DEPARTMENT OF PHYSICS

NORTH LAKHIMPUR UNIVERSITY

Syllabus approved by the

Board of Studies, Department of Physics

held on 17th May 2025

for

M.Sc. in Physics

1.0 Introduction:

The M.Sc. in Physics program at North Lakhimpur College (Autonomous) is a postgraduate course launched in 2021**,** aimed at fostering a deep understanding of the physical sciences while nurturing critical thinking, research skills, and innovation. Rooted in the legacy of a department established in 1966, the program is designed in line with the transformative vision of the National Education Policy (NEP) 2020**,** which emphasizes holistic, multidisciplinary, and flexible education. Graduates of the M.Sc. Physics program are envisioned as scientifically competent, ethically grounded, and globally aware individuals who can contribute meaningfully to scientific research, higher education, sustainable development, and technological advancement. The program aims to align with India's broader goals of creating a knowledge economy and self-reliant (Atmanirbhar) nation, as emphasized in NEP 2020.The Department is staffed by experienced faculty members with diverse specializations that includes Material Science, Electronics and Photonics and high energy Physics. It regularly organizes seminars, counseling sessions, and lecture series featuring renowned physicists to inspire and guide students. Notably, the Department hosts 'SPARK,' an international symposium on physics, providing a platform for researchers to engage with contemporary advancements in the field.

1.1 Nature and extent of the M.Sc. (Physics):

The Master of Science (M.Sc.) in Physics at North Lakhimpur College is a postgraduate academic program designed to deepen the learner's understanding of fundamental and applied concepts in physics, while nurturing the cognitive, affective, and psychomotor domains of learning. Rooted in the constructivist and outcome-based education model, the program equips students with the ability to acquire, apply, and innovate knowledge in diverse fields of Physics. In accordance with NEP 2020, the program fosters

- Multidisciplinary and holistic education with scientific depth and societal relevance
- Emphasis on critical thinking, creativity, and research-based learning,
- Inclusion of technology-enhanced, flexible, and learner-centric approaches
- Development of ethics, values, and a global yet local perspective

The curriculum of the program entails component that would help students to attain the Program Learning Outcomes (PLOs), Course learning Outcomes (CLOs), Skill and Ability Enhancement Outcomes, Graduate Attributes, National Relevance and Progression.

1.2 Aims of Master's degree Programme in Physics: The Master's degree program in Physics aims to

1. Equip students with a thorough and critical understanding of core and advanced concepts in physics, while also familiarizing them with emerging areas such as nanotechnology, quantum information, and computational modelling.
2. Train students to design and execute complex experiments, utilize modern instruments and software tools, and analyze data with a high degree of accuracy and scientific integrity.
3. Provide rigorous training in mathematical physics and computational methods to enable the formulation and solution of intricate physical problems.
4. Foster the ability to connect physics with other scientific domains—like materials science, energy, and biosciences—enhancing the relevance and impact of their knowledge in innovation and entrepreneurship.
5. Encourage logical analysis, hypothesis testing, and creative problem-solving in both theoretical and applied contexts.
6. Develop competence in presenting scientific information effectively through oral, written, and visual formats suited to both academic and professional audiences.
7. Promote ethical research practices, awareness of societal challenges, and a sense of responsibility towards sustainability and environmental stewardship.
8. Prepare students to adapt to future developments in science and technology through self-directed learning, digital proficiency, and lifelong curiosity.
9. Encourage students to undertake original research, review scientific literature critically, and contribute new knowledge through innovation and inquiry-driven learning.
10. Equip learners with the skills and mindset needed to engage with global scientific challenges while contributing to national development goals as envisioned in NEP 2020.

1.3 Graduate Attributes:

Graduate Attributes are the measurable learning outcomes that encapsulate the knowledge, skills, attitudes, and values a student acquires by the time they graduate from a program, enabling them to function effectively in their personal, professional, and civic life. The expected graduate attributes after the completion of the M.sc program in Physics are expected to be as follows:

1. **In-depth Disciplinary Knowledge**: In depth and advanced knowledge of core and emerging areas of physics and can apply this knowledge to solve complex theoretical and experimental problems.

2. **Research and Inquiry Competence**: Ability to engage in original research through hypothesis formulation, literature review, experimentation or modeling, and data interpretation, leading to innovation and knowledge creation.

3. **Analytical and Problem-Solving Skills**: Capacity to analyze physical situations using logical reasoning, mathematical modeling, and computational methods, and develop feasible solutions to scientific problems.

4. **Experimental and Technical Proficiency**: Skilled in designing, conducting, and analyzing experiments using advanced laboratory equipment and digital tools, with attention to precision, reproducibility, and safety.

5. **Communication and Scientific Writing**: Ability to clearly communicate complex scientific ideas and results through oral presentations, research papers, reports, and digital media, adhering to scientific standards.

6. **Interdisciplinary Perspective**: Understanding of how physics integrates with other fields such as materials science, energy studies, computational science, and engineering, encouraging innovation across domains.

7. **Ethical and Social Responsibility**: Awareness of professional ethics, social equity, environmental sustainability, and the role of physics in addressing global and local societal challenges.

8. **Digital Literacy and Technology Use**: Proficiency in the use of modern ICT tools, programming, simulation software, and online platforms to support scientific research, learning, and communication.

9. **Lifelong Learning Orientation**: Commitment to continuous professional development, adaptability to new knowledge and technologies, and enthusiasm for self-directed and lifelong learning.

10. **Leadership and Teamwork**: Ability to work effectively as an individual or in a collaborative team, demonstrating leadership, coordination, and interpersonal skills in academic and professional contexts.

11. **National Commitment and Global Readiness**: Graduates are prepared to contribute to national development goals as responsible citizens and professionals, while also being globally competent and competitive in international academic, research, and industry environments.

1.4 Qualification descriptor:

Qualification Descriptors are benchmark statements that define the nature and characteristics of learning expected at a specific academic level, helping to ensure consistency, transparency, and comparability across programs and institutions. The qualification descriptor for a student graduating with a Bachelor of Science in Physics will be able to:

1. **Comprehensive Knowledge and Understanding**: Graduates should demonstrate **systematic and coherent understanding** of classical and modern physics, with an ability to critically analyze foundational and advanced topics such as quantum mechanics, electrodynamics, statistical mechanics, and condensed matter physics.

2. **Mastery of Theoretical and Experimental Methods**: Graduates should exhibit **advanced competence** in applying theoretical frameworks and experimental techniques to investigate, model, and analyze physical systems, using appropriate instruments, tools, and computational methods.

3. **Application of Knowledge in Interdisciplinary and Real-world Contexts**: Graduates should be able to **apply physics knowledge** to interdisciplinary areas such as nanoscience, energy systems, photonics, electronics, and biophysics, and relate scientific findings to industrial applications, innovation, and technology development.

4. **Research and Innovation Capability**: Graduates should possess the **capacity to identify, define, and investigate scientific problems**, conduct original research or project work, and contribute new insights through critical evaluation of existing knowledge and independent innovation.

5. **Advanced Analytical and Mathematical Competence**: Graduates should be able to use **mathematical reasoning, numerical methods, and computational techniques** to formulate and solve complex physical problems with accuracy and rigor.

6. **Communication Proficiency**: Graduates should demonstrate the ability to **communicate complex scientific ideas** and results clearly and effectively to both expert and non-expert audiences, through oral presentations, technical writing, academic papers, and digital platforms.

7. **Ethical, Social, and Environmental Awareness**: Graduates should understand and adhere to **ethical standards in research**, recognize the **societal and environmental implications** of scientific work, and be committed to **sustainable and inclusive development**.

8. **Digital and Technological Fluency**: Graduates should exhibit fluency in the use of **ICT tools, programming environments, data analysis software**, and digital learning platforms relevant to contemporary physics research and practice.

9. **Autonomy, Lifelong Learning, and Adaptability**: Graduates should be capable of **independent learning, reflective practice, and adaptability**, staying updated with advancements in physics and allied fields for continuous professional and personal growth.

10. **National Commitment and Global Competence**: Graduates should be prepared to **contribute meaningfully to national goals** (such as scientific research, education, and

innovation) while being **globally competent** to pursue higher studies, international collaboration, or employment in advanced research and technology sectors.

1.5 Programme Specific Outcome:

Program Specific Outcomes (PSOs) are the abilities, understanding and skills that a student is expected to demonstrate upon successful completion of a particular program in a specific discipline. These outcomes are tailored to the discipline and reflect the knowledge, skills, and competencies that students will acquire, focusing on what is unique or essential to that program. The PSOs expected after completion of the Master's program in Physics are listed as follows.

1. **Advanced Understanding of Core and Emerging Areas**: Develop a deep and critical understanding of core areas of physics such as classical mechanics, quantum mechanics, electrodynamics, statistical mechanics, and solid-state physics, along with exposure to emerging areas like nanoscience, soft materials quantum information, and computational physics etc

2. **Experimental Proficiency**: Acquire the ability to design and conduct experiments independently, analyze data critically using modern instrumentation and computational tools, and interpret results in alignment with theoretical principles.

3. **Mathematical and Analytical Skills**: Develop and apply advanced mathematical techniques to solve complex physical problems using analytical, numerical, and simulation-based methods.

4. **Interdisciplinary and Application-oriented Knowledge**: Demonstrate understanding of interdisciplinary applications of physics in areas such as materials science, biophysics, photonics, energy science, and electronics, promoting innovation and entrepreneurship.

5. **Critical Thinking and Problem Solving**: Enhance logical reasoning, scientific thinking, and problem-solving abilities that can be applied to theoretical, experimental, and applied physics challenges.

6. **Communication and Scientific Writing**: Develop the ability to effectively communicate scientific ideas, methods, and findings through oral presentations, research reports, publications, and proposals, using appropriate formats and standards.

7. **Ethical, Social and Environmental Responsibility**: Inculcate professional ethics, awareness of societal responsibilities, and sustainability concerns, fostering an understanding of the broader implications of physics in society and policy.

8. **Lifelong Learning and Digital Competence:** Demonstrate self-directed learning, adaptability to new developments, and proficiency with digital tools, supporting continuous professional growth in academia, research, industry, or teaching.

9. **Research Orientation and Innovation Capacity**: Cultivate a research-oriented mindset, with the capacity to identify scientific problems, review literature, formulate hypotheses, and engage in original investigation and innovation.
10. **National and Global Competence**: Prepare students to contribute to nation-building in alignment with NEP 2020 goals, while being globally competent professionals equipped for higher studies, competitive exams, R&D, or entrepreneurship.

1.6 Course learning outcomes:

Course Learning Outcomes (CLOs) are measurable statements that articulate the knowledge, skills, attitudes, and values students should acquire through learning experiences in a specific course. The students, on completion of the Bachelors program in Physics are expected to

- Recall and reproduce key physical principles, mathematical formulations, and experimental techniques relevant to the course content.
- Explain the fundamental concepts and theoretical frameworks in physics and interpret physical phenomena using appropriate models and representations.
- Apply theoretical knowledge and mathematical methods to solve complex physical problems and analyze experimental data.
- Deconstruct physical systems and processes to identify interactions, compare models, and evaluate assumptions or limitations.
- Assess the validity of experimental results, theoretical approaches, and computational models using logical reasoning and scientific judgement.
- Formulate new problem-solving strategies, design experiments, develop simulations or models, and propose innovative solutions or hypotheses.
- Communicate scientific knowledge, experimental results, and theoretical insights effectively in written and oral formats, adhering to academic standards.
- Demonstrate awareness of ethical issues in research, environmental sustainability, and societal relevance of physics applications.
- Plan and conduct small-scale research projects independently or in teams, including literature review, methodology design, data analysis, and reporting.
- Use modern ICT tools, programming languages, and simulation software to analyze physical systems and visualize results.

1.7 Teaching Learning Methodologies:

The teaching-learning methodology in Physics integrates a diverse blend of pedagogical approaches to ensure deep conceptual understanding and skill development. Traditional lectures continue to play a foundational role by introducing core concepts and theoretical frameworks. These are complemented by interactive sessions that encourage student participation and active engagement. Problem-Based Learning (PBL) strategies present students with real-life or theoretical challenges, fostering critical thinking, collaborative problem-solving, and peer-led learning. Laboratory work remains central, enabling students to apply theoretical knowledge through hands-on experimentation while honing skills in measurement, data analysis, and instrumentation. They are encouraged to maintain laboratory notebooks. Modern labs are increasingly supplemented with virtual simulations and remote tools. Computational methods using platforms like Python, MATLAB, simulations support visualization and modelling of complex systems, enhancing students' conceptual grasp and analytical capabilities. Project-based learning, through mini or capstone projects, promotes research aptitude, innovation, and teamwork, often involving literature review, data analysis, and presentation. Tutorials and dedicated problem-solving sessions provide focused support for mathematical techniques and conceptual clarity, often in a mentoring format. Seminars and group discussions are also included as integral part of the teaching learning mechanism to enhance communication skill and to develop a deeper understanding of topics. Moreover, use of ICT and digital tools are encouraged for resource sharing and knowledge dissemination. Faculty mentoring is practiced to support personalized academic guidance and career planning Together, these methods create a holistic, student-centred learning environment aligned with modern pedagogical best practices.

1.8 Assessment and Outcome Measurement Methods

The assessment strategy in Physics education is designed to be comprehensive and multidimensional, ensuring both continuous engagement and final evaluation of learning outcomes. The internal assessment, contributing 30% of the total weightage, is conducted throughout the course that includes two sessional exams, class tests, assignments, library work, seminars aligned with course learning outcomes (CLOs), and tutorial performance assessed through participation in discussions and presentations. In contrast, the end semester exam, carrying 70% of weightage, evaluates cumulative understanding at the end of the semester. This typically includes a comprehensive written theory exam comprising short-answer questions, derivations, numerical problems, and conceptual essays. Practical exams assess experimental skills, viva voce performance, and the quality of lab records. Laboratory records, regular attendance, and the timely completion of experiments also contribute to evaluation. For students undergoing internships or apprenticeships, assessment is based on the quality of work undertaken, reflective reports, supervisor evaluations, and presentations, ensuring alignment with both academic and industry standards.

2.0 Certification Criteria

2.1 Other Key Criteria for PG Programme

- **Summer Internship/Apprenticeship/Community engagement**: Summer internship/apprenticeship or community engagement is mandatory for all the students pursing M.Sc. in Physics.
- A dissertation should be submitted mandatorily for the project work.

Summary of the PG Course Structure as per NEP 2020 Guidelines

SEMESTER-I

Course	Course Title	Course Code	Credit	Marks	End Sem Marks	Internal Assessment
Core - I	Quantum Mechanics	CC-MPHY-4-101	4	80	56	24
Core - II	Mathematical Physics	CC-MPHY-4-102	4	80	56	24
Core- III	Classical Mechanics	CC-MPHY-4-103	4	80	56	24
Elective	Computational Methods	EL-MPHY-T1-101	1	40	28	12
		EL-MPHY-P3-101	3	60	60	
Other Course	Research methodology	OC-MPHY-4-101	4	80	56	24
Total			20	420	312	108

SEMESTER-II

Course	Course Title	Course Code	Credit	Marks	End Sem Marks	Internal Assessment
Core - IV	Condensed Matter Physics	CC-MPHY-4-201	4	80	56	24
Core - V	Electronics	CC-MPHY-4-202	4	80	56	24
Core- VI	Electrodynamics	CC-MPHY-4-203	4	80	56	24
Elective	Atomic and Molecular Spectroscopy	EL-MPHY-4-201	4	80	56	24
	Internship/ Apprenticeship/ Community engagement		4	80		
Total			20	400	224	96

SEMESTER-III

Course	Course Title	Course Code	Credit	Marks	End Sem Marks	Internal Assessment
Core - VII	Nuclear Physics	CC-MPHY-4-301	4	80	56	24
Core - VIII	Advanced Quantum Mechanics	CC-MPHY-4-302	4	80	56	24
Core- IX	General Laboratory - 01	CC-MPHY-4-203	4	80	80	
DSE	High Energy Physics - I / Condensed Matter Physics (Low-Dimensional Systems and Soft Matter Physics**)**	DSE-MPHY-4-201	4	80	56	24
	Research Project/		4	80	80	
Total			20	400	328	72

SEMESTER-IV

Course	Course Title	Course Code	Credit	Marks	End Sem Marks	Internal Assessment
Core - I	Statistical Mechanics	CC-MPHY-4-401	4	80	56	24
Core - II	General Lab - 02	CC-MPHY-4-302	4	80	56	24
Core- III	Particle Physics	CC-MPHY-4-203	2	40	28	12
DSE	High Energy Physics - II / Solid State Devices and Fabrication Techniques	DSE-MPHY-4-201	4	80	56	24
	Research Project		6	120	120	
Total			20	400	316	84

Course: Core - I
Course Title: Quantum Mechanics
Course Code: MPHY-CC-4-101
Nature of the Course: Core
Total Credit assigned: 04
Component of the Course: L- 50, P- 0, T- 10
Distribution of Marks: End Semester: 56 In Semester: 24

Course Objectives: The Objectives of this course are to:

CO-1: Understand the foundational concepts in mathematical frameworks of quantum mechanics to prepare students for advanced topics.
CO-2: Understand the foundational concepts in matrix formulation of quantum mechanics.
CO-3: Understand the concept of angular momentum in quantum systems, including orbital and spin angular momenta, their algebra, and the theory of angular momentum addition.
CO-4: Apply various approximation methods in quantum mechanics such as perturbative and semi-classical methods to analyse and predict outcomes of complex quantum systems.

Course Content:

Unit	Contents	M	L	P	T
I	**Recapitulation of Fundamental Concepts** Review of wave mechanics, Time dependent and time independent Schrödinger equation and its application to some important problems: free particle, infinite and finite potential well, delta function potential, simple harmonic oscillator (operator method).	8	6	0	2
II	**Mathematical Foundations of Quantum Mechanics** Hilbert space, state vectors, Dirac's Bra-Ket notation, Operators in quantum mechanics, Postulates of quantum mechanics, Heisenberg's Matrix formulation of quantum mechanics, Algebra of Operators, Eigenvalues and eigenfunctions, Measurements, Observables and Uncertainty Relations, Time evolution of a state and expectation values, Schrödinger versus Heisenberg picture, Symmetries and Conservation laws.	16	15	0	3
III	**Angular Momentum Algebra** Orbital Angular Momentum: general formalism, Matrix Representation, Geometrical Representation, Eigenfunctions and Eigenvalues of L^2 and L_z, Eigenfunctions of Orbital Angular Momentum, spherical harmonics. Stern Gerlach Experiment and emergence of the idea of quantum spin, Spin Angular Momentum, General Theory of Spin, Spin1/2 and the Pauli Matrices. Addition of Angular momenta, Clebcsh-Gordon Coefficients.	16	15	0	3
IV	**Perturbation theory and approximation methods** Time independent perturbation theory and applications: Nondegenerate and Degenerate Perturbation theories and applications- quantum rotators and anharmonic oscillators, Fine structure, Zeeman Effect and Stark effect in hydrogen atom. Variational methods, Time-dependent perturbation theory, Fermi's Golden Rule, Applications to absorption and emission of radiation, WKB Approximation.	16	14	0	2

		56	50	0	10

Mode of In-Semester Assessment:

A. Two Sessional Tests:	**Sessional I**	**20**
	Sessional II	**20**
B. Other Sessional Activities:	**Attendance**	**10**
	Seminar/Class tests/Sudden tests	**10**
	Home assignments/ Library work	**10**

Total In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO-1: Solve fundamental quantum mechanical problems such as the particle in a box, harmonic oscillator, and delta potential using time-independent Schrödinger equation.

CLO-2: Describe the mathematical structure of quantum mechanics including Hilbert spaces, operators, and the postulates; apply Dirac notation and operator algebra to basic problems.

CLO-3: Construct, apply and analyse angular momentum operators, their algebra, and matrix representations.

CLO-4: Construct, apply and justify approximation-based models for complex quantum systems and analyse their physical implications using perturbation and time-dependent approaches.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge		CO1, CO2				
Conceptual Knowledge		CO2, CO3	CO2, CO3, CO4	CO3		
Procedural Knowledge			CO2, CO3, CO4	CO4	CO4	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	0	1	2	3	3	2	2	2

CLO2	3	3	0	1	2	3	3	2	2	2
CLO3	3	3	0	1	2	3	3	2	2	2
CLO4	3	3	0	1	2	3	3	2	2	2
Average	3	3	0	1	2	3	3	2	2	2

(3=High, 2= Moderate 1= Low)

Suggested Readings:

1. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Education.
2. G. Aruldhas, Quantum Mechanics, PHI Learning.
3. P.M. Mathews & K. Venkatesan, A Textbook of Quantum Mechanics, McGraw Hill Education.
4. R. Shankar, Principles of Quantum Mechanics, 2nd Edition, Springer, 1994.
5. Nouredine Zettili, Quantum Mechanics: Concepts and Applications, Wiley.
6. L. I. Schiff, Quantum Mechanics, 3rd Edition, McGraw-Hill, 1968.
7. Claude Cohen-Tannoudji, Bernard Diu, and Frank Laloë, Quantum Mechanics (2 Vols), Wiley, 2005.
8. **J. J. Sakurai and Jim Napolitano,** *Modern Quantum Mechanics*, 2nd Edition, Pearson Education, 2014.
9. **R. Shankar,** *Principles of Quantum Mechanics*, 2nd Edition, Springer, 1994.
10. **L. I. Schiff,** *Quantum Mechanics*, 3rd Edition, McGraw-Hill, 1968.
11. **Claude Cohen-Tannoudji, Bernard Diu, and Frank Laloë,** *Quantum Mechanics* (2 Vols), Wiley, 2005.
12. **A. Ghatak and S. Lokanathan,** *Quantum Mechanics: Theory and Applications*, 5th Edition, Springer, 2004.
13. J. J. Sakurai and Jim Napolitano, Modern Quantum Mechanics, 2nd Edition, Pearson Education, 2014.

Course Code: CC-4-MPHY -102
Course Title: Mathematical Physics

Nature of the Course: Core

Total Credits assigned: 04
Components of the course: L- 46, P-0, T- 14
Distribution of Marks: End Semester: Theory: 56, Practical: 0, In Semester: 24

Course Objectives:

CO1: Acquaint students with the fundamentals of vector calculus, Linear vector spaces and matrix algebra and enable them to **understand** and **apply** the ideas in various contexts.

CO2: To help the students **understand** and **apply** the basics of group, and group representation theory.
CO3: To enable students **understand** and **apply** the tensor analysis in various physical and mathematical problems.

Unit	**Contents**	Marks	L	P	T
I	**Linear Vector Spaces:** Review of vector analysis; definition of vector spaces; finite dimensional vector spaces: linear independence, basis and dimensionality, inner product of vectors and norm of vector, Schemidt's orthogonalization method, Schwarz's and Bessel's inequalities; matrices: orthogonal, Hermitian, unitary and normal matrices; linear operators: matrix representation of linear operators; linear transformation: similarity transformation, orthogonal and unitary transformations; eigenvectors and eigenvalues, diagonalization of matrices (or operators); infinite dimensional vector space: Hilbert space, Fock space.	25	22		8

Unit	Contents	Marks	L	P	T
II	**Group Theory**: Groups, subgroups, classes and characters, cosets, factor group, normal subgroup, point symmetry group, direct and semidirect product of groups, homomorphism and isomorphism, representation of a group, Lie groups, generators of continuous group, rotation groups, unitary groups, special unitary groups. **(Lectures: 15, Marks: 14**	20	12		4
III	**Tensor Analysis:** Basics of tensor algebra, line element and metric tensor, associated tensors, Christoffel's symbols, geodesics, covariant derivatives, Riemannian Christoffel's tensor or curvature tensor, Bianchi identities.	11	10		4

(L= Lecture, P = Practical, T = Tutorial)

Course Learning Outcomes: After the end of the course the students will be able to:

CLO1: understand the fundamentals of vector calculus, linear vector spaces and matrix algebra and will be able to **apply** them to **analyse** various mathematical and physical problems.

CLO2: to **understand** and **apply** the basics of group, and group representation theory.
CLO3: to **understand** and **apply** the tensor analysis in various physical and mathematical problems.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		CO1,CO2 CO3	CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2 ,CO3	
Procedural Knowledge		CO1,CO2 CO3	CO1,CO2, CO3	CO1,CO2,C O3,	CO1,CO2 CO3	
Meta-cognitive Knowledge		CO1,CO2 CO3	CO1,CO2CO3,	CO1,CO2,C O3	CO1,CO2 CO3	

Mapping of PSO with CLO

CLO/PSO	PSO1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO8	PSO9	PSO10
CLO 1	3	1	3	2	3	2	2	2	2	2
CLO 2	3	1	3	2	3	2	2	2	2	2
CLO 3	3	1	3	2	3	2	2	2	2	2
Avg.	3	1	3	2	3	2	2	2	2	2

Mode of In-Semester Assessment: (24 Marks)

A. Two Sessional Test:

Sessional I: 30
Sessional II: 30

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total Marks: 70

20% from each component to contribute to the total marks of 24.

Suggested Readings

1. Mathematical Methods for Physicists, G. B. Arfken and H. J. Weber, Elsevier Academic Press.
2. Mathematical Method for Physics and Engineering, K. F. Riley, M. P. Hobson, and S.
J. Bence, Cambridge University Press.
3. Essential Mathematical Methods for the Physical Sciences, K. F. Riley and M. P. Hobson, Cambridge University Press.
4. Mathematical Methods in the Physical Sciences, Mary L. Boas, John Wiley & Sons.
5. Mathematical Physics: Basics, S. D. Joglekar, Universities Press.
6. Mathematical Physics: Advance, S. D. Joglekar, Universities Press.
7. Mathematical Physics with Application, Problems and Solution, U. Balakrishnan, Ane Books Pvt. Ltd.
8. Elements of Group Theory for Physicists, A.W. Joshi, New Age International.
9. Group Theory in Physics, J. F. Cornwell, Academic Press.
10. Group Theory in a Nutshell for Physicists, A. Zee, Princeton University Press.
11. Tensor Calculus, Barry Spain, Radha Publishing House (Kolkata).
12. General Theory of Relativity, P. A. M. Dirac, Prentice-Hall of India.

13. Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, S. Weinberg, Wiley and Sons.

Course Code: CC-4-MPHY-103
Course Title: Classical Mechanics - II
Nature of the course: Major (Theory)
Component of the course: L: 48, P: 0, T: 12
Distribution of credits: Theory: 04
Distribution of Marks: End Semester: Theory: 56, In Semester: 24

Course objectives: The objectives of the course are to
CO 1: enable students develop deep understanding of classical mechanics using advanced formalisms such as Lagrangian and Hamiltonian mechanics
CO 2: enable students explore the dynamics of systems with constraints, symmetries, and conservation laws, and learn to analyze motion in central potentials and rotating frames.
CO 3: emphasizes the geometrical and algebraic structure of dynamical systems through concepts such as phase space, canonical transformations, Poisson brackets, and the Hamilton-Jacobi equation.
CO 4: enable students gain proficiency in applying these principles to physical systems, including harmonic oscillators, central force problems, and rigid body dynamics, laying a strong foundation for further studies in theoretical physics and advanced mechanics.

Course content

Unit	Content	Marks	L	P	T
I	**Unit -I: Lagrangian and Hamiltonian Formalisms** Lagrange equation and applications, cyclic co-ordinates, conservation of liner momentum, angular momentum and total energy. Hamilton's equations of motion. Applications: Hamiltonian for a harmonic oscillator, solution of Hamilton's equation for Simple Harmonic Oscillations; particle in a central force field- conservation of angular momentum and energy. Flows in phase space, solvable vs. differentiable, equilibria and linear stability theory, bifurcation in Hamiltonian system	14	12		3
II	**Unit -II Motion in central potential:** Motion in a central potential, Maps, winding numbers and orbital stability, Hidden symmetry in the Kepler problem, Small Oscillations, Solution of one-dimensional harmonic oscillator problem, forced oscillations in one dimension, Damped harmonic motion in one-dimension general solution of the problem, Displacement as a function of time, Systems with many degrees of freedom.	14	12		3
III	**Unit- III: Transformation in configuration space** Geometry of motion in configuration space, canonical moment and covariance of Lagrange's equation in configuration space. Hamiltonian dynamics and transformations in phase space, Generating functions, Poisson brackets, Hamilton-Jacobi equation, Action-angle variables.	14	12		3
IV	**Unit IV: Linear transformations, rotations and rotating frames**	14	12		3

	Linear transformations, rotations and rotating frames, similarity transformations, linear transformations and eigen value problem, dynamics in rotating reference frames. Rigid Body Dynamics, Definition of Rigid body, Eulerian Angles, Euler's theorem, Angular momentum and kinetic energy, Moment of inertia tensor, Euler's equation of motion, Symmetrical top				

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment: (24 Marks)

B. Two Sessional Test:

Sessional I: 20
Sessional II: 20

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total: 70

20% from each component to contribute to the total marks of 24

Course learning outcome: After the successful completion of the course, the students are expected to

CLO 1: **describe** the principles of Lagrangian and Hamiltonian mechanics, including conservation laws and symmetries.

CLO 2: **explain** the dynamics of mechanical systems in configuration and phase space, including central force motion and rotating frames.

CLO 3: **apply** Lagrange's and Hamilton's equations to solve physical problems such as harmonic oscillators and central potential systems.

CLO 4: **analyze** the behaviour and stability of dynamical systems using techniques such as linear stability analysis, phase space flows, and bifurcation theory.

CLO 5: evaluate the use of canonical transformations, Poisson brackets, and conserved quantities in simplifying and solving dynamical problems.

CLO 6: construct solutions to complex mechanical problems using Hamilton-Jacobi theory and action-angle variables.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		CO 1, CO 2	CO 3	CO 2, CO 3		
Procedural Knowledge		CO 2	CO 3, CO 4	CO 2, CO 3	CO 4	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO/PSO	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO 8	PSO 9	PSO 10
CLO 1	3	1	3	2	3	1	1	1	2	1
CLO 2	3	1	3	2	3	1	1	1	2	1
CLO 3	3	1	3	2	3	1	1	1	2	1
CLO 4	3	1	3	2	3	2	1	1	2	1
CLO 5	3	1	3	2	3	1	1	1	2	1
CLO 6	3	1	3	2	3	2	1	1	2	1
Avg.	3	1	3	2	3	1.3	1	1	2	1

Suggested Readings:

1. Classical Mechanics, Joseph L. McCauley, Cambridge University Press.
2. Classical Mechanics, H. Goldstein, Addison Wesley.
3. Classical Mechanics, N.C. Rana& P.S. Joag, Tata McGraw Hill.
4. Classical Mechanics of Particles and Rigid Bodies, Kiran C Gupta, Wiley Eastern Limited.
5. Introduction to Classical Mechanics, R.G. Takwale & P.S. Puranic, Tata McGraw Hill.

Course: Core - Elective
Course Title: Computational Methods
Course Code: EL-P3–PHY-101
Nature of the Course: Theory + Practical
Total Credit assigned: 02(theory) + 02 (Practical) = 04
Component of the Course: L- 20, P- 60, T- 10
Distribution of Marks: End Semester: Theory: 28, Practical: 40, In Semester: 12

Course Objectives: The Objectives of this course are to:
CO-1: Understand basic concepts of probability and probability distributions, with applications to data analysis.

CO-2: Apply numerical methods for solving roots of transcendental and algebraic equations.

CO-3: Compute numerical integrals, derivatives, and solve ordinary differential equations using standard numerical methods.

CO-4: Apply curve fitting techniques and interpolation methods for analysing datasets.

Unit	Contents	M	L	P	T
I	**Unit I: Probability** Elementary probability theory, random variables, binomial, Poisson and Normal distributions, central limit theorem, chi-square test.	6	3	20	1
II	**Unit II: Roots of Transcendental Equations** Determination of root of functions, roots of transcendental equations: Bisection method, method of false position, Newton-Raphson method.	8	5	20	2
III	**Unit III: Numerical Integration and Differentiation** trapezoidal and Simpson's methods, numerical differentiation: Finite difference methods, central difference formula, extrapolation, Solution of first-order ordinary differential equation, Runge-Kutta method.	8	7	20	4
IV	**Unit IV: Curve Fitting** Linear and non-linear curve fitting: Least Square Method, Lagrange interpolation polynomial, Newton-Gregory method.	6	5	20	3
		28	**20**	**60**	**10**

Mode of In-Semester Assessment:

A. Two Sessional Tests:	Sessional I	20
	Sessional II	20
B. Other Sessional Activities:	Attendance	10

Seminar/Class tests/Sudden tests	10
Home assignments/ Library work	10

Total In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Course Learning Outcomes (CLOs): At the end of the course, students will be able to:

CLO1: Understand and apply fundamental concepts of probability theory and commonly used probability distributions.
CLO2: Solve transcendental and algebraic equations using methods like Bisection, Newton-Raphson, Regula-Falsi and Runge-Kutta.
CLO3: Perform numerical integration and differentiation; apply Runge-Kutta method to solve differential equations.
CLO4: Fit curves to data using least squares and interpolation techniques such as Lagrange and Newton-Gregory methods.

Cognitive Map Based on Revised Bloom's Taxonomy

Knowledge Dimension	**Remember**	**Understand**	**Apply**	**analyze**	**Evaluate**	**Create**
Factual Knowledge	CO1	CO1, CO2	CO1			
Conceptual Knowledge	CO2	CO2, CO3	CO2 CO3 CO4			
Procedural Knowledge			CO2 CO3 CO4	CO2 CO3 CO4	CO2 CO3 CO4	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	3	2	2	2	3	2	2	2
CLO2	3	3	3	2	2	2	3	2	2	2
CLO3	3	3	3	2	2	2	3	2	2	2
CLO4	3	3	3	2	2	2	3	2	2	2
Average	3	3	3	2	2	2	3	2	2	2

Suggested Readings

1. S. C. Gupta & V. K. Kapoor – *Fundamentals of Mathematical Statistics*, Sultan Chand & Sons.
2. Erwin Kreyszig – *Advanced Engineering Mathematics*, Wiley.
3. B. S. Grewal – *Numerical Methods in Engineering and Science*, Khanna Publishers.
4. R. Sastry – *Introductory Methods of Numerical Analysis*, PHI.

5. M. K. Jain, S. R. K. Iyengar & R. K. Jain – *Numerical Methods for Scientific and Engineering Computation*, New Age International.
6. John E. Freund – *Mathematical Statistics*, Pearson Education.
7. William Feller – *An Introduction to Probability Theory and Its Applications*, Wiley.
8. Richard L. Burden & J. Douglas Faires – *Numerical Analysis*, Cengage Learning.

Course: Other
Course Title: Research Methodology
Course Code: OC-T4–PHY- 101
Nature of the Course: Theory
Total Credit assigned: 04
Component of the Course: L- 40, P- 0, T- 20
Distribution of Marks: End Semester: Theory: 56, In Semester: 24

Course Objectives: The Objectives of this course are to:
CO 1: Understand the fundamentals of research and develop a clear understanding of research problems.
CO 2: Acquire skills for accurate data collection and effective use of scaling and measurement tools.
CO 3: Process, analyse, and interpret research data using statistical tools.
CO 4: Create effective research reports and ensuring academic integrity.

Course Contents:

Unit	Contents	M	L	P	T
I	**Introduction to Research** Defining the Research Problem: What is a Research Problem, Selecting the Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem, An Illustration, Conclusion. Research theory and practice: Research basics, Research theory, Structuring the research project, Research ethics, Finding and reviewing the literature. Defining the Research Problem: Selection of a research Problem, Necessity of Defining the Problem, Technique Involved in Defining a Problem: An Illustration. Research Design: Meaning of Research Design, Need for Research Design, features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs	10	10	0	5
II	**Data Collection** Measurement in Research: Measurement Scales, Sources of Error in Measurement, Tests of Sound Measurement, Technique of Developing Measurement Tools. Scaling: Meaning of Scaling, Scale Classification Bases, Important Scaling Techniques, Scale Construction Techniques. Methods of Data Collection: Collection of Primary Data, Observation Method, Collection of Data through Schedules, Some Other Methods of Data Collection	15	10	0	5
III	**Data Analysis** Processing and Analysis of Data: Processing Operations, Some Problems in Processing. Elements/Types of Analysis: Statistics in Research, Measures of Central Tendency, Measures of Dispersion, Measures of Asymmetry (Skewness), Measures of Relationship, Simple Regression Analysis, Multiple Correlation and Regression, Partial Correlation, Association in Case of Attributes.	15	10	0	5

IV	**Report Writing** Interpretation and Report Writing: Technique of Interpretation, Precaution in Interpretation. Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report Types of Reports, Mechanics of Writing a Research Report, Precautions for Writing Research Reports, plagiarism.	15	10	0	5
		56	**40**	**0**	**20**

Mode of In-Semester Assessment:

A. Two Sessional Tests:	Sessional I	20
	Sessional II	20
B. Other Sessional Activities:	Attendance	10
	Seminar/Class tests/Sudden tests	10
	Home assignments/ Library work	10

Total In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Course Learning Outcomes (CLOs): At the end of the course, students will be able to:

CLO-1: Remember and explain fundamental concepts of research and research design.

CLO-2: Demonstrate the ability to collect and measure data using appropriate techniques.

CLO-3: Analyse and interpret research data using statistical methods.

CLO-4: Create coherent research reports demonstrating ethical and professional standards.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Factual Knowledge	CO1	CO1, CO2	CO3			
Conceptual Knowledge	CO1	CO2, CO3	CO3	CO4	CO4	
Procedural Knowledge		CO2	CO3	CO4	CO4	CO5
Metacognitive Knowledge						CO5

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	2	1	1	3	2	3	3	2	2	2
CLO2	2	1	2	3	2	3	3	2	2	2

CLO3	3	2	2	3	2	3	3	2	2	2
CLO4	2	1	2	3	2	3	3	2	2	2
Average	2.25	1.25	1.75	3	2	3	3	2	2	2

Suggestive Reading List:

1. C.R. Kothari – Research Methodology: Methods and Techniques, New Age International.
2. Ranjit Kumar – Research Methodology: A Step-by-Step Guide for Beginners, Sage Publications.
3. John W. Creswell – Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Pearson.
4. Uma Sekaran and Roger Bougie – Research Methods for Business, Wiley.

Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams – The Craft of Research, University of Chicago Press.

Semester-II

Course Code: CC-4 -MPHY--203

Course Title: Electrodynamics

Nature of the Course: Core

Total Credits assigned: 04
Components of the course: L- 46, P-0, T- 14
Distribution of Marks: End Semester: Theory: 56, Practical: 0, In Semester: 24
Course Objectives:

CO1: To enable the students **apply** Maxwell's equations to **understand** and **analyse** the phenomena of electromagnetic wave propagation in different media and **derive** various results.

CO2: To enable the students **apply** Maxwell's equations to **understand** and **analyse** the phenomena of electromagnetic radiation.

CO3: To enable the students **to understand** and **justify** the connection between electrodynamics and relativity and **prove** and **derive** various results

Course Contents:

Unit	**Contents**	Marks	L	P	T
I	**Electromagnetic Waves:** Propagation of electromagnetic waves in different media, Dispersion, Frequency dependence of σ, μ and ε, dispersion in non-conductors, anomalous dispersion, free electrons in conductors and plasma, Wave Guides, TE waves in rectangular wave guide. Coaxial transmission lines	16	9		3
II	**Theory of Electromagnetic Radiation**: Electromagnetic Radiation: Retarded potentials, electric dipole radiation, radiation from an arbitrary distribution of charges and current, Lienard-Wiechert potentials, fields due to uniformly moving charge, and accelerated charge, Linear and circular acceleration, angular distribution of radiated power, Bremsstrahlung and Synchrotron radiation, Radiation reaction, Abraham-Lorentz formula.	20	18		6

Unit	Contents	Marks	L	P	T
III	**Relativity and Electrodynamics**: Structure of space-time, Four vectors and Lorentz transformation, Proper time and velocity, Relativistic energy, and momentum. Magnetism as relativistic phenomena, Potential formulation of relativistic electrodynamics Electromagnetic field tensor, Dual tensor, Covariant formulation of electrodynamics.	20	18		6

(L= Lecture, P = Practical, T = Tutorial)

Course Learning Outcomes: After the end of the course th students will be able to

CLO1: **apply** Maxwell's equations to **understand** and **analyse** the phenomena of electromagnetic wave propagation in different media, **derive** and **justify** various results.

CLO2: **apply** Maxwell's equations to **understand** and **analyse** the phenomena of electromagnetic radiation.

CLO3: **understand** and **justify** the connection between electrodynamics and relativity, and to **prove** various results.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2, CO3	
Procedural Knowledge		CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2, CO3	

Meta-cognitive Knowledge		CO1,CO2, CO3	CO1,CO2, CO3	CO1,CO2, CO3	CO1, CO2, CO3	

Mapping of PSO with CLO

CLO/PSO	PSO1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO8	PSO9	PSO10
CLO 1	3	1	3	2	3	2	2	2	2	3
CLO 2	3	1	3	2	3	2	2	2	2	3
CLO 3	3	1	3	2	3	2	2	2	2	3
Avg.	3	1	3	2	3	2	2	2	2	3

Mode of In-Semester Assessment: (24 Marks)

C. Two Sessional Test:

Sessional I: 30
Sessional II: 30

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total Marks: 70

20% from each component to contribute to the total marks of 24.

Suggested Readings

1. Introduction to Classical Electrodynamics, D.J. Griffiths, Prentice Hall of India.
2. Classical Electrodynamics, J.D. Jackson, John Wiley.
3. Electromagnetic waves and Radiating systems, Edward C Jordan and Keith G. Balmain, PHI Pvt. Ltd.
4. ‘Electromagnetic Wave and radiating systems’, Jordan, E.C. and Balmain, K.G., Prentice Hall of India

Course Title: Electronics
Course Code: CC-4–MPHY-202
Nature of the Course: Core (Theory)
Total Credit assigned: 04 Credits
Component of the Course: L-54, P-0 , T-06
Distribution of Marks : End Semester: 56 In Semester: 24

Course Objectives (COs)
The objectives of this course are to:

CO1. Understand the fundamentals of transistors and their biasing, configuration, and applications in amplification.
CO2. Introduce different types of field-effect transistors (FETs) including MOSFET, CMOS, and FINFET, and their electronic characteristics.
CO3. Explore nonlinear applications of operational amplifiers and active filters.
CO4. Familiarize students with the architecture and programming of microprocessors and microcontrollers (8085 and 8051).
CO5. Develop the ability to analyze, design, and simulate analog and digital electronic circuits used in embedded systems and signal processing applications.

Course Content:

Unit	Contents	M	L	P	T
I	**Transistor Fundamentals: (DC)** Introduction to voltage and current source and measuring devices, Concept of source loading, implication and mitigation of source loading, BJT fundamentals and biasing techniques, β independence, Early effect, load line, amplifying action, Emitter follower, impedance matching application, ac models: T and π, analysis and design of small signal amplifier, IC circuit current mirror, open collector, pull up resistor. Bootstrapped and Darlington amplifier. **Field effect transistors:** JFET, MESFET and MOSFET, structure, working, derivation of the equations of IV characteristics under different conditions, active load, introduction to CMOS and FINFET technology.	**20**	**20**		**02**
II	**Op Amp non-linear applications:** (DD) Voltage limiters, comparators, zero detector, Schmitt trigger, voltage to frequency and frequency to voltage converter, small-signal diodes, sample-and-hold circuits.	**18**	**17**		**02**

	(DC) Frequency response of an op-amp and active filter: Gain and phase shift vs. frequency, Bode plots, compensated frequency response, slew rate, active filter, first and second order low pass and high pass. Butterworth filter, band reject filter.				
III	**Introduction to Microprocessor and Microcontroller:** (DD) Introduction to microprocessor: Architecture of digital computer system, Von Neumann and Harvard architecture, different microprocessors, architecture, pin diagram, different bus, programming model using intel 8085, register set, memory organization, instruction set. Timing and control circuitry. Timing states. Instruction cycles, timing diagram of MOV and MVI. **Simple programming**: addition, subtraction, multiplication etc. Introduction to 8051 microcontroller and embedded systems.	**18**	**17**		**02**

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment:

A. Two Sessional Tests:	**Sessional I**	**20**
	Sessional II	**20**
B. Other Sessional Activities:	**Attendance**	**10**
	Seminar/Class tests/Sudden tests	**10**
	Home assignments/ Library work	**10**

Total In- Semester Assessment Marks: **70**

20% from each component to contribute to the total marks of 24.

Course Learning Outcomes (CLOs)

Upon successful completion of this course, students will be able to:

CLO1. Recall fundamental concepts of BJT, FETs, and basic electronics terminology like source loading, biasing techniques, etc.

CLO2. Understand the working principles and IV characteristics of transistors (BJT, MOSFET, CMOS, FINFET) and op-amps in nonlinear applications.

CLO3. Apply transistor models (T and π), biasing methods, and amplifier circuits in analyzing and designing small signal amplifiers and current mirrors.

CLO4. Analyze the frequency response of op-amps, active filters (low-pass, high-pass, band-reject), and Schmitt triggers using Bode plots.

CLO5. Evaluate operational amplifier designs for nonlinear applications such as voltage limiters, comparators, sample-hold circuits, and converters.

CLO6. Create simple assembly language programs using Intel 8085 and implement control and data operations using microprocessors and microcontrollers.

Cognitive Map of Course Objective based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO2	CO1, CO2				
Conceptual Knowledge		CO1, CO2, CO3, CO4	CO1, CO2, CO3	CO3, CO4	CO3, CO4	CO5
Procedural Knowledge		CO3, CO4	CO3, CO4, CO5	CO4, CO5	CO4, CO5	CO5
Metacognitive Knowledge						CO5

Mapping of PSO with CLO

CLO / PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	2	2	2	3	1	1	2	1	2
CLO2	3	3	3	2	3	2	1	2	2	2
CLO3	3	3	3	2	3	2	1	2	3	2
CLO4	3	3	3	2	3	2	1	2	2	2
CLO5	3	3	3	2	3	2	1	2	2	2
CLO6	3	3	3	3	3	2	1	3	3	3
Average	3.00	2.83	2.83	2.17	3.00	1.83	1.00	2.17	2.17	2.17

Mapping Scale:

- **3** = Strongly related
- **2** = Moderately related
- **1** = Slightly related

Suggested Readings:

1. Electronic Principles A.P. Malvino Tata McGraw Hill
2. Op amps and Linear Integrated Circuits R.K. Gaekwad Prentice Hall of India
3. Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill
4. Integrated Electronics: Analog and Digital Circuit Systems J. Millman and C. Halkias McGraw Hill
5. Digital Principles and Applications D.P. Leach and A.P. Malvino Tata McGraw Hill
6. Semiconductor Materials and Devices M.S. Tyagi John Wiley and Sons
7. Physics of Semiconductor Devices S.M. Sze Wiley Eastern Ltd.
8. The Art of Electronics P. Horowitz and W. Hill Cambridge University Press
9. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.

Course Code: CC-4-MPHY-203
Name of the course: Condensed Matter Physics
Component of the course: L:60, P:0, T:0
Type: Major (Theory)
Credits: 04
Distribution of Credits: Theory: 04
Distribution of Marks: End Semester: Theory: 56, In Semester: 24
Course objectives: This course aims to:

1. **Introduce and develop theoretical models of electrical conduction in metals**, beginning with classical (Drude-Lorentz) and progressing to quantum (Sommerfeld) approaches, with emphasis on understanding electronic properties such as Fermi energy, density of states, and thermal conductivity.
2. **Provide a comprehensive understanding of semiconductor physics**, covering both intrinsic and extrinsic materials, carrier statistics, mobility, Fermi level behavior, and transport phenomena including the Hall effect.
3. **Explain the physical principles and technological implications of semiconductor devices**, including rectifying behavior in Schottky and ohmic contacts, junction rectifiers, and transistor operation based on carrier dynamics.
4. **Explore the role of imperfections in solids**, detailing point defects, dislocations, color centers, and atomic diffusion mechanisms, with Fick's laws as a quantitative framework.
5. **Introduce the fundamental principles of superconductivity**, including thermodynamic behavior, the BCS theory, quantization effects, critical currents, and applications such as the Josephson effect.

Course content

Unit	Content	Marks	L	P	T
I	**Free Electron Theory of Metals** Drude Lorentz classical theory, Sommerfeld quantum theory in one dimension: Fermi energy, total energy, Density of states, Sommerfeld quantum theory in three dimensions: filling of energy levels, density of available electronic states, Average kinetic energy, Application of free electron gas model: electronic specific heat, contact potential between two metals, photoelectric effects of metals, thermal conductivity in metals, failure of the free electron model.	15	17		
II	**Semiconductors** Intrinsic and extrinsic semi-conductor, carrier concentration, Fermi level, semiconductor statistics: intrinsic and extrinsic region, mobility and electrical conductivity, Magnetic field effect: Hall effect. Rectifying properties of barriers: Schottky theory of metal semiconductor contact, comparison of ohmic and Schottky barrier, surface states junction rectifiers. Transistors: amplifying action of the transistor, minority concentration in the base and emitter- collector region	15	16		
III		12	12		

	Imperfections in Crystalline Solids Introductory concept, Point defects, Schottky and Frenkel defect, Colour centres, Dislocation, Diffusion, Fick's law.				
IV	**Superconductivity** Thermodynamics of superconducting transition, isotope effect, BCS theory, consequences of BCS theory and comparison with experimental results, supercurrents and critical currents, quantization of magnetic flux and applications, Josephson effect and applications.	14	15		

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment: (24 Marks)

D. Two Sessional Test:

Sessional I: 20
Sessional II: 20

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total: 70

20% from each component to contribute to the total marks of 24

Course learning outcome: After the successful completion of the course, the students are expected to

1. **Apply classical and quantum models** (Drude-Lorentz and Sommerfeld theories) to explain the electronic properties of metals, including Fermi energy, density of states, and specific heat.
2. **Analyze semiconductor behavior**, including intrinsic and extrinsic carrier concentrations, Fermi levels, mobility, conductivity, and effects of external magnetic fields such as the Hall effect.
3. **Differentiate between various types of semiconductor junctions**, including Schottky and ohmic contacts, and explain the working principles of transistors and their amplifying action.
4. **Describe different types of crystal defects**, including point defects, dislocations, and diffusion processes governed by Fick's law.

5. **Understand and explain the phenomena of superconductivity**, including thermodynamic transitions, BCS theory, flux quantization, Josephson effects, and their applications.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO 4	CO 2				
Conceptual Knowledge		CO 1, CO 2, CO 3, CO 4, CO 5	CO 1, CO 2, CO 3, CO 4,	CO 1, CO 3. CO 5	CO 5	
Procedural Knowledge		CO 1, CO 4, CO 5	CO 1, CO 4	CO 1, CO 5	CO 5	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO/PSO	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO 8	PSO 9	PSO 10
CLO 1	3	1	3	2	1	3	1	1	1	1
CLO 2	3	2	3	3	2	2	2	1	3	3
CLO 3	3	2	3	3	2	2	2	1	3	3
CLO 4	3	3	3	3	2	2	1	1	2	3
CLO 5	3	2	3	3	1	2	2	1	1	1
Avg.	3	2	3	2.8	2	2.75	1.6	1	2	2.2

Suggested Readings:

1. Introduction to Solid State Physics, C. Kittel, John Wiley & Sons.
2. Solid State Physics, A. J. Dekker, Macmillan India Ltd.
3. Elementary Solid-State Physics, M. A. Omar, Pearson Education.
4. Crystallography Applied to Solid State Physics, A.R. Verma and O.N. Srivastava, New Age International.
5. Solid State Physics, N. W. Ashcroft and N. D. Mermin, Brooks/Cole.

Course Code: EL-MPHY-4-201
Course Title: Atomic & Molecular Spectroscopy
Type: Elective (Theory)
Component of the course: L: , P: 0, T:
Distribution of credits: Theory: 04
Distribution of Marks: End Semester: Theory: 56, In Semester: 24
Course Objectives: The objectives of the course are
CO 1: to provide students with a comprehensive understanding of the interaction between electromagnetic radiation and atoms, with a focus on atomic energy levels and spectral line formation with special reference to multielectron systems and x rays.
CO 1: enabling students understand the fundamental principles of molecular spectroscopy, analysing molecular spectra and extract structural information of the molecule.
CO 2: familiarize the students with advanced spectroscopic techniques; such as Raman spectroscopy, photoelectron spectroscopy, spin resonance techniques (NMR, ESR), Mössbauer spectroscopy, and Fourier Transform Spectroscopy.

CO 3: enable students develop insight into Laser spectroscopy

Course content:

Unit	Content	Marks	L	P	T
I	**Unit I: Atomic Spectroscopy** **(Lectures: 20)** Fine structure of hydrogen atom, relativistic correction, Lamb shift, Spectra of alkali atoms, spin orbit interaction and fine structure in alkali atoms, level scheme of two electron atoms-equivalent and non-equivalent electrons, ground and excited states of two electron atoms, interaction energy in L-S and j-j coupling for two electrons, Zeeman effect, Paschen-Back effect, Stark effect, hyperfine structure of hydrogen and alkali atoms, spectra of multi electron atoms, X-ray spectra, width and shape of spectral lines, X ray emission spectra and Moseley's law,	20	22		
II	**Molecular Spectroscopy** Regions of the spectrum, types of molecules, Rotational Spectra for rigid and non-rigid rotators, isotopic effect in rotational spectra, intensity of spectral lines, information derived from rotational spectra, microwave spectrometer, Vibrational spectra for anharmonic oscillator, vibration-rotation spectra, Infra-red spectrometer, Electronic spectra of molecules-Born-Oppenheimer approximation, vibrational analysis of electronic band spectra, fine structure of electronic band spectra, Fortrat Diagram Raman spectra, Raman spectrometer, Photoelectron spectroscopy, Spin resonance spectroscopy- NMR, ESR, Mössbauer spectroscopy, Fourier Transform Spectroscopy	20	22		

III	**Laser Spectroscopy** Spontaneous and stimulated emission, Einstein's A and B Coefficients, Fundamentals of Lasers-properties, Spatial and temporal coherency, basic elements, threshold condition, rate equation, population inversion, Laser resonator and modes, types of lasers- solid state laser, gas laser, semiconductor laser, applications of laser spectroscopy, Laser Cooling, Ammonia Masers-two level and three level	16	16		

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment: (24 Marks)

E. **Two Sessional Test:**

Sessional I: 20
Sessional II: 20

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total: 70

20% from each component to contribute to the total marks of 18

Course learning Outcome: After the completion of the course, the students will be able to

CLO 1: analyze atomic structure and spectra, including fine and hyperfine structures, apply relativistic and quantum corrections, interpret spectral effects under external fields, and understand X-ray spectra and spectral line broadening in single and multi-electron atoms.

CLO 2: explore the interaction of electromagnetic radiation with molecules across different spectral regions (microwave, infrared, visible, UV, and X-ray), distinguish between different transitions in molecules, understand their spectral signatures and interpret the molecular spectra.

CLO 3: understand the principles, instrumentation, and applications of Raman spectroscopy, photoelectron spectroscopy, spin resonance techniques (NMR, ESR), Mössbauer spectroscopy, and Fourier Transform Spectroscopy.

CLO 4: explain the theory of spontaneous and stimulated emission, Einstein coefficients, and laser threshold conditions, understand the design and functioning of different types of lasers and their application in high-resolution spectroscopy and explore the concept and implementation of laser cooling and maser systems.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge		CO 1, CO 3	CO 1	CO 1, CO 3		
Procedural Knowledge		CO 1, CO 2	CO 1, CO 2	CO 1		
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO/PSO	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO 8	PSO 9	PSO 10
CLO 1	3	2	3	2	3	2	1	2	2	1
CLO 2	3	2	2	3	3	2	2	2	2	1
CLO 3	3	2	2	3	3	2	2	2	2	3
CLO 4	3	2	2	3	3	2	2	2	2	1
Avg	3	2	2.25	3	3	2	1.75	2	2	1.5

Suggested Readings:

1. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain, 2nd Edition,
2. Dorling Kindersley (India) Pvt. Ltd, Pearson Education in South Asia.
3. Molecular spectroscopy, Banwell and McCash Tata McGraw Hill
4. Molecular Structure and Spectroscopy G. Aruldhas Prentice Hall of India
5. Molecular Spectra and Molecular Structure G. Herzberg, McGraw Hill
6. Lasers and Nonlinear Optics, B.B. Laud New Age International
7. Laser Spectroscopy-Basic Concepts and Instrumentation, Wolfgang Demtröder, Springer
8. Modern Spectroscopy, J M Hollas, John Wiley& Sons
9. Elements of Laser and Non-Linear Optics, G D Baruah, Prakashan, Meerut
10. Atomic and Molecular Spectra, Raj Kumar, Kedar Nath Ram Nath

Course: Core – VII
Course Title: Nuclear Physics
Course Code: MPHY-CC-4-101
Nature of the Course: Core
Total Credit assigned: 04
Component of the Course: L- 60, P- 0, T- 0
Distribution of Marks: End Semester: 56 In Semester: 24

Course Objectives: The Objectives of this course are to:

CO 1: Understand the intrinsic properties and fundamental parameters of nuclei such as mass, radii, binding energy, and excited states.
CO 2: Explain, analyse and evaluate nucleon-nucleon forces.
CO 3: Analyse nuclear reactions, apply conservation laws, and compute Q-values and reaction cross sections.
CO 4: Describe the working principles of nuclear detectors.

Course Content:

Unit	Contents	M	L	P	T
I	Review of nuclear properties, Nuclear Forces: properties of nuclear forces, exchange forces, meson theory of nuclear forces. Nuclear models: Review of liquid drop model and its applications, shell model, L-S coupling, magnetic moment and Schmidt lines, limitations of the shell model.	10	10	0	0
II	Two body problem: General form of nucleon-nucleon forces, the deuteron problem (ground states and excited states), central and tensor forces, nucleon-nucleon scattering at low energies.	16	18	0	0
III	Nuclear reactions: Reaction channels, nuclear reaction mechanisms, scattering cross-section, compound nucleus, partial wave analysis of nuclear reaction, resonance, Breit-Wigner single level formula, B-W formula incorporating spin, nuclear fission, neutrino hypothesis and general features of beta-ray spectrum, Fermis theory of beta-decay, Currie plot, selection rules.	20	22	0	0
IV	Detection of radiations: Basic principle of Scintillation, Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.	10	10	0	0
		56	**60**	**0**	**0**

Mode of In-Semester Assessment:

A.	Two Sessional Tests:	Sessional I	20
		Sessional II	20
B.	Other Sessional Activities:	Attendance	10
		Seminar/Class tests/Sudden tests	10

Home assignments/ Library work 10

--Total

In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO 1: analyse and evaluate the basic nuclear models including the liquid drop and shell models, and interpret nuclear stability using these models.

CLO 2: CO 2: Explain, analyse and evaluate nucleon-nucleon forces.

CLO 3: analyse nuclear reactions, apply conservation laws, and compute Q-values and reaction cross sections.

CLO 4: Describe the working principles of nuclear detectors.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO1	CO1, CO2				
Conceptual Knowledge	CO1	CO2, CO3	CO2, CO3, CO4	CO3		
Procedural Knowledge			CO2, CO3, CO4	CO4		
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	1	3	2	3	3	2	2	2
CLO2	3	3	1	3	2	3	3	2	2	2
CLO3	3	3	1	3	2	3	3	2	2	2
CLO4	3	3	1	3	2	3	3	2	2	2
Average	3	3	1	3	2	3	3	2	2	2

(3=High, 2= Moderate 1= Low)

Suggested Readings:

1. Introductory nuclear Physics by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
2. Concepts of nuclear physics by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
3. Introduction to the physics of nuclei & particles, R.A. Dunlap. (Thomson Asia, 2004).
4. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press
5. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
6. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
7. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde (IOP- Institute of Physics Publishing, 2004).

8. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).
9. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
10. Theoretical Nuclear Physics, J.M. Blatt & V. F. Weisskopf (Dover Pub.Inc., 1991)

Course: Core-VIII
Course Title: Advanced Quantum Mechanics
Course Code: MPHY-CC-4-102
Nature of the Course: Theory
Total Credit assigned: 04
Component of the Course: L- 50, P- 0, T- 10
Distribution of Marks: End Semester: 56 In Semester: 24

Course Objectives: The Objectives of this course are to:
CO-1: Understand, analyse and apply quantum mechanical principles applied to many-particle systems and identical particles.
CO-2: Understand and apply scattering theory techniques to analyse quantum interactions.
CO-3: Understand and apply relativistic quantum theories leading to quantum electrodynamics.

Course Content:

Unit	Contents	M	L	P	T
I	**Quantum theory of many particles systems:** Schrödinger Equation for many particle systems, multielectron atoms, Interchange Symmetry, Systems of Distinguishable Non-Interacting Particles, Systems of Identical Particles, Exchange Degeneracy, Summarization Postulate, Symmetric and Antisymmetric Functions, Systems of Identical Non-Interacting Particles, Slater determinant, Pauli Exclusion Principle, construction of periodic table.	16	15	0	5
II	**Quantum Scattering Theory:** Scattering Cross Section, Connecting the Angles in the Lab and CoM Frames, Cross Sections in the Lab and the CoM frame, Scattering Amplitude of Spinless Particles, Scattering Amplitude and Differential Cross Section, The Born Approximation, Partial Wave analysis for elastic and inelastic Scattering, Scattering of Identical Particles.	20	17	0	3
III	**Relativistic Quantum Mechanics:** Limitations of Non-relativistic Schrodinger equation, Klein Gordon Equation and its solution, Physical interpretation, Probability current density & Inadequacy of Klein-Gordon equation, Dirac Equation and its plane wave solutions, , α and β matrices and related algebra, Idea of Dirac Sea, negative energy states and antiparticles, Spin angular momentum of Dirac particles, non-relativistic limit of Dirac equation, Dirac equation in electromagnetic field and the emergence of quantum electrodynamics.	20	18	0	2
		56	**50**	**0**	**10**

Mode of In-Semester Assessment:

A. Two Sessional Tests:	Sessional I	20
	Sessional II	20
B. Other Sessional Activities:	Attendance	10
	Seminar/Class tests/Sudden tests	10
	Home assignments/ Library work	10

Total In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO-1: Explain the quantum behaviour of systems consisting of many particles and identify effects due to particle indistinguishability.

CLO-2: Apply approximation methods such as the Born approximation and partial wave analysis to physical scattering problems.

CLO-3: Understand, analyse and apply relativistic quantum mechanics, including the Klein-Gordon and Dirac equations.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	**Remember**	**Understand**	**Apply**	**Analyse**	**Evaluate**	**Create**
Factual Knowledge	CO1, CO2	CO1				
Conceptual Knowledge	CO1, CO2	CO2, CO3	CO2	CO3		
Procedural Knowledge		CO3	CO3	CO3	CO2	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	1	1	2	3	3	2	2	2
CLO2	3	3	1	1	2	3	3	2	2	2
CLO3	3	3	1	1	2	3	3	2	2	2
Average	3	3	1	1	2	3	3	2	2	2

Suggested Readings:

1. J. J. Sakurai and Jim Napolitano, *Modern Quantum Mechanics*, Pearson
2. David J. Griffiths, *Introduction to Quantum Mechanics*, Pearson
3. P. M. Mathews & K. Venkatesan, *A Textbook of Quantum Mechanics*, McGraw Hill
4. G. Aruldhas, *Quantum Mechanics*, PHI Learning
5. Franz Schwabl, *Quantum Mechanics*, Springer
6. L. I. Schiff, *Quantum Mechanics*, McGraw Hill
7. Stephen Gasiorowicz, *Quantum Physics*, Wiley
8. Walter Greiner, *Quantum Mechanics: An Introduction*, Springer

Course Title: General laboratory- I
Course Code: CC-MPHY-4-303 (Lab)
Nature of the Course: Practical (Lab)
Total Credit assigned: 04 Credits
Component of the Course: L-, P-120 , T-
Distribution of Marks : End Semester: 80

Course Objectives:
After completing the course (lab), students will be able to:

CO1. Understand the working principles of analog and digital electronic circuits, including amplifiers, multivibrators, and converters.
CO2. Analyze and design sequential and combinational logic circuits using flip-flops, counters, and comparators.
CO3. Develop skills in constructing, testing, and troubleshooting electronic circuits.
CO4. Interpret and analyze frequency response and logic outputs to evaluate circuit performance.
CO5. Apply theoretical concepts to practical implementation using ICs like 7476, 7485, and R-2R ladder network.
CO6. Build foundational skills for digital system design relevant to real-world electronics and embedded systems.

Course Content:

Unit	Contents	M	L	P	T
Practical	**List of Experiments:** **(At least 75% of the experiments listed below must be performed by each student)** 1. To study astable, monostable, and bistable multivibrator and to obtain the value of the unknown capacitors. 2. To design and study D/A converter using R-2R Ladder network. 3. To draw the frequency response curve of an RC coupled amplifier with and without negative feedback and compare the bandwidth. 4. To design a transistor amplifier for a gain of 7 using Voltage divider biasing method. 5. To design square wave generator for a frequency of 500Hz and 2 KHz. 6. To design and construct basic flip-flops R-S, J-K, J-K Master slave flip-flops using gates and verify their truth tables.	**80**		**120**	

	7. To realize and study of Shift Register. i SISO (Serial in Serial out) ii PO (Serial in Parallel out) iii PIPO (Parallel in Parallel out) iv PISO (Parallel in Serial out) 8. To design and test 3-bit binary asynchronous counter using flip-flop IC 7476 for the given sequence. 9. To study the characteristics curves of (i) FET (ii) MOSFET 10. To realize One & Two Bit Comparator and study of 7485 magnitude comparator.				

(L=Lecture, P=Practical, T=Tutorial)

Expected Course Learning outcomes (CLOs):
After the completion of the course, the students are expected:

CLO1. Construct and analyze multivibrator circuits and determine unknown component values using waveforms.
CLO2. Design and implement D/A conversion using R-2R ladder networks.
CLO3. Analyze and compare amplifier frequency response with and without negative feedback.
CLO4. Design amplifiers and waveform generators (square wave) using transistor biasing techniques.
CLO5. Construct and verify the operation of basic flip-flops, shift registers, and counters using ICs.
CLO6. Measure and interpret characteristic curves of FET and MOSFET devices.
CLO7. Implement and test combinational logic circuits including one- and two-bit comparators.

Mapping of PSO with CLO

CLO / PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	2	3	3	2	3	2	1	2	2	2
CLO2	2	3	3	2	2	2	1	3	2	2
CLO3	2	3	3	2	3	2	1	2	2	2
CLO4	2	3	3	2	3	2	1	2	2	2
CLO5	2	3	2	3	3	2	1	2	3	2
CLO6	2	3	3	2	3	2	1	2	2	2
CLO7	2	3	2	2	2	2	1	2	2	2
CLO8	2	3	2	3	3	2	1	3	2	3
Average	2.00	3.00	2.63	2.25	2.75	2.00	1.00	2.25	2.12	2.12

Mapping Scale:

- **3** = Strongly related
- **2** = Moderately related
- **1** = Slightly related

Cognitive Map of Course Objectives based on Revised Bloom's Taxonomy

Knowledge Dimension \ Cognitive Process	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO1	CO1	CO5			
Conceptual Knowledge		CO1, CO2	CO2, CO5	CO4	CO4	CO6
Procedural Knowledge		CO3	CO3, CO4	CO2, CO4	CO4, CO5	CO2, CO6
Metacognitive Knowledge					CO6	CO6

Suggested Readings:

1. Electronic principles by Albert Malvino, McGraw Hill Education.
2. Digital Principals and applications by Leach and Malvino, McGraw Hill Education.

Course: Elective (DSE)
Course Title: High Energy Physics I
Course Code: MPHY-DE-4-301
Nature of the Course: DSE (Theory)
Total Credit assigned: 04
Component of the Course: L- 50, P- 0, T- 10
Distribution of Marks: End Semester: 56 In Semester: 24

Course Objectives: The Objectives of this course are to:

CO-1: Understand and analyse the fundamentals of relativistic wave equations with a focus on the Dirac equation.

CO-2: Understand, analyse and apply quantum field theory through Lagrangian and Hamiltonian formulations.

CO-3: Understand, analyse and apply quantum electrodynamics (QED) including S-matrix formulation and Feynman diagram techniques.

Course Content:

Unit	Contents	M	L	P	T
I	**Dirac equation** Natural units, Lorentz covariance and four vector notations; Dirac equation in covariant form and its solution (free particle spinors), Dirac gamma matrices, adjoint equation and conserved current, negative energy states and concept of antiparticles, Lorentz covariance of Dirac equation, bilinear covariants, Dirac equation for zero mass particles (the two-component neutrino), helicity states, Majorana and Weyl spinor.	16	15	0	5
II	**Quantum Field theory** Concept of field and quantization, introduction to quantum field theory, Lagrangian field theory, Euler–Lagrange equations, Hamiltonian formalism, Fock space, Second Quantization, Quantization of real and complex scalar field, Dirac field and electromagnetic field, concept of particles and antiparticles, energy, momentum and charge of the field, C, P, T transformation properties, vacuum in field theory.	20	17	0	3
III	**Quantum Electrodynamics** S-matrix, covariant perturbation theory, path integral formalism, Wicks theorem and contractions, Propagators, electron interaction with electromagnetic field, QED Lagrangian, Feynman Rules and Feynman diagrams, calculation of simple QED processes, Cross-sections and decay rates, Yukawa and Columb interaction, s channel, u channel and t channel processes and Mandelstam variables (s, t, u parameters), electron-muon scattering, Moller scattering, Bhaba scattering, Compton scattering (Klein-Nishima formula).	20	18	0	2
		56	**50**	**0**	**10**

Mode of In-Semester Assessment:

A. Two Sessional Tests:	Sessional I	20
	Sessional II	20
B. Other Sessional Activities:	Attendance	10

Seminar/Class tests/Sudden tests	10
Home assignments/ Library work	10

---Total

In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO-1: Explain the formulation and physical interpretation of the Dirac equation, including its solutions and applications.
CLO-2: Analyze the Lorentz covariance of Dirac equations and discuss the concept of spinors, bilinear covariants, and helicity states.
CLO-3: Apply and analyse the principles of quantum field theory to formulate Lagrangian and Hamiltonian equations.
CLO-4: Apply and analyse the second quantization of different fields and their symmetries (C, P, T).
CLO-5: Construct and interpret Feynman diagrams for QED processes and compute scattering cross-sections.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO-1	CO-1				
Conceptual Knowledge	CO-1	CO-2	CO-3	CO-2	CO-4	CO-5
Procedural Knowledge		CO-4	CO-3	CO-5	CO-4	CO-5
Metacognitive Knowledge						

Mapping of PSO with CLO

CLOs \ PSOs	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO-1	3	3	1	1	1	2	2	2	2	2
CLO-2	3	3	1	2	1	2	2	2	2	2
CLO-3	3	3	1	3	2	2	2	2	2	2
CLO-4	3	3	1	3	2	2	2	2	2	2
CLO-5	3	3	1	3	2	2	2	2	2	2
Average	3	3	1	2.4	1.6	2	2	2	2	2

Suggested Readings

1. M.E. Peskin and D.V. Schroeder – An Introduction to Quantum Field Theory, CRC Press.
2. Lewis H. Ryder – Quantum Field Theory, Cambridge University Press.
3. Franz Mandl and Graham Shaw – Quantum Field Theory, Wiley.
4. A. Zee – Quantum Field Theory in a Nutshell, Princeton University Press.
5. Michael E. Taylor – Quantum Mechanics for Mathematicians, Springer.

6. Paul Roman – Introduction to Quantum Field Theory, Wiley.
7. Steven Weinberg – The Quantum Theory of Fields, Vol. I & II, Cambridge University Press.
8. J.D. Bjorken and S.D. Drell – Relativistic Quantum Mechanics, McGraw Hill.
9. P.A.M. Dirac – The Principles of Quantum Mechanics, Oxford University Press.
10. Palash B. Pal, An Introductory Course of Particle Physics.
11. Amitabha Lahiri and Palash B. Pal, A first book of Quantum Field Theory.

Course Code: DS-MPHY-4-301(B)

Course Title: Low-Dimensional Systems and Soft Matter Physics

Type: Elective (Theory)

Component of the course: L:60 , P: 0, T:
Distribution of credits: Theory: 04
Distribution of Marks: End Semester: Theory: 56, In Semester: 24
Course objectives: The objectives of the course are
CO 1: to introduce students to the physics of quantum confinement, its effect on the properties of the material and the applications in optoelectronics and superconductivity

CO 2: to acquaint the with the classification, synthesis, and lattice structure of various 2D materials including graphene, TMDCs, and MXenes and their applications in nanoelectronics, photodetectors, logic devices, and energy storage.

CO 3: to develop a foundational understanding of ferroelectricity through dipole theory and thermodynamic principles, covering both first- and second-order phase transitions

CO 4: to introduce the distinct properties of soft matter systems, emphasizing the roles of entropy, mesoscopic length scales, and thermal fluctuations

Course content

Unit	Content	Marks	L	P	T
I	**Low dimension systems** Overview of 0D, 1D and 2D systems, size and dimensionality effects: size effect, conduction electrons and dimensionality, Fermi gas and density of states, potential wells, partial confinement, properties dependent on density of states, excitons, single electron tunnelling, Coloumb interaction in low dimension, dielectric constant in low dimension Applications: Infrared detectors, quantum dot lasers, superconductivity.	15	17		
II	**Graphene and 2D materials** 2D materials, isolation of graphene, classification of 2D materials: elemental: graphene , compound :transition metals dichalcogenides (TMDCs), hexagonal boron nitride, MXenes and hybrid 2D materials, lattice structure of graphene and TMDs, application of 2D materials: FET and logic devises, photodetectors, sensing and energy storage	15	17		
III	**Ferroelectric properties** General theory of ferroelectric materials, Dipole theory of ferroelectricity, thermodynamics of ferroelectricity, first and second order transitions, anti-ferroelectricity	11	9		
IV	**Soft Matters**	15	17		

	Introduction to soft matters, distinction of soft matter from hard condensed matter, Force, energy time scale in soft matter, role of entropy and mesoscopic length scale in soft matters, Brownian motion, basic phenomenology of soft condensed matter system: colloids, polymers, membranes, liquid crystals, biological soft matters their viscous, elastic and visco- elastic behaviour				

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment: (24 Marks)

F. Two Sessional Test:

Sessional I: 30
Sessional II: 30

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total: 90

20% from each component to contribute to the total marks of 24

Course Learning Outcomes: After the completion of the course, the student will be able to

CLO 1: describe and explain the physical characteristics of low dimension systems and their quantum confinement effects, analyse the behaviour of different phenomena in confined geometry and apply the knowledge of low-dimensional systems to understand the working principles of quantum dot lasers, IR detectors, and superconductors.

CLO 2: classify 2D materials based on their composition and structure, illustrate the lattice structure and physical properties of graphene and other 2D materials, evaluate the suitability of 2D materials for applications in logic devices, sensors, photodetectors, and energy storage and demonstrate understanding of the synthesis and isolation techniques of 2D materials

CLO 3: explain the origin and behaviour of ferroelectricity using dipole theory and thermodynamics, distinguish between first-order and second-order phase transitions in ferroelectric materials and analyze the characteristics and significance of anti-ferroelectric materials in various contexts.

CO 4: differentiate soft matter from hard condensed matter based on force, energy, and time scales, interpret the role of entropy and mesoscopic length scales in the behaviour of soft matter systems, describe the dynamics of colloids, polymers, membranes, and biological materials, including their viscoelastic properties and apply concepts of Brownian motion and viscoelasticity to model soft matter behaviour in physical and biological systems.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge		CO 2	CO 2	CO 2		
Conceptual Knowledge		CO 1, CO 2, CO 3, CO 4	CO 1, CO 2, CO 4	CO 2, CO 3		
Procedural Knowledge		CO 1, CO 2	CO 1, CO 2	CO 2		
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO/PSO	PSO 1	PSO 2	PSO 3	PSO 4	*PSO 5*	*PSO 6*	PSO 7	PSO 8	PSO 9	PSO 10
CLO 1	3	2	3	2	3	2	1	1	2	1
CLO 2	3	2	2	3	2	2	2	3	3	2
CLO 3	3	2	3	2	3	2	2	1	2	1
CLO 4	3	2	3	3	3	2	2	2	3	2
Avg	3	2	2.75	2.5	2.75	2	1.75	1.75	2.5	1.5

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Suggested readings

1. Introduction to nanotechnology. Charles P. Poole Jr, Frank J. Owens, Willey
2. Soft Condensed Matter , R. A. L. Jones
3. Principles of Condensed Matter Physics, P. M. Chaikin & T. C. Lubensky,
4. Soft Matter Physics, M. Doi
5. Introduction to Soft Matter physics, Luwel Zhou
6. Elements of Solid State Physics J.P Srivastavat, Prentice Hall India

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Semester IV

Course Title: Statistical Mechanics
Course Code: MPHY-CC-4-401
Nature of the Course: Core
Total Credits assigned: 04
Components of the course: L- 46, P-0, T- 14
Distribution of Marks: End Semester: Theory: 56, Practical: 0, In Semester: 24

Course Objectives:
The Statistical Mechanics is one of the most important branches of physics which is required to understand the properties matter in bulk on the basis of the dynamical behaviours of its microscopic constituents. As such the objectives of this course are:

CO1: To enable students to understand about the statistical basis of thermodynamics
CO2: To compute various thermodynamic observables using partition functions across classical and quantum ensembles, emphasizing the role of phase space and ergodicity.

CO3: To enable the students understand the Bose-Einstein and Fermi-Dirac statistics and the their various applications.

CO4: To understand and apply the formalism of statistical mechanics of Interacting Systems and Phase Transitions.

Unit	Content	Marks	L	P	T
I	**Statistical Basis of Thermodynamics:** Review of Thermodynamics, Statistical basis of thermodynamics: macroscopic and the microscopic states, connection between statistics and thermodynamics, accessible states, the idea of entropy, Helmholtz free energy, Gibbs free energy and their various uses, entropy of mixing and Gibbs paradox.	8	7		2
II	**Elements of ensemble theory:**Phase space of a classical system, the micro canonical ensemble, Liouville's theorem and its consequences, quantum stats and the phase space. Canonical ensemble: ergodic hypothesis, the probability of a small system exchanging only energy with a heat reservoir to have a specific energy in equilibrium, the idea of a canonical ensemble, and the probability of a randomly chosen system in a canonical ensemble to have a specific energy, partition function and various applications.	17	14		4
	Grand canonical ensemble: definition, a system in equilibrium with a particle energy reservoir, a system in grand canonical ensemble, grand partition function and applications. Formulation of quantum statistical				

	mechanics: pure and mixed states, density matrix, statistics of the various ensembles (micro canonical, canonical, grand canonical ensembles).				
III	**Ideal Bose and Fermi systems:** Review of BE and FD statistics. Ideal Bose gases, thermodynamic behaviour of an ideal Bose gas and Fermi gas. Magnetic behaviour of idea Fermi gas (Pauli paramagnetism, Landau diamagnetism.)	18	15		4
IV	**Statistical Mechanics of Interacting systems:** Clusters, classical cluster expansion, formalism of second quantization, creation and annihilation operators and their properties for bosons and fermions, Hamiltonian in terms of second quantized operators, imperfect Bose gases. **Phase Transition:**Basics of phase transition, the Ising model (one dimension), liquid helium, He-4 and He-3, the lambda-transition, Tisza's two-fluid model, the theories of Landau and Feynman, equilibrium properties near absolute zero, super-fluidity	13	10		4

Expected Course Learning Outcome:
After the completion of this course it is expected that the students will be able to

CLO1: understand and justify and explain the connection between statistical mechanics and thermodynamics and apply to solve various physical problems.

CLO2: understand and **justify** formalism of statistical mechanics and **apply** it to compute various thermodynamic observables.

CLO3: understand Ideal Bose and Fermi Statistics and it various applications.

CLO4: understand the basics of phase transition and the formalism of statistical mechanics for interacting system and learn how to calculate various thermodynamic observables.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge		CO 1	CO1	CO1		
Conceptual Knowledge		CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	
Procedural Knowledge		CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	
Metacognitive Knowledge		CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	CO1,CO2, CO3, CO4	

Mapping of PSO with CLO

CLO/PSO	PSO1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6	PSO 7	PSO8	PSO9	PSO10
CLO 1	3	1	3	2	3	2	1	2	2	2
CLO 2	3	1	3	2	3	2	1	2	2	2
CLO 3	3	1	3	2	3	2	1	2	2	2
Avg.	3	1	3	2	3	2	1	2	2	2

Mode of In-Semester Assessment: (24 Marks)

A. **Two Sessional Test:**

Sessional I: 30
Sessional II: 30

B. Other Sessional Activities Marks:

i) Attendance: 10

ii) Seminar/Class test/ Sudden test: 10

iii) Home assignments/ Library work: 10

Total Marks: 70

20% from each component to contribute to the total marks of 24.

Suggested Readings:

1. Statistical Mechanics, K. Huang, John Wiley and Sons.
2. Statistical Mechanics, R. K. Pathria, Butterwork Heinemann.
3. Statistical Mechanics, K. M. Khanna, Today and Tomorrow, New Delhi.
4. Statistical Mechanics, B. K. Agarwal, M. Eisner, New Age International Publishers.
5. Fundamentals of Statistical Mechanics, B.B. Laud, New Age International Publishers.
6. A Primer of Statistical Mechanics, R. B. Singh, New Age International Publisher.

Course Title: General laboratory- II
Course Code: CC-P4–MPHY-402 (Lab)
Nature of the Course: Practical (Lab)
Total Credit assigned: 04 Credits
Component of the Course: L-, P-120 , T-
Distribution of Marks : End Semester: 80

Course Objectives:
After completing the course (lab), students will be able to:

CO1. Understand quantum mechanical phenomena and experimental verification (e.g., Frank-Hertz, Zeeman effect, uncertainty principle).
CO2. Perform experiments to determine fundamental physical constants and parameters (e.g., e/m, Stefan's constant, bandgap).
CO3. Analyze the magnetic, electric, and thermal properties of materials using modern experimental techniques (e.g., B-H curve, ESR, Curie and Neel temperature).
CO4. Investigate solid-state physics concepts such as crystal lattice vibrations, resistivity variation in semiconductors, and dispersion relations.
CO5. Interpret optical and spectroscopic phenomena using lasers and molecular spectra (e.g., He–Ne laser wavelength, I_2 spectra).
CO6. Develop hands-on laboratory skills, including data collection, analysis, and error estimation for physical experiments.

Course Content:

Unit	Contents	M	L	P	T
Practical	**List of Experiments:** **(At least 75% of the experiments listed below must be performed by each student)** 1. To determine the plateau and optimal operating voltage of a Geiger-Müller counter. 2. Verify the Heisenberg's uncertainty principle using He-Ne laser. 3. To determine the wavelength of He-Ne laser light. 4. To determine the value of e/m by bar magnet method. 5. To study the dispersion relation for the monoatomic and diatomic lattice 6. Determine the coercivity, retentivity, and saturation magnetization of a given ferromagnetic specimen using B–H loop curve 7. To Determine the Lange g-factor by Electron Spin Resonance Method 8. To determine the Curie temperature of phase transition for (a) ferroelectric materials and (b) for ferrites 9. To determine the Stefan's Constant. 10. To determine the Neel temperature of an anti-ferromagnetic material by Gouy's method. 11. Frank-Hertz Experiment. 12. To study the vibrational spectra of I_2 molecule.	**80**		**120**	

	13. To determine the value of e/m by Zeeman effect. 14. To measure the resistivity of a semiconductor with temperature by four probe method and to determine its bandgap.					

(L=Lecture, P=Practical, T=Tutorial)

Expected Course Learning outcomes (CLOs):
After the completion of the course, the students are expected:

CLO1. Demonstrate quantum physical phenomena through laboratory experiments (e.g., uncertainty principle, Frank-Hertz, Zeeman effect).
CLO2. Determine fundamental physical constants and relate them to theoretical principles (e.g., *e/m*, Stefan's constant, g-factor).
CLO3. Analyze magnetic properties of materials using techniques such as B–H curve, ESR, and Neel temperature measurement.
CLO4. Examine ferroelectric and ferrite phase transitions using temperature-dependent measurements.
CLO5. Interpret spectroscopic data of diatomic molecules and laser-based experiments to understand vibrational and optical properties.
CLO6. Apply concepts of solid-state physics to experiments on dispersion relations, resistivity, and crystal properties.
CLO7. Develop hands-on laboratory skills, including data collection, analysis, and error estimation for physical experiments.

Mapping of PSO with CLO

CLO / PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	2	2	3	2	1	2	2	2
CLO2	3	3	3	2	3	2	1	2	3	2
CLO3	3	3	2	3	3	2	1	2	3	2
CLO4	3	3	2	3	2	2	2	2	2	2
CLO5	3	3	3	2	2	3	1	2	3	2
CLO6	3	3	3	3	3	2	2	2	3	2
CLO7	3	3	3	2	3	3	3	3	3	2
Average	**3.00**	**3.00**	**2.57**	**2.43**	**2.57**	**2.29**	**1.57**	**2.14**	**2.71**	**2.00**

Mapping Scale:

- **3** = Strongly related
- **2** = Moderately related
- **1** = Slightly related

Cognitive Map of Course Objectives based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO1, CO2	CO1, CO2	CO2			

Conceptual Knowledge		CO1, CO3	CO3, CO4	CO1, CO3	CO3, CO4	
Procedural Knowledge		CO2, CO3	CO2, CO3, CO4, CO5	CO3, CO4, CO6	CO4, CO6	CO6
Metacognitive Knowledge			CO6	CO6	CO6	CO6

Suggested Reading:

1. B. L. Worsnop and H. T. Flint, Advanced Practical Physics, Asia Publishing House.
2. Optics, A. K. Ghatak, Tata McGraw Hill.
3. Fundamentals of Optics Jenkins and White McGraw Hill.
4. Optics A. R Ganesan, Eugune Hecht.

Core – XII
Course Title: Particle Physics
Course Code: MPHY-CC-4-403
Total Credit assigned: 02
Component of the Course: L- 30, P- 0, T- 0
Distribution of Marks: End Semester: 28 In Semester: 12

Course Objectives: The Objectives of this course are to:

CO-1: Acquaint and Understand the classification, properties, and quantum numbers of elementary particles and their symmetries.

CO-2: Understand and analyse the Standard Model and quark model, including SU(2) and SU(3) symmetry groups, and particle multiplets.

CO-3: Understand and analyse conservation laws, symmetry principles, and quantum chromodynamics (QCD) in hadron structure.

CO-4: Understand and analyse the four fundamental forces, their mediators, and use Feynman diagrams to interpret particle interactions.

CO-5: Understand, analyse and evaluate weak interactions and symmetry violations (P, CP, CPT), and connect particle physics concepts to cosmology.

Course Content:

Unit	Contents	M	L	P	T
I	**Elementary particles:** Discovery and important properties, Classification based on interactions and spin, The Standard Model (qualitative treatment only), Quantum Numbers associated with the elementary particles, Properties and basic interactions of Quarks and Leptons, Baryon Number, Strangeness, Charge (C), Parity (P) and CP, Symmetries and Conservation laws, Gell-Mann Nishijima Formula, Quark Model, eightfold way of classification, Baryon and Meson Octets and Decuplets. symmetry groups - SU(2), SU(3), discovery of J/Ψ and upsilon, masses of elementary particle, Structure of hadrons: introduction to Quantum chromodynamics.	14	15	0	0
II	**Fundamental Forces:** Fundamental Forces, Mediators of fundamental interactions, Introduction to basic Feynman Diagrams. Basic electromagnetic interaction, Weak interaction in Beta Decay, Tau-Theta Puzzle, Lee-Yang Hypothesis, Wu's Experiment and Parity Violation in Weak Interaction, Concept of CP conservation, Cronin-Fitch experiment, CP violation in Kaon Decay, CPT symmetry, matter-antimatter asymmetry, connection of particle physics with cosmology.	14	15	0	0
		28	**30**	**0**	**0**

Mode of In-Semester Assessment:

A. Two Sessional Tests: Sessional I 20
Sessional II 20

B. Other Sessional Activities: Attendance 10
Seminar/Class tests/Sudden tests 10
Home assignments/ Library work 10
--Total
In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 12.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO-1: Recall and describe basic properties and classifications of elementary particles and their associated quantum numbers.

CLO-2: Explain and apply symmetry principles, SU(2)/SU(3) group theory, and the quark model to classify hadrons.

CLO-3: Analyze particle multiplets using Gell-Mann-Nishijima formula and evaluate implications of quantum numbers.

CLO-4: Illustrate fundamental forces and mediators using Feynman diagrams and explain processes like beta decay and CP violation.

CLO-5: Assess experimental evidence (Wu, Cronin-Fitch, etc.) for symmetry violation and connect particle physics to cosmological questions.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1	CO1, CO2				
Conceptual Knowledge	CO1	CO2, CO3, CO4, CO5	CO2, CO3, CO4, CO5	CO3, CO4	CO5	
Procedural Knowledge			CO4	CO3, CO4	CO5	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	0	2	2	2	3	2	2	2
CLO2	3	3	0	2	2	2	3	2	2	2
CLO3	3	3	0	2	2	2	3	2	2	2
CLO4	3	3	1	2	2	2	3	2	2	2
CLO5	3	3	2	2	2	2	3	2	2	2
Average	3	3	0.6	2	2	2	3	2	2	2

Suggested Readings:

1. Griffiths David, Introduction to Elementary Particles, Wiley-VCH.
2. Perkins, D.H., Introduction to High Energy Physics, Cambridge University Press.
3. Halzen, Francis and Martin, Alan D., Quarks and Leptons: An Introductory Course in Modern Particle Physics, Wiley.
4. Povh, B., Rith, K., Scholz, C., and Zetsche, F., Particles and Nuclei: An Introduction to the Physical Concepts, Springer.
5. Cottingham, W. N. and Greenwood, D. A., An Introduction to the Standard Model of Particle Physics, Cambridge University Press.
6. G. Kane, Modern Elementary Particle Physics, Addison-Wesley.
7. E. Leader, Particles and Symmetries, Cambridge University Press.
8. Palash B. Pal, An Introductory Course of Particle Physics.

Course: DSE
Course Title: High Energy Physics II
Course Code: MPHY-DE-4-401
Nature of the Course: DSE (Theory)
Total Credit assigned: 04
Component of the Course: L- 50, P- 0, T- 10
Distribution of Marks: End Semester: 56 In Semester: 24

Course Objectives: The Objectives of this course are to:

CO-1: Understand the principles of symmetry and group theory in quantum field theory, including Lie groups and gauge symmetries.

CO-2: Comprehend symmetry breaking mechanisms in gauge theories including spontaneous symmetry breaking and the Higgs mechanism.

CO-3: Analyze the theoretical structure and components of the Standard Model of particle physics and its implications.

CO-4: Apply group theoretical tools and Lagrangian formulation to derive particle interactions within the Standard Model framework.

CO-5: Explore limitations of the Standard Model and understand qualitative aspects of physics beyond the Standard Model.

Course content

Unit	Contents	M	L	P	T
I	**Group Theories for Quantum Fields** Symmetries in physics, Representation of the Lorentz group, Lie groups and Lie algebra, unitary and special unitary groups U(1), SU(2)and SU(3), Tensor method in SU(n), Young tableaux. Noether's theorem, gauge theories of interactions, gauge symmetries (global and local), abelian gauge theory and QED Lagrangian, Gauge invariance and the electromagnetic field strength. Maxwell's equations, non-abelian gauge theories (Yang-Mills theories).	15	15	0	3
II	**Symmetry Breaking in Gauge Theories** Concept of Symmetry breaking, Hidden Symmetry, Spontaneous symmetry breaking in U(1) and SU(2) invariant Lagrangian, Goldstone theorem and Goldstone bosons, Higgs mechanism and Higgs boson.	15	15	0	0
III	**The Standard Model:** Weak hypercharge and weak isospin, Lagrangian for weak interaction, SU(2)xU(1) invariant Lagrangian and Electroweak unification, electro-weak theory (Glashow-Weinberg-Salam model), Choice of Higgs field for electroweak symmetry breaking, Mass of gauge bosons, mass of fermions, mass of Higgs boson, Final electroweak Lagrangian, Introduction to QCD, Final Standard Model Lagrangian, Grand unification (qualitative idea only).	20	18	0	3

IV	**Beyond the Standard Model** Limitations of the Standard Model, neutrino oscillation and neutrino mass, matter-antimatter asymmetry, dark matter and dark energy, connection of particle physics with cosmology.	6	6	0	0
		56	**54**	**0**	**6**

Mode of In-Semester Assessment:

A. Two Sessional Tests:	Sessional I	20
	Sessional II	20
B. Other Sessional Activities:	Attendance	10
	Seminar/Class tests/Sudden tests	10
	Home assignments/ Library work	10

--Total

In- Semester Assessment Marks: 70

20% from each component to contribute to the total marks of 24.

Expected Course Learning Outcomes: After completion of the course, learners will be able to-

CLO-1: Recall key symmetry principles and identify Lie groups and their representations relevant to quantum field theory.

CLO-2: Explain the concept of gauge symmetry, spontaneous symmetry breaking, and apply Noether's theorem and the Higgs mechanism.

CLO-3: Apply group theoretical techniques and analyze Lagrangian to derive implications of spontaneous symmetry breaking and electroweak unification.

CLO-4: Analyze and evaluate the structure of the Standard Model, including fermion masses, gauge boson masses, and QCD interactions.

CLO-5: Understand and critically assess the limitations of the Standard Model and outline the motivation for physics beyond it.

Cognitive Map of Course Outcomes based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	CO1	CO1, CO2	CO2			
Conceptual Knowledge	CO1	CO2, CO3	CO3, CO4	CO4		
Procedural Knowledge		CO2	CO3, CO4	CO4	CO5	
Metacognitive Knowledge						

Mapping of PSO with CLO

CLO \PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	3	0	2	2	2	3	2	2	2
CLO2	3	3	0	2	2	2	3	2	2	2
CLO3	3	3	0	2	2	2	3	2	2	2
CLO4	3	3	0	2	2	2	3	2	2	2
CLO5	3	3	0	2	2	2	3	2	2	2
Average	3	3	0	2	2	2	3	2	2	2

Suggested Reading

1. Cheng, T.P., and Li, L.F., *Gauge Theory of Elementary Particle Physics*, Oxford University Press.
2. Peskin, M.E., and Schroeder, D.V., *An Introduction to Quantum Field Theory*, Addison-Wesley.
3. Weinberg, S., *The Quantum Theory of Fields (Vols. 1–3)*, Cambridge University Press.
4. Quigg, C., *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions*, Princeton University Press.
5. Mohapatra, R.N., *Unification and Supersymmetry*, Springer.
6. Zee, A., *Quantum Field Theory in a Nutshell*, Princeton University Press.
7. Donoghue, J.F., Golowich, E., and Holstein, B. R., *Dynamics of the Standard Model*, Cambridge University Press.
8. Amitabha Lahiri and Palash B. Pal, A first book of Quantum Field Theory.

MSc
Semester-IV

Course Title: Solid-State Devices and Fabrication Techniques
Course Code: EC-4–MPHY-401(B)
Nature of the Course: DSC (Theory)
Total Credit assigned: 04 Credits
Component of the Course: L-53, P-0 , T-07
Distribution of Marks : End Semester: 56 In Semester: 24

Course Objectives:
By the end of this course, students will be able to:

- **CO1.** Understand the fundamental steps involved in semiconductor device fabrication, including oxidation, doping, deposition, and etching processes.
- **CO2.** Explore the physics and characteristics of FET-based devices such as JFETs, MOSFETs, and emerging FET technologies using novel materials.
- **CO3.** Learn about the operation principles and characteristics of optoelectronic devices such as photodiodes, solar cells, and LEDs.
- **CO4.** Understand the principles, methods of preparation, and analysis techniques for thin films, including surface characterization.
- **CO5.** Develop the ability to compare, evaluate, and select appropriate materials and fabrication techniques for specific device applications.
- **CO6.** Gain foundational insight into third-generation devices and materials for flexible, transparent, and nanoelectronics applications.

Course Content:

Unit	Contents	M	L	P	T
I	**Semiconductor Process Technology:** Overview on Semiconductor Manufacturing (ICs), Cleanroom and Wafer Preparation, Processes in Semiconductor Fabrication: Oxidation, Diffusion and Ion Implantation, Photolithography and Etching, Thin Film Deposition: Sputtering, Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), Molecular Beam Epitaxy (MBE), Wet chemical Etching, Dry Etching, Annealing, Metallization	14	14		01
II	**Field-effect transistors: (DC)** FETs: JFETs - device characteristics, pinch-off, saturation, gate control, I-V characteristics, MOSFETs -fabrication, operation, linear and saturation regions, I-V characteristics, types of MOSFETs. Overview of GaAs MESFET, HEMT Semiconductor Materials for FET Channels: Elemental, Compound semiconductors, 2D materials, Dielectric Materials for Gate Insulation, Contact and Interconnect	12	12		01

	Materials, Advanced and Emerging Materials:- Organic semiconductors and nanomaterials (CNTs, nanowires), Heterostructures and 2D material integration, Material challenges in flexible and transparent FETs, Nanostructured FETs				
III	**Optoelectronic devices: (DC)** **Photodetectors: P**hotoconductors, Photodiodes, operation of an illuminated junction, current and voltage, Quantum efficiency and response speed, p-i-n photodiode, avalanche photodiode. **Solar cells:** p-n junction solar cells, maximum power transfer rectangle and conversion efficiency. Third generation solar cells: Dye-Sensitized solar cells, Quantum dot solar cells, optical concentration. **LEDs:** Radiative transitions and optical absorptions, Light Emitting Diodes - Structure, optical characteristics, quantum efficiency. Organic LEDs	**16**	**16**		**01**
IV	**Thin films:** Introductory concepts, methods of preparation of thin films (vacuum evaporation, chemical vapour deposition, sputtering), thickness determination, conductivity of thin film, effect of thickness on transport properties, Thomson's theory, Fuch's theory, elementary concept of surface crystallography, surface structure analysis of thin films (SEM, TEM and AFM)	**14**	**14**		**01**

(L=Lecture, P=Practical, T=Tutorial)

Mode of In-Semester Assessment:

A. Two Sessional Tests:	**Sessional I**	**20**
	Sessional II	**20**
B. Other Sessional Activities:	**Attendance**	**10**
	Seminar/Class tests/Sudden tests	**10**
	Home assignments/ Library work	**10**
Total In- Semester Assessment Marks:		**70**

20% from each component to contribute to the total marks of 24.

Expected Course Learning outcomes: (CLOs):

After the completion of the course, the students are expected:

- **CLO1. Define and explain** the sequence of semiconductor fabrication processes and cleanroom protocols, including oxidation, doping, and deposition.
- **CLO2. Describe and analyze** the working principles, I–V characteristics, and fabrication of FETs and MOSFETs, including advanced FET structures.
- **CLO3. Identify and explain** the working mechanisms of various optoelectronic devices, including photodetectors, solar cells, and LEDs.
- **CLO4. Demonstrate understanding** of thin film deposition techniques, thickness measurement, and impact of film properties on electrical transport.
- **CLO5. Compare** materials used in device fabrication (e.g., 2D materials, organics, nanowires) and evaluate their roles in flexible and high-performance electronics.
- **CLO6. Apply the knowledge** of semiconductor processes and devices to evaluate performance limitations and suggest material/technological improvements for emerging devices.

Cognitive Map of Course Objective based on Revised Bloom's Taxonomy

Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	CO1, CO3	CO1, CO3				
Conceptual Knowledge		CO2, CO3	CO2, CO3	CO2, CO5	CO5	
Procedural Knowledge		CO1, CO4	CO1, CO4	CO4, CO5	CO5	CO6
Metacognitive Knowledge			CO6	CO5, CO6	CO6	CO6

Mapping of PSO with CLO

Mapping Scale:

- **3** = Strongly related
- **2** = Moderately related
- **1** = Slightly related

CLO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CLO1	3	2	1	1	1	1	2	2	2	2
CLO2	3	3	2	2	2	1	2	2	2	2
CLO3	3	2	2	2	2	1	2	2	2	2
CLO4	3	2	3	3	1	1	2	2	2	2
CLO5	3	3	1	3	3	2	3	3	3	2
CLO6	2	3	1	3	3	2	3	3	3	2
Average	**2.83**	**2.5**	**1.67**	**2.33**	**2**	**1.33**	**2.33**	**2.33**	**2.33**	**2**

Reference Books:

1. Solid State Electronic Devices, B. G. Streetman, S. K. Banerjee, Pearson Education
2. Semiconductor Physics and Devices, S. Sze, M-K Lee, Wiley
3. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
4. Electronic Devices & circuits, S. Salivahanan & N.S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
5. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press.
6. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
7. **P. Bhattacharya**, *Semiconductor Optoelectronic Devices*, Pearson
8. **Jasprit Singh**, *Semiconductor Optoelectronics: Physics and Technology*, McGraw-Hill
9. **K.L. Chopra**, *Thin Film Phenomena*, McGraw-Hill
10. Ohring, Milton, Materials Science of Thin Films, Academic Press.