, W. H. Freeman, 2008.
2. R. K. Hobbie and B. J. Roth, Intermediate Physics for Medicine and Biology (5th Edition), Springer, 2015.
3. W. Hoppe, W. Lohmann, H. Markl, and H. Ziegler, Biophysics, Springer-Verlag, 1983.

Reference Books

1. M. B. Jackson, *Molecular and Cellular Biophysics*, Cambridge University Press, 2006.
2. G. R. Ivanitsky, *Modern Biophysics*, Mir Publishers, 1988.
3. E. L. R. Stryer, *Biochemistry* (9th Edition), W. H. Freeman, 2019 (selected chapters).

Online Resources

1. NPTEL – Biophysics Prof. Amar Nath Gupta, IIT Kharagpur, <https://nptel.ac.in/courses/115105001>
2. MIT OpenCourseWare – 8.592J / HST.452J – Statistical Physics in Biology – <https://ocw.mit.edu>
3. iBiology – Biophysics lecture series – <https://www.ibiology.org>

Course Outcomes

On the successful completion of the course, students will be able to:

1. Recall the physical principles applied to biological systems.
2. Explain the structure and function of biomolecules, membranes, and molecular motors.
3. Apply Nernst equation and diffusion laws to analyze membrane potentials and transport phenomena.
4. Analyze enzyme kinetics using Michaelis-Menten and Lineweaver-Burk plots.
5. Evaluate the effects of radiation on biological systems and the use of spectroscopic techniques.

6. Design simple biophysical models for processes like diffusion across membranes or nerve conduction.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

GENERIC ELECTIVE COURSE 1

Semester: I

Code:

**2. MEDICAL PHYSICS
(Theory)**

Credits: 3

Prerequisite: --

Objectives

- Recall the physical principles underlying medical imaging, radiation therapy, and physiological measurements.
- Explain the working principles of X-ray, CT, MRI, Ultrasound, and PET imaging.
- Apply radiation physics concepts to calculate dose, half-life, and shielding requirements.
- Analyze the interaction of radiation with tissue and its application in diagnosis and therapy.
- Evaluate the selection of appropriate imaging modalities for specific clinical conditions.
- Design basic treatment plans for radiation therapy using dosimetry principles.

Unit I: Radiation Physics (10 Hours)

Structure of atom and nucleus - Radioactive decay - Decay law - Half-life and activity units - Interaction of radiation with matter: photoelectric effect, Compton scattering, pair production - Attenuation and half-value layer - Radiation dosimetry: absorbed dose, equivalent dose, effective dose - Problems on decay and dosimetry.

Unit II: Diagnostic Radiology (10 Hours)

X-ray tube and production - Bremsstrahlung and characteristic X-rays - X-ray spectra and factors affecting output - Image formation and detectors - Image quality: contrast, resolution, noise - Fluoroscopy and digital subtraction angiography - Dose considerations - Problems on X-ray spectra and image quality.

Unit III: CT and Nuclear Medicine (10 Hours)

Principles of CT - Image reconstruction - Hounsfield units - CT dose indices - Gamma camera - SPECT - PET: coincidence detection and annihilation - Radiopharmaceuticals - Problems on CT and PET.

Unit IV: MRI and Ultrasound (10 Hours)

Principles of NMR - Larmor frequency - T1 and T2 relaxation - Pulse sequences and image contrast - Applications and safety - Principles of ultrasound - Modes: A, B, M-mode - Doppler ultrasound - Image artifacts - Clinical applications - Problems on Larmor frequency and relaxation.

Unit V: Radiation Therapy and Physiological Measurements (8 Hours)

Teletherapy and brachytherapy - Linear accelerator - Treatment planning - 3D-CRT and IMRT - Dosimetry in therapy - ECG, EEG, EMG - Blood pressure and pulse oximetry - Spirometry - Problems on treatment planning.

Unit VI: Current Contours (Self-Directed Learning Activities for Continuous Internal Assessments Only)

Radiation transport simulation - CT image reconstruction - PET simulation - MRI pulse sequence simulation - Treatment planning calculations - ECG signal acquisition.

Primary Textbooks

1. B. H. Brown, P. V. Lawford, R. H. Smallwood, and D. R. Hose, *Medical Physics and Biomedical Engineering*, CRC Press, 2015.
2. S. Webb, *The Physics of Medical Imaging*, Institute of Physics Publishing, 2002.
3. F. M. Khan, *The Physics of Radiation Therapy* (5th Edition), Lippincott Williams & Wilkins, 2014.
4. W. R. Hendee and E. R. Ritenour, *Medical Imaging Physics* (Wiley-Liss, 2002)

Reference Books

1. J. Bushberg, J. Seibert, E. Leidholdt, and J. Boone, *The Essential Physics of Medical Imaging* (4th Edition), Wolters Kluwer, 2020.
2. W. R. Hendee and E. R. Ritenour, *Medical Imaging Physics* (4th Edition), Wiley-Liss, 2002.
3. R. K. Hobbie and B. J. Roth, *Intermediate Physics for Medicine and Biology* (5th Edition), Springer, 2015.

Online Resources

1. NPTEL – Medical Imaging Analysis (Prof. Ganapathy Krishnamurthi, IIT Madras) – <https://nptel.ac.in/courses/102106094>
2. Radiology Educational Videos – Radiology Masterclass – <https://www.radiologymasterclass.co.uk>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the physical principles of radiation, imaging, and physiological measurements.
2. Explain the working principles of X-ray, CT, MRI, Ultrasound, PET, and SPECT.
3. Apply radiation physics concepts to solve medical physics problems.
4. Analyze the interaction of radiation with tissue in imaging and therapy.
5. Evaluate appropriate imaging modality for specific clinical conditions.
6. Design a basic radiation therapy treatment plan using dosimetry.

MAPPING MATRIX: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I	GENERIC ELECTIVE COURSE 1	Semester: I
Code:	3. ADDITIVE MANUFACTURING (Theory)	Credits: 3

Prerequisite: --

Objectives

- Recall the fundamentals, evolution, and classification of additive manufacturing processes.
- Explain the working principles of SLA, SGC, LOM, and FDM technologies.
- Apply CAD software to convert part files into STL format and prepare models for 3D printing.
- Analyze the advantages, limitations, and material requirements of different AM processes.
- Evaluate the appropriate AM technique for specific industrial applications.
- Design and print simple 3D models using FDM technology.

Unit I: Introduction to Additive Manufacturing (10 Hours)

History and evolution - AM vs. CNC machining - Steps in AM process - Classification: liquid-based, solid-based, powder-based - Materials for AM: polymers, metals, ceramics, composites - Advantages and applications - Problems on material selection and process comparison.

Unit II: 3D Printing and Data Preparation (10 Hours)

Process chain - CAD software overview - Design rules and support structures - STL file format: generation, errors, and repair - Other formats (AMF, 3MF) - Slicing parameters - G-code generation - Slicing software (Cura, PrusaSlicer) - Problems on STL repair and slicing optimization.

Unit III: SLA and Liquid-Based Processes (10 Hours)

Working principle - Photopolymers and photopolymerization - Laser scanning and after-curing - Applications and limitations - DLP - CLIP - PolyJet and MultiJet Printing - Comparison of SLA vs. DLP - Case studies.

Unit IV: SGC and Solid-Based Processes (9 Hours)

SGC: working principle, electrostatic toner application, flash exposure - Applications and limitations - LOM: working principle, sheet materials, laser cutting, layer bonding - Applications and limitations - Comparison of SGC and LOM - Case studies.

Unit V: FDM and Practical Demonstration (9 Hours)

Working principle - Filament extrusion and materials - Support structures - Applications and limitations - Hands-on 3D printing demonstration - Post-processing techniques - Emerging technologies: metal AM, SLM, EBM, bioprinting, 4D printing - Problems on FDM process parameters.

Unit VI: Current Contours (Self-Directed Learning Activities for Continuous Internal Assessments Only)

STL file generation and repair - Slicing parameter optimization - Comparative analysis of AM processes - Material selection case studies - Cost analysis of AM vs. traditional manufacturing - Post-processing techniques.

Primary Textbooks

1. Ian Gibson, David W. Rosen, and Brent Stucker, Additive Manufacturing Technologies, Springer, 2015.
2. Chua Chee Kai and Leong Kah Fai, 3D Printing and Additive Manufacturing, World Scientific, 2015.

Reference Books

1. Andreas Gebhardt, Understanding Additive Manufacturing, Hanser Publications, 2011.
2. N. Hopkinson, R. J. M. Hague, and P. M. Dickens, Rapid Manufacturing, Wiley, 2006.

Online Resources

1. NPTEL – Fundamentals Of Additive Manufacturing Technologies (Prof. Sajan Kapil, IIT Guwahati) <https://nptel.ac.in/courses/112103306>
2. NIELIT – Certificate Course in Additive Manufacturing (3D Printing) – <https://nielit.gov.in> (Verified course details available)
3. Coursera – 3D Printing Specialization (University of Illinois) – <https://www.coursera.org/specializations/3d-printing-additive-manufacturing>
4. Ultimaker Cura (Free slicing software) – <https://ultimaker.com/software/ultimaker-cura>
5. Prusa Research (Free resources) – <https://www.prusa3d.com>

Course Outcomes

Upon completion of this course students should be able to

1. Recall the fundamentals, classification, and evolution of additive manufacturing.
2. Explain the working principles of SLA, SGC, LOM, and FDM technologies.
3. Apply CAD and slicing software to prepare models for 3D printing.
4. Analyze the advantages, limitations, and material requirements of AM processes.
5. Evaluate the appropriate AM technique for specific industrial applications.
6. Design and print simple 3D models using FDM technology.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

SKILL ENHANCEMENT COURSE 1

Semester: I

Code:

**COMPUTATIONAL PHYSICS USING
PYTHON
(Theory)**

Credits: 2

Prerequisite: --

Objectives

- Recall Python programming fundamentals including data types, control structures, functions, and modules.
- Explain the implementation of curve fitting, numerical integration, and root-finding algorithms.
- Apply Python to solve linear equations, nonlinear equations, and ordinary differential equations.
- Analyze physical systems using Monte Carlo simulations and numerical error analysis.
- Evaluate the accuracy, stability, and convergence of numerical methods for physics problems.
- Design Python programs to simulate physical systems and visualize results.

Unit I: Python Programming Fundamentals (8 hours)

Introduction to Python and Jupyter Notebook - Variables and data types - Data structures: list, tuple, dict, set - Operators and conditional statements - Looping and control statements - Functions and lambda functions - List comprehensions - Modules: NumPy, Matplotlib, SciPy.

Unit II: Curve Fitting and Numerical Integration (8 hours)

Method of least squares - Straight-line, exponential, and power law fits - Goodness of fit - Trapezoidal and Simpson's rules - Error analysis - Physics applications: area under curves, expectation values.

Unit III: Solutions of Linear and Nonlinear Equations (8 hours)

Gauss elimination and Gauss-Jordan method - Matrix inversion - Bisection method - Newton-Raphson method - Secant method - Convergence and pitfalls - Physics applications: energy eigenvalues, equilibrium positions.

Unit IV: Numerical Solution of Ordinary Differential Equations (6 hours)

Euler method - Local and global truncation errors - Fourth-order Runge-Kutta (RK4) method - Second-order ODEs reduction to first-order system - Physics applications: harmonic oscillator, pendulum, projectile motion. Physics Applications: Damped and driven harmonic oscillator - Simple pendulum - Projectile motion with air resistance.

Unit V: Monte Carlo Techniques (6 hours)

Random numbers and generators - Tests for randomness - Monte Carlo simulation: integration, π estimation, radioactive decay - Random walks - Metropolis algorithm (introduction) - Physics applications: hydrogen atom electron distribution.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Data visualization using Matplotlib - Implementation of curve fitting and numerical integration - ODE solvers for physical systems - Monte Carlo simulations - Case study: Simulation of physical systems using Python.

Case Study / Mini-Project (Outside Lecture Hours – CIA Component)

Students apply computational techniques to simulate a physical system of their choice (eg. harmonic oscillator, pendulum, projectile motion, radioactive decay, or hydrogen atom). Deliverables: Project report, well-commented Jupyter Notebook, and short presentation.

Primary Textbooks

1. Hans Petter Langtangen, A Primer on Scientific Programming with Python (5th Edition), Springer, 2016.
2. Mark Newman, Computational Physics, CreateSpace Independent Publishing, 2012.
3. David J. Pine, Introduction to Python for Science and Engineering, CRC Press, 2019.

Reference Books

1. William H. Press, Numerical Recipes: The Art of Scientific Computing (3rd Edition), Cambridge University Press, 2007.
2. Allen B. Downey, Think Python (2nd Edition), O'Reilly Media, 2015.
3. V. Rajaraman, Computer Oriented Numerical Methods, PHI Learning, 2005.
4. S. S. Sastry, Introductory Methods of Numerical Analysis (5th Edition), PHI Learning, 2012.

Online Resources

1. Scientific Computing Using Python by Prof. Mahendra Verma, IIT Kanpur
<http://www.digimat.in/nptel/courses/video/115104135/115104135.html>
2. Google Colab – <https://colab.research.google.com>
3. W3Schools Python Tutorial – <https://www.w3schools.com/python/>
4. Python.org Official Documentation – <https://docs.python.org/3/>
5. NumPy Documentation – <https://numpy.org/doc/stable/>
6. Matplotlib Documentation – <https://matplotlib.org/stable/contents.html>
7. SciPy Documentation – <https://docs.scipy.org/doc/scipy/>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall Python syntax, data structures, control flow, functions, and modules.
2. Explain curve fitting, numerical integration, and root-finding methods.
3. Apply numerical methods to solve linear/nonlinear equations and ODEs.
4. Analyze numerical errors and convergence of algorithms.
5. Evaluate Monte Carlo simulations for physical problems.
6. Design Python programs to simulate physical systems.

MAPPING MATRIX: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	3	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

VALUE ADDED COURSE 1

Semester: I

Code:

**ETHICAL PRACTICES IN RESEARCH
(Theory)**

Credits: 2*

Prerequisite: --

Objective

- Recall the fundamental principles of research ethics, integrity, and responsible conduct of research.
- Explain the various forms of research misconduct and their consequences.
- Apply ethical principles to real-world research scenarios and publication practices.
- Analyze institutional policies and guidelines for promoting ethical research practices.
- Evaluate the effectiveness of different mechanisms for preventing research misconduct.
- Design a comprehensive research plan incorporating ethical considerations and authorship guidelines.

Unit I: Foundations of Research Ethics (8 hours)

Definition and scope of research ethics - Historical guidelines: Nuremberg Code, Declaration of Helsinki, Belmont Report - National and international bodies (ICMR, UGC, COPE, ORI) - Institutional Ethics Committee and IRB - Research integrity: core values and responsible conduct - UGC Regulations 2018 - Scientific misconduct: fabrication, falsification, plagiarism - Questionable practices: duplication, salami slicing, ghost authorship, citation manipulation, conflict of interest.

Unit II: Plagiarism and Publication Ethics (8 hours)

Types of plagiarism: direct, self-plagiarism, mosaic - Paraphrasing and citation practices - Plagiarism detection software (Turnitin, iThenticate) - UGC guidelines on plagiarism - Authorship criteria (ICMJE guidelines) - Contributors vs. authors - Responsible publication practices - Predatory journals - Retraction and correction policies - COPE flowcharts - Peer review process and responsibilities.

Unit III: Data Management and Responsible Conduct (6 hours)

Research data lifecycle - Data collection and recording - Laboratory notebooks - Data ownership and intellectual property - FAIR principles - Data repositories - Data retention policies - Reproducibility and open science - Pre-registration of studies - Reporting negative results - Landmark fraud cases and lessons learned - Collaborative research issues - Conflict of interest management.

Unit IV: Institutional Policies and Responsible Research (6 hours)

Mandatory RCR training - Institutional policies - Mentor responsibilities - Whistleblower protection - Reporting and investigation procedures - Role of Ombudsperson and Research Integrity Officer - Institutional Ethics Committee - Disciplinary actions - Creating a culture of integrity - Best practices for research groups.

Unit V: Research Plan and Ethical Framework (4 hours)

Components of an ethical research plan - Literature review and citation practices - Experimental design and data collection - Authorship and publication strategy - Conflict of interest disclosure - Data sharing and repository selection - Framework for institutional policies - Case study discussions.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Reflection essays on ethical dilemmas - Analysis of plagiarism cases - Development of personal code of ethics - Role-play on authorship disputes - Data management plan preparation - Mock Institutional Ethics Committee review.

Primary Textbooks

1. Francis L. Macrina, *Scientific Integrity: Text and Cases in Responsible Conduct of Research* (4th Edition), ASM Press, 2014.
2. Nicholas H. Steneck, *Introduction to the Responsible Conduct of Research*, Office of Research Integrity (ORI), 2007. (Free PDF available)
3. UGC, *Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions Regulations*, 2018.

Reference Books

1. Committee on Science, Engineering, and Public Policy, *On Being a Scientist: A Guide to Responsible Conduct in Research* (3rd Edition), National Academies Press, 2009.
2. D. B. Resnik, *What is Ethics in Research and Why is it Important?*, National Institute of Environmental Health Sciences, 2020.
3. C. K. Gunsalus, *The Young Scientist's Guide to Ethical Research*, University of Illinois, 2019.

Online Resources

1. Research and Publication Ethics (Dr. Anirban Ghosh, Netaji Subhas Open University) https://onlinecourses.swayam2.ac.in/e-learning/preview/nou25_ge91
2. UGC MOOCS, Research Ethics (68), <https://ugcmoocs.inflibnet.ac.in/index.php/courses/view Ug/272>
3. COPE (Committee on Publication Ethics) – <https://publicationethics.org>
4. ORI (Office of Research Integrity) – <https://ori.hhs.gov>
5. ICMJE Guidelines for Authorship – <http://www.icmje.org>
6. UGC (University Grants Commission) – Academic Integrity Guidelines – <https://www.ugc.ac.inCourse Outcomes>

Course Outcomes

Upon completion of this course students should able to:

1. Recall the key principles of research ethics, integrity, and responsible conduct.
2. Explain the different types of research misconduct and their impact on science.
3. Apply ethical guidelines to real-world scenarios involving authorship and data management.
4. Analyze institutional policies and procedures for promoting research integrity.

5. Evaluate the effectiveness of mechanisms for preventing research misconduct.
6. Design a research plan incorporating ethical considerations and publication ethics.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	–	–	1	1	–	2	1
CO2	3	3	2	–	–	2	1	–	2	1
CO3	3	2	3	–	–	2	2	–	2	1
CO4	3	3	3	–	–	3	1	2	2	2
CO5	3	3	3	–	–	3	1	2	2	2
CO6	3	2	3	–	–	2	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

CORE COURSE 3

Semester: II

Code:

**QUANTUM MECHANICS
(Theory)**

Credits: 4

Prerequisite: PHY 501 C: Mathematical Physics; PHY 502 C: Classical and Relativistic Mechanics

Objectives

- Recall the postulates, operator formalism, and mathematical framework of quantum mechanics.
- Explain the physical significance of wavefunctions, commutation relations, uncertainty principle, and spin.
- Apply Schrödinger equation to solve exactly solvable systems.
- Analyze physical systems using perturbation theory, variational method, and angular momentum algebra.
- Evaluate the predictions of relativistic quantum mechanics and quantum information protocols.
- Formulate quantum mechanical models for identical particles, entangled states, and relativistic particles.

Unit I: The Schrödinger Equation and Operator Formalism (12 Hrs)

Time-dependent Schrödinger equation - Physical meaning and conditions on wavefunctions - Conservation of probability - Expectation values - Ehrenfest's theorem - Basic postulates of quantum mechanics - Linear, adjoint, and Hermitian operators - Commutators and simultaneous eigenfunctions - Heisenberg uncertainty relation - Bra and ket vectors - Hilbert space - Schrödinger and Heisenberg pictures..

Unit II: Exactly Solvable Problems (12 Hrs)

Particle in a box (infinite square well) - Rectangular barrier potential and tunnel effect - Rigid rotator - Hydrogen atom: radial equation, energy levels, degeneracy - Harmonic oscillator: analytic and ladder operator methods.

Unit III: Approximation Methods (12 Hrs)

Time-independent perturbation theory: non-degenerate and degenerate states - Applications: harmonic oscillator with perturbations, Stark effect - Variational method: ground state of helium atom - Time-dependent perturbation theory - Fermi's Golden Rule - Applications: photoelectric effect and selection rules.

Unit IV: Angular Momentum and Identical Particles (12 Hours)

Angular momentum operators and commutation relations - Eigenvalues and eigenfunctions - Spin angular momentum - Addition of angular momenta - Clebsch-Gordan coefficients - Identical particles: symmetric and antisymmetric wavefunctions - Pauli exclusion principle - Slater determinants - Applications: helium atom, periodic table.

Unit V: Relativistic Quantum Mechanics (12 Hours)

Klein-Gordon equation: probability and current densities, plane wave solutions, negative energy problem - Dirac equation: Dirac matrices, probability and current densities - Plane wave solutions and negative energy states (hole theory) -

Zitterbewegung - Spin of the Dirac particle - Non-relativistic limit: Pauli equation
- Magnetic moment of electron - Fine structure (qualitative).

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Numerical solutions of Schrödinger equation - Visualization of wavefunctions and probability densities - Simulation of quantum tunneling - Perturbation theory calculations - Angular momentum matrix element calculations - Quantum circuit simulation using Qiskit - Case studies.

Books for Study

1. P. M. Mathews and K. Venkatesan, A Text Book of Quantum Mechanics (Tata McGraw Hill, New Delhi, 1987).
2. G. Aruldas, Quantum Mechanics, 2nd Ed. (PHI Learning Private Limited, New Delhi, 2009)
3. L. Schiff, Quantum Mechanics (Tata McGraw Hill, New Delhi, 1968)
4. S. Rajasekar and R. Velusamy, Quantum Mechanics: The Fundamentals (CRC Press, Boca Raton, 2015)

Books for Reference

1. M.S. Rogalski and B. Palmer, Quantum Mechanics (Gordon & Breach, Amsterdam, 1999).
2. S. Rajasekar and R. Velusamy, Quantum Mechanics: Advanced Topics (CRC Press, Boca Raton, 2015).

Online/Web Resources

1. NPTEL – Quantum Mechanics and Applications (Prof. Ajoy Ghatak, IIT Delhi) - <https://nptel.ac.in/courses/115102023>
2. NPTEL – Quantum Mechanics I (Prof. P. Ramadevi, IIT Bombay) <https://nptel.ac.in/courses/115101107>
3. <http://physics.mq.edu.au/~jcresser/Phys304/Handouts/QuantumPhysicsNotes.pdf>
4. <https://www.wolframalpha.com/examples/science-and-technology/physics/quantum-physics>.
5. <http://quantumphysics.iop.org>.

Course Outcomes

Upon completion of this course students should be able to

1. Recall the postulates, operator formalism, and key equations of quantum mechanics.
2. Explain wavefunction interpretation, commutation relations, uncertainty principle, and spin.
3. Apply Schrödinger equation to harmonic oscillator, hydrogen atom, and barrier tunneling.
4. Analyze systems using perturbation theory, variational method, and angular momentum algebra.
5. Evaluate relativistic quantum mechanics predictions and quantum information protocols.
6. Formulate wavefunctions for identical particles and entangled states.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

CORE COURSE 4

Semester: II

Code:

**THERMAL AND STATISTICAL
PHYSICS
(Theory)**

Credits: 4

Prerequisite: PHY 501 C: Mathematical Physics; PHY 502 C: Classical and Relativistic Mechanics

Objectives

1. Recall the laws of thermodynamics, thermodynamic potentials, phase space, and density of states.
2. Explain the principles of microcanonical, canonical, and grand canonical ensembles and their interrelations.
3. Apply ensemble methods to calculate thermodynamic quantities for ideal gases, blackbody radiation, and Fermi gases.
4. Analyze the thermodynamic behavior of systems using partition functions, density of states, and fluctuation theory.
5. Evaluate the predictions of quantum statistics for Bose-Einstein condensation and degenerate Fermi gases.
6. Formulate partition functions for classical and quantum systems and derive distribution functions.

Unit I: Equilibrium Thermodynamics and Foundations (12 hours)

Thermodynamic potentials - Maxwell's relations - Applications: phase transitions (Clapeyron and Clausius-Clapeyron equations) - Microstates and macrostates - Phase space: μ -space and Γ -space - Density of states in energy and momentum space - Ensemble average and principle of a priori probability - Thermodynamic probability - Boltzmann entropy relation ($S = k \log W$) - Liouville's theorem.

Unit II: Microcanonical Ensemble (10 hours)

Microcanonical distribution and averages - Entropy and $S = k \log W$ - Entropy of a perfect gas - Gibbs paradox and resolution - Sackur-Tetrode equation - Thermodynamic quantities: temperature, pressure, chemical potential.

Unit III: Canonical Ensemble (14 hours)

Canonical distribution and averages - Canonical partition function (Z) - Thermodynamic quantities from Z : internal energy, entropy, Helmholtz free energy, pressure, heat capacity - Maxwell velocity and energy distributions - Most probable velocity and mean kinetic energy - Ideal gas and equipartition theorem - Comparison: microcanonical vs. canonical - Fluctuations and Einstein theory.

Unit IV: Grand Canonical Ensemble (10 hours)

Grand canonical distribution and averages - Grand canonical partition function (Ξ) - Thermodynamic functions: pressure, number density, entropy, Gibbs free energy - Ideal gas in grand canonical ensemble - Density and energy fluctuations - Fluctuation-dissipation theorem - Comparison of ensembles.

Unit V: Quantum Statistics and Phase Transitions (14 hours)

Bosons and fermions - Symmetric and antisymmetric wavefunctions - Bose-Einstein and Fermi-Dirac statistics - Partition functions for bosons and fermions - Derivation of distribution functions - Thermal wavelength - Bose-Einstein

condensation: critical temperature, condensate fraction, thermodynamic properties - Blackbody radiation (photon gas) - Fermi gas at low temperature: Fermi energy, momentum, temperature - Heat capacity of electron gas - Pauli paramagnetism.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Numerical computation of density of states - Simulation of Maxwell-Boltzmann distribution - Calculation of partition functions - Visualization of Bose-Einstein condensation - Fermi energy calculations - Monte Carlo simulation of Ising model - Phase transition simulations.

Primary Textbooks

1. B. K. Agarwal and M. Eisner, Statistical Mechanics, New Age International, New Delhi, 2020.
2. S. L. Kakani and C. Hemrajani, Statistical Mechanics, Viva Books Private Limited, New Delhi, 2017.
3. A. K. Saxena, An Introduction to Thermodynamics and Statistical Mechanics, Alpha Science International, New Delhi, 2010.
4. Satya Prakash, Statistical Mechanics, Kedar Nath Ram Nath, Meerut, 2008.
5. S. Chandra and M. K. Sharma, A Textbook on Statistical Mechanics, CBS Publisher, New Delhi, 2016.
6. S. C. Garg, R. M. Bansal and C. K. Ghosh, Thermal Physics: Kinetic Theory, Thermodynamics and Statistical Mechanics, McGraw Hill, New Delhi, 2013.

Reference Books

1. R. K. Pathria and P. D. Beale, Statistical Mechanics (4th Edition), Academic Press, Cambridge, 2021. (Gold standard)
2. F. Reif, Fundamentals of Statistical and Thermal Physics, Sarat Books, Kolkata, 2010. (Classic)
3. D. A. McQuarrie, Statistical Mechanics, Viva Books India, New Delhi, 2018.
4. K. Huang, Statistical Mechanics (2nd Edition), Wiley, 1987. (Advanced)
5. W. Greiner, L. Neise and H. Stocker, Thermodynamics and Statistical Mechanics, Springer, New York, 2001.

Online Resources

NPTEL Courses (Indian)

1. NPTEL – Statistical Mechanics (Prof. Ashwin Joy, IIT Madras)
2. NPTEL – Thermodynamics: Classical To Statistical (Prof. Sandip Paul, IIT Guwahati) – <https://nptel.ac.in/courses/104103112>
3. NPTEL – Statistical Mechanics (Prof. Girish S. Setlur, IIT Guwahati) – <https://nptel.ac.in/courses/115103113>
4. NPTEL – Statistical Mechanics (Prof. Dipanjan Chakraborty, IISER Mohali) <https://nptel.ac.in/courses/115106126>

International Open Courseware

1. Prof. David Tong, Statistical Physics Lecture Notes, University of Cambridge – <http://www.damtp.cam.ac.uk/user/tong/statphys/sp.pdf> (Verified – excellent free resource)
2. MIT OpenCourseWare – 8.044 Statistical Physics I – <https://ocw.mit.edu/courses/8-044-statistical-physics-i-spring-2013/>

3. MIT OpenCourseWare – 8.333 Statistical Mechanics I – <https://ocw.mit.edu/courses/8-333-statistical-mechanics-i-statistical-mechanics-of-particles-fall-2013/>

Additional Resources

1. Bose-Einstein Condensation – University of Colorado Boulder Notes – Search “BEC lecture notes”
2. Fermi Gas and White Dwarfs – University of Cambridge Astrophysics Notes – Search “Chandrasekhar limit derivation”

YouTube Resources

1. Prof. V. Balakrishnan (NPTEL) – Search “Balakrishnan statistical mechanics”
2. Prof. David Tong – Search “Tong statistical mechanics”
3. Tiberiu Tesileanu – Search “Statistical mechanics explained”

Course Outcomes

At the end of this course, students will be able to:

1. Recall the laws of thermodynamics, thermodynamic potentials, and phase space concepts.
2. Explain the postulates of statistical mechanics, ensemble theory, and Boltzmann entropy relation.
3. Apply ensemble methods to derive thermodynamic properties of ideal gases.
4. Analyze blackbody radiation, Fermi gas, and fluctuations in thermodynamic quantities.
5. Evaluate the conditions for Bose-Einstein condensation and degenerate Fermi gases.
6. Formulate partition functions and distribution functions for physical systems.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution

Year: I

CORE PRACTICAL 2

Semester: II

Code:

**GENERAL PHYSICS AND
ELECTRONICS– I
(Practical)**

Credits: 4

Prerequisite:

Objectives

- Recall advanced physical principles and experimental techniques in mechanics, optics, thermodynamics, and electronics.
- Explain the working principles of sophisticated instruments including spectrometers, interferometers, strain gauges, CROs, and microcontrollers.
- Apply precision measurement techniques to determine physical constants and material properties with high accuracy.
- Analyze experimental data using advanced statistical methods, error propagation, and curve fitting.
- Evaluate experimental uncertainties, systematic errors, and propose improvements to enhance measurement precision.
- Design and execute complex experimental protocols requiring multi-step procedures and data analysis, including microcontroller-based automation.

Section A: General Physics Experiments (Any 8 Experiments)

1. Determination of electronic charge (q), number of elementary charges (n), and specific charge (σ) by elliptical fringes method
2. Determination of Shear Modulus and Damping Coefficient using Torsional Pendulum
3. Determination of bulk modulus of a liquid by ultrasonic wave propagation
4. Study of Nonlinear Dynamics – Period Doubling Bifurcation in a Driven Damped Pendulum
5. BH loop – Energy loss of a magnetic material – Anchor ring using B.G./CRO
6. Measurement of Planck's Constant using LED and Spectrometer (Precision Method)
7. Determination of Charge to Mass Ratio (e/m) of Electron by magnetron method
8. Determination of Rydberg Constant using Hydrogen Spectrum and Spectrometer
9. Determination of Refractive Index Dispersion using Minimum Deviation Method
10. Determination of Forbidden Energy Gap of Semiconductor using Optical Absorption
11. Determination of Stefan-Boltzmann Constant using Electrical Method
12. Determination of Specific Heat Ratio ($\gamma = C_p/C_v$) by Clement-Desormes Method
13. Verification of Stefan-Boltzmann Law
14. Determination of Curie Temperature of Ferroelectric Material (Barium Titanate)
15. Measurement of Thermal Conductivity of a Bad Conductor using Lee's Disc Method
16. Study of P-V-T Relationship for a Real Gas (Boyle's Law Verification)

Section B: Analog Electronics Experiments (Any 4 Experiments)

1. Study of characteristics of LED, photodiode, and phototransistor – Spectral response and I-V characteristics
2. Characteristics of UJT – Relaxation oscillator
3. Characteristics of SCR – V-I characteristics and triggering methods
4. Active Low Pass Filter using Op-Amp – Frequency response and cutoff frequency
5. Study of phase-shift oscillator using Op-Amp – Frequency calculation and waveform analysis
6. Design and study of Schmitt trigger using Op-Amp – Hysteresis loop and trigger levels
7. Study of Schmitt Trigger using IC 7414 – Hysteresis and Trigger Level Measurement
8. Astable and monostable multivibrators using IC 555
9. Study of Voltage Controlled Oscillator (VCO) using IC 555
10. Study of Timer IC 555 as Bistable Multivibrator
11. Design and Study of Wien Bridge Oscillator using Op-Amp
12. Study of Phase Locked Loop (PLL) using IC 565 – Lock range and capture range

Books for Study

1. C. L. Arora, *B.Sc. Practical Physics*, S. Chand & Company, New Delhi.
2. S. L. Gupta and V. Kumar, *Practical Physics*, Pragati Prakashan, Meerut.
3. Harnam Singh, *Advanced Practical Physics*, S. Chand, New Delhi.
4. Worsnop and Flint, *Advanced Practical Physics*, Asia Publishing House.
5. S. P. Singh, *Advanced Practical Physics for Students*, Pragati Prakashan.

Reference Books

1. Ouseph, C.C., Rao, U.J. and Vijayendran, V., *Practical Physics and Electronics*, S. Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai, 2015.
2. Vijayendran, V., *Introduction to Integrated Electronics (Digital and Analog)*, Viswanathan Publishers, Chennai, 2009.
3. K. G. Mazumdar and B. Ghosh, *Advanced Practical Physics*, New Central Book Agency.
4. B. L. Theraja and A. K. Theraja, *A Textbook of Electrical Technology*, S. Chand.
5. A. P. Malvino and D. J. Bates, *Electronic Principles*, McGraw-Hill.
6. R. A. Gayakwad, *Op-Amps and Linear Integrated Circuits*, Pearson.
7. D. Chattopadhyay and P. C. Rakshit, *Electronics Fundamentals and Applications*, New Age International.
8. V. K. Mehta and Rohit Mehta, *Principles of Electronics*, S. Chand.
9. John R. Taylor, *An Introduction to Error Analysis*, University Science Books.
10. A. Beiser, *Concepts of Modern Physics*, McGraw-Hill.
11. D. Halliday, R. Resnick and J. Walker, *Fundamentals of Physics*, Wiley.
12. P. Horowitz and W. Hill, *The Art of Electronics*, Cambridge University Press.

Online/Web Resources

1. NPTEL Physics Laboratory Courses
2. MIT OpenCourseWare Physics Labs
3. All About Circuits Electronics Tutorials

4. Electronics Tutorials
5. HyperPhysics Laboratory Resources

YouTube Resources

1. NPTEL Physics Laboratory
1. Neso Academy – Electronics
2. Physics Practical Videos
3. MIT OpenCourseWare Physics Experiments

Course Outcomes

Upon completion of this course students should be able to

1. Recall the principles of mechanics, optics, thermodynamics, and analog electronics experiments.
2. Explain the operation of spectrometers, ultrasonic instruments, magnetic measurement systems, and electronic devices.
3. Apply experimental techniques to determine physical constants and material properties.
4. Analyze experimental observations using graphical methods, statistical analysis, and error estimation.
5. Evaluate measurement uncertainties and assess the performance of experimental setups.
6. Design and perform experiments involving advanced measurements and analog electronic circuits.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	2	–	1	2	1	1	–
CO2	3	3	2	2	–	2	2	1	1	–
CO3	3	2	3	3	2	2	3	2	2	1
CO4	3	3	3	3	2	2	3	3	2	1
CO5	3	3	3	3	2	3	3	3	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Code:	1. MICROPROCESSOR ARCHITECTURES AND MICROCONTROLLER SYSTEMS (Theory)	Credits: 4
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Unit IV: 8051 Instruction Set and Assembly Programming (12 hours)

Addressing Modes: Immediate, register, direct, indirect, indexed. Instruction Set: Data Transfer (MOV, MOVX, MOVC, PUSH, POP, XCH) – Arithmetic (ADD, ADDC, SUBB, INC, DEC, MUL, DIV, DA) – Logical (ANL, ORL, XRL, Rotate, SWAP, Bit operations) – Branch (LJMP, AJMP, SJMP, JZ, JNZ, CJNE, DJNZ, CALL, RET). Programming Examples: Time delay generation using timers – Block transfer – Code conversion – Sorting – Square wave generation.

Unit V: 8051 Interrupts and Advanced Interfacing (12 hours)

Interrupt vector table – Enabling and disabling interrupts (IE register) – Interrupt priority (IP register) – Timer interrupts (TF0, TF1) – External hardware interrupts (INT0, INT1) – Serial communication interrupts (RI, TI) – Nested interrupts. Seven-segment display (multiplexed) – LCD (16x2) interface – ADC0804 and DAC0808 interface – Stepper motor interface – Sensor interfacing (temperature LM35, pressure, humidity) – PWM generation. Digital thermometer – Frequency counter – Waveform generator – DC motor speed control.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Assembly language programming practice using 8085 simulator – Development of 8051 programs using Keil IDE and EDSim51 simulator – Interfacing simulation of 8255 PPI with 8085 – ADC and DAC interfacing simulation – 8051 timer programming for waveform generation – LCD and seven-segment display interfacing using 8051 – Stepper motor control using 8051 – Mini-project: Design of digital thermometer or frequency counter using 8051 microcontroller – Comparative study of 8085 and 8051 architectures for specific applications.

Books for Study

1. Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications with 8085 (6th Edition), Penram International Publishing, 2013.
2. A. Nagoor Kani, Microprocessors & Microcontrollers, RBA Publications, 2009.
3. B. Ram, Fundamentals of Microprocessors & Microcontrollers, Dhanpat Rai Publications, New Delhi, 2016.
4. Muhammad Ali Mazidi, Janice Gillispie Mazidi, and Rolin D. McKinlay, The 8051 Microcontroller and Embedded Systems (2nd Edition), Pearson Education, 2008.
5. V. Vijayendran, *Fundamentals of Microprocessor-8085* (3rd Edition), S. Viswanathan Pvt. Ltd., 2005.

Text Books

1. Douglas V. Hall, Microprocessors and Interfacing: Programming and Hardware (2nd Edition), Tata McGraw Hill, 2008.
2. Kenneth J. Ayala, The 8051 Microcontroller: Architecture, Programming and Applications (3rd Edition), Cengage Learning, 2004.
3. A. P. Godse and D. A. Godse, Microprocessors, Technical Publications, Pune, 2009.
4. Barry B. Brey, The Intel Microprocessors: 8086/8088, 80186, 80286, 80386 and 80486 (3rd Edition), Prentice-Hall of India, New Delhi, 1995.

5. J. Uffrenbeck, The 8086/8088 Family: Design, Programming and Interfacing, Prentice-Hall of India, New Delhi.

Online Resources

1. NPTEL - *Microprocessors and Microcontrollers* (Prof. Santanu Chattopadhyay, IIT Kharagpur) <https://nptel.ac.in/courses/108105102>
2. NPTEL - *Embedded Systems* *Embedded Systems*, (Prof. Santanu Chaudhary, IIT Delhi) <https://nptel.ac.in/courses/108102045>

Simulators and Tools

1. 8085 Simulator (Jubin Mitra) - <https://learning-microprocessors.sourceforge.io/8085-simulator.html>
2. 8051 Simulator (EDSim51) - <http://www.edsim51.com>
3. Keil uVision IDE - <https://www.keil.com/product/brochures/uv4.pdf>
4. Intel 8051 Official Datasheet

Course Outcomes

Upon completion of this course students should be able to

1. Recall the architecture, pin functions, and register organization of 8085 and 8051.
2. Explain addressing modes, interrupt handling, memory interfacing, and data transfer schemes.
3. Apply assembly language programming to write, debug, and execute programs on 8085 and 8051.
4. Analyze the interfacing of ADC, DAC, stepper motor, sensors, and displays with MP/MC.
5. Evaluate the performance and suitability of 8085/8051 for specific embedded applications.
6. Design a complete embedded system (e.g., digital thermometer, frequency counter) using 8051.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I DISCIPLINE CENTRIC ELECTIVE COURSE 2 Semester: II

Code: 2. EMBEDDED SYSTEMS AND ARTIFICIAL INTELLIGENCE Credits: 4

(Theory)

Prerequisite: --

Objectives

1. Recall the architecture and components of modern embedded systems including microcontrollers, sensors, actuators, and communication interfaces.
2. Explain the principles of embedded programming, real-time operation, and intelligent sensing systems.
3. Apply programming techniques to interface sensors, actuators, and wireless communication modules.
4. Analyze embedded systems in terms of timing performance, memory utilization, power consumption, and reliability.
5. Evaluate machine learning approaches suitable for resource-constrained embedded devices.
6. Design and implement embedded AI solutions for real-world applications.

Unit I: Modern Embedded Systems Architecture (10 hours)

Embedded Systems: Embedded systems: definition, characteristics, and applications - Design constraints: power, cost, size, reliability, real-time operation - Modern embedded platforms: ARM Cortex-M, ESP32, Arduino, Raspberry Pi Pico - Architecture: CPU, memory, GPIO, timers, ADC, communication peripherals - Development environments: Arduino IDE, PlatformIO, ESP-IDF - Embedded system design workflow.

Unit II: Sensors, Actuators, and Communication Protocols (10 hours)

Sensors: temperature, light, humidity, gas, motion, ultrasonic, inertial - Sensor calibration and signal conditioning - Actuators: LEDs, buzzers, relays, DC motors, servo motors - Communication interfaces: UART, I2C, SPI - Interfacing displays, RTC, and sensor modules - Wireless communication: WiFi, Bluetooth Low Energy (BLE), MQTT - LoRa communication - Smart sensing and data acquisition applications.

Unit III: Embedded Programming and Real-Time Operating Systems (14 hours)

Embedded C/C++ fundamentals: digital I/O, bit manipulation, timers, interrupts, PWM, ADC - MicroPython programming - Real-time systems: task scheduling, timing constraints - FreeRTOS fundamentals: tasks, queues, semaphores, inter-task communication - Debugging and performance analysis: serial debugging, memory usage, power optimization.

Unit IV: Introduction to Artificial Intelligence and Machine Learning (12 hours)

AI and ML overview: supervised and unsupervised learning, classification and regression - Data handling: sensor data collection, preprocessing, feature extraction - Training, validation, and testing datasets - Neural networks:

perceptron, multi-layer networks, activation functions - Model evaluation: accuracy, precision, recall, overfitting, underfitting - ML tools: TensorFlow, Scikit-Learn, Edge Impulse.

Unit V: Edge AI and TinyML (14 hours)

Cloud vs. edge computing: benefits of local AI inference - TinyML fundamentals: running ML models on microcontrollers - TensorFlow Lite Micro and Edge Impulse - Model deployment: conversion, quantization, memory constraints - Performance optimization: inference time, memory footprint, energy efficiency - Applications: environmental monitoring, gesture recognition, voice commands, predictive maintenance, smart instrumentation.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Emerging developments in Edge AI, TinyML, and Industrial IoT - Hands-on exercises on sensor interfacing, FreeRTOS, and TinyML deployment - Mini-project: Design and deploy an end-to-end embedded AI system.

Text Books

1. Trevor Martin, The Designer's Guide to the Cortex-M Processor Family (2nd Edition), Newnes, 2016.
2. Jacob Beningo, Reusable Firmware Development: A Practical Approach to APIs, HALs and Drivers, Apress, 2017.
3. Pete Warden and Daniel Situnayake, TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers, O'Reilly Media, 2019.
4. Shawn Hymel and Hackster.io, TinyML Cookbook: Combine artificial intelligence and ultra-low-power embedded devices, Packt Publishing, 2022.
5. David T. Smith, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C (4th Edition), E-Man Press, 2021.

Reference Books

1. Jean J. Labrosse, MicroC/OS-II: The Real-Time Kernel, CRC Press, 2002.
2. Joseph Yiu, *The Definitive Guide to ARM Cortex-M3 and Cortex-M4 Processors* (3rd Edition), Newnes, 2013.
3. Neil Cameron, ESP32 Formats and Communication: The Internet of Things, Elektor International Media, 2022.
4. Francois Chollet, Deep Learning with Python (2nd Edition), Manning Publications, 2021.
5. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow (3rd Edition), O'Reilly Media, 2022
6. K. V. K. K. Prasad, Embedded/Real-Time Systems: Concepts, Design and Programming (2nd Edition), Dreamtech Press, 2017.

Online Resources

1. Prof. Santanu Chaudhary, Embedded Systems, IIT Delhi – <https://nptel.ac.in/courses/108102045>
2. Prof. Anupam Basu, Embedded Systems, IIT Kharagpur – <https://nptel.ac.in/courses/106105159>

3. Prof. Sudip Misra, Introduction to Internet of Things, IIT Kharagpur – <https://nptel.ac.in/courses/106105166>
4. Prof. Balaraman Ravindran, Introduction to Machine Learning, IIT Madras – <https://nptel.ac.in/courses/106106139>
5. Harvard CS50's Introduction to Artificial Intelligence with Python – <https://cs50.harvard.edu/ai/>
6. Fast.ai – Practical Deep Learning for Coders – <https://course.fast.ai/>
7. LiteRT for Microcontrollers – <https://www.tensorflow.org/lite/microcontrollers>
8. Wokwi (ESP32, Arduino, Raspberry Pi Pico Simulator) – <https://wokwi.com>
9. Tinkercad (Arduino Simulator) – <https://www.tinkercad.com/circuits>
10. ESP32 Official Documentation – <https://docs.espressif.com/projects/esp-idf/>
11. Arduino Reference – <https://www.arduino.cc/reference/en/>
12. FreeRTOS – <https://www.freertos.org>

Course Outcomes

Upon completion of this course students should be able to:

1. Describe the architecture and operation of modern embedded platforms, sensors, and communication interfaces.
2. Explain the principles of embedded programming, real-time systems, and intelligent sensing.
3. Develop embedded applications using C/C++ or MicroPython for sensor interfacing and communication.
4. Analyze embedded systems with respect to timing, memory, power, and reliability.
5. Evaluate machine learning techniques for resource-constrained embedded devices.
6. Design and implement an embedded AI solution for real-world applications.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

GENERIC ELECTIVE COURSE 2

Semester: II

Code:

**1. CLEAN ENERGY TECHNOLOGY
(Theory)**

Credits: 3

Prerequisite: --

Objectives

- Recall the fundamental concepts of electrochemistry, thermodynamics of electrochemical cells, and polarization losses.
- Explain the working principles of solar cells, fuel cells, electrolyzers, and energy storage devices.
- Apply the principles of photovoltaic conversion, fuel cell operation, and water splitting to real-world energy systems.
- Analyze the performance characteristics of different energy conversion devices.
- Evaluate the suitability of different clean energy technologies for specific applications.
- Design a simple energy system combining harvesting, conversion, and storage components.

Unit I: Fundamentals of Electrochemistry and Energy Systems (10 hours)

Electrochemical cell and Faraday's laws - Electrode potentials and standard hydrogen electrode - Nernst equation - Thermodynamics of electrochemical cells - Polarization losses: activation, concentration, ohmic - Tafel equation - Butler-Volmer equation.

Unit II: Solar Photovoltaics (10 hours)

Photovoltaic effect and solar spectrum - p-n junction solar cell: working, I-V characteristics, fill factor, efficiency - Equivalent circuit and loss mechanisms - Types: crystalline silicon, thin-film (CdTe, CIGS, a-Si), DSSC, perovskite - Tandem and multi-junction devices - Current status and trends.

Unit III: Fuel Cells (10 hours)

Fuel cells vs. batteries - Operating principle and thermodynamics - Reversible voltage and efficiency - Polarization losses and I-V characteristics - Types: PEMFC, PAFC, DMFC, AFC, MCFC, SOFC - Applications: portable, stationary, automotive - Hydrogen as energy carrier: production, storage, safety.

Unit IV: Hydrogen Energy and Water Splitting (9 hours)

Water electrolysis: alkaline, PEM, solid oxide - Types of hydrogen: grey, blue, green - Artificial photosynthesis - Electrocatalytic water splitting: OER and HER - Photoelectrochemical cells: principle, photoelectrodes, band alignment - Current challenges.

Unit V: Energy Storage Systems (9 hours)

Supercapacitors: EDLCs and pseudocapacitors - Batteries: primary vs. secondary - Li-ion battery: working, cathode/anode materials, electrolytes - Charging/discharging characteristics, capacity, C-rate, cycle life - Solid-state, Li-S, Na-ion, and redox flow batteries - Future trends.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of I-V characteristics of solar cells and fuel cells - Nernst equation calculations - Analysis of polarization losses - Design of solar-powered system with battery storage - Comparative analysis of battery technologies - Study of hydrogen production methods.

Primary Textbooks

1. Allen J. Bard and Larry R. Faulkner, *Electrochemical Methods: Fundamentals and Applications* (2nd Edition), John Wiley & Sons, 2004.
2. J. Larminie and A. Dicks, *Fuel Cell Systems Explained* (2nd Edition), John Wiley, 2003.
3. Tetsuo Soga, *Nanostructured Materials for Solar Energy Conversion*, Elsevier Science, 2006.

Reference Books

1. D. Linden and T. B. Reddy, *Handbook of Batteries* (4th Edition), McGraw-Hill, 2010.
2. M. S. Whittingham and A. J. Jacobson, *Intercalation Chemistry*, Academic Press, 1982.
3. G. A. Nazri and G. Pistoia, *Lithium Batteries: Science and Technology*, Kulwer Academic Publishers, 2004.
4. M. Wakihara and O. Yamamoto, *Lithium Ion Batteries: Fundamentals and Performance*, Wiley-VCH, 1996.

Online Resources

1. NPTEL – *Solar Photovoltaics: Principles, Technologies and Materials* (Prof. Ashish Garg, IIT Kanpur) <https://nptel.ac.in/courses/113104084>
2. NPTEL – *Fuel Cell Technology* (Dr. Anil Verma, Prof. S. Basu, IIT Delhi) <https://nptel.ac.in/courses/103102015>
3. NPTEL – *Electrochemical Energy Storage* (Prof. Subhasish Basu Majumder, IIT Kharagpur) <https://nptel.ac.in/courses/113105102>

Course Outcomes

Upon completion of this course students should be able to

1. Recall the fundamental concepts of electrochemical cells, thermodynamics, and polarization losses.
2. Explain the working principles of solar cells, fuel cells, and energy storage devices.
3. Apply photovoltaic conversion and water splitting principles to design energy systems.
4. Analyze I-V characteristics, efficiency, capacity, and cycle life of energy devices.
5. Evaluate the environmental and economic viability of clean energy technologies.
6. Design a small-scale clean energy system for a specific application.

Mapping Matrix: CO–PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

GENERIC ELECTIVE COURSE 2

Semester: II

Code:

**2. ADVANCED MATERIALS
(Theory)**

Credits: 3

Prerequisite: --

Objectives

1. Recall the classification, properties, and applications of advanced functional materials.
2. Explain the structure-property relationships in 2D materials, quantum dots, perovskites, and metamaterials.
3. Apply the principles of quantum confinement, topological order, and electromagnetic metamaterials to device design.
4. Analyze the performance of advanced materials in electronics, photonics, and energy devices.
5. Evaluate the suitability of different advanced materials for specific technological applications.
6. Design a conceptual device using advanced materials for a given application.

Unit I: Two-Dimensional (2D) Materials (10 hours)

Classification of 2D materials: graphene, TMDs, h-BN, MXenes, phosphorene - van der Waals heterostructures - Graphene: structure, electronic band structure, properties, synthesis, characterization, applications - TMDs: structure, indirect-to-direct bandgap transition, valleytronics, applications - Other 2D materials: h-BN, MXenes, phosphorene, silicene.

Unit II: Quantum Dots and Nanocrystals (9 hours)

Quantum size effect and tunable bandgap - 0D, 1D, and 2D confinement - Colloidal quantum dots: synthesis, core-shell structures, photoluminescence, applications - Perovskite quantum dots: structure, tunable emission, stability, applications - Quantum rods, wells, wires, and superlattices.

Unit III: Metamaterials and Plasmonics (10 hours)

Definition and history - Left-handed materials and negative refractive index - Split-ring resonators - Permittivity and permeability models - Cloaking and transformation optics - Surface plasmons and localized surface plasmon resonance - Applications: SERS, plasmonic sensing, perfect lenses - Metasurfaces and flat optics.

Unit IV: Topological Materials and Spintronics (9 hours)

Quantum Hall and Quantum Spin Hall effects - Topological insulators: edge states, Dirac cone, applications - Spintronics: spin injection, GMR, TMR, spin-transfer torque - MRAM and magnetic sensors - Weyl semimetals, Dirac semimetals, Majorana fermions - Topological quantum computing.

Unit V: Functional and Emerging Materials (10 hours)

Thermoelectric materials: Seebeck coefficient, figure of merit ZT, applications - Multiferroics and magnetoelectrics: coupling, applications - High-entropy alloys: core effects, properties, applications - MXenes and MAX phases: structure,

properties, applications - Future materials: MOFs, COFs, materials for quantum technologies.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of electronic band structure of graphene and TMDs - Calculation of quantum confinement effects - Simulation of metamaterial properties - Analysis of topological insulator surface states - Design of photodetector using 2D materials - Comparative analysis of thermoelectric materials.

Primary Textbooks

1. Mark J. Mehl, *Introduction to 2D Materials*, Cambridge University Press, 2020.
2. Victor I. Klimov, *Nanocrystal Quantum Dots* (2nd Edition), CRC Press, 2010.
3. N. Engheta and R. W. Ziolkowski, *Metamaterials: Physics and Engineering Explorations*, Wiley-IEEE Press, 2006.
4. John H. Davies, *The Physics of Low-Dimensional Semiconductors*, Cambridge University Press, 1998.

Reference Books

1. A. H. Castro Neto, *Graphene: Fundamentals and Emergent Applications*, Elsevier, 2012.
2. S. Maekawa, *Concepts in Spin Electronics*, Oxford University Press, 2006.
3. Y. S. Hor, *Topological Insulators: Fundamentals and Perspectives*, Springer, 2015.
4. B. S. Murty, *High-Entropy Alloys*, Elsevier, 2014.
5. J. M. D. Coey, *Magnetism and Magnetic Materials*, Cambridge University Press, 2010.

Online Resources

1. NPTEL – *Plasmonics and Metamaterials* – Search “NPTEL plasmonics”
2. NPTEL – *Quantum Dots for Energy Applications* – Search “NPTEL quantum dots”
3. NanoHub – Online simulations for 2D materials and plasmonics – <https://nanohub.org>

Course Outcomes

Upon completion of this course students should be able to

1. Recall the classification, synthesis, and properties of 2D materials, quantum dots, and metamaterials.
2. Explain quantum confinement, Dirac cone, topological protection, and negative refractive index.
3. Apply principles of advanced materials to design simple devices.
4. Analyze electronic, optical, and magnetic properties using band structure and electromagnetic theory.
5. Evaluate performance of advanced materials for specific applications.
6. Design a conceptual advanced material-based device with appropriate material selection.

Mapping Matrix: CO–PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

GENERIC ELECTIVE COURSE 2

Semester: II

Code:

**3. POLYMER AND BIO MATERIALS
(Theory)**

Credits: 3

Prerequisite: --

Objectives

1. Recall the classification, synthesis, and characterization methods for polymers and biomaterials.
2. Explain the structure-property relationships in polymers, biopolymers, hydrogels, and biocompatible materials.
3. Apply the principles of polymer physics and bio-interactions to design materials for medical applications.
4. Analyze the mechanical, thermal, and degradation properties of polymers and biomaterials.
5. Evaluate the biocompatibility and suitability of biomaterials for specific medical applications.
6. Design a conceptual biomaterial-based device for a given medical application.

Unit I: Fundamentals of Polymer Science (10 hours)

Classification of polymers - Polymerization: step-growth vs. chain-growth, addition vs. condensation - Degree of polymerization and molecular weight - Polymer architecture: linear, branched, crosslinked - Tacticity and crystallinity - Glass transition and melting temperatures - Characterization: GPC, viscometry, DSC, TGA, FTIR, NMR.

Unit II: Polymer Physics and Properties (9 hours)

Flory-Huggins theory - Polymer chain conformations - Mechanical properties: stress-strain behavior, modulus, toughness - Viscoelasticity, creep, stress relaxation - Time-temperature superposition - Polymer composites - Conductive polymers and applications.

Unit III: Biopolymers and Natural Materials (9 hours)

Polysaccharides: cellulose, chitin, starch, alginate - Proteins: collagen, gelatin, silk fibroin - Nucleic acids: DNA, RNA - Biodegradable polymers: PLA, PGA, PLGA, PCL - Degradation mechanisms - Electrospinning and 3D printing of biopolymers.

Unit IV: Biomaterials for Medical Applications (10 hours)

Generations of biomaterials - Host response and biocompatibility - Metallic biomaterials: stainless steel, titanium, biodegradable metals - Ceramic biomaterials: alumina, zirconia, hydroxyapatite, bioactive glasses - Polymeric biomaterials: PMMA, silicone, UHMWPE, polyurethane, PEEK - Applications.

Unit V: Hydrogels, Drug Delivery, and Tissue Engineering (10 hours)

Hydrogels: classification, swelling, stimuli-responsive - Drug delivery systems: controlled release, encapsulation, targeted delivery - Tissue engineering: scaffold design, cell sources, growth factors - Bioprinting principles and bioinks - Regulatory and ethical aspects.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Analysis of polymer structure-property relationships - Simulation of polymer chain conformations - Design of drug delivery system - Analysis of degradation profiles - Literature review on emerging biomaterials - Design of tissue engineering scaffold.

Primary Textbooks:

1. L. H. Sperling, *Introduction to Physical Polymer Science* (5th Edition), John Wiley & Sons, 2015.
2. B. D. Ratner, A. S. Hoffman, F. J. Schoen, and J. E. Lemons, *Biomaterials Science: An Introduction to Materials in Medicine* (4th Edition), Elsevier, 2020.
3. S. A. Ranganathan, *Polymer Chemistry*, Pragati Prakashan, 2018.

Reference Books:

1. J. R. Fried, *Polymer Science and Technology* (3rd Edition), Prentice Hall, 2014.
2. D. W. van Krevelen and K. te Nijenhuis, *Properties of Polymers* (4th Edition), Elsevier, 2009.
3. R. Langer and N. A. Peppas, *Advances in Drug Delivery*, Pergamon Press, 2012.
4. C. T. Laurencin and L. S. Nair, *Nanotechnology and Tissue Engineering*, CRC Press, 2008.

Online Resources:

1. NPTEL – *Polymer Science and Technology* – Search “NPTEL polymer science”
2. NPTEL – *Introduction to Biomaterials* – Search “NPTEL biomaterials”
3. NPTEL – *Tissue Engineering* – Search “NPTEL tissue engineering”

Course Outcomes

Upon completion of this course students should be able to

1. Recall the classification of polymers, polymerization methods, and biomaterials.
2. Explain structure-property relationships, viscoelasticity, and degradation mechanisms.
3. Apply polymer physics principles to analyze mechanical behavior and properties.
4. Analyze interactions between biomaterials and biological systems.
5. Evaluate biocompatibility and performance of biomaterials for medical applications.
6. Design a simple biomaterial-based device for a given medical application.

Mapping Matrix: CO–PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

SKILL ENHANCEMENT COURSE 2

Semester: II

Code:

**MACHINE LEARNING TECHNIQUES IN
PHYSICS
(Theory)**

Credits: 2

Prerequisite: --

Objectives

1. Recall the fundamental concepts of supervised, unsupervised, and reinforcement learning, and Python ML libraries.
2. Explain the principles of regression, classification, neural networks, and model evaluation.
3. Apply scikit-learn to implement ML algorithms on physics datasets.
4. Analyze model performance using confusion matrices, ROC curves, cross-validation, and learning curves.
5. Evaluate and select appropriate ML algorithms for different physics problems.
6. Design and implement neural network models using TensorFlow/Keras for physics applications.

Unit I: Foundations of Machine Learning and Data Preprocessing (8 hours)

ML fundamentals: supervised, unsupervised, reinforcement learning - Features, labels, training, test, validation sets - Bias-variance tradeoff, underfitting, overfitting, regularization (L1, L2) - Cross-validation - Data preprocessing: handling missing data, feature scaling, encoding categorical variables - Statistical foundations: probability distributions, correlation, covariance.

Unit II: Regression and Classification (7 hours)

Linear regression: cost function, gradient descent, polynomial regression, regularization - Logistic regression: sigmoid function, decision boundary, multi-class classification - Evaluation metrics: accuracy, precision, recall, F1-score, ROC curve, AUC - Other methods: k-NN, decision trees, random forests, SVM - Applications in physics: particle identification, signal/background classification.

Unit III: Unsupervised Learning and Dimensionality Reduction (7 hours)

k-means clustering, elbow method, silhouette analysis - Hierarchical clustering, DBSCAN - Applications: particle track clustering, event categorization - Curse of dimensionality - PCA and t-SNE - Applications: data compression, visualization of high-dimensional detector data.

Unit IV: Neural Networks and Deep Learning (7 hours)

Perceptron and activation functions - Multi-layer perceptron: forward propagation, backpropagation, optimization algorithms - Deep learning: dropout, batch normalization, hyperparameter tuning - Convolutional Neural Networks: convolution, pooling layers, architectures - Transfer learning.

Unit V: Advanced Topics and Physics Applications (7 hours)

Autoencoders and anomaly detection - Variational Autoencoders - Physics-informed machine learning - Graph Neural Networks for particle physics -

Transformers in physics - Applications: track reconstruction, jet tagging, surrogate modeling.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Data preprocessing and exploratory data analysis - Implementation of regression and classification models - Hyperparameter tuning - Clustering and PCA implementation - Building and training neural networks - Final project: Apply ML to real physics dataset (particle identification, galaxy classification, signal/background classification).

Primary Textbooks

1. Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow (3rd Edition), O'Reilly Media, 2022.
2. Pankaj Mehta et al., A High-Bias, Low-Variance Introduction to Machine Learning for Physicists, Physics Reports, 2019 (free PDF available).
3. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.
4. G. Carleo et al., Machine Learning and the Physical Sciences, Reviews of Modern Physics, **91**, 045002 (2019).
5. Goodfellow, Y. Bengio, and A. Courville, Deep Learning, MIT Press, 2016.
6. E. Alpaydin, Introduction to Machine Learning (4th Edition), MIT Press, 2020

Online Resources

NPTEL Courses (Indian)

1. Prof. Balaraman Ravindran, Introduction to Machine Learning, IIT Madras
2. Prof. Sudeshna Sarkar, Machine Learning for Data Science, IIT Kharagpur

International Open Courseware

1. MIT OpenCourseWare – 6.036 Introduction to Machine Learning

Free Online Resources

1. Scikit-learn Documentation – <https://scikit-learn.org/stable/>
2. TensorFlow Tutorials – <https://www.tensorflow.org/tutorials>
3. PyTorch Tutorials – <https://pytorch.org/tutorials/>
4. Kaggle – Datasets and competitions – <https://www.kaggle.com>
5. Google Colab – Free GPU notebooks – <https://colab.research.google.com>

Physics-Specific ML Resources

1. ML for Particle Physics – <https://ml4physics.org>
2. HEP ML Community – <https://iml.web.cern.ch>

YouTube Resources

1. Prof. Andrew Ng – Search “Andrew Ng machine learning”
2. StatQuest with Josh Starmer – Search “StatQuest machine learning”
3. 3Blue1Brown – Neural networks series – Search “3Blue1Brown neural networks”

Course Outcomes

Upon completion of this course students should be able to

1. Recall ML concepts and Python ML libraries.
2. Explain regression, classification, gradient descent, backpropagation, and regularization.
3. Apply scikit-learn to implement ML algorithms on physics datasets.
4. Analyze model performance using validation, confusion matrices, and ROC curves.
5. Evaluate neural network architectures for specific physics problems.
6. Design and train a neural network using TensorFlow/PyTorch.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	3	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

NON-MAJOR ELECTIVE COURSE 1

Semester: II

Code:

**1. PHYSICS IN EVERYDAY LIFE
(Theory)**

Credits: 2

Prerequisite: --

Objectives

1. Recall the basic physical principles behind common everyday phenomena.
2. Explain the physics behind household appliances, transportation, sports, and natural phenomena.
3. Apply physical reasoning to understand safety practices and efficient use of technology.
4. Analyze common myths and misconceptions using basic physical principles.
5. Evaluate the role of physics in modern life and technology.
6. Create simple demonstrations to explain physical phenomena to non-scientific audiences.

Unit I: Physics at Home (6 hours)

Refrigerator: heat transfer and cooling - Microwave oven: heating mechanism - Pressure cooker: boiling point and pressure - Induction cooktop: electromagnetic heating - Light bulbs: LED vs. CFL vs. incandescent - Television: LCD, LED, OLED principles - Sound systems: speaker operation - Remote control: infrared signals - Air conditioner and fan: cooling mechanisms - Water heater: electric heating - Soap and surface tension: cleaning action.

Unit II: Physics on the Move (6 hours)

Car engine: four-stroke cycle - Brakes: hydraulic principle - Seat belts and airbags: inertia and safety - Tyres: friction and traction - Gears: mechanical advantage - Bicycle stability: gyroscopic effect - Electric trains: working principle - Aeroplane: lift, thrust, drag, weight, Bernoulli's principle - Ship: buoyancy and Archimedes principle.

Unit III: Physics in Sports and Entertainment (4 hours)

Cricket: swing bowling (Bernoulli's principle) - Tennis: topspin and slice - Football: curve ball (Magnus effect) - Swimming: drag and buoyancy - Skiing and skating: friction and pressure - Cinema: persistence of vision - 3D movies: polarization - Music instruments: string, wind, percussion - Acoustics: echo and reverberation.

Unit IV: Physics in Nature (4 hours)

Sky color: Rayleigh scattering - Sunsets: scattering of light - Rainbows: dispersion and total internal reflection - Lightning: charge separation and discharge - Thunder: speed of sound vs. light - Clouds: condensation and adiabatic cooling - Rain and water cycle - Seasons: Earth's tilt - Day and night: Earth's rotation - Tides: gravitational pull - Earthquakes: seismic waves.

Unit V: Physics Myths and Misconceptions (4 hours)

Scientific reasoning behind common myths: coin dropped from building, mobile phone at petrol pump, falling cat, duck's quack, cell phones and cancer, standing

under tree during lightning, surviving fall by jumping, mirrors reversing left and right, stars twinkling vs. planets.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simple demonstrations of everyday physics - Analysis of common phenomena - Myth busting using physics - Creating awareness content

Primary Textbook (Simple and Accessible):

1. Louis A. Bloomfield, *How Things Work: The Physics of Everyday Life* (6th Edition), Wiley, 2015. (Available in Indian edition)

Suggested Reading (Indian Context):

2. V. K. Sally, *Physics in Daily Life*, Pustak Mahal, 2009. (Simple, affordable, Indian context)

Reference Books (Optional)

3. Richard Feynman, *Six Easy Pieces: Essentials of Physics Explained by Its Most Brilliant Teacher*, Basic Books, 2011.
4. Jearl Walker, *The Flying Circus of Physics* (2nd Edition), Wiley, 2006.

Free Online Resources (Accessible to All)

1. Veritasium (YouTube) – Physics of everyday life – <https://www.youtube.com/user/1veritasium>
2. MinutePhysics (YouTube) – Short animated physics explanations – <https://www.youtube.com/user/minutephysics>
3. Physics Girl (YouTube) – Everyday physics demonstrations – <https://www.youtube.com/c/physicsgirl>
4. Khan Academy – Physics Library – <https://www.khanacademy.org/science/physics>
5. PhET Interactive Simulations – University of Colorado – <https://phet.colorado.edu> (Free simulations)

Course Outcomes

Upon completion of this course students should able to:

1. Recall physical principles such as pressure, buoyancy, friction, electricity, magnetism, and optics in everyday contexts.
2. Explain how common appliances work using basic physics.
3. Apply principles of heat transfer, sound, and light to daily activities.
4. Analyze safety practices using physics reasoning.
5. Evaluate the impact of physics on modern life, entertainment, and transportation.
6. Create simple demonstrations to explain everyday physics to others..

Create simple demonstrations to explain everyday physics to others.CO-PO

Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

NON-MAJOR ELECTIVE COURSE 1

Semester: II

Code:

**2. ENERGY FOR SUSTAINABLE
LIVING
(Theory)**

Credits: 2

Prerequisite: --

Objectives

1. Recall the basic concepts of energy, its forms, sources, and units of measurement.
2. Explain the difference between renewable and non-renewable energy sources.
3. Apply energy conservation principles to daily life activities and household energy use.
4. Analyze personal and household energy consumption patterns.
5. Evaluate the environmental impact of different energy sources.
6. Design a simple energy conservation plan for home or institution.

Unit I: What is Energy? (6 hours)

Different forms of energy: kinetic, potential, thermal, electrical, chemical, nuclear, light, sound - Energy transformation in daily life - Law of conservation of energy - Units: Joule, calorie, kilowatt-hour - Energy and power difference - Power ratings of appliances - Human energy: calories and food - Energy in transportation, cooking, and heating.

Unit II: Energy Sources (6 hours)

Coal: formation, mining, power plants - Oil and petroleum: extraction, refining, products - Natural gas: uses and advantages - Firewood and biomass: traditional uses - Environmental problems: pollution, greenhouse gases, climate change - Solar energy: solar panels and water heaters - Wind energy: wind turbines - Hydropower: dams and run-of-river - Geothermal, tidal, wave energy - Biomass and biogas - Nuclear energy: fission, pros and cons, safety, waste - Fusion: energy of the sun.

Unit III: Energy at Home (4 hours)

Reading electricity bill - Energy consumption of common appliances - Standby power (vampire power) - Tips to save electricity - Energy-efficient appliances and BEE star ratings - Insulation, natural lighting, solar water heaters - Reducing fuel consumption in vehicles - Passive solar design and natural ventilation - Rainwater harvesting.

Unit IV: Energy and Environment (4 hours)

Air pollution from fossil fuels: smog and acid rain - Greenhouse effect and global warming - Carbon footprint: calculation and reduction - Ozone layer depletion - Energy security for India - Energy poverty and access to electricity - Role of renewable energy - National Solar Mission - Electric vehicles: benefits and challenges - Energy storage: batteries and pumped hydro - Future energy scenarios.

Unit V: Action for Sustainability (4 hours)

Individual actions: reducing electricity, LED bulbs, unplugging devices, public transport, reduce-reuse-recycle, composting, tree planting - Community actions: energy audits, solar panels, rainwater harvesting, biogas plants, awareness campaigns - Global actions: Paris Agreement, India's commitments, Sustainable Development Goals (SDG 7, SDG 13) - Role of youth.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Calculating personal/household energy consumption - Conducting simple energy audit - Comparing electricity bills - Researching renewable energy projects - Creating awareness posters - Case study: Solar-powered community project.

Primary Textbook (Simple and Accessible):

1. Richard A. Dunlap, *Sustainable Energy* (2nd Edition), Cengage Learning, 2019. (Indian edition available)

Suggested Reading (Indian Context):

2. Ministry of New and Renewable Energy (MNRE), *Renewable Energy in India: A Handbook*, Free PDF available at <https://mnre.gov.in>

Free Online Resources:

3. David J. C. MacKay, *Sustainable Energy – Without the Hot Air* – Free PDF – <https://www.withouthotair.com>
4. Our World in Data – Energy – <https://ourworldindata.org/energy> (Simple graphs and explanations)
5. NPTEL – Sustainable Energy Technology – Prof. Sayak Banerjee, IIT Hyderabad – <https://nptel.ac.in/courses/112106318>
6. International Energy Agency (IEA) – Energy explained – <https://www.iea.org> (Simple language)
7. Bureau of Energy Efficiency (BEE), India – Star rating information – <https://beeindia.gov.in>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall different forms of energy and their units.
2. Explain how various energy sources are used to generate electricity.
3. Apply energy conservation principles to reduce electricity and fuel bills.
4. Analyze the energy consumption of common household appliances.
5. Evaluate the environmental consequences of fossil fuel use.
6. Design a simple energy conservation plan for home or college.

Mapping Matrix: CO-PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I	NON-MAJOR ELECTIVE COURSE 1	Semester: II
Code:	3. ENERGY, ENVIRONMENT, AND SOCIETY (Theory)	Credits: 2

Prerequisite: --

Objectives

1. Recall the relationship between energy use, environmental impact, and social development.
2. Explain the global energy scenario and India's energy challenges.
3. Apply the concepts of environmental economics to evaluate energy policies.
4. Analyze the social and economic consequences of energy choices.
5. Evaluate different energy policies and their impact on society and environment.
6. Develop a perspective on sustainable development and energy justice.

Unit I: Energy and Human Development (6 hours)

Energy use through history: from human and animal power to industrial revolution - Energy as driver of economic growth - GDP and energy consumption relationship - Human Development Index and energy access - Energy poverty and impact on education, health, livelihoods - Energy ladder - World energy consumption trends - Developed vs. developing countries - India's energy scenario: growing demand, import dependence, energy security.

Unit II: Energy Technologies and Their Impacts (6 hours)

Coal: mining impacts, power plant pollution, health effects - Oil: extraction, spills, refining - Natural gas and fracking - Climate impact: CO₂ emissions and greenhouse effect - Nuclear: fuel cycle, radioactive waste, accidents (Chernobyl, Fukushima), pros and cons - Solar: land use and materials - Wind: bird mortality, noise - Hydro: community displacement, ecosystem impacts - Geothermal and biomass: localized emissions, deforestation - Trade-offs: no energy source is completely clean.

Unit III: Environment and Climate Change (4 hours)

Air pollution sources: thermal plants, vehicles, industries - Pollutants and health effects - Smog episodes - Indoor air pollution - Water consumption and pollution in energy production - Land use and waste - Greenhouse effect and global warming - Impacts: temperature rise, sea level, extreme weather - India's vulnerability - UNFCCC, Kyoto Protocol, Paris Agreement - India's Nationally Determined Contributions.

Unit IV: Energy Policy and Economics (4 hours)

Electricity for all: Saubhagya scheme - National Solar Mission - Renewable energy targets - Subsidies: fossil fuel vs. renewable - Electric vehicle policy - Energy efficiency: PAT scheme, UJALA program - Externalities: hidden costs of energy - Carbon pricing: carbon tax vs. cap-and-trade - Green GDP - Energy justice: unequal distribution, gender dimensions - Just transition.

Unit V: Sustainable Energy Future (4 hours)

1.5°C and 2°C scenarios - Net zero emissions - India's 2070 target - Renewable energy potential and intermittency - Energy storage and green hydrogen - Role of nuclear and carbon capture - Individual choices and community energy projects - Student role and energy literacy - Sustainable Development Goals - Optimism vs. realism: technology, policy, youth action.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Analysis of India's energy mix - Case study on energy poverty - Debate on nuclear vs. renewable - Policy analysis of carbon pricing - Research on local environmental impacts - Creating awareness campaigns.

Primary Textbook (Simple and Accessible):

1. Benjamin K. Sovacool, *Energy and Society: A Critical Perspective*, Routledge, 2019. (Select chapters)

Suggested Reading (Indian Context):

2. Navroz K. Dubash, *Handbook of Climate Change and India: Development, Politics and Governance*, Oxford University Press, 2012. (Indian perspective)

Free Online Resources:

3. Intergovernmental Panel on Climate Change (IPCC) – Summaries for policymakers – <https://www.ipcc.ch> (Simple language summaries)
4. Down To Earth Magazine – Environment and energy news – <https://www.downtoearth.org.in> (Indian context)
5. Centre for Science and Environment (CSE), India – Reports – <https://www.cseindia.org>
6. United Nations Sustainable Development Goals – <https://sdgs.un.org> (Simple explanations)
7. Our World in Data – Energy and Environment – <https://ourworldindata.org>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the historical relationship between energy use and human development.
2. Explain the concepts of energy poverty, energy security, and energy justice.
3. Apply the principles of environmental economics to energy decisions.
4. Analyze the social and health impacts of fossil fuel-based energy systems.
5. Evaluate energy policies such as carbon pricing, subsidies, and renewable energy incentives.
6. Develop a perspective on balancing development needs with environmental protection.

Mapping Matrix: CO–PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: I

NON-MAJOR ELECTIVE COURSE 1

Semester: II

Code:

**4. RENEWABLE ENERGY IN DAILY LIFE
(Theory)**

Credits: 2

Prerequisite: --

Objectives

1. Recall the different types of renewable energy sources applicable to daily life.
2. Explain how solar, wind, biomass, and other renewables can be used at home.
3. Apply the concepts of renewable energy to reduce dependence on grid electricity.
4. Analyze the feasibility of installing solar panels, solar water heaters, or biogas plants at home.
5. Evaluate the costs, benefits, and practical challenges of adopting renewable energy.
6. Design a renewable energy plan for a household or small institution.

Unit I: Solar Energy at Home (6 hours)

Solar panels: working principle and types - Rooftop solar: on-grid, off-grid, hybrid systems - Net metering and electricity bill reduction - Government subsidies and schemes - Calculating panel requirements, space, orientation - Cost, payback period, maintenance - Solar water heaters: flat plate vs. evacuated tube - Savings calculation - Solar cookers: box type vs. parabolic type - Practical tips and limitations.

Unit II: Wind, Biomass, and Other Renewables at Home (6 hours)

Small wind turbines: working, suitability, cost - Hybrid systems (solar + wind) - Biogas plants: production from organic waste, types, uses - Practical challenges and government support - Micro-hydro for homes near streams - Heat pumps: ground source and air source.

Unit III: Energy Storage and Backup (4 hours)

Need for storage in off-grid solar - Battery types: lead-acid vs. lithium-ion - Battery capacity calculation - Charging, discharging, maintenance - Home inverter and UPS - Solar inverter vs. regular inverter - Electric vehicles: charging at home, solar charging, cost savings.

Unit IV: Practical Steps to Adopt Renewables (4 hours)

Energy audit: calculating electricity use - Identifying energy waste - Renewable energy potential assessment - Cost of solar systems (1 kW to 5 kW) - Subsidy details and bank loans - Payback period and ROI - Finding reliable installers - Warranties and installation process - Troubleshooting and maintenance.

Unit V: Case Studies and Action Plan (4 hours)

Urban home with rooftop solar - Rural home with solar - School with solar panels - Apartment with solar water heaters - Biogas plant in village - Commercial building with net metering - Challenges and solutions for renters - Step-by-step guide to adopting renewables - Energy efficiency first - Budgeting and timeline.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Calculating household electricity consumption - Researching government subsidy schemes - Comparing solar panel types and costs - Designing rooftop solar system - Visiting local solar installation - Biogas plant feasibility study - Energy audit of home or college - Creating renewable energy awareness campaign.

Primary Textbook (Simple and Accessible)

1. Christopher Martin and D. Yogi Goswami, *Renewable Energy: A First Course*, CRC Press, 2020. (Indian edition available)

Suggested Reading (Indian Context)

2. Ministry of New and Renewable Energy (MNRE), *Rooftop Solar Guidebook* – Free PDF at <https://mnre.gov.in>

Free Online Resources

1. MNRE (Ministry of New and Renewable Energy) – Rooftop solar guidelines – <https://mnre.gov.in> (Indian government)
2. Solarify – Indian solar news and information – <https://www.solarify.in>
3. NREL PVWatts Calculator – Free tool to estimate solar energy – <https://pvwatts.nrel.gov>
4. Bridge to India – Solar market reports (free summaries) – <https://bridgetoindia.com>
5. NPTEL – Solar Energy Technology – Prof. V.V. Satyamurty, IIT Kharagpur - <https://nptel.ac.in/courses/112105051>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall different renewable energy technologies and their household applicability.
2. Explain how solar panels, water heaters, biogas plants, and small wind turbines work.
3. Apply net metering concept to reduce electricity bills.
4. Analyze financial viability of rooftop solar using payback calculations.
5. Evaluate practical challenges of adopting renewables at home.
6. Design a basic renewable energy plan for a home or small business.

Mapping Matrix: CO–PO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE COURSE 5

Semester: III

Code:

**ELECTROMAGNETIC THEORY
(Theory)**

Credits: 4

Prerequisite:

Objectives

- Recall the fundamental laws of electrostatics, magnetostatics, and electromagnetism.
- Explain the physical significance of divergence, curl, boundary conditions, Poynting vector, and retarded potentials.
- Apply Maxwell's equations to derive wave equations and analyze propagation in different media.
- Analyze electromagnetic wave phenomena including polarization, reflection, refraction, and waveguide modes.
- Evaluate the applicability of scalar and vector potentials, Lienard-Wiechert potentials, and Larmor's formula for radiation problems.
- Formulate solutions to boundary value problems using method of images and design waveguides for specific cutoff frequencies.

Unit I: Electrostatics and Boundary Value Problems (14 hours)

Coulomb's law and Gauss's law - Divergence and curl of electrostatic field - Electric field and potential of a dipole - Poisson and Laplace equations - Boundary conditions and uniqueness theorem - Green's theorem - Method of images: point charge with grounded, insulated, and charged conducting sphere - Conducting sphere in uniform electric field - Energy stored in a capacitor.

Unit II: Electrostatics of Dielectrics and Magnetostatics (14 hours)

Electric quadrupole and multipole expansion - Dielectric polarization - Field due to polarized sphere - Clausius-Mossotti relation - Biot-Savart law and Ampere's law - Divergence and curl of magnetic induction - Comparison of electrostatics and magnetostatics - Magnetic vector potential - Magnetic field of current loop - Applications of Ampere's law.

Unit III: Maxwell's Equations and Conservation Laws (14 hours)

Faraday's law of induction - Self and mutual inductance - Equation of continuity - Maxwell's displacement current - Maxwell's equations in free space, linear media, and harmonically varying fields - Lorentz and Coulomb gauge - Retarded potentials - Poynting's theorem and Poynting vector - Conservation of momentum - Radiation from oscillating dipole.

Unit IV: Electromagnetic Wave Propagation (15 hours)

Plane waves in free space, isotropic media, anisotropic media, and conducting media - Polarization: linear, circular, elliptical - Reflection and refraction - Fresnel's equations - Total internal reflection - Metallic reflection - Dispersion in gases - Propagation in ionized gases (plasma) - Phase and group velocity - Brewster angle and critical angle.

Unit V: Waveguides and Radiation (15 hours)

Propagation between parallel conducting plates - Rectangular and circular waveguides - TE, TM, and TEM modes - Cutoff frequency - Retarded potentials - Lienard-Wiechert potentials - Field of moving point charge - Radiation from accelerated charge: Larmor's formula - Motion of charges in uniform field.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Numerical solutions of Laplace and Poisson equations - Simulation of electric field lines - Computation of waveguide cutoff frequencies - Visualization of wave propagation - Analysis of Fresnel equations - Simulation of radiation patterns - Case study: Electromagnetic shielding.

Text Books

1. D. J. Griffiths, Introduction to Electrodynamics (4th Edition), Pearson, New York, 2013.
2. D. K. Cheng, Field and Wave Electromagnetics (2nd Edition), Pearson, New Delhi, 2015.
3. J. D. Jackson, Classical Electrodynamics (3rd Edition), Wiley, New York, 2021.
- A. K. Saxena, Electromagnetic Theory and Applications, Narosa, New Delhi, 2013.
4. Satya Prakash, Electromagnetic Theory and Electrodynamics, Kedar Nath Ram Nath, New Delhi, 2016.
5. K. K. Chopra and G. C. Agarwal, Introduction to Electromagnetic Theory, Kedar Nath Ram Nath, Meerut, 2010.
6. J. R. Reitz, F. J. Milford, and R. W. Christy, Foundations of Electromagnetic Theory (4th Edition), Pearson, New Delhi, 2010.
7. W. Pauli, Electrodynamics, Dover, 2000.

Reference Books

1. G. Herzberg, Matthew N. O. Sadiku, Principles of Electromagnetics, Oxford, 2015.
2. John D. Kraus and Daniel A. Fleisch, Electromagnetics with Applications (5th Edition), McGraw-Hill, 2001.
3. Prabir K. Basu and Hrishikesh Dhasmana, Electromagnetic Theory, Springer, New Delhi, 2022.
4. George E. Owen, Introduction to Electromagnetic Theory, Dover, 2003.
5. David K. Cheng, Fundamentals of Engineering Electromagnetics, Pearson, 2020.

Online/Web Resources

1. NPTEL – Electromagnetic Theory (Prof. D.K. Ghosh, IIT Bombay)
<https://nptel.ac.in/courses/115101005>
2. NPTEL – Electromagnetic Theory – (Prof. K Pradeep Kumar, IIT Kanpur),
<https://nptel.ac.in/courses/108104087>
3. Introduction to Electromagnetic Theory (Prof. Manoj Harbola, IIT Kanpur) –
<https://nptel.ac.in/courses/115104088>
4. MIT OpenCourseWare – 8.07 Electromagnetism II –
<https://ocw.mit.edu/courses/8-07-electromagnetism-ii-fall-2012/>

5. MIT OpenCourseWare – 8.03 Physics III: Vibrations and Waves – <https://ocw.mit.edu/courses/8-03sc-physics-iii-vibrations-and-waves-fall-2016/>
6. Prof. Walter Lewin (MIT) – Electromagnetism Lecture Videos – Search “Walter Lewin electromagnetism”

Course Outcomes

Upon completion of this course students should be able to

1. Recall Coulomb’s law, Gauss’s law, Ampere’s law, Faraday’s law, and Maxwell’s equations.
2. Explain the physical meaning of divergence, curl, boundary conditions, Poynting theorem, and retarded potentials.
3. Apply Maxwell’s equations to derive wave equations for free space, dielectrics, conductors, and plasma.
4. Analyze wave propagation, polarization, Fresnel equations, total internal reflection, and waveguide modes.
5. Evaluate Lienard-Wiechert potentials and Larmor’s formula for radiation from accelerated charges.
6. Formulate solutions to electrostatic boundary value problems using method of images and Green’s theorem.

CO–PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO7	PSO1	PSO3	PSO10
CO1	3	2	2	1	–	1	2	–
CO2	3	3	2	1	–	2	2	–
CO3	3	2	3	2	2	2	3	1
CO4	3	3	3	2	2	2	3	2
CO5	3	3	3	2	2	3	2	2
CO6	3	2	3	2	3	2	3	3

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE COURSE 6

Semester: III

Code:

**CONDENSED MATTER PHYSICS
(Theory)**

Credits: 4

Prerequisite:

Objectives

- Recall the concepts of Bravais lattices, reciprocal lattice, Brillouin zones, and crystal structures.
- Explain the mechanisms of lattice vibrations, phonons, thermal properties, and magnetic ordering.
- Apply free electron theory and band theory to calculate electrical and thermal properties of solids.
- Analyze magnetic properties using Langevin, Weiss, and Heisenberg models.
- Evaluate the BCS theory of superconductivity and its experimental verifications.
- Formulate solutions for band structure using Kronig-Penney model and design interpretations of X-ray diffraction patterns.

Unit I: Crystal Structure and Diffraction (14 hours)

Bravais lattices: primitive vectors, unit cells, Wigner-Seitz cell - Symmetry operations and classification of 2D and 3D lattices - Crystal structures: NaCl, CsCl, ZnS, Diamond - Packing density: hcp and ccp - Reciprocal lattice and Brillouin zones - Atomic scattering factor and structure factor - Experimental methods: Laue, rotation, powder methods - Pattern analyses.

Unit II: Lattice Vibrations and Thermal Properties (14 hours)

Vibration of monoatomic and diatomic lattices - Acoustical and optical modes - Force constants and long wavelength limits - Quantization of lattice vibrations and phonons - Inelastic neutron scattering - Normal modes - Lattice heat capacity: Einstein and Debye models - Anharmonic effects - Thermal conductivity and Umklapp process - Dispersion relation.

Unit III: Free Electron Theory, Energy Bands, and Semiconductors (15 hours)

Free electron gas in 3D: energy levels, density of states - Fermi-Dirac distribution - Heat capacity of electron gas - Electrical conductivity and Ohm's law - Hall effect - Thermal conductivity and Wiedemann-Franz law - Nearly free electron model - Origin of energy band gap - Bloch functions - Kronig-Penney model - Classification of metals, semiconductors, insulators - Semiconductors: bandgap, holes, effective mass - Intrinsic and extrinsic semiconductors - p-n junction basics - Hall voltage and coefficient.

Unit IV: Magnetic Properties of Solids (14 hours)

Origin of magnetism - Langevin theory of diamagnetism and paramagnetism - Quantum theory of paramagnetism - Weiss theory - Hund's rules - Adiabatic demagnetization - Pauli paramagnetism - Ferromagnetism: Curie-Weiss law, saturation magnetization - Heisenberg exchange interaction - Magnons -

Ferromagnetic domains, coercive force, hysteresis - Ferrimagnetism and antiferromagnetism.

Unit V: Dielectrics, Ferroelectrics, and Superconductivity (15 hours)

Dielectric properties and polarization mechanisms - Ferroelectric crystals: displacive and order-disorder - Ferroelectric domains - Superconductivity: occurrence, Meissner effect - Type I and Type II superconductors - Heat capacity, energy gap, isotope effect - London equation - BCS theory: ground state, Cooper pairs - Flux quantization - Josephson effects - SQUID - High-temperature superconductors - Applications.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Computation of phonon dispersion relations - Simulation of Fermi surface and density of states - Band structure calculation - X-ray diffraction pattern simulation - Calculation of magnetic susceptibility - BCS theory parameters estimation - Visualization of crystal structures - Case study: Superconducting materials.

Text Books

1. Kittel, Introduction to Solid State Physics (8th Edition), Wiley Eastern, New Delhi, 2012.
2. N. W. Ashcroft and N. D. Mermin, Solid State Physics, Harcourt College Publishers, Philadelphia, 1976.
3. J. S. Blakemore, Solid State Physics (2nd Edition), Cambridge University Press, Cambridge, 1985.
4. J. Dekker, Solid State Physics, Macmillan India, 2000.
5. S. O. Pillai, Solid State Physics (7th Edition), New Age International, New Delhi, 2014.
6. J. P. Srivastava, Elements of Solid State Physics, Prentice-Hall of India, 2006.
7. J. R. Christman, Fundamentals of Solid State Physics, John Wiley & Sons, NY, 1988.

Reference Books

1. Steven H. Simon, The Oxford Solid State Basics, Oxford University Press, UK, 2018.
2. Michael P. Marder, Condensed Matter Physics (2nd Edition), John Wiley & Sons, UK, 2019.
3. T. P. Sheahen, Introduction to High-Temperature Superconductors, Plenum Press, New York, 1994.
4. P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press, 2000.
5. G. Burns, Solid State Physics, Academic Press, 1990.

Online/Web Resources

1. Prof. Amal Kumar Das, Solid State Physics, IIT Kharagpur – <https://nptel.ac.in/courses/115105099>
2. Prof. G. Rangarajan, Condensed Matter Physics, IIT Madras – <https://nptel.ac.in/courses/115106061>

3. Prof. P. K. Basu, Semiconductor Optoelectronics, IIT Delhi – <https://nptel.ac.in/courses/115105120>
4. MIT OpenCourseWare – 8.511 Theory of Solids I – <https://ocw.mit.edu/courses/8-511-theory-of-solids-i-fall-2004/>
5. MIT OpenCourseWare – 8.231 Physics of Solids – <https://ocw.mit.edu/courses/8-231-physics-of-solids-i-fall-2006/>
6. University of Cambridge – Condensed Matter Physics Lecture Notes – Search “Cambridge CMP notes”

Course Outcomes

Upon completion of this course students should be able to

1. Recall Bravais lattices, reciprocal lattice, Brillouin zones, and common crystal structures.
2. Explain lattice vibrations, phonons, Einstein/Debye models, and magnetic ordering.
3. Apply free electron theory and nearly free electron model to compute conductivity, Hall effect, and band gaps.
4. Analyze magnetic properties using Langevin, Weiss, Heisenberg, and band theories.
5. Evaluate BCS theory predictions for superconductivity.
6. Formulate Kronig-Penney model solutions and design indexing of X-ray diffraction patterns.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO7	PO8	PSO2	PSO4	PSO9
CO1	3	2	2	1	–	1	2	–	1
CO2	3	3	2	1	–	2	2	–	1
CO3	3	2	3	2	2	2	3	1	2
CO4	3	3	3	2	2	2	3	2	2
CO5	3	3	3	2	2	3	2	2	2
CO6	3	2	3	2	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE PRACTICAL 3

Semester: III

Code:

**GENERAL PHYSICS AND
ELECTRONICS – II
(Practical)**

Credits: 4

Objectives

- Recall advanced experimental techniques for determining thermal, optical, and electrical properties of materials.
- Explain the working principles of advanced instruments including ultrasonic interferometers, four-probe setups, Thomson's apparatus, polarimeters, and PLL circuits.
- Apply precision measurement techniques to determine band gap, thermal conductivity, e/m , polarizability, and magnetic susceptibility.
- Analyze experimental data using advanced statistical methods, curve fitting, and error propagation.
- Evaluate the performance of semiconductor lasers, photodiodes, VCO, PLL, and digital comparator circuits.
- Design and implement advanced analog and digital circuits including pulse modulators, voltage regulators, and digital comparators.

List of Experiments (25 Experiments – Any 12 to be performed)

Section A: General Physics Experiments (Any 4 Experiments)

1. Determination of charge (q), number of charges (n), and specific charge (σ) by Hyperbolic Fringes Method
2. Determination of Thermal Conductivity of a Good Conductor – Forbes' Method
3. Determination of Planck's Constant using Photoelectric Cell (with Filters)
4. Determination of Band Gap Energy of a Semiconductor using Four-Probe Method with Temperature Variation
5. Determination of Self-Inductance (L) of a Coil by Anderson's Bridge Method
6. Determination of e/m of an Electron by Thomson's Method
7. Determination of Wavelength of a Laser Source using Plane Diffraction Grating and Thickness of a Wire
8. Determination of Polarizability of Liquids by finding Refractive Indices at Different Wavelengths
9. Determination of Magnetic Susceptibility of a Paramagnetic Solution using Quincke's Tube Method
10. Determination of Specific Rotatory Power of a Liquid using Polarimeter
11. Determination of Hall Coefficient of a Semiconductor

Section B: Digital Electronics Experiments (Any 4 Experiments)

1. Study of decoder and encoder ICs (IC 74138 Decoder, IC 74148 Encoder)
2. Study of digital comparator using XOR and NAND gates – 1-bit and 4-bit comparator
3. Study of Arithmetic Logic Unit (ALU) using IC 74181 – Arithmetic and Logic Operations
4. Study of Multiplexer and Demultiplexer using IC 74151 (8:1 MUX) and IC 74138 (1:8 DEMUX)
5. Study of Flip-Flops – SR, JK, D, and T using NAND/NOR gates

6. Study of Counters – Asynchronous and Synchronous Counters using IC 7490, IC 7493
7. Study of Shift Registers – SISO, SIPO, PISO, PIPO using IC 7495
8. Study of Digital to Analog Converter (DAC) – R-2R Ladder and Binary Weighted Methods
9. Study of Analog to Digital Converter (ADC) – Successive Approximation and Dual Slope Methods
10. Study of BCD to Seven-Segment Decoder/Driver using IC 7447
11. Study of 4-bit Binary Adder/Subtractor using IC 7483
12. Study of Priority Encoder using IC 74148
13. Study of Frequency Divider using IC 7490 and IC 7493
14. Study of Binary to Gray Code Converter using XOR Gates
15. Study of Gray to Binary Code Converter using XOR Gates

Section C: Microprocessor and Microcontroller Based Experiments (Any 4 Experiments)

1. Study of 8085 Microprocessor – Multibyte Decimal Addition and Subtraction
2. Interfacing Seven-Segment Display with 8085 through 8255 PPI
3. Control of Stepper Motor using 8085 Microprocessor and 8255 PPI
4. Interfacing 8255 PPI with 8085 – LED and Switch Interface
5. Interfacing ADC 0808/0809 with 8085 for Analog Signal Measurement
6. Interfacing DAC 0808 with 8085 for Waveform Generation (Sine, Square, Triangular, Sawtooth)
7. Study of 8051 Microcontroller – Arithmetic Operations (Addition, Subtraction, Multiplication, and Division) and LCD Interfacing using Embedded C
8. Serial Communication between Two 8051 Microcontrollers using UART

BOOKS FOR STUDY

1. S. L. Gupta and V. Kumar, *Practical Physics*, Pragati Prakashan.
2. Ouseph, C.C., Rao, U.J. and Vijayendran, V., *Practical Physics and Electronics*, S. Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai, 2015.
3. Harnam Singh, *Advanced Practical Physics*, S. Chand.
4. Ramesh S. Gaonkar, *Microprocessor Architecture, Programming and Applications with 8085*, Penram.
5. Muhammad Ali Mazidi, Janice Gillispie Mazidi and Rolin D. McKinlay, *The 8051 Microcontroller and Embedded Systems: Using Assembly and C*, Pearson Education.
- A. K. Ray and K. M. Bhurchandi, *Advanced Microprocessors and Peripherals*, McGraw-Hill.
6. Vijayendran, V., *Fundamentals of Microprocessor – 8085: Architecture, Programming and Interfacing*, 3rd Edition, S. Viswanathan (Printers & Publishers) Pvt. Ltd., Chennai, 2009.
7. Morris Mano and Michael Ciletti, *Digital Design*, Pearson.
8. R. P. Jain, *Modern Digital Electronics*, McGraw-Hill.
9. R. S. Sedha, *Digital Electronics*, S. Chand.
10. D. V. Hall and J. McGraw, *Microprocessors and Interfacing: Programming and Hardware*.

Reference Books

1. A. P. Malvino, *Digital Computer Electronics*.
2. Kenneth J. Ayala, *The 8051 Microcontroller*.
3. Walter A. Triebel and Avtar Singh, *The 8085 Microprocessor*.
4. Floyd, *Digital Fundamentals*.
5. Horowitz and Hill, *The Art of Electronics*.

Online/Web Resources

1. NPTEL Microprocessors and Microcontrollers
2. NPTEL Digital Circuits
1. 8051 Microcontroller Tutorials
2. Electronics Hub Microprocessor Tutorials
3. GeeksforGeeks 8085 Programming

YouTube Resources

1. Neso Academy – Microprocessors
2. Gate Smashers – Microprocessor and Microcontroller
3. NPTEL Electronics and Communication
4. Easy Engineering Classes
5. Tutorials Point – 8051 Programming

Course Outcomes

Upon completion of this course students should be able to

- Recall the working principles of ultrasonic interferometers, four-probe apparatus, Thomson's apparatus, polarimeters, and PLL.
- Explain the underlying physics of experiments in thermal physics, solid state physics, optics, and advanced electronics.
- Apply precision measurement techniques to determine band gap, thermal conductivity, e/m , polarizability, and magnetic susceptibility.
- Analyze interference patterns, photoelectric emission, polarimeter readings, and electronic waveforms.
- Evaluate the performance of laser diodes, photodiodes, VCOs, PLLs, and voltage regulators.
- Design and implement pulse modulators, voltage regulators, digital comparators, and encoder/decoder circuits.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO7	PO8	PO10	PSO7	PSO8
CO1	3	2	2	2	–	1	2	1	1
CO2	3	3	2	2	–	2	2	1	1
CO3	3	2	3	3	2	2	3	2	2
CO4	3	3	3	3	2	2	3	3	2
CO5	3	3	3	3	2	3	3	3	2
CO6	3	2	3	3	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II DISCIPLINE CENTRIC ELECTIVE COURSE 3 Semester: III

Code: 1. QUANTUM COMPUTATION AND INFORMATION PROCESSING Credits: 4
(Theory)

Objectives

- Recall the basic concepts of qubits, quantum gates, and quantum circuits.
- Explain the principles of quantum entanglement, no-cloning theorem, and quantum teleportation.
- Apply quantum gates to construct simple quantum circuits and algorithms.
- Analyze the working of Deutsch-Jozsa, Grover, and Shor's algorithms.
- Evaluate the security of quantum cryptography protocols.
- Design simple quantum circuits and implement basic quantum error correction codes.

Unit I: Foundations of Quantum Computation (12 hours)

Qubits and Bloch sphere representation - Superposition and measurement - Quantum gates: Pauli gates, Hadamard, Phase, $\pi/8$ gate - Controlled gates: CNOT, CZ, Toffoli, Fredkin - Universal quantum gates - Quantum circuits - No-cloning theorem - Quantum parallelism.

Unit II: Entanglement and Quantum Communication (12 hours)

Bell states: generation and measurement - EPR paradox - Bell's theorem and CHSH inequality - Experimental tests - Quantum teleportation - Superdense coding - Quantum cryptography: BB84, Ekert91, B92 protocols - Quantum key distribution - Quantum repeaters.

Unit III: Quantum Algorithms – Part I (12 hours)

Deutsch algorithm - Deutsch-Jozsa algorithm - Bernstein-Vazirani algorithm - Simon's algorithm - Quantum Fourier Transform - Phase estimation - Order finding - Shor's factoring algorithm - Period finding.

Unit IV: Quantum Algorithms – Part II and Applications (12 hours)

Grover's search algorithm - Amplitude amplification - Quantum counting - Quantum walks - Quantum simulation - Quantum machine learning - Variational quantum eigensolver - Quantum approximate optimization algorithm.

Unit V: Quantum Error Correction and Hardware (12 hours)

Decoherence and noise - Bit-flip and phase-flip errors - Three-qubit repetition code - Shor's nine-qubit code - Steane code - Surface codes - Fault-tolerant quantum computing - Threshold theorem - Quantum hardware: superconducting qubits, trapped ions, topological qubits - NISQ devices - Quantum supremacy.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of quantum circuits using Qiskit or Cirq - Implementation of quantum algorithms - Quantum teleportation simulation - BB84 protocol simulation - Quantum error correction implementation - Visualization of Bloch sphere - Case study: Current quantum computing platforms.

Text Books

1. M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information (10th Anniversary Edition), Cambridge University Press, 2010.
2. N. D. Mermin, Quantum Computer Science: An Introduction, Cambridge University Press, 2007.
3. P. Kaye, R. Laflamme, and M. Mosca, An Introduction to Quantum Computing, Oxford University Press, 2007.

Reference Books

1. J. Preskill, Lecture Notes on Quantum Computation, Caltech, 1998 – <http://www.theory.caltech.edu/people/preskill/ph229/>
2. R. Laflamme and D. Cory, Introduction to Quantum Computing, Institute for Quantum Computing, 2010.
3. S. J. Lomonaco Jr., Quantum Computation: A Grand Mathematical Challenge, AMS, 2002.

Online/Web Resources

1. NPTEL - Quantum Computation and Quantum Information (Prof. Chiranjib Mitra, IISER Kolkata) <https://nptel.ac.in/courses/115106925>
2. NPTEL - Quantum Information and Computing, (Prof. Dipan Ghosh, IIT Bombay) <https://nptel.ac.in/courses/115101092>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the postulates of quantum mechanics relevant to quantum computing.
2. Explain quantum entanglement, Bell states, no-cloning theorem, and teleportation.
3. Apply single-qubit and two-qubit gates to construct quantum circuits.
4. Analyze Deutsch-Jozsa, Grover's search, and Shor's factoring algorithms.
5. Evaluate the security of quantum cryptography protocols against eavesdropping.
6. Design quantum circuits for simple algorithms and implement basic quantum error correction.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

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Year: II DISCIPLINE CENTRIC ELECTIVE COURSE 3 Semester: III

Code: 2. ADVANCED QUANTUM MECHANICS AND Credits: 4
APPLICATIONS
(Theory)

Objectives

- Recall the variational principle, WKB method, Hartree-Fock method, and Born-Oppenheimer approximation.
- Explain the adiabatic theorem, sudden approximation, LS coupling, and Dirac equation predictions.
- Apply variation method and WKB approximation to estimate ground state energies and tunneling probabilities.
- Analyze many-electron systems using Slater determinants, term symbols, and Hartree-Fock equations.
- Evaluate Dirac equation predictions for electron spin, g-factor, and fine structure of hydrogen atom.
- Formulate quantum mechanical models for molecular structure and introduce basic concepts of field quantization.

Unit I: Density Matrix Formalism, Coherent States, and Quantum Dots (12 hours)

Pure and mixed states - Density operator: properties and time evolution - Statistical mixtures - Two-level systems and Bloch vector - Open quantum systems - Harmonic oscillator coherent states: properties, minimum uncertainty - Squeezed states - Quantum dots: electronic structure, confinement regimes, applications.

Unit II. Spin Angular Momentum and Nuclear Magnetic Resonance (12 hours)

Spin operators and Pauli matrices - Spinor representations - Addition of angular momentum - Clebsch-Gordan coefficients - Spin-orbit coupling - NMR: basic principle, Larmor precession - Bloch equations - Relaxation times (T₁, T₂) - Spin echo - Fourier transform NMR - Applications to quantum information.

Unit III: Quantum Information, Entanglement, and Quantum Algorithms (12 hours)

Qubits and quantum gates - Quantum circuits - No-cloning theorem - Shannon and von Neumann entropy - Bell states - EPR paradox - Bell's theorem and CHSH inequality - Deutsch-Jozsa algorithm - Grover's search - Shor's factoring - Quantum teleportation - Quantum cryptography (BB84) - Quantum supremacy.

Unit IV: Quantum Dynamics and Linear Response Theory (12 hours)

Time evolution operator - Schrödinger, Heisenberg, and interaction pictures - Floquet theory - Rabi oscillations - Bloch-Siegert shift - Response functions and susceptibility - Kubo formula - Fluctuation-dissipation theorem - Quantum Hall effect - Quantum noise.

Unit V: Variational Method, WKB Approximation, and Many-Electron Systems (12 hours)

Variation principle: ground state of Helium, excited states - Hydrogen molecule ion - WKB approximation: asymptotic solutions, turning points, connection formulae - Barrier penetration and alpha decay - Hartree-Fock method - Slater determinants - Electron correlation - Born-Oppenheimer approximation.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Numerical implementation of variational method - WKB tunneling probability calculations - Density matrix evolution simulation - Quantum circuit simulation using Qiskit - NMR pulse sequence simulation - Hartree-Fock calculations - Visualization of coherent and squeezed states - Case study: Quantum dots in quantum computing.

Text Books

1. Satya Prakash, Advanced Quantum Mechanics, Kedar Nath Ram Nath, Meerut, 2014.
2. P. M. Mathews and K. Venkatesan, Quantum Mechanics, McGraw Hill, New Delhi, 2010.
3. K. D. Krori, Principles of Non-Relativistic and Relativistic Quantum Mechanics, Prentice Hall of India, New Delhi, 2012.
4. V. K. Thankappan, Quantum Mechanics, New Age International, New Delhi, 2003.

Reference Books

1. J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics (3rd Edition), Cambridge University Press, 2021.
2. M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 2010.
3. P. Slichter, Principles of Magnetic Resonance (3rd Edition), Springer, 1990.
4. G. D. Mahan, Many-Particle Physics (3rd Edition), Springer, 2000.

Online Resources:

1. NPTEL - Advanced Quantum Mechanics With Applications (Prof. Saurabh Basu, IIT Guwahati) <https://nptel.ac.in/courses/115103104>
2. Prof. Judith McGovern, Advanced Quantum Mechanics, University of Manchester – <https://theory.physics.manchester.ac.uk/~judith/AQMI/PHYS30201.pdf>
3. MIT OpenCourseWare – 8.06 Quantum Physics III – <https://ocw.mit.edu/courses/8-06-quantum-physics-iii-spring-2018/>
4. MIT OpenCourseWare – 8.05 Quantum Physics II – <https://ocw.mit.edu/courses/8-05-quantum-physics-ii-fall-2013/>

Course Outcomes:

Upon completion of this course students should be able to:

1. Recall the variational principle, WKB connection formulae, and Dirac matrix properties.
2. Explain the Hartree-Fock method, Born-Oppenheimer approximation, and LS coupling.

3. Apply variation method to Helium atom and WKB approximation to barrier penetration.
4. Analyze many-electron atomic spectra using term symbols, selection rules, and Zeeman effect.
5. Evaluate Dirac equation predictions for electron spin, g-factor, and fine structure.
6. Formulate molecular orbitals using LCAO and introduce basic concepts of quantum field theory.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

GENERIC ELECTIVE COURSE 3

Semester: III

Code:

**1. NANOFABRICATION AND
CHARACTERIZATION TECHNIQUES
(Theory)**

Credits: 3

Objectives

- Recall the fundamental concepts of top-down and bottom-up nanofabrication, vacuum technology, and key characterization techniques.
- Explain the working principles of physical vapor deposition, chemical vapor deposition, lithography, etching, and major characterization tools.
- Apply the principles of nanofabrication to select appropriate methods for specific nanostructures.
- Analyze characterization data to determine structural, morphological, and chemical properties of nanomaterials.
- Evaluate the suitability of different fabrication and characterization techniques based on material type and desired feature size.
- Design a basic nanofabrication process flow for a simple device and select appropriate characterization methods.

Unit I: Foundations of Nanofabrication (10 hours)

Length scales and nanoscale importance - Top-down vs. bottom-up approaches - Surface-to-volume ratio - Cleanroom facilities and safety - Vacuum technology: ranges, pumps, pressure measurement - Wafer cleaning and surface passivation - Substrate selection.

Unit II: Patterning and Lithography (10 hours)

Optical lithography: photoresists, spin coating, exposure, development - Resolution limits - Electron beam lithography - Focused ion beam lithography - Nanoimprint lithography - Self-assembly - Wet and dry etching: RIE, DRIE, ICP - Etch selectivity.

Unit III: Thin Film Deposition Techniques (10 hours)

Physical vapor deposition: thermal evaporation, e-beam evaporation, sputtering, PLD, MBE - Chemical vapor deposition: thermal, LPCVD, PECVD, MOCVD - Atomic layer deposition - Bottom-up synthesis: sol-gel, hydrothermal, colloidal, electrochemical deposition.

Unit IV: Microscopy and Structural Characterization (10 hours)

Scanning electron microscopy: electron-matter interactions, detectors, EDS/EDX - Transmission electron microscopy: bright/dark field, SAED, HRTEM, STEM, EELS - Scanning probe microscopy: STM, AFM modes, SNOM.

Unit V: Spectroscopic and Compositional Characterization (8 hours)

X-ray diffraction: Bragg's law, phase identification, crystallite size - X-ray photoelectron spectroscopy: chemical shift, elemental identification - Auger electron spectroscopy - Raman spectroscopy - UV-Vis-NIR spectroscopy - Photoluminescence - FTIR - TGA and DSC.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of lithography process - Virtual SEM/TEM image analysis - XRD pattern indexing - XPS spectrum analysis - Design of nanofabrication process flow - Case study: Thin film solar cell fabrication - Comparative analysis of techniques.

Primary Textbooks

1. Sulabha K. Kulkarni, Nanotechnology: Principles & Practices (4th Edition), Springer/Capital Publishing Company, 2023. (Excellent for UG/PG level)
2. Guozhong Cao and Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications (2nd Edition), World Scientific, 2011.
3. Charles P. Poole Jr. and Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, 2007.
4. Milton Ohring, Materials Science of Thin Films (2nd Edition), Academic Press, 2002. (For deposition techniques)

Reference Books

1. K. L. Chopra, Thin Film Phenomena, McGraw-Hill, 1969. (Classic)
2. David B. Williams and C. Barry Carter, Transmission Electron Microscopy: A Textbook for Materials Science (2nd Edition), Springer, 2009.
3. John C. Vickerman and Ian S. Gilmore, Surface Analysis: The Principal Techniques (2nd Edition), Wiley, 2009.
4. B. D. Cullity and S. R. Stock, Elements of X-Ray Diffraction (3rd Edition), Prentice Hall, 2001.
5. Bharat Bhushan, Springer Handbook of Nanotechnology (4th Edition), Springer, 2017.
6. Mark A. Ratner and Daniel Ratner, Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson Education, 2003.

Online Resources

NPTEL Courses (Highly Recommended)

1. NPTEL - Thin Film Technology, Prof. Samit Kumar Ray, IIT Kharagpur – <https://nptel.ac.in/courses/127105531>
2. NPTEL - Techniques of Materials Characterization, Prof. Shibayan Roy, IIT Kharagpur – <https://nptel.ac.in/courses/113105101>
3. NPTEL - Nanotechnology, Science and Applications, Prof. Prathap Haridoss, IIT Madras – <https://nptel.ac.in/courses/113106093>
4. NPTEL - Nanomaterials and their Properties, Prof. Krishanu Biswas, IIT Kanpur – <https://nptel.ac.in/courses/113104102>

Other Resources

1. MIT OpenCourseWare – 6.701 Introduction to Nanotechnology – <https://ocw.mit.edu>
2. NanoHub.org – Online simulations and tutorials for nano education – <https://nanohub.org>
3. Virtual Labs by IITs – Nanotechnology virtual labs – Search “Virtual Labs IIT nanotechnology”

YouTube Resources

1. Applied Science (Ben Krasnow) – Search “Applied Science SEM”
2. NPTEL IIT Kharagpur – Search “NPTEL Thin Film Technology Samit Ray”

3. Branch Education – Search “Branch Education semiconductor fabrication”

Course Outcomes

Upon completion of this course students should be able to:

1. Recall key concepts of top-down vs. bottom-up approaches, vacuum systems, and major characterization tools.
2. Explain the physics behind PVD, CVD, lithography, SEM, TEM, AFM, XRD, XPS, and Raman spectroscopy.
3. Apply nanofabrication knowledge to select appropriate synthesis methods for nanoparticles, nanowires, and thin films.
4. Analyze microscopy images and XRD patterns to determine size, morphology, and crystal structure.
5. Evaluate strengths and limitations of different characterization techniques for specific nanomaterials.
6. Design a process flow for fabricating a simple nanostructure with appropriate characterization.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2	2	1	–	1	2	–	1
CO2	3	3	2	1	–	2	2	–	1
CO3	3	2	3	2	2	2	3	1	2
CO4	3	3	3	3	2	2	3	2	2
CO5	3	3	3	2	2	3	2	2	2
CO6	3	2	3	3	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

GENERIC ELECTIVE COURSE 3

Semester: III

Code:

**2. PLASMA PHYSICS AND APPLICATIONS
(Theory)**

Credits: 3

Objectives

- Recall the fundamental concepts of plasma, Debye shielding, plasma frequency, and plasma parameters.
- Explain the motion of charged particles in electric and magnetic fields, including various drifts.
- Apply fluid and kinetic descriptions to model plasma behavior and derive plasma waves.
- Analyze the properties of different plasma waves and instabilities.
- Evaluate plasma applications in fusion energy, space physics, and industrial processing.
- Formulate basic plasma models for controlled fusion and space plasma scenarios.

Unit I: Introduction to Plasma (10 hours)

Definition of plasma - Natural and laboratory plasmas - Debye shielding and Debye length - Plasma frequency - Plasma parameter - Criteria for plasma - Quasi-neutrality - Thermal ionization - Electrical discharges - Electron impact and photoionization.

Unit II: Single Particle Motion (10 hours)

Motion in uniform electric and magnetic fields - Cyclotron frequency and Larmor radius - $E \times B$ drift - Gradient and curvature drifts - Polarization drift - Magnetic mirrors and loss cone - Adiabatic invariants - Applications: Van Allen belts, magnetic confinement.

Unit III: Plasma as a Fluid – MHD (10 hours)

Fluid description of plasma - Continuity and momentum equations - MHD approximation - Frozen-in flux theorem - Magnetic pressure and tension - MHD equilibrium - Diffusion in plasma: classical, ambipolar, Bohm – Conductivity.

Unit IV: Waves in Plasma (10 hours)

Plasma oscillations and Langmuir waves - Ion acoustic waves - Landau damping - Electromagnetic waves in plasma: cutoff frequency - Waves in magnetized plasma: ordinary and extraordinary waves - Whistlers - Alfvén waves - Plasma heating methods.

Unit V: Plasma Applications (8 hours)

Fusion reactions and Lawson criterion - Magnetic confinement: tokamak, stellarator - ITER - Inertial confinement fusion - Space plasma: solar wind, magnetosphere, auroras - Ionosphere and radio wave propagation - Industrial applications: etching, deposition, sputtering, PECVD - Plasma propulsion - Plasma diagnostics.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of single particle motion - Calculation of Debye length and plasma frequency - Dispersion relation analysis - MHD equilibrium simulation - Case study: Tokamak plasma confinement - Analysis of fusion reactor parameters - Literature review on industrial plasma applications.

Primary Textbooks

1. F. F. Chen, Introduction to Plasma Physics and Controlled Fusion (3rd Edition), Springer, 2018. (Gold standard – accessible)
2. Richard Fitzpatrick, Plasma Physics: An Introduction (2nd Edition), CRC Press, 2022.

Reference Books:

1. J. A. Bittencourt, *Fundamentals of Plasma Physics* (3rd Edition), Springer, 2011.
2. R. O. Dendy, *Plasma Dynamics*, Oxford University Press, 1995.
3. D. A. Gurnett and A. Bhattacharjee, *Introduction to Plasma Physics*, Cambridge University Press, 2017.
4. S. N. Goswami, *Plasma Physics*, Pragati Prakashan, 2018.

Online Resources

NPTEL Courses (Highly Recommended):

1. Prof. V.K. Tripathi, Prof. Vijayshri, Plasma Physics: Fundamentals and Applications, IIT Delhi - <https://nptel.ac.in/courses/115102020>
2. Prof. M.V. Sunil Krishna, *Plasma Physics and Applications*, IIT Roorkee – <https://nptel.ac.in/courses/115107447>

Free Online Resources:

1. MIT OpenCourseWare – 22.611 Introduction to Plasma Physics – <https://ocw.mit.edu/courses/22-611j-introduction-to-plasma-physics-i-fall-2006/>
2. F. F. Chen – Lecture Notes (UCLA) – Search “Chen plasma physics lecture notes” (free PDF available)

YouTube Resources

1. Prof. F. F. Chen – Search “FF Chen plasma physics lectures”
2. Plasma Physics and Fusion Energy (Princeton Plasma Physics Lab) – Search “PPPL lectures”

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the definition of plasma, Debye length, plasma frequency, and fundamental parameters.
2. Explain single-particle motion, guiding center drifts, adiabatic invariants, and magnetic mirroring.
3. Apply fluid equations and MHD to describe plasma equilibrium and waves.
4. Analyze dispersion relations for plasma oscillations, ion acoustic waves, and electromagnetic waves.
5. Evaluate principles of plasma confinement for fusion and space plasma phenomena.
6. Formulate simplified plasma models for industrial applications.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2	2	1	–	1	2	–	1
CO2	3	3	2	1	–	2	2	–	1
CO3	3	2	3	2	2	2	3	1	2
CO4	3	3	3	2	2	2	3	2	2
CO5	3	3	3	2	2	3	2	2	2
CO6	3	2	3	2	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

GENERIC ELECTIVE COURSE 3

Semester: III

Code:

**3. MATERIALS SYNTHESIS AND
CHARACTERIZATION
(Theory)**

Credits: 3

Objectives

- Recall the fundamental concepts of length scales, dimensionality, crystal systems, and basic characterization principles.
- Explain the working principles of top-down/bottom-up synthesis, physical/chemical deposition methods, and major characterization tools.
- Apply synthesis methods to prepare nanomaterials using appropriate techniques.
- Analyze characterization data to determine morphology, structure, and optical properties.
- Evaluate the suitability of different synthesis and characterization techniques for specific materials and applications.
- Design a basic materials synthesis and characterization protocol for a given application.

Unit I: Introduction to Nanomaterials (8 hours)

Length scales and surface-to-volume ratio - Low-dimensional nanostructures: 0D, 1D, 2D - Band theory and density of states - Quantum confinement - Excitons and Bohr radius - Moore's law and lithographic techniques.

Unit II: Synthesis of Nanomaterials (12 hours)

Top-down fabrication: ball milling, mechanical alloying - Physical vapor deposition: thermal evaporation, e-beam, sputtering, PLD, MBE - Chemical vapor deposition: thermal, PECVD, MOCVD - Solution-based methods: sol-gel, hydrothermal, colloidal synthesis, electrochemical deposition - Bottom-up approaches: self-assembly, green synthesis.

Unit III: Microscopy and Structural Characterization (10 hours)

Electron-matter interactions - Scanning electron microscopy: working, detectors, EDS - Transmission electron microscopy: bright/dark field, SAED, HRTEM - Scanning tunneling microscopy - Atomic force microscopy: contact, tapping, non-contact modes.

Unit IV: Spectroscopic and Diffraction Characterization (10 hours)

X-ray diffraction: Bragg's law, phase identification, crystallite size - X-ray photoelectron spectroscopy: chemical shift, elemental analysis - Auger electron spectroscopy - UV-Vis-NIR spectroscopy: bandgap determination, SPR - Photoluminescence spectroscopy - FTIR and Raman spectroscopy.

Unit V: Properties and Applications (8 hours)

Optical properties: absorption, emission, luminescence - Plasmonics and SERS - Carrier transport in low-dimensional systems - Thermionic emission and tunneling - Applications: LEDs, solar cells, sensors, drug delivery - Safety and handling of nanomaterials.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of XRD patterns - Virtual SEM/TEM image analysis - Crystallite size calculation - Bandgap determination from UV-Vis - Design of synthesis protocol - Case study: ZnO nanoparticles - Literature review on emerging nanomaterials.

Primary Textbooks

1. Sulabha K. Kulkarni, Nanotechnology: Principles & Practices (4th Edition), Springer/Capital Publishing Company, 2023. (Excellent for UG/PG level)
2. Guozhong Cao and Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications (2nd Edition), World Scientific, 2011.
3. Charles P. Poole Jr. and Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, 2007.

Reference Books

1. M. Hosokawa, K. Nogi, M. Naito, and T. Yokoyama, Nanoparticle Technology Handbook, Elsevier, 2012.
2. Bharat Bhushan, Springer Handbook of Nanotechnology (4th Edition), Springer, 2017.
3. B. D. Cullity and S. R. Stock, Elements of X-Ray Diffraction (3rd Edition), Prentice Hall, 2001.
4. David B. Williams and C. Barry Carter, Transmission Electron Microscopy (2nd Edition), Springer, 2009.

Online Resources

NPTEL Courses (Highly Recommended)

1. NPTEL- Nanotechnology, Science and Applications, (Prof. Prathap Haridoss, IIT Madras) <https://nptel.ac.in/courses/113106093>
2. NPTEL - Thin Film Technology, Prof. Samit Kumar Ray, IIT Kharagpur – <https://nptel.ac.in/courses/127105531>
3. NPTEL - Techniques of Materials Characterization, Prof. Shibayan Roy, IIT Kharagpur – <https://nptel.ac.in/courses/113105101>

Other Resources

1. MIT OpenCourseWare – 3.091 Introduction to Solid State Chemistry – <https://ocw.mit.edu>
2. NanoHub.org – Online simulations and tutorials for nano education – <https://nanohub.org>
3. Virtual Labs by IITs – Nanotechnology virtual labs – Search “Virtual Labs IIT nanotechnology”

YouTube Resources

1. Applied Science – Search “Applied Science SEM”
2. Branch Education – Search “Branch Education semiconductor”

Course Outcomes

Upon completion of this course students should be able to:

1. Recall key concepts of length scales, dimensionality, quantum confinement, and surface-to-volume ratio.
2. Explain working principles of PVD, CVD, sol-gel, hydrothermal synthesis, SEM, TEM, XRD, XPS, and AFM.
3. Apply appropriate synthesis methods to produce nanomaterials with controlled size and shape.
4. Analyze microscopy images and XRD patterns to determine size, morphology, and crystal structure.
5. Evaluate strengths and limitations of different characterization techniques for specific nanomaterials.
6. Design a process flow for synthesizing and characterizing a nanomaterial for a target application.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2	2	1	–	1	2	–	1
CO2	3	3	2	1	–	2	2	–	1
CO3	3	2	3	2	2	2	3	1	2
CO4	3	3	3	3	2	2	3	2	2
CO5	3	3	3	2	2	3	2	2	2
CO6	3	2	3	3	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

NON-MAJOR ELECTIVE COURSE 2

Semester: III

Code:

**1. MOBILE PHONES FROM PHYSICS
PERSPECTIVE
(Theory)**

Credits: 2

Prerequisite: --

Objectives

- Recall the basic physics principles behind mobile phone operation.
- Explain how signals, antennas, batteries, touchscreens, and cameras work.
- Apply safety guidelines related to radiation, battery care, and charging.
- Analyze common mobile phone issues using physics reasoning.
- Evaluate the health and safety aspects of mobile phone use.
- Develop informed opinions about mobile phone technology and its impact.

Unit I: How Mobile Phones Connect (6 hours)

Electromagnetic waves: radio waves, microwaves - Frequency and wavelength relationship - Mobile bands: 2G to 5G - Antenna working principle - Cell towers and handover - Signal strength and factors affecting it - Voice call and SMS transmission - Internet on phone: Wi-Fi vs. mobile data.

Unit II: The Phone Hardware (6 hours)

Lithium-ion batteries: working, charging, degradation - Fast and wireless charging - Battery safety - Capacitive touchscreen: working principle - LCD vs. AMOLED displays - Resolution, refresh rate, power consumption - Camera: lens, sensor (CCD/CMOS), megapixels, aperture - Optical vs. digital zoom - Low light photography.

Unit III: Sensors and Features (4 hours)

Accelerometer: orientation detection, step counting - Gyroscope for gaming and VR - Magnetometer as compass - Proximity and ambient light sensors - Fingerprint and face recognition - GPS and location tracking - Speaker, microphone, vibration motor working.

Unit IV: Radiation, Health, and Safety (4 hours)

Electromagnetic radiation from phones - SAR (Specific Absorption Rate): definition, safe limits - Health effects and WHO classification - Blue light and sleep disruption - Eye strain and night mode - Overheating and safe charging practices - Battery swelling and replacement.

Unit V: Mobile Communication Technology (4 hours)

Evolution: 1G to 5G - 5G: millimeter waves, small cells, benefits - Tower radiation vs. phone radiation - Myths and facts - Satellite phones and Starlink - Foldable phones.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Wavelength and frequency calculations - SAR value analysis - Battery capacity and charging time analysis - Display technology comparison - Research on 5G technology - Case study on radiation and health.

Primary Textbook (Simple and Accessible)

1. Louis E. Frenzel, *Principles of Electronic Communication Systems* (5th Edition), McGraw-Hill, 2022. (Selected chapters only – simplified)

Suggested Reading (Non-Technical)

2. David A. Johnson, *Mobile Technology: A Simple Guide for Non-Techies*, Independently Published, 2020.
3. Tom Wheeler, *From Gutenberg to Google: The History of Our Future*, Brookings Institution Press, 2019.

Free Online Resources:

4. GSMA – Mobile technology explained – <https://www.gsma.com> (Simple explanations)
5. WHO – Electromagnetic fields and public health – <https://www.who.int/peh-emf> (Health information)
6. How Stuff Works – Cell Phones – <https://electronics.howstuffworks.com/cell-phone.htm>
7. TRAI (Telecom Regulatory Authority of India) – <https://www.trai.gov.in> (Indian regulations)

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the basic components of a mobile phone and their functions.
2. Explain how electromagnetic waves, antennas, batteries, touchscreens, and cameras work.
3. Apply safety practices for charging, battery use, and radiation exposure.
4. Analyze common problems like slow charging, overheating, and poor signal.
5. Evaluate the scientific evidence on mobile phone radiation and health.
6. Develop a balanced understanding of mobile phone technology.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

NON-MAJOR ELECTIVE COURSE 2

Semester: III

Code:

**2. BASICS OF COMMUNICATION
TECHNOLOGY
(Theory)**

Credits: 2

Prerequisite: --

Objectives

- Recall the basic concepts of communication – sender, receiver, channel, signal, noise.
- Explain how wired and wireless communication work.
- Apply knowledge of communication to everyday situations.
- Analyze the advantages and limitations of different communication technologies.
- Evaluate the impact of communication technology on society.
- Develop informed choices about using different communication services.

Unit I: Fundamentals of Communication (6 hours)

Sender, message, channel, receiver, noise - Analog vs. digital signals - Signal-to-noise ratio - Modulation: AM and FM - Comparison and applications.

Unit II: Wired Communication (6 hours)

Telegraph and Morse code - Telephone: sound to electrical signals - Fiber optic cables: total internal reflection - Advantages over copper - Undersea cables - LAN cables.

Unit III: Wireless Communication (4 hours)

Radio broadcasting: AM and FM - TV broadcasting and DTH - Mobile communication: cells, handover, roaming - 2G to 5G - Satellites: geostationary vs. LEO, GPS, Starlink - Wi-Fi: router, frequencies, range, security - Bluetooth: pairing and applications.

Unit IV: Internet and Data Communication (4 hours)

Internet: packet switching, IP addresses - Bandwidth, download/upload speed, latency - Fiber vs. cable vs. DSL vs. 5G - Streaming and buffering - Video calls - Cloud and data centers.

Unit V: Communication and Society (4 hours)

Positive and negative impacts - Digital divide - 6G and Li-Fi - Quantum communication - Privacy tips and secure communication.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Comparison of AM and FM frequencies - Signal-to-noise ratio analysis - Internet speed analysis - Research on mobile communication evolution - Case study: Undersea fiber optic cables - Satellite orbits and applications.

Primary Textbook (Simple and Accessible)

1. James O'Shea, *The Telephone and Its Several Inventors*, McFarland & Company, 2019. (Historical perspective)

Suggested Reading (Non-Technical)

2. Tom Standage, *The Victorian Internet: The Remarkable Story of the Telegraph*, Bloomsbury, 2014. (Interesting history)
3. Andrew Blum, *Tubes: A Journey to the Center of the Internet*, Ecco Press, 2013.

Online Resources

4. How Stuff Works – Communication – <https://www.howstuffworks.com/communication> (Simple explanations)
5. Internet Society – How the internet works – <https://www.internetsociety.org>
6. Fiber Optic Association – Free tutorials – <https://www.thefoa.org> (Simple language)
7. TRAI (Telecom Regulatory Authority of India) – <https://www.trai.gov.in>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the basic elements of any communication system.
2. Explain how telegraph, telephone, radio, TV, fiber optics, satellite, and internet work.
3. Apply understanding of signals and noise to improve communication quality.
4. Analyze bandwidth and speed requirements for different applications.
5. Evaluate the social and economic impact of communication technologies.
6. Develop awareness of emerging communication technologies

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

NON-MAJOR ELECTIVE COURSE 2

Semester: III

Code:

**3. INTRODUCTION TO DIGITAL AND
WIRELESS TECHNOLOGIES
(Theory)**

Credits: 2

Prerequisite: --

Objectives

- Recall the basic concepts of digital technology and wireless communication.
- Explain how digital devices and wireless networks work.
- Apply understanding of digital and wireless technologies to daily tasks.
- Analyze the differences between analog and digital systems.
- Evaluate the security and privacy aspects of digital and wireless technologies.
- Develop awareness of emerging technologies.

Unit I: Digital Technology Basics (6 hours)

Binary system: bits, bytes, storage units - Data representation: text, images, sound - Analog vs. digital comparison - Computer working: input, processing, storage, output - Smartphone components and operating systems.

Unit II: Wireless Technologies (6 hours)

Radio waves and frequency spectrum - Wi-Fi: router, SSID, security protocols - Bluetooth: pairing and applications - Mobile communication: 2G to 5G evolution - Coverage and data speed.

Unit III: Digital Communication (4 hours)

Data travel: IP addresses, domain names, DNS - Email working: SMTP, POP, IMAP - App communication with servers - Cloud storage - Encryption and end-to-end encryption - Streaming services: buffering and quality adaptation.

Unit IV: Security and Privacy (4 hours)

Hacking, malware, phishing - Data breaches and identity theft - Strong passwords and two-factor authentication - Antivirus and firewalls - HTTPS and VPN - App permissions and privacy settings.

Unit V: Future Technologies (4 hours)

Smart home devices and IoT - Voice assistants and AI basics - 5G applications: self-driving cars, remote surgery, VR - 6G future.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Binary and ASCII conversion - Analog vs. digital system comparison - Wi-Fi security analysis - Research on 5G technology - Case study: IoT security - Cybersecurity awareness campaign.

Textbooks and References

Primary Textbook (Simple and Accessible):

1. Andrew Blum, *Tubes: A Journey to the Center of the Internet*, Ecco Press, 2013. (Story of how the internet works)

Suggested Reading (Non-Technical):

2. Cory Doctorow, *Information Doesn't Want to Be Free: Laws for the Internet Age*, McSweeney's, 2014. (Digital rights)
3. Bruce Schneier, *Click Here to Kill Everybody*, W. W. Norton & Company, 2019. (Security)

Free Online Resources:

4. Google's "How the Internet Works" – <https://www.google.com/search/howsearchworks> (Simple interactive)
5. Stay Safe Online – Cybersecurity tips – <https://staysafeonline.org>
6. Internet of Things (IoT) Explained – <https://www.iotforall.com> (Simple language)
7. NPTEL – Introduction to Digital and Wireless Communication – <https://nptel.ac.in/courses/117105080>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the meaning of bits, bytes, binary, analog, digital, and wireless.
2. Explain how computers, smartphones, Wi-Fi, Bluetooth, and mobile networks work.
3. Apply knowledge to troubleshoot basic connectivity issues.
4. Analyze the advantages of digital over analog systems.
5. Evaluate security practices for safe use of digital and wireless technologies.
6. Develop awareness of IoT, smart homes, and future technologies.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

NON-MAJOR ELECTIVE COURSE 2

Semester: III

Code:

**4. INTRODUCTION TO SPACE AND
ASTRONOMY
(Theory)**

Credits: 2

Prerequisite: --

Objectives

- Recall the basic concepts of astronomy, celestial objects, and the universe.
- Explain the working of telescopes, the life cycle of stars, and the structure of the solar system.
- Apply observational knowledge to identify celestial objects and phenomena.
- Analyze the scale and structure of the universe using simple physical principles.
- Evaluate the methods used by astronomers to study the universe.
- Develop an informed appreciation of space exploration and its significance.

Unit I: The Night Sky (5 Hours)

What is astronomy? - The celestial sphere - Constellations and star names - Apparent motion of stars and planets - Why stars rise and set - Why seasons change - The Moon: phases, eclipses, tides - Observing the night sky with the naked eye - Using star charts and mobile apps.

Unit II: The Solar System (5 Hours)

The Sun: size, temperature, energy source - Planets: Mercury to Neptune - Terrestrial vs. Jovian planets - Why Pluto is a dwarf planet - Moons and rings - Asteroids, comets, and meteoroids - What are shooting stars? - The scale of the solar system - How planets are formed.

Unit III: Stars and Their Life (5 hours)

What is a star? - How stars shine (nuclear fusion) - Stellar colors and temperatures - Life cycle of stars: birth, main sequence, red giant, white dwarf, supernova, neutron star, black hole - Our Sun as a star - Why stars twinkle - Star clusters and nebulae - How astronomers study stars.

Unit IV: Galaxies and the Universe (5 hours)

What is a galaxy? - Our Milky Way galaxy - Spiral, elliptical, and irregular galaxies - How many galaxies are there? - What is the universe? - How big is it? - The Big Bang theory - Expansion of the universe - Dark matter and dark energy - What is the fate of the universe?.

Unit V: Telescopes and Space Exploration (4 Hours)

How telescopes work - Refracting vs. reflecting telescopes - Observatories on Earth and in space - Hubble Space Telescope - James Webb Space Telescope - Indian space missions: Chandrayaan, Mangalyaan, Gaganyaan - Human spaceflight - International Space Station - Search for exoplanets - Are we alone? - Careers in astronomy.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Observing the night sky - Identifying constellations - Moon phase tracking - Solar system model making - Visit to a planetarium - Astronomy quiz - Group discussion on space exploration.

Textbooks and References

Primary Textbook (Simple and Accessible):

1. Patrick Moore, Astronomy: A Complete Introduction, Teach Yourself, 2015.
2. Dionysius Lardner, Handbook of Astronomy, Forgotten Books, 2018.
3. Bhism Yadav, Basics of Astronomy: Introduction to Space, Galaxies, Cosmos and Celestial Bodies, 2025

Suggested Reading (Non-Technical):

1. Carl Sagan, Cosmos, Abacus, 1983.
2. Neil deGrasse Tyson, Astrophysics for People in a Hurry, W. W. Norton, 2017.
3. Mohit Kumar Sharma and Suresh Chandra, A Textbook of Astronomy and Astrophysics, TechSar, 2019

Free Online Resources:

1. NASA – Astronomy Basics
2. ISRO – Indian Space Missions
3. Stellarium – Free planetarium software
4. SkyView – Astronomy mobile app
5. NPTEL – Introduction to Astronomy - <https://nptel.ac.in/courses/115105046>
6. YouTube – Khan Academy Astronomy

Course Outcomes

Upon completion of this course students should able to:

1. Recall the basic concepts of astronomy, celestial objects, and the universe.
2. Explain the structure of the solar system, life cycle of stars, and the scale of the universe.
3. Identify constellations and celestial objects using observation skills.
4. Analyze the methods used by astronomers to study the universe.
5. Evaluate the importance of space exploration and its impact on society.
6. Develop an appreciation for astronomy and space science.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	–	2	–
CO4	3	3	3	2	2	2	3	–	2	1
CO5	3	3	3	2	2	3	2	–	2	2
CO6	3	2	3	2	3	2	3	–	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE COURSE 7

Semester: IV

**Code: ATOMIC AND MOLECULAR SPECTROSCOPY
(Theory)**

Credits: 4

Prerequisite: --

Objectives

- Recall the vector atom model, coupling schemes, selection rules, and Born-Oppenheimer approximation.
- Explain the origins of atomic spectra, Zeeman/Stark effects, and rotational, vibrational, electronic, and Raman transitions.
- Apply selection rules and group theory to interpret atomic and molecular spectra.
- Analyze spectral data to determine molecular structure, bond lengths, force constants, and dissociation energies.
- Evaluate the suitability of IR, Raman, and UV-Vis spectroscopy for different molecular systems.
- Design spectroscopic experiments to identify unknown substances and determine molecular parameters.

Unit I: Atomic Structure and Spectra (14 hours)

Quantum states of electrons - Hydrogen atom spectrum - Stern-Gerlach experiment - Spin-orbit interaction - LS and JJ coupling schemes - Fine and hyperfine structure - Spectroscopic terms and selection rules - Central field approximation - Term symbols for multi-electron atoms - Normal and anomalous Zeeman effect - Paschen-Back effect - Linear and quadratic Stark effect - Auger transitions - Compton effect - Light sources, monochromators, detectors.

Unit II: Molecular Bonding and Quantum Chemistry (14 hours)

Covalent, ionic, and van der Waals interactions - Born-Oppenheimer approximation - Hybrid orbitals (sp , sp^2 , sp^3) - LCAO and molecular orbital theory - Valence bond theory - Hückel approximations: butadiene and benzene - Symmetry elements and point groups - Character tables - Selection rules and molecular vibrations.

Unit III: Rotational and Vibrational Spectroscopy (14 hours)

Rotational spectra of diatomic molecules: rigid rotor, energy levels, transitions - Isotopic substitution - Non-rigid rotor - Rotational spectra of linear, symmetric, and asymmetric tops - Microwave instrumentation - Vibrational spectra: harmonic oscillator, anharmonicity, overtones - Rovibrational spectra: P, Q, R branches - Characteristic group frequencies - FTIR principles and instrumentation.

Unit IV: Electronic Spectroscopy of Molecules (12 hours)

Vibrational coarse structure: progressions and sequences - Franck-Condon principle - Dissociation energy - Predissociation - Rotational fine structure and Fortrat diagram - Electronic structure of diatomic molecules - Molecular term symbols - UV-Vis spectroscopy instrumentation - Beer-Lambert law - Applications.

Unit V: Raman Spectroscopy and Advanced Techniques (12 hours)

Quantum and classical theory of Raman effect - Selection rules - Rotational and vibrational Raman spectra - Stokes and anti-Stokes lines - Depolarization ratio - Complementary nature of IR and Raman - Raman spectrometer: lasers, monochromators, detectors - FT-Raman spectroscopy - Nonlinear Raman techniques (CARS).

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of atomic spectra - Analysis of rotational-vibrational spectra - Calculation of bond lengths and force constants - Interpretation of IR and Raman spectra - Franck-Condon factor calculations - Simulation of Zeeman and Stark effects - Case study: Spectroscopic identification of unknown compounds.

Primary Textbooks

1. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy (5th Edition), McGraw-Hill, 2006. (Units III, IV, V)
2. G. Aruldas, Molecular Structure and Spectroscopy (2nd Edition), Prentice Hall of India, 2014. (Units II, III, IV)
3. H. E. White, Introduction to Atomic Spectra, McGraw Hill, 2016. (Unit I)
4. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules (2nd Edition), Pearson, 2003. (Units I, II)

Reference Books

1. J. M. Hollas, Modern Spectroscopy (4th Edition), John Wiley & Sons, 2004.
2. W. Demtröder, Molecular Physics, Wiley-VCH, 2005.
3. I. N. Levine, Quantum Chemistry (7th Edition), Prentice-Hall of India, 2014.

Online Resources**NPTEL Courses**

1. Atomic and Molecular Spectroscopy, Prof. Amal Kumar Das, IIT Kharagpur, <https://nptel.ac.in/courses/115105100>
2. Fundamentals of Spectroscopy, Prof. Sayan Bagchi/Prof. Anirban Hazra, NCL Pune/IISER Pune, <https://nptel.ac.in/courses/104106122>

International Resources

1. MIT OpenCourseWare – 5.80 Small-Molecule Spectroscopy – <https://ocw.mit.edu/courses/5-80-small-molecule-spectroscopy-and-dynamics-fall-2008/>
2. NIST Atomic Spectra Database – <https://physics.nist.gov/PhysRefData/ASD/>
3. AIST Spectral Database – <https://sdb.sdb.aist.go.jp> (Free IR, Raman spectra)

Course Outcomes

At the end of this course, students will be able to:

1. Recall the vector atom model, LS/JJ coupling, Born-Oppenheimer approximation, and Hückel theory.
2. Explain fine and hyperfine structure, Zeeman, Stark effects, rotational, vibrational, Raman spectra, and Franck-Condon principle.
3. Apply selection rules to predict allowed transitions in atomic and molecular spectra.
4. Analyze rotational-vibrational spectra to determine bond lengths, force constants, and dissociation energies.
5. Evaluate the complementary nature of IR and Raman spectroscopy for structure determination.
6. Design spectroscopic protocols for identifying molecular species using IR, Raman, and UV-Vis techniques.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE COURSE 8

Semester: IV

Code:

**CLASSICAL AND QUANTUM OPTICS
(Theory)**

Credits: 4

Prerequisite: --

Objectives

- Recall the fundamental principles of classical optics including interference, diffraction, and polarization.
- Explain the quantum nature of light, photon statistics, and the concept of coherence.
- Apply Maxwell's equations to study wave propagation in dispersive and anisotropic media.
- Analyze optical phenomena using Fourier optics, correlation functions, and quantum state descriptions.
- Evaluate the predictions of quantum optics for entanglement, Bell's inequality, and quantum key distribution.
- Formulate mathematical models for photon statistics, coherent states, and squeezed states of light.

Unit I: Classical Optics (16 hours)

Laws of reflection and refraction - Fermat's principle - Paraxial approximation and lens equation - Matrix optics and ABCD law for Gaussian beams - Huygens-Fresnel principle - Interference: Young's double slit, thin films, Michelson interferometer, Fabry-Perot etalon - Diffraction: Fresnel and Fraunhofer - Single slit, double slit, circular aperture - Diffraction grating and resolving power - Linear, circular, and elliptical polarization.

Unit II: Fourier Optics and Coherence (14 hours)

Spatial frequency and Fourier transform properties of lenses - Fraunhofer diffraction as Fourier transform - Convolution and correlation - Optical filtering and image processing - Abbe's theory of image formation - Phase contrast microscopy - Temporal and spatial coherence - Coherence length and time - Mutual coherence function and degree of coherence.

Unit III: Quantum Nature of Light (14 hours)

Photoelectric effect and Compton scattering - Wave-particle duality - Quantization of EM field - Photon number states (Fock states) - Creation and annihilation operators - Photon statistics: thermal and coherent states - Coherent and squeezed states of light - Quantum efficiency and noise - Photodetectors: PMT, APD, SPAD, SNSPD.

Unit IV: Quantum Optics Phenomena (14 hours)

Poissonian, Bose-Einstein, sub-Poissonian, and super-Poissonian statistics - Mandel Q parameter - Photon antibunching - Hong-Ou-Mandel effect - Spontaneous parametric down-conversion - Bell states, polarization and time-bin entanglement - Bell's inequality and CHSH inequality - Jaynes-Cummings model - Vacuum Rabi splitting.

Unit V: Applications of Quantum Optics (14 hours)

Quantum key distribution: BB84 and Ekert91 protocols - Quantum teleportation and repeaters - Linear optical quantum computing - Boson sampling - Super-resolution microscopy (STED, STORM) - Quantum lithography - Heisenberg-limited measurements - Quantum sensing with squeezed light (LIGO) - Ghost imaging and entangled photon microscopy.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Simulation of interference and diffraction patterns - Analysis of Fourier transforms in optical systems - Calculation of coherence functions - Simulation of photon statistics - Quantum state visualization - Analysis of Bell's inequality violations - Case study: Quantum key distribution protocols.

Primary Text Books

1. Eugene Hecht, Optics (5th Edition), Pearson Education, 2017.
2. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics (3rd Edition), Wiley, 2019.
3. M. O. Scully and M. S. Zubairy, Quantum Optics, Cambridge University Press, 1997.
4. Christopher Gerry and Peter Knight, Introductory Quantum Optics, Cambridge University Press, 2005.
5. Joseph W. Goodman, Introduction to Fourier Optics (4th Edition), W. H. Freeman, 2017.

Reference Books

1. Leonard Mandel and Emil Wolf, Optical Coherence and Quantum Optics, Cambridge University Press, 1995.
2. Rodney Loudon, The Quantum Theory of Light (3rd Edition), Oxford University Press, 2000.
3. Mark Fox, Quantum Optics: An Introduction, Oxford University Press, 2006.
4. G. Grynberg, A. Aspect, and C. Fabre, Introduction to Quantum Optics, Cambridge University Press, 2010.
5. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communications (6th Edition), Oxford University Press, 2006.
6. A. Ghatak, Optics (6th Edition), McGraw Hill Education, 2017.
7. S. C. Gupta, Optics and Photonics: Fundamentals and Applications, PHI Learning, 2019.

Online/Web Resources

1. NPTEL - Modern Optics, Prof. Partha Roy Choudhuri, IIT Kharagpur , <https://nptel.ac.in/courses/115105104>
2. NPTEL - Applied Optics, Prof. Akhilesh Kumar Mishra, IIT Roorkee, <https://nptel.ac.in/courses/115107131>
3. NPTEL - Essentials of Quantum Optics, Prof. Amarendra Kumar Sarma, IIT Guwahati, <https://nptel.ac.in/courses/115103790>
4. Introduction to Non-linear Optics and its Applications, Prof. Samudra Roy, IIT Kharagpur, <https://nptel.ac.in/courses/115105105>
5. MIT OpenCourseWare – 8.06 Quantum Physics III – <https://ocw.mit.edu/courses/8-06-quantum-physics-iii-spring-2018/>

6. MIT OpenCourseWare – 6.974 Fundamentals of Photonics –
<https://ocw.mit.edu/courses/6-974-fundamentals-of-photonics-spring-2006/>

Course Outcome

Upon completion of this course students should be able to

1. Recall the laws of reflection, refraction, interference, diffraction, and polarization of light.
2. Explain the wave-particle duality of light, photon statistics, and coherence.
3. Apply Maxwell's equations to study wave propagation in dispersive media.
4. Analyze interference and diffraction patterns using Fourier optics and coherence theory.
5. Evaluate quantum entanglement of photons and its applications in quantum information.
6. Design mathematical descriptions of coherent, squeezed, and entangled states of light.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2	2	1	–	1	2	–	1
CO2	3	3	2	1	–	2	2	–	1
CO3	3	2	3	2	2	2	3	1	2
CO4	3	3	3	2	2	2	3	2	2
CO5	3	3	3	2	2	3	2	2	2
CO6	3	2	3	2	3	2	3	3	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

CORE COURSE 9

Semester: IV

Code:

**NUCLEAR AND PARTICLE PHYSICS
(Theory)**

Credits: 4

Prerequisite: --

Objectives

- Recall the properties of nuclei, nuclear forces, and the classification of elementary particles.
- Explain the deuteron ground state, nuclear shell model, radioactivity, and reaction mechanisms.
- Apply the shell model, Gamow's theory of alpha decay, and Fermi's theory of beta decay to calculate nuclear properties and decay rates.
- Analyze nuclear reactions using Q-value, cross-section concepts, partial wave analysis, and the Breit-Wigner formula.
- Evaluate the quark model predictions for hadrons and the evidence for neutrino oscillations.
- Formulate the wavefunction for the deuteron and the symmetry classification of particles using SU(2) and SU(3).

Unit I: Nuclear Properties and Two-Body Problem (16 hours)

Nuclear composition, mass, binding energy - Nuclear size and charge distribution - Spin, parity, magnetic dipole, electric quadrupole moment - Nuclear force and exchange interaction - Deuteron ground state: wave equation, S-state and D-state admixture - Low energy n-p scattering: scattering length, spin dependence - Effective range theory - Non-central force and quadrupole moment - Magnetic moment of deuteron - n-n scattering - Exchange interaction and saturation.

Unit II: Nuclear Models (12 hours)

Fermi gas model: proton and neutron gases, Fermi energy - Liquid drop model: Weizsäcker semi-empirical mass formula - Bohr-Wheeler theory of fission - Shell structure and magic numbers - Spin-orbit interaction - Extreme single-particle shell model: spin, parity, magnetic moments - Collective model: vibrations and rotations.

Unit III: Radioactivity and Interaction of Radiation (12 hours)

Alpha decay and Gamow's theory - Geiger-Nuttall law - Beta decay: Fermi's theory, selection rules - Parity violation and neutrino helicity - Electron capture - Gamma ray interaction: photoelectric effect, Compton scattering, pair production - Multipole radiations - Selection rules for gamma emission - Internal conversion.

Unit IV: Nuclear Reactions (12 hours)

Types: direct and compound reactions - Conservation laws - Reaction kinematics: Q-value, threshold energy - Nuclear cross-section and partial wave analysis - Principle of detailed balance - Compound nucleus: formation, decay, resonance - Breit-Wigner formula - Direct reactions and PWBA - Nuclear reactors: production and power - Nuclear power in India.

Unit V: Elementary Particle Physics (12 hours)

Classification: leptons, hadrons, gauge bosons, Higgs - Conservation laws - CPT theorem - Muons and muon decay - SU(2) and SU(3) symmetries - Eightfold Way and Gell-Mann-Okubo formula - Quark hypothesis and QCD - Quark structures of mesons and baryons - Charm, beauty, top quarks - Higgs boson - Neutrino oscillations and mass.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Calculation of binding energy and Q-values - Simulation of alpha decay barrier penetration - Analysis of beta decay spectra - Shell model calculations - Particle physics data analysis - Quark model classification - Neutrino oscillation probability - Case study: Nuclear reactor physics.

Primary Text Books

1. S. N. Ghoshal, Nuclear Physics (2nd Edition), S. Chand, New Delhi, 2018. – Units 1,2,3, and 4
2. M. L. Pandya and R. P. S. Yadav, Elements of Nuclear Physics, Kedar Nath Ram Nath, Meerut, 2020. – Units 1, 2, and 3
3. D. C. Tayal, Nuclear Physics, Himalaya Publishing House, Mumbai, 2020. – Units 3, 4, and 5
4. A. B. Gupta and H. Roy, Physics of the Nucleus, Books and Allied, Kolkata, 2011. – Units 1, 2, and 4
5. J. Singh, Fundamentals of Nuclear Physics, Pragati Prakashan, Mumbai, 2012. – Units 1, 3, and 5

Reference Books

1. K. S. Krane, Introductory Nuclear Physics, Wiley, New York, 1987. – Units 1,2,3, and 4 (Classic)
2. S. B. Patel, Nuclear Physics: An Introduction, Wiley, New Delhi, 1991. – Units 2, 3 and 5
3. R. D. Evans, The Atomic Nucleus, McGraw Hill, New York, 1955. – Unit 3 (Classic for radioactivity)
4. B. R. Martin and G. Shaw, Particle Physics (4th Edition), Wiley, 2017. – Unit 5 (Modern, rigorous)
5. D. Griffiths, Introduction to Elementary Particles (2nd Edition), Wiley-VCH, 2008. – Unit 5 (Pedagogical)
6. R. A. Powsner, M. R. Palmer and E. R. Powsner, Essentials of Nuclear Medicine Physics, Wiley, 2021. – Unit 4 (Nuclear medicine applications)
7. C. P. De Los Heros, Probing Particle Physics with Neutrino Telescopes, World Scientific, 2020. – Unit 5 (Neutrino astrophysics)

Online/Web Resources

1. **NPTEL - Nuclear and Particle Physics, Prof. Poullose Poullose, IIT Guwahati** – <https://nptel.ac.in/courses/115103101>
2. NPTEL - Nuclear Physics: Fundamentals and Applications, Prof. H.C. Verma, IIT Kanpur – <https://nptel.ac.in/courses/115104043>
3. Particle Physics and the Standard Model, Prof. Nirmal Raj, IISc Bangalore – <https://nptel.ac.in/courses/115108642>

Course Outcome

Upon completion of this course students should be able to:

1. Recall the basic properties of nuclei, nuclear forces, and conservation laws of particle physics.
2. Explain deuteron properties, nuclear models, and decay mechanisms.
3. Apply shell model, liquid drop model, and decay theories to nuclear problems.
4. Analyze nuclear reaction kinematics, cross-sections, and resonance phenomena.
5. Evaluate quark model classification, neutrino oscillations, and beyond-Standard Model physics.
6. Formulate deuteron wavefunction and SU(3) weight diagrams for hadrons.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Code:	1. PHYSICS OF NANOMATERIALS AND NANOTECHNOLOGY (Theory)	Credits: 4
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graphene transistors - Quantum dots as qubits - Health and environmental risks - Green nanotechnology.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Calculation of density of states - Simulation of quantum confinement - Bandgap calculation for quantum dots - Carbon nanotube chirality analysis - Design of quantum dot-based device - Case study: Nanomaterials in energy and medicine.

Primary Textbooks

1. C. P. Poole Jr. and F. J. Owens, *Introduction to Nanotechnology*, John Wiley & Sons, 2007.
2. Sulabha K. Kulkarni, *Nanotechnology: Principles & Practices* (4th Edition), Springer/Capital Publishing, 2023.
3. Guozhong Cao and Ying Wang, *Nanostructures and Nanomaterials: Synthesis, Properties, and Applications* (2nd Edition), World Scientific, 2011.

Reference Books

1. P. Harrison, *Quantum Wells, Wires and Dots: Theoretical and Computational Physics of Semiconductor Nanostructures* (4th Edition), Wiley, 2016.
2. M. S. Dresselhaus, G. Dresselhaus, and P. Avouris, *Carbon Nanotubes: Synthesis, Structure, Properties, and Applications*, Springer, 2001.
3. S. Maekawa, *Concepts in Spin Electronics*, Oxford University Press, 2006.
4. V. I. Klimov, *Nanocrystal Quantum Dots* (2nd Edition), CRC Press, 2010.
5. M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2010 (selected chapters).

Online Resources

1. NPTEL – Nano structured materials-synthesis, properties, self assembly and applications – Prof. A.K. Ganguli, IIT Delhi – <https://nptel.ac.in/courses/118102003>
2. NPTEL – Nanomaterials and their Properties, Prof. Krishanu Biswas, IIT Kanpur - <https://nptel.ac.in/courses/113104102>
3. NPTEL – Nanostructures and Nanomaterials, Dr. Anandh Subramaniam, Dr. Kantesh Balani, IIT Kanpur – <https://nptel.ac.in/courses/118104008>
4. NanoHub.org – Online simulations for quantum dots, CNTs, graphene – <https://nanohub.org>
5. PhET Simulation – Quantum Dots – <https://phet.colorado.edu>

Course Outcome

Upon completion of this course students should be able to:

1. Recall fundamental concepts of quantum confinement, length scales, density of states, and nanostructure types.
2. Explain size-dependent optical, electrical, and magnetic properties of nanomaterials.
3. Apply particle-in-a-box model to predict energy levels and density of states.
4. Analyze electronic band structure of carbon nanostructures and their unique properties.
5. Evaluate performance of nanoscale devices such as SET, GMR, and spintronic memories.
6. Design a conceptual nanodevice for a given application.

CO–PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	2	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II DISCIPLINE CENTRIC ELECTIVE COURSE 4 Semester: IV

Code: 2. CRYSTAL GROWTH AND THIN FILM Credits: 4
TECHNOLOGY
(Theory)

Prerequisite: --

Objectives

- Recall the fundamental theories of nucleation, supersaturation, and crystal growth mechanisms.
- Explain the principles of solution, melt, vapour, and thin film growth techniques.
- Apply phase diagrams, solubility data, and nucleation theories to design crystal growth protocols.
- Analyze the influence of growth parameters on crystal quality and defects.
- Evaluate the suitability of different growth methods for specific materials and applications.
- Design and optimize a complete crystal growth or thin film deposition process for a given material.

Unit I: Nucleation Theory and Fundamentals (12 hours)

Importance and classification of crystal growth - Homogeneous, heterogeneous, and secondary nucleation - Classical nucleation theory: Gibbs-Thomson equations - Kinetic theory - Metastable zone width and Meir's solubility diagram - Saturation and supersaturation - Phase diagrams for crystal growth - Congruent and incongruent melting - Selection of growth method.

Unit II: Solution and Gel Growth Techniques (12 hours)

Solvent selection and solubility - Growth by evaporation, slow cooling, temperature gradient - Seeded growth - Gel growth: principle, structure, chemical reaction method - Flux growth and hydrothermal growth - Growth of KDP, ADP, TGS crystals.

Unit III: Melt Growth Techniques (12 hours)

Thermodynamics of melt growth - Zone refining - Bridgman method: apparatus, crucibles, heaters, growth process - Vertical and horizontal Bridgman - Gradient freeze - Czochralski technique: apparatus, seed preparation, pulling rate, diameter control, doping - Float zone technique - Skull melting.

Unit IV: Vapour Growth and Epitaxial Techniques (12 hours)

Physical Vapour Transport: sublimation, condensation, transport agents - Chemical Vapour Transport: transport reactions, temperature variation - Liquid Phase Epitaxy: phase diagram, growth kinetics - Metal-Organic Chemical Vapour Deposition: precursors, growth mechanism - Molecular Beam Epitaxy: UHV conditions, RHEED monitoring - Applications: III-V heterostructures, quantum wells.

Unit V: Thin Film Deposition and Characterization (12 hours)

Physical Vapour Deposition: thermal evaporation, e-beam, sputtering, PLD - Chemical Vapour Deposition: thermal, PECVD, LPCVD - Atomic Layer Deposition:

self-limiting growth - Thin film characterization: thickness measurement, XRD, SEM, TEM, AFM, EDX, XPS - Optical and thermal characterization - Chemical etching.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Nucleation rate calculations - Phase diagram analysis - Simulation of Czochralski growth - Design of Bridgman growth protocol - Thin film deposition parameter analysis - Characterization data interpretation - Case study: Silicon growth for semiconductor industry.

Text Books

1. Govindhan Dhanaraj, Kullaiah Byrappa, Vishwanath Prasad, Michael Dudley (Eds.), Handbook of Crystal Growth, Springer, 2010.
2. J. C. Brice, Crystal Growth Processes, John Wiley and Sons, New York, 1986.
3. P. Santhana Ragavan and P. Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam, 2001.
4. J. W. Mullin, Crystallization, Elsevier, Butterworth-Heinemann, London, 2004.
5. Ichiro Sunagawa, Crystals: Growth, Morphology and Perfection, Cambridge University Press, Cambridge, 2005.
6. Milton Ohring, Materials Science of Thin Films (2nd Edition), Academic Press, 2002. [Recommended for Unit 5]
7. Donald L. Smith, Thin-Film Deposition: Principles and Practice, McGraw-Hill, 1995. [Recommended for Unit 5]

Reference Books

1. H. L. Bhat, Introduction to Crystal Growth: Principles and Practice, CRC Press, Taylor & Francis Group, Boca Raton, Florida, 2015.
2. K. Byrappa and T. Ohachi, Crystal Growth Technology, William Andrew Publishing, 2003.
3. Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, Taylor & Francis Group, Boca Raton, Florida, 2009.
4. A. C. Zettlemoyer, Nucleation (Edited), Marcel Dekker, Inc., New York, 1969.
5. B. R. Pamplin, Crystal Growth, Pergamon Press, Oxford, 1975.
6. K. Sangwal, Elementary Crystal Growth (Edited), SAAN Publishers, Lublin, 1994.

Online Resources

1. Thin Film Technology, Prof. Samit K Ray, IIT Kharagpur – <https://nptel.ac.in/courses/127105531>
2. Prof. Pallab Banerji, Processing of Semiconducting Materials, IIT Kharagpur – <https://vit.digimat.in/nptel/courses/video/113105025/113105025.html> (Covers bulk crystal growth, Czochralski, Bridgman, epitaxy, MOCVD, MBE)
3. Prof. Sushobhan Avasti and Prof. Shankar Selvaraja, Fundamentals of Micro and Nanofabrication, IISc Bangalore – <https://nptel.ac.in/courses/102108078> (Covers crystal growth, PVD, CVD, lithography, etching)

4. DigiMat – NPTEL Video Course: Thin Film Technology (60 lectures) – <http://kcl.digimat.in/nptel/courses/video/127105531/L42.html>
5. Johannes Kepler University Linz – Crystal Growth and Epitaxy – <https://studienhandbuch.jku.at/183541?id=183541&lang=en>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall the basic concepts of nucleation, supersaturation, phase diagrams, and crystal defects.
2. Explain the working principles of solution, melt, vapour growth, and thin film deposition.
3. Apply Gibbs-Thomson equation and kinetic theory to calculate nucleation rates and critical nucleus size.
4. Analyze the effect of growth parameters on crystal size, perfection, and defect density.
5. Evaluate advantages and limitations of different growth techniques for specific materials.
6. Design a growth protocol for a given material including crucible selection and characterization.

CO-PO Mapping Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	1	2	–	1	–
CO2	3	3	2	1	–	2	2	–	1	–
CO3	3	2	3	2	2	2	3	1	2	–
CO4	3	3	3	3	2	2	3	2	2	1
CO5	3	3	3	2	2	3	2	2	2	2
CO6	3	2	3	3	3	2	3	3	2	2

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

**ENTREPRENEURSHIP/INDUSTRY
BASED COURSE**

Semester: IV

Code:

**SOLAR ENERGY TECHNOLOGIES AND
ENERGY STORAGE SYSTEMS
(Theory)**

Credits: 3

Prerequisite: --

Objectives

- Understand the fundamental principles of solar radiation and the physical processes involved in solar energy conversion.
- Acquire knowledge of solar thermal technologies and their applications for sustainable energy generation.
- Understand the physics, design principles, and performance characteristics of photovoltaic devices and systems.
- Analyze the operating principles, characteristics, and applications of various energy storage technologies.
- Understand recent developments in solar energy technologies and evaluate their role in sustainable energy.

Unit I: Fundamentals of Solar Energy and Solar Radiation (7 hours)

Energy scenario and renewable resources - Solar energy potential - Structure of Sun - Solar constant and spectrum - Blackbody radiation - Earth-Sun geometry and solar angles - Air mass - Direct, diffuse, and global radiation - Measurement using pyranometer and pyr heliometer - Optical properties: absorption, reflection, transmission.

Unit II: Solar Thermal Energy Conversion (8 hours)

Principles of solar thermal conversion - Selective absorbing surfaces - Flat plate and concentrating collectors - Solar water heaters, cookers, dryers - Solar distillation and ponds - Solar thermal power generation - Thermal energy storage - Performance parameters and applications.

Unit III: Solar Photovoltaic Technology (7 hours)

Photovoltaic energy conversion - Semiconductor materials - Photovoltaic effect - Solar cell construction and working - I-V characteristics, fill factor, efficiency - Factors affecting performance - Types: monocrystalline, polycrystalline, thin-film, perovskite - PV modules and arrays - Stand-alone and grid-connected systems - Applications.

Unit IV: Energy Storage Systems (7 hours)

Need for energy storage - Storage system characteristics - Electrochemical storage: lead-acid, nickel-based, lithium-ion, sodium-ion, flow batteries - Supercapacitors - Thermal energy storage (sensible and latent heat) - Phase Change Materials - Hydrogen production and storage - Fuel cells - Comparative assessment.

Unit V: Solar Energy Systems and Emerging Technologies (6 hours)

Hybrid renewable energy systems - Solar PV grid integration - Smart grid concept - Building Integrated Photovoltaics - Floating solar and agrivoltaic systems -

Solar-powered electric vehicles - Green hydrogen and solar fuels - Environmental impacts - Future prospects.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Literature reviews, technical report writing, seminar presentations, poster making, industrial visit reports, and online course certifications on recent advancements in solar energy.

Primary Textbooks

1. K. Jager, O. Isabella, A. H. M. Smets, R. A. C. M. M. van Swaaij and M. Zeman, Solar Energy – Fundamentals, Technology and Systems, Delft University of Technology, 2014.
2. G. D. Rai, Non-Conventional Energy Sources, Khanna Publishers, New Delhi.
3. D. P. Kothari, K. C. Singal and Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI Learning Pvt. Ltd., New Delhi.

Reference Books

1. S. P. Sukhatme and J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw-Hill Education.
2. C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd.
3. John A. Duffie and William A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons.
4. John Twidell and Tony Weir, Renewable Energy Resources, Routledge.
5. Robert A. Huggins, Energy Storage, Springer.

Online Resources

1. NPTEL - Fundamentals of Solar Photovoltaics and Technologies, Prof. Ashish Garg, IIT Kanpur, <https://nptel.ac.in/courses/115104001>
2. NPTEL - Solar Energy Technology, Prof. V.V. Satyamurty, IIT Kharagpur, <https://nptel.ac.in/courses/112105051>
3. NPTEL - Solar Energy Engineering and Technology, Prof. Pankaj Kalita, IIT Guwahati, <https://nptel.ac.in/courses/115103123>
4. TU Delft OpenCourseWare – Solar Energy Course
5. NREL PVWatts Calculator – <https://pvwatts.nrel.gov>
6. SolarGIS – Solar resource maps – <https://solargis.com>
7. MNRE (Ministry of New and Renewable Energy) – <https://mnre.gov.in>
8. SECI (Solar Energy Corporation of India) – <https://seci.co.in>

Course Outcomes

Upon completion of this course students should be able to:

1. Recall and define the principles of solar radiation, solar geometry, and solar energy conversion.
2. Explain the design, operation, and performance of solar thermal energy systems.
3. Apply semiconductor physics principles to analyze photovoltaic devices and their performance.
4. Analyze and compare various energy storage technologies based on operating principles and applications.

5. Evaluate emerging solar energy technologies and their significance in sustainable development.
6. Design integrated solar energy systems with appropriate storage solutions for real-world applications.

CO–PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	–	2	–	2	–	2	–
CO2	3	3	2	2	2	2	2	2	2	2
CO3	3	3	3	3	2	2	3	2	2	–
CO4	3	3	3	2	2	2	3	2	2	2
CO5	3	3	3	2	3	3	3	3	3	3
CO6	3	3	3	2	3	3	3	3	3	3

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.

Year: II

PROJECT WORK

Semester: IV

Code:

Credits: 5

Prerequisite: --

Objectives

- Identify a relevant research problem or case study in a chosen area of physics through extensive literature survey.
- Review and critically evaluate existing research literature to establish the context and significance of the study.
- Apply appropriate experimental, computational, analytical, or industry-oriented methodologies to investigate the identified problem.
- Design and execute a systematic investigation, including data collection, analysis, and interpretation.
- Synthesize findings to draw meaningful conclusions and assess the limitations of the study.
- Communicate the research outcomes effectively through a written thesis and oral presentation.

Course Outcomes

1. Identify a research problem or case study in a selected domain of physics through extensive literature survey.
2. Critically review and evaluate existing literature to establish the research gap and objectives.
3. Execute appropriate experimental, computational, analytical, or industry-oriented methods to generate data or insights.
4. Analyze and interpret the results to derive scientifically valid conclusions.
5. Synthesize findings into a coherent thesis with proper discussion of limitations and future scope.
6. Defend the research work through an oral presentation and viva voce examination.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	2	3	3	-	3	2	2	3	2	-
CO2	2	3	3	-	2	2	2	3	2	-
CO3	2	2	2	3	2	2	3	3	2	1
CO4	2	3	3	3	2	3	3	3	2	1
CO5	2	3	3	2	2	3	3	3	2	2
CO6	2	2	2	-	2	2	2	3	2	3

3 = High, **2** = Moderate, **1** = Low, **-** = No significant contribution.

Year: II

VALUE ADDED COURSE 2

Semester: IV

Code:

**INTELLECTUAL PROPERTY RIGHTS
IN SCIENCE AND TECHNOLOGY
(Theory)**

Credits: 2*

Prerequisite: --

Objectives

- Recall the fundamental concepts of Intellectual Property Rights and their types.
- Explain the legal framework and procedures for filing patents, copyright registration, and trademark registration in India.
- Apply IPR principles to identify patentable inventions and protect research outputs.
- Analyze case studies of IP disputes and infringement to understand legal and commercial implications.
- Evaluate the strategic importance of IPR in research commercialization, technology transfer, and start-ups.
- Design a basic IP strategy for a research project or technology startup.

Unit I: Introduction to Intellectual Property Rights (6 hours)

Concept and meaning of intellectual property - WIPO and TRIPS Agreement - IPR in India: laws and amendments - Overview of patents, copyrights, trademarks, trade secrets, industrial designs, geographical indications - Comparison of IPR types - IPR in academia vs. industry - IPR policies of funding agencies.

Unit II: Patents (8 hours)

Definition and patentability criteria: novelty, inventive step, industrial applicability - Patentable and non-patentable subject matter - Indian Patents Act, 1970 - Patent filing process: prior art search, drafting specifications, claims - Forms, fees, publication, examination - Opposition and grant - International patent filing and PCT procedure - Patent infringement and remedies - Case studies: pharmaceutical, software, biotechnology patents.

Unit III: Copyright, Trademarks, and Other IPR (6 hours)

Copyright: scope, works, ownership, rights, duration, registration - Fair use and Creative Commons licenses - Trademarks: definition, types, distinctiveness, registration process - Infringement and passing off - Industrial designs: registration process - Geographical indications - Trade secrets and NDAs - Semiconductor layout design and plant variety protection.

Unit IV: Technology Transfer and Commercialization (5 hours)

Technology transfer: modes and processes - Technology Transfer Office - Agreements: MTA, NDA, MoU - Licensing terms and royalty structures - Start-ups and IP - Incubation centers - IP valuation and patent landscaping - Government funding agencies - Case studies: successful technology transfers.

Unit V: IPR Strategy for Researchers and Start-ups (4 hours)

Prior art searches and patent landscaping - Identifying patentable inventions - Publication vs. filing timing - Laboratory notebooks and invention disclosure -

Working with patent attorneys - Freedom to operate analysis - IP portfolio management - Compulsory licensing - Traditional knowledge and biopiracy - IPR and public health.

Unit VI: Current Contours (Self-directed learning activities for Continuous Internal Assessments Only)

Prior art search exercise - Patent drafting exercise - Case study analysis of IP disputes - Trademark search exercise - Technology transfer case study - IP strategy development - Mock patent filing process - Copyright registration exercise.

Primary Textbooks

1. P. Narayanan, *Intellectual Property Law* (4th Edition), Eastern Law House, 2022.
2. David I. Bainbridge, *Intellectual Property* (9th Edition), Pearson, 2012.
3. WIPO, *Introduction to Intellectual Property: Theory and Practice*, World Intellectual Property Organization, 2016. (Free PDF available)

Reference Books

1. Elizabeth Verkey, *Intellectual Property Rights*, Eastern Book Company, 2021.
2. V. K. Ahuja, *Law Relating to Intellectual Property Rights* (3rd Edition), LexisNexis, 2022.
3. Deborah E. Bouchoux, *Intellectual Property: The Law of Trademarks, Copyrights, Patents, and Trade Secrets* (5th Edition), Cengage Learning, 2017.

Online Resources

1. Indian Patent Office (IPO) – <https://ipindia.gov.in>
2. WIPO (World Intellectual Property Organization) – <https://www.wipo.int>
3. USPTO (United States Patent and Trademark Office) – <https://www.uspto.gov>
4. EPO (European Patent Office) – <https://www.epo.org>
5. NPTEL – Intellectual Property Rights and Competition Law, Prof. K. D. Raju, Prof. Niharika Sahoo Bhattacharya, IIT Kharagpur – <https://nptel.ac.in/courses/110105139>

Course Outcome

1. Recall the definitions, types, and legal frameworks of IPR including patents, copyrights, trademarks, trade secrets, and industrial designs.
2. Explain the patent filing process, patentability criteria, and copyright registration in India.
3. Apply IPR principles to identify protectable subject matter in research outputs.
4. Analyze case studies of IP disputes to understand infringement and enforcement.
5. Evaluate the role of IPR in technology transfer, licensing, start-ups, and commercialization.
6. Design a basic IP strategy for protecting research innovations.

CO-PO Mapping Matrix

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	2	2	1	–	2	–	2	–	–
CO2	3	3	2	1	–	3	–	2	–	–
CO3	3	2	3	2	2	2	–	2	–	–
CO4	3	3	3	2	2	2	–	3	–	–
CO5	3	2	3	2	2	3	2	2	2	2
CO6	3	2	3	2	3	2	2	2	2	3

3 = High, **2** = Moderate, **1** = Low, **–** = No significant contribution.