Department of Physics
Savitribai Phule Pune University, Pune 411007

Course: M. Sc. (Physics)

Course Structure and Syllabus for M.Sc-Physics as per National Education Policy (NEP 2020)

(w. e. f. Academic year 2023-24 and onwards)

Preamble

National Education Policy 2020 (NEP 2020) aimed to nurture intrinsic abilities of the students and offer flexibility of learning the topics of student's interest within a framework. In view of nurturing various facets of the students varieties of options are offered to the them. Understanding of basic physics is important in view of learning how to express keen observations in the language of physics and also from the view point of theoretical and experimental framework of Physics and its applications.

The curriculum for the M. Sc. (Physics) program is designed to cater to the requirement of National Education Policy 2020 as per University Grants Commission (UGC) guidelines. In the present structure, due consideration is given to Core and Elective Courses (Discipline specific – Physics). Furthermore, continuous assessment is an integral part of the NEP 2020, which will facilitate systematic and thorough learning towards better understanding of the subject. The systematic and planned curricula divided into two years (comprised of four semesters) shall motivate the student for pursuing higher studies in Physics and inculcate enough skills for becoming a successful teacher/researcher/entrepreneur.

Objectives of the course :

1. To foster scientific attitude, provide in-depth knowledge of basic as well as advanced concepts of Physics.
2. To enrich knowledge through problem solving, minor/major projects, seminars, tutorials, experiments, review of research articles/papers, participation in scientific events, study visits, etc.
3. To create foundation for research and development in Physics.
4. To help students to learn various experimental and computational tools thereby developing analytical abilities to address real world problems.
5. To train students in skills related to research, education, industry and market.
6. To help students to build-up a progressive and successful career in Physics.

ELIGIBILITY: As per the rules and regulations published by SPPU, Pune.

DURATION: Two years (Four semester course)

EXAMINATION: As per the BOOKLET prepared by Savitribai Phule Pune University, Pune.

Course Structure

SEMESTER-I

Semester I : Total No. of Credits: 22, [Major core (14)+Major Elective (4) + RM (4) + OJT (0)+RP(0)]			
MAJOR CORE			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 501 MJ	APPLIED ELECTRONICS	2	12
PHY 502 MJ	CLASSICAL MECHANICS	2	13
PHY 503 MJ	QUANTUM MECHANICS-I	2	14
PHY 504 MJ	MATHEMATICAL METHODS IN PHYSICS	4	15
PHY 505 MJP	BASIC PHYSICS LABORATORY	4	17,19
PHY 506 MJP	COMPUTER PROGRAMMING AND NUMERICAL METHODS		
	MAJOR CORE TOTAL	**14**	
MAJOR ELECTIVE (ANY TWO)			
Subject Code	**Subject Title**	**Credits**	
PHY 510 MJ	FUNDAMENTALS OF ELECTRONICS	2	21
PHY 511 MJ	FUNDAMENTALS OF CLASSICAL MECHANICS	2	22
PHY 512 MJ	ELEMENTARY FLUID MECHANICS	2	23
PHY 513 MJ	BASICS OF ELECTRONIC CIRCUIT DESIGN	2	24
	MAJOR ELECTIVE TOTAL	**4**	
PHY 500 RM	RESEARCH METHODOLOGY	4	25
SEMESTER-I TOTAL		**22**	

SEMESTER-II

Semester II : Total No. of Credits: 22, [Major core (14) + Major Elective (4) + RM (0) + OJT (4)+RP(0)]			
MAJOR CORE			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 551 MJ	STATISTICAL MECHANICS	2	27
PHY 552 MJ	ELECTRODYNAMICS -I	4	28
PHY 553 MJ	QUANTUM MECHANICS-II	4	29
PHY 554 MJP	BASIC PHYSICS LABORATORY	4	31,33
PHY 555 MJP	COMPUTER PROGRAMMING AND NUMERICAL METHODS		
	MAJOR CORE TOTAL	**14**	
MAJOR ELECTIVE (ANY TWO)			
Subject Code	**Subject Title**	**Credits**	
PHY 560 MJ	ESSENTIALS OF STATISTICAL PHYSICS	2	35
PHY 561 MJ	ATOMIC AND MOLECULAR PHYSICS	2	36
PHY 562 MJ	THERMAL PHYSICS	2	37
PHY 563 MJ	BASICS OF ATOMS AND MOLECULES	2	38
	MAJOR ELECTIVE TOTAL	**4**	
PHY 550 OJT	ON-JOB TRAINING	4	39
SEMESTER-II TOTAL		**22**	

T: Theory, P: practical

Exit option: 1 YEAR, 2 SEMESTERS PG Diploma (44 Credits)

SEMESTER-III

Semester III : Total No. of Credits: 22, [Major core (14)+Major Elective (4) + RM (0) + OJT (0)+RP(4)]			
MAJOR CORE			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 601 MJP	ADVANCED PHYSICS LABORATORY-I	2	41
PHY 602 MJ	SOLID STATE PHYSICS	4	43
PHY 603 MJ	ELECTRODYNAMICS-II	2	45
PHY 604-623 MJ	MAJOR CORE SPECIAL PAPER – I (Any one special paper from Annexure-I)	4	46-93
PHY 604-623 MJP	MAJOR CORE SPECIAL LABORATORY-I (One special laboratory from Annexure-I)	2	46-93
	MAJOR CORE TOTAL	**14**	
MAJOR ELECTIVE			
Subject Code	**Subject Title**	**Credits**	
PHY 625 - 646 MJ	ELECTIVE (Any two Electives from Annexure-I)	2+2	96-118
	MAJOR ELECTIVE TOTAL	**4**	
PHY 600 RP	RESEARCH PROJECT-I	4	119
SEMESTER-III TOTAL		**22**	

Please see the Annexure-I for the list of Special paper-I, Special Laboratory-I (Lab course associated with the Special Paper-I) and Elective subjects, offered in semester-III.

SEMESTER-IV

Semester IV : Total No. of Credits: 22, [Major core (12) +Major Elective (4) + RM (0) + OJT (0)+RP(6)]			
MAJOR CORE			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 651 MJP	ADVANCED PHYSICS LABORATORY-II	2	121
PHY 652 MJ	NUCLEAR PHYSICS	4	123
PHY 653-672 MJ	MAJOR CORE SPACIAL PAPER – II (Any one special paper from Annexure-II)	4	125-172
PHY 653-672 MJP	MAJOR CORE SPECIAL LABORATORY-II (One special laboratory from Annexure-II)	2	125-172
	MAJOR CORE TOTAL	**12**	
MAJOR ELECTIVE			
Subject Code	**Subject Title**	**Credits**	
PHY 675-696 MJ	ELECTIVE (Any two Electives from Annexure-II)	2+2	175-197
	MAJOR ELECTIVE TOTAL	**4**	
PHY 650 RP	RESEARCH PROJECT-II (RP)	6	198
SEMESTER-IV TOTAL		**22**	

Please see the Annexure-II for the list of Special paper-II, Special Laboratory-II (Lab course associated with the Special Paper-II) and Elective subjects, offered in semester-IV .

T: Theory, P: practical

2 YEARS, 4 SEMESTERS PG Degree (88 Credits)

Annexure-I: (Semester-III)

MAJOR CORE SPECIAL PAPER-I (ANY ONE)			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 604 MJ	ACCELERATOR PHYSICS-I	4	46
PHY 605 MJ	ADVANCED QUANTUM MECHANICS-I	4	49
PHY 606 MJ	ASTRONOMY AND ASTROPHYSICS-I	4	51
PHY 607 MJ	BIOELECTRONICS-I	4	53
PHY 608 MJ	BIOPHYSICS-I	4	56
PHY 609 MJ	CHEMICAL PHYSICS – I	4	59
PHY 610 MJ	CONDENSED MATTER PHYSICS-I	4	62
PHY 611 MJ	ENERGY STUDIES-I	4	64
PHY 612 MJ	GENERAL RELATIVITY AND BLACK HOLES -I	4	67
PHY 613 MJ	LASER-I	4	69
PHY 614 MJ	MATERIALS SCIENCE-I	4	71
PHY 615 MJ	NANOTECHNOLOGY-I	4	74
PHY 616 MJ	NONEQUILIBRIUM STATISTICAL MECHANICS -I	4	77
PHY 617 MJ	NONLINEAR DYNAMICS-I	4	79
PHY 618 MJ	NUCLEAR TECHNIQUES-I	4	81
PHY 619 MJ	PHYSICS OF SEMICONDUCTOR DEVICES-I	4	84
PHY 620 MJ	PLASMA PHYSICS AND TECHNOLOGY – I	4	87
PHY 621 MJ	QUANTUM INFORMATION AND QUANTUM COMPUTATION -I	4	89
PHY 622 MJ	SOFT CONDENSED MATTER-I	4	91
PHY 623 MJ	THIN FILM PHYSICS AND DEVICE TECHNOLOGY-I	4	93

MAJOR CORE SPECIAL LAB-I (Laboratory associated with SPECIAL PAPER-I)		
Subject Code	**Subject Title**	**Credits**
PHY 604 MJP	ACCELERATOR PHYSICS LABORATORY -I	2
PHY 605 MJP	ADVANCED QUANTUM MECHANICS LABORATORY-I	2
PHY 606 MJP	ASTRONOMY AND ASTROPHYSICS LABORATORY -I	2
PHY 607 MJP	BIOELECTRONICS LABORATORY -I	2
PHY 608 MJP	BIOPHYSICS LABORATORY -I	2
PHY 609 MJP	CHEMICAL PHYSICS LABORATORY – I	2
PHY 610 MJP	CONDENSED MATTER PHYSICS LABORATORY -I	2
PHY 611 MJP	ENERGY STUDIES LABORATORY -I	2
PHY 612 MJP	GENERAL RELATIVITY AND BLACK HOLES LABORATORY -I	2
PHY 613 MJP	LASER LABORATORY -I	2
PHY 614 MJP	MATERIALS SCIENCE LABORATORY -I	2
PHY 615 MJP	NANOTECHNOLOGY LABORATORY -I	2
PHY 616 MJP	NONEQUILIBRIUM STATISTICAL MECHANICS LABORATORY -I	2
PHY 617 MJP	NONLINEAR DYNAMICS LABORATORY -I	2
PHY 618 MJP	NUCLEAR TECHNIQUES LABORATORY -I	2
PHY 619 MJP	PHYSICS OF SEMICONDUCTOR DEVICES LABORATORY -I	2
PHY 620 MJP	PLASMA PHYSICS AND TECHNOLOGY LABORATORY – I	2
PHY 621 MJP	QUANTUM INFORMATION AND QUANTUM COMPUTATION LABORATORY - I	2
PHY 622 MJP	SOFT CONDENSED MATTER LABORATORY -I	2
PHY 623 MJP	THIN FILM PHYSICS AND DEVICE TECHNOLOGY LABORATORY -I	2

ELECTIVES SUBJECTS FOR SEMESTER-III [ANY TWO]			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 625 MJ	METHODS OF EXPERIMENTAL PHYSICS-I	2	96
PHY 626 MJ	METHODS OF EXPERIMENTAL PHYSICS-II	2	97
PHY 627 MJ	X-RAY CRYSTALLOGRAPHY	2	98
PHY 628 MJ	BIOPHOTONICS	2	99
PHY 629 MJ	MEDICAL PHYSICS	2	100
PHY 630 MJ	OPTOELECTRONICS	2	101
PHY 631 MJ	RADIATION PHYSICS	2	102
PHY 632 MJ	BASICS OF SEMICONDUCTORS	2	103
PHY 633 MJ	PHOTODEVICES	2	104
PHY 634 MJ	RIETVELD ANALYSIS	2	105
PHY 635 MJ	RADIATION BIOLOGY	2	106
PHY 636 MJ	PHYSICS OF DIAGNOSTIC INSTRUMENTS	2	107
PHY 637 MJ	METHODS OF COMPUTATIONAL PHYSICS-I	2	108
PHY 638 MJ	METHODS OF COMPUTATIONAL PHYSICS-II	2	109
PHY 639 MJ	SPECIAL TOPICS IN QUANTUM MECHANICS	2	111
PHY 640 MJ	ADVANCED MATHEMATICAL PHYSICS	2	112
PHY 641 MJ	QUANTUM MANY BODY THEORY	2	113
PHY 642 MJ	CLASSICAL FIELD THEORY	2	114
PHY 643 MJ	RELATIVISTIC QUANTUM MECHANICS	2	115
PHY 644 MJ	GROUP THEORY IN PHYSICS	2	116
PHY 645 MJ	ADVANCED STATISTICAL MECHANICS	2	117
PHY 646 MJ	DENSITY FUNCTIONAL THEORY	2	118

Annexure-II: (Semester-IV)

MAJOR CORE SPECIAL PAPER-II (ANY ONE)			
Subject Code	**Subject Title**	**Credits**	**Pg. No**
PHY 653 MJ	ACCELERATOR PHYSICS-II	4	125
PHY 654 MJ	ADVANCED QUANTUM MECHANICS-II	4	127
PHY 655 MJ	ASTRONOMY AND ASTROPHYSICS-II	4	129
PHY 656 MJ	BIOELECTRONICS-II	4	131
PHY 657 MJ	BIOPHYSICS-II	4	134
PHY 658 MJ	CHEMICAL PHYSICS – II	4	137
PHY 659 MJ	CONDENSED MATTER PHYSICS-II	4	139
PHY 660 MJ	ENERGY STUDIES-II	4	141
PHY 661 MJ	GENERAL RELATIVITY AND BLACK HOLES-II	4	145
PHY 662 MJ	LASER-II	4	147
PHY 663 MJ	MATERIALS SCIENCE-II	4	149
PHY 664 MJ	NANOTECHNOLOGY-II	4	152
PHY 665 MJ	NONEQUILIBRIUM STATISTICAL MECHANICS -II	4	155
PHY 666 MJ	NONLINEAR DYNAMICS-II	4	157
PHY 667 MJ	NUCLEAR TECHNIQUES-II	4	159
PHY 668 MJ	PHYSICS OF SEMICONDUCTOR DEVICES –II	4	162
PHY 669 MJ	PLASMA PHYSICS AND TECHNOLOGY – II	4	165
PHY 670 MJ	QUANTUM INFORMATION AND QUANTUM COMPUTATION -II	4	167
PHY 671 MJ	SOFT CONDENSED MATTER-II	4	170
PHY 672 MJ	THIN FILM PHYSICS AND DEVICE TECHNOLOGY-II	4	172

MAJOR CORE SPECIAL LABORATORY-II (Laboratory associated with SPECIAL PAPER-II)		
Subject Code	**Subject Title**	**Credits**
PHY 653 MJP	ACCELERATOR PHYSICS LABORATORY -II	2
PHY 654 MJP	ADVANCED QUANTUM MECHANICS LABORATORY-II	2
PHY 655 MJP	ASTRONOMY AND ASTROPHYSICS LABORATORY -II	2
PHY 656 MJP	BIOELECTRONICS LABORATORY -II	2
PHY 657 MJP	BIOPHYSICS LABORATORY -II	2
PHY 658 MJP	CHEMICAL PHYSICS LABORATORY – II	2
PHY 659 MJP	CONDENSED MATTER PHYSICS LABORATORY -II	2
PHY 660 MJP	ENERGY STUDIES LABORATORY -II	2
PHY 661 MJP	GENERAL RELATIVITY AND BLACK HOLES LABORATORY-II	2
PHY 662 MJP	LASER LABORATORY -II	2
PHY 663 MJP	MATERIALS SCIENCE LABORATORY -II	2
PHY 664 MJP	NANOTECHNOLOGY LABORATORY -II	2
PHY 665 MJP	NONEQUILIBRIUM STATISTICAL MECHANICS LABORATORY -II	2
PHY 666 MJP	NONLINEAR DYNAMICS LABORATORY -II	2
PHY 667 MJP	NUCLEAR TECHNIQUES LABORATORY -II	2
PHY 668 MJP	PHYSICS OF SEMICONDUCTOR DEVICES LABORATORY -II	2
PHY 669 MJP	PLASMA PHYSICS AND TECHNOLOGY LABORATORY – II	2
PHY 670 MJP	QUANTUM INFORMATION AND QUANTUM COMPUTATION LABORATORY - II	2
PHY 671 MJP	SOFT CONDENSED MATTER LABORATORY -II	2
PHY 672 MJP	THIN FILM PHYSICS AND DEVICE TECHNOLOGY LABORATORY -II	2

Syllabus

M.Sc-I (Semester-I)

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 501 MJ	Course Title: Applied Electronics
Credit: 02	

Course Objectives:

1. In this course emphasis will be given on basics concepts related to operational amplifier their applications.
2. Students will also be trained to understand basic requirements of Oscillator, Power Supply, Regulators and their properties
3. In Digital Electronics, basic understanding of building block and their applications will be given.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	OP-AMP : Op Amp Theory, Linear Op Amp Circuits, Non Linear Op Amp Circuits, applications (Adder, subtractor, active filters, AC voltmeter). Positive and negative feedback and their effects on the performance of amplifier, Barkhausen criteria, Oscillators-LC and RC : Wien bridge, phase shift Hartley and Colpitt. IC based oscillators and timer circuits. Regulated power supplies-series, shunt and line filters, Wave shaping circuits.	
Module-2	Credits: 1	10 L , 5 T
	Digital Electronics-Logic gates, Arithmetic circuits, Flip Flops, Digital integrated circuits-NAND & NOR gates as building blocks, X-OR Gate, simple combinational circuits, K-Map, Half & Full adder, Flip-flop, shift register, counters, Basic principles of A/D & D/A converters; Simple applications of A/D & D/A converters. Introduction to Microprocessors. Elements of Microprocessors.	

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

1. Understand characteristics features of operational amplifier and trained to design operational amplifier-based circuit.
2. Students will have basics understanding of oscillator, power supply and regulator and their functioning.
3. Students will get flavour of digital electronic circuits and their applications.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Electronics Principles, A. P. Malvino, Tata McGraw Hill, New Delhi.
2. *Electronics Fundamentals and Applications, J. D. Ryder, John Wiley-Eastern Publications.*
3. Integrated Circuits, Milman and Halkias, Prentice-Hall Publications.
4. *Digital Principles and Applications, A. P. Malvino, D.P. Leach, McGraw Hill Book Co. 4th Edition (1986).*

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 502 MJ	Course Title: Classical Mechanics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of classical mechanics and provide a solid foundation for advanced studies in physics and engineering.

2. To introduce important techniques that are necessary to build core concepts in classical mechanics, enabling students to analyze complex physical systems with precision and clarity.

3. To develop problem-solving skills with appropriate rigor that helps the student to improve their analytical ability in tackling real-world challenges in classical mechanics and related fields.

Course Contents:

Module-1	Credits: 1	10 L , 5 T
	Central forces: Stability of orbits, classification of orbits. Scattering in central force fields: center of mass and laboratory frames of reference, scattering kinematics. Rutherford scattering. Non-inertial reference frames, Pseudo forces: centrifugal, Coriolis and Euler forces. Applications	
Module-2	Credits: 1	10 L , 5 T
	Canonical Transformations, Hamilton-Jacobi equation. Action-angle variables. Rigid body dynamics: Euler-Chasle theorems, Moment of inertia tensor. Euler's equation of motion, Euler angles. Symmetric top. Small oscillations: normal modes and normal coordinates. Generalization to continuum limit.	

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

1. have understood the fundamental concepts of classical mechanics subject, enabling them to comprehend and analyze the behavior of particles, rigid bodies, and systems under various forces and constraints.

2. have acquired the problem-solving skills essential to classical mechanics subject, allowing them to confidently apply mathematical techniques and physical principles to solve complex and diverse mechanical problems.
3. be prepared to undertake advanced topics in classical mechanics subject, empowering them to explore specialized areas and contribute to cutting-edge research and technological advancements in the field.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Classical Mechanics, Goldstein, Poole, & Safko (Pearson).
2. Mechanics, Landau & Lifshitz (Butterworth-Heinemann).
3. Classical Mechanics, Taylor (University Science Books).
4. Classical Mechanics, Rana & Joag (McGraw Hill).
5. Classical Mechanics, Gregory (Cambridge University Press).
6. Classical Dynamics of Particles and Systems, Marion & Thornton (Cambridge University Press).
7. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics, Greiner (Springer).
8. Classical Dynamics: A Contemporary Approach, Jose & Saletan (Cambridge University Press).
9. Classical Mechanics, Strauch (Springer).
10. Classical Mechanics, A.K. Raychaudhuri (Oxford University Press)

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 503 MJ	Course Title: Quantum Mechanics-I
Credit: 02	

Course Objectives: The primary objective is to teach the students the physical and mathematical basis of Quantum Mechanics for non-relativistic systems

1. To introduce the students to formalism of Quantum Mechanics and elementary applications
2. To introduce important concepts to build core concepts in Quantum Mechanics
3. To develop problem solving skills with appropriate rigour that helps the student to improve their analytical ability in Quantum Mechanics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Revision of 1-D problems. Formalism of Quantum Mechanics: State Vectors, basis, Observables and operators, Inner product, Hermitian operators, Eigenvalues and Eigenfunctions, Unitary transformations, Simple harmonic oscillator by operator method, Time-evolution of a quantum system: Schrödinger, Heisenberg and Interaction pictures, Constants of the motion. Schrodinger equation in 3-D.	
Module-2	Credits: 1	10 L , 5 T
	Angular Momentum: Orbital angular momentum operators, Raising and lowering operators, Spherical harmonics. Spherically symmetric potentials, hydrogen atom. Spin angular momentum: Pauli matrices and spin 1/2 eigenstates.	

Learning Outcomes: Upon completion of the course, the student will learn

1. Solving the 1-D Schrodinger equation for standard potentials such as simple harmonic oscillators
2. The mathematical formalism of quantum theory.
3. Angular momentum and 3-D problems
4. The Spectrum of Hydrogen atom
5. Spin angular momentum

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Mechanics, Cohen-Tannaudji, Din, Laloe Vols. I & II (John Wiley).
2. Modern Quantum Mechanics, J. J. Sakurai (Addison Wesley).
3. Quantum Mechanics, D. J. Griffiths (Pearson Education).
4. Quantum Mechanics, L. I. Schiff (McGraw-Hill).
5. Principles of Quantum Mechanics, R. Shankar, Springer
6. Quantum Physics, S. Gasiorowicz (Wiley International).
7. Quantum Mechanics(Non-Relativistic Theory), L.D. Landau and E.M. Lifshitz (Elsevier).
8. Quantum Mechanics: Fundamentals, K. Gottfried and T-Mow Yan (Springer).
9. Introduction to Quantum Mechanics, L. Pauling and E. B. Wilson (McGraw Hill).
10. Quantum Mechanics, B. Crasemann and J.D. Powel (Addison-Wesley).
11. Quantum Mechanics -Vol. I & II, A.P Messiah (Dover).
12. The Principles of Quantum Mechanics, P. A. M. Dirac (Clarendon Press, Oxford).
13. Quantum Chemistry, I. Levine (Allyn and Bacon).
14. A Modern Approach to Quantum Mechanics, J. Townsend (University Science Books).
15. Essential Quantum Mechanics, G.E. Bowman (Oxford University Press).
16. Quantum Physics, M. Le Bellac (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 504 MJ	Course Title: Mathematical Methods in Physics
Credit: 04	

Course Objectives: Mathematical Methods in Physics is the integral part for thorough understanding and learning of any subject that come under Physics. The primary objectives of the study are,

1. To strengthen the basic logic behind the mathematical formulation of laws of Physics.
2. To introduce important mathematical techniques that are necessary to build core concepts in Physics.
3. To develop problem solving skills with appropriate rigour that helps the student to improve their analytical ability.

Course Contents:

Module-1	Credits: 2	20 L , 10 T
	Linear Vector spaces and operators : Vector spaces, Linear independence, Bases, dimensionality isomorphisms. Linear transformations, inverses, matrices, similarity transformations, Eigenvalues and Eigenvectors. Inner product, orthogonality and completeness, complete orthogonal set, Gramm Schmidt orthogonalization procedure, Self-adjoint and unitary transformations. Eigenvalues and Eigenvectors of Hermitian and Unitary transformations, diagonalization. Hilbert spaces: Complete orthonormal sets of functions. Weierstrass's theorem (without proof) approximation by polynomial. Fourier series. Applications of Fourier series. Differential Equations and Special Functions: Power series solutions of second order differential equations (any one of Legendre, Bessel, Hermite, Laguerre as special examples properties of these functions). Legendre polynomials, Spherical harmonics and associated Legendre polynomials. Hermite polynomials. Sturm-Liouville systems and orthogonal polynomials.	
Module-2	Credits: 2	20 L , 10 T
	Complex Analysis : Analytical functions, Cauchy-Riemann conditions, Rectifiable arcs, Line integrals, Cauchy's theorem, Cauchy integral formula, Derivatives of analytical functions, Liouville's theorem. Power series Taylor's theorem, Laurent's theorem. Calculus of residues, evaluation of real definite integrals, summation of series, elementary discussion of branch cuts, Applications : Principal value integrals and dispersion relations. Fourier integrals, Fourier transform, Parseval Relations, Convolution, Applications; Laplace transform, Bromwich contour, simple applications. Contour integral solutions of differential equations. Introduction to Green's functions and some applications to partial differential equations.	

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

1. Understand the concept of linear vector spaces and Eigenvalue problems that occur frequently in Physics
2. Thorough understanding of differential equations and their applications to Physics
3. Apply the powerful machinery of complex analytical function theory to physical problem.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Finite dimensional vector spaces, P. R. Halmos (Springer Verlag).
2. Mathematics of Classical and Quantum Physics, F.W. Byron and R.W. Fuller (Dover).
3. Mathematics for Physicists, Dennery & Krzywicki (Dover).
4. Linear Algebra, K. Hoffman and R. Kunze (Pearson).

5. M. Artin, Algebra, (Pearson).
6. Matrix Analysis, R.A. Horn and C.R. Johnson (Cambridge University Press).
7. Differential Equations with Applications, G. Simmons (Pearson).
8. Complex variables and Applications, R. V. Churchill (McGraw Hill).
9. Complex variables, Ablowitz and Fokas (Cambridge Univ. Press).
10. Complex analysis, Ahlfors (Springer).
11. Fourier series and Boundary value problems, R. V. Churchill (McGraw Hill).
12. Functions of Mathematical Physics, B. Spain and M.G. Smith (Van Nostrand Reinhold).
13. Green's Functions and Boundary value problems, I. Stakgold and M.J. Holst (Wiley).
14. Mathematical Physics, S. Hassani (Springer).
15. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, (Academic Press).
16. Mathematical Methods in Classical and Quantum Physics, Tulsi Dass and S.K. Sharma (Orient Blackswan).
17. V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, ANE, Books 2019
18. Advanced Engineering Mathematics, E. Kreyszig (John Wiley & Sons).
19. Mathematical Methods of Physics, J. Mathews and R.L. Walker (Addison Wesley).
20. Advanced Engineering Mathematics, E. Kreyszig (John Wiley & Sons).

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 505 MJP	Course Title: Basic Physics Laboratory
Credit: 04	

Course Objectives:

1. To get trained to perform experiments in Physics.
2. To introduce important experimental techniques.
3. To Collect data and revise an experimental procedure iteratively
4. To develop experimental skills.

Course Contents

	List of experiments	
	The proposed list of the experiments for Basic Physics Laboratory I (Any 12 experiments) 1. Characteristics of operational amplifier 2. UJT and FET characteristics 3. Magnetic Susceptibility 4. Temperature transducer (T to F converter) 5. Thermionic emission 6. Mass Absorption 7. Counting Statistics 8. Zeeman Effect 9. Fabry Perot Interferometer 10. Michelson interferometer 11. Absorption spectra of I_2 molecule 12. Determination of Seebeck coefficient and understanding of Thermocouple working. 13. Recording and analysis of B-H curve 14. Millikan Oil drop method 15. Determination of e/m ratio 16. Franck-Hertz experiment	

Learning Outcomes: Upon completion of the course, the student would

1. learn to formulate hypotheses and devise and perform experiments to test a hypothesis. as individuals and in a team.
2. have gained training in conducting experiments in Physics
3. learn to apply scientific methodologies for problem solving.
4. have learned important techniques in Experimental Physics
5. have developed skills in designing and conducting experiments in Physics

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:

1) Assesment of experimental skills and outcomes
2) Viva-Voce

REFERENCES:

1. Atomic Spectra and Atomic Structure by G. Herzberg, New York Dover Publication.
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, Tata, McGraw-Hill Publishing Company Limited.
3. Electronics Principles, A. P. Malvino, Tata McGraw Hill, New Delhi.
4. Fundamentals of Statistical and Thermal Physics, F. Reif (International Student Ed.) McGraw Hill..
5. Introduction to electrodynamics, D. J. Griffiths, Prentice Hall.
6. Solid State Physics, A. J. Dekkar, Prentice Hall.

7. Fundamentals of Optics, Jenkins and White, McGraw-Hill, International Edition.
8. Physics Lab. Experiments, Jerry D. Wilson, D. C. Heath and Company.
9. Elementary Solid State Physics, M. Ali Omar, (Addision-Wesely).
10. Foundations of Experimental Physics, Shailaja Mahamuni, Deepti Sidhaye, Sulabha Kulkarni, CRC Press.
11. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy. (Wiley Eastern Limited, New Delhi) .

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Core
Course Code: PHY 506 MJP	Course Title: Computer Programming and Numerical Methods
Credit: 04	

Course Objectives:

1. To train the students to gain knowledge on numerical analysis and understand the basics of FORTRAN 90/95 programming language.
2. To introduce important numerical and programming techniques.
3. To develop numerical and algorithmic skills using FORTRAN 90/95 programming language.

Course Contents

	A. Basic Linux commands, text editors and gnuplot (in Lab); FORTAN Commands and Computer basics. B. Exercises for acquaintance (only some experiments are listed here): (Using FORTRAN 90/95): 1. To find the largest or smallest among a set of numbers. 2. To arrange a given set of numbers in ascending/descending order using Bubble sort algorithm. 3. To generate and print first hundred prime numbers. 4. Matrix addition and multiplication using subroutine. 5. Transpose of a square matrix using only one array. 6. Evaluate a polynomial using Horner's method. C. Numerical Methods: 1. Root finding methods (i) Bisection Method (ii) Newton-Raphson Method (iii) Secant method and applications. 2. Regression models: (i) Linear fit, (ii) Spline fit and applications. (a) Fit a given data set as well as find the standard deviation or error. 3. Lagrange Interpolation and Divided difference interpolation and its uses. 5. Numerical differentiation using forward, backward and mean difference method 6. Numerical Integration : (i) Simpson's rule, (ii) Gaussian Quadrature and applications. 7. Numerical solution of a first order differential equation. (Euler's methods) and applications. 8. Solution of simultaneous equations : (i) Gaussian Elimination method and applications. (Note: The course is expected to comprise 20 exercises).	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in numerical analysis and write their own FORTRAN programs.
2. have learned important techniques in numerical and programming techniques
3. have developed numerical and algorithmic skills
4. have developed enough skills to implement knowledge in quickly learning other programming languages.

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies

1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

1. Programming in Fortran 90/95 V. Rajaraman (Prentice-Hall of India).
2. A first course in Computational Physics, 2nd Ed., P. L. DeVries & J. E. Hasbun

(Jones & Bartlett)
3. Computer Oriented Numerical Methods, V. Rajaraman (Prentice Hall of India).
4. Numerical Methods for Scientist and Engineers, H. M. Antia (Tata McGraw Hill).
5. Numerical Methods with Fortran IV case studies, Dorn & McCracken (John Wiley & Sons).
6. Numerical Recipes in FORTRAN (2nd Edn.), W. H. Press, S. A. Teakalsky, W. T. Vellerling, B. P.Flannery (Cambridge University Press).

Course Information	
Year and Semester: M. Sc-I, Semester-I	Major Elective
Course Code: PHY 510 MJ	Course Title: Fundamentals of Electronics
Credit: 02	

Course Objectives:

1. One of the objectives is to give training of analysis a given electronic circuit in the light of various network theorems.
2. Other objective of the course is to give through understanding of basic structure of transistor along with design aspect of the transistor based circuits.
3. Third objective is to introduce basics concepts related to Differential amplifier.
4. Overall for all above mentioned concepts, problem solving skills with appropriate reason will be nurtured that helps the student to improve their analytical ability in the analysis of the electronic circuits.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Network theorem: Kirchhoff's law, Superposition theorem, Thevenin's theorem, Norton's theorem, Maximum power transfer theorem, Bi-junction Transistor (BJT): Transistor fundamentals, Transistor biasing circuits.	
Module-2	Credits: 1	10 L , 5 T
	Transistor: AC models, Voltage amplifiers, CC and CB amplifiers, Class A and B Power Amplifiers, push pull for PA system, Differential Amplifier, its parameters, Common Mode Rejection Ration (CMRR).	

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

1. Students will be trained to analyse a given electronic circuit with the help of network theorems.
2. Students will be made aware about basics concepts related to BJT and a design aspect transistor-based circuits will also be developed.
3. Students will also be given understanding of characteristics of differential amplifier and trained for applications based on the same.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Electronics Principles, A. P. Malvino, Tata McGraw Hill, New Delhi.
2. Electronics Fundamentals and Applications, J. D. Ryder, John Wiley-Eastern Publications.
3. Integrated Circuits, Milman and Halkias, Prentice-Hall Publications.
4. Digital Principles and Applications, A. P. Malvino, D.P. Leach, McGraw Hill Book Co., 4th Edition (1986).

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Elective
Course Code: PHY 511 MJ	Course Title: Fundamentals of Classical Mechanics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of classical mechanics and develop a solid understanding of Newtonian mechanics and prerequisite definitions.
2. To introduce important techniques that are necessary to build core concepts in Lagrangian and Hamiltonian dynamics, along with symmetries and constant of motions
3. To develop problem-solving skills with appropriate rigour that helps the student to improve their analytical ability in order to grasp the upcoming topic at advanced level.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Review of Newtonian mechanics, Generalized coordinates and momenta, Phase space, Variational Calculus, Hamilton's principle of least action, Derivation of Lagrangian and Hamilton's equations of motion from principle of least action.	
Module-2	Credits: 1	10 L , 5 T
	Symmetries and Noether's theorem, phase portraits of some simple systems, Poisson brackets. Introduction to central forces: two body problem, application to planetary motion: Kepler's laws.	

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

1) have understood the fundamental concepts of classical mechanics subject, including Newtonian mechanics, generalized coordinates, and Hamiltonian mechanics, providing a strong foundation for further studies in physics and related fields.

2) have acquired the problem-solving skills essential to classical mechanics subject, enabling them to analyze and solve intricate problems involving variational calculus, Hamilton's equations, and phase space dynamics.

3) be prepared to undertake advanced topics in classical mechanics subject, allowing them to delve into more complex areas such as celestial mechanics, symplectic geometry, and other specialized branches of classical mechanics, and engage in research and applications in these domains.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies: Descriptive written examinations Assignments

REFERENCES:

1. Classical Mechanics, Goldstein, Poole, & Safko (Pearson).
2. Mechanics, Landau & Lifshitz (Butterworth-Heinemann).
3. Classical Mechanics, Taylor (University Science Books).
4. Classical Mechanics, Rana & Joag (McGraw Hill).
5. Classical Mechanics, Gregory (Cambridge University Press).
6. Classical Dynamics of Particles and Systems, Marion & Thornton (Cambridge University Press).
7. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics, Greiner (Springer).
8. Classical Dynamics: A Contemporary Approach, Jose & Saletan (Cambridge University Press).
9. Classical Mechanics, Strauch (Springer).
10. Classical Mechanics, A.K. Raychaudhuri (Oxford University Press)

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Elective
Course Code: PHY 512 MJ	Course Title: Elementary Fluid Mechanics
Credit: 02	

Course Objectives:

1. To introduce students to the basic concepts of fluid mechanics
2. To introduce important techniques that are necessary to build core concepts in fluid dynamics

Course Contents

Module-1	Credits: 1	10 L , 5 T
	General characteristics of a fluid. Velocity field. Flow patterns. Basic hydrostatics. Hydrostatic pressure distribution. Hydrostatic forces on plane and curved surfaces. Buoyancy and stability. Pressure distribution in rigid body motion.	
Module-2	Credits: 1	10 L , 5 T
	Reynold Transport theorem, Conservation laws in fluids. Bernoulli equation. Differential equations for mass, linear momentum, angular momentum, and energy. Euler equation, viscous fluids.	

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

1. understand the fundamental concepts such as Reynold number, Conservation of mass.
2. understand the Euler equation.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Fluid Mechanics by F. M White, McGraw-Hill India (2017).
2. Fluid Dynamics for Physicists by T. E. Faber, Cambridge University Press (1995).
3. Fluid Mechanics by Landau & Lifshitz, Butterworth-Heinemann (1987).

Course Information	
Year and Semester: M.Sc-I, Semester-I	Major Elective
Course Code: PHY 513 MJ	Course Title: Basics of Electronic Circuit Design
Credit: 02	

Course Objectives:

1. One of the objectives is to give an idea about basic aspects of electricity and electronics. For the analysis of electronic circuits emphasis will be given on various network theorems.
2. Other objective of the course is to give through understanding of basic structure of diode, special diodes and transistor along with design aspect of the transistor based circuits.
3. Overall for all above mentioned concepts, problem solving skills with appropriate reason will be nurtured that helps the student to improve their analytical ability in the analysis of the electronic circuits.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Fundamentals of electricity, Fundamentals of Electronics components and their working, Analysis of Voltage, current, Power in a active circuits in the light of network theorem. Basics of semiconductor, Special purpose diode	
Module-2	Credits: 1	10 L , 5 T
	General Amplifier characteristics, Basics of transistor characteristics, Different configurations of the transistor, Thermal Stability: Transistor biasing and Transistor Dissipation, Hybride equivalent circuit for a transistor, Frequency response, Negative and positive feedback	

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

1. Students will get an understanding of basic aspects of electricity and electronics. Students will be trained for the analysis of electronic circuits with the help of various network theorems.
2. Students will get through understanding of basic structure of diode, special diodes and transistor along with design aspect of the transistor based circuits.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Electronics Principles, A. P. Malvino, Tata McGraw Hill, New Delhi.
2. Electronics Fundamentals and Applications, J. D. Ryder, John Wiley-Eastern Publications.
3. Integrated Circuits, Milman and Halkias, Prentice-Hall Publications.
4. Digital Principles and Applications, A. P. Malvino, D.P. Leach, McGraw Hill Book Co., 4th Edition (1986).

Course Information	
Year and Semester: M.Sc-I, Semester-I	
Course Code: PHY 500 RM	Course Title: Research Methodology
Credit: 04	

M.Sc-I (Semester-II)

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Core
Course Code: PHY 551 MJ	Course Title: Statistical Mechanics
Credit: 02	

Course Objectives:

1. This course introduces students to statistical mechanics, which is part of the foundation of several branches of physics.
2. It shows how the postulates explain the general laws of thermodynamics as well as properties of classical and quantum gases, other condensed matter systems in equilibrium, and phase transitions.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Canonical Ensemble, Grand canonical ensemble, Gibb's Canonical ensemble, Equivalence of ensembles, Partition function and thermodynamical variables, Density and energy fluctuations, Application to the problem of adsorption. Applications to spin systems, Ising model, Mean Field techniques for calculating partition function. Introduction to phase transitions: First order and second order phase transition, Phase equilibria. Statistics of Identical Particles.	
Module-2	Credits: 1	10 L , 5 T
	Ideal Bose gas: Bose-Einstein statistics, Thermodynamic behaviour, Bose-Einstein condensation in ideal Bose gas. Applications: Black body radiation. Planck's law and its limiting cases, Stefan-Boltzmann law. Specific heat of solids (Einstein and Debye models). Ideal Fermi gas.: Fermi-Dirac statistics, Partition function, Thermodynamic behaviour Applications: Degenerate electron gas (free electrons in a metal), Fermi energy. Density matrix: Pure states and statistical mixtures.	

Learning Outcomes: Upon completion of the course, the student will

1. understand how a probabilistic description of nature at the microscopic level gives rise to deterministic laws at the macroscopic level.
2. Understand thermal properties of classical and quantum gases and other condensed systems
3. be prepared to undertake advanced statistical mechanics and condensed matter courses.

Instructional design: Lecture method, Tutorial method , Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Mechanics, Pathria and Beale (Academic Press).
2. Statistical Mechanics, Huang (Wiley).
3. Statistical Physics of Particles, Kardar (Cambridge University Press).
4. Statistical and Thermal Physics, Gould & Tobochnik (Princeton University Press).
5. An Introduction to Statistical Mechanics and Thermodynamics, Swendsen (Oxford
6. University Press).
7. Thermodynamics and Statistical Mechanics, Greiner, Neise, Stocker, Springer, 2010.
8. Statistical Mechanics, Reif
9. Statistical Physics (Part 1), L.D. Landau and E. M. Lifhsitz (Elsevier)

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Core
Course Code: PHY 552 MJ	Course Title: Electrodynamics-I
Credit: 04	

Course Objectives:
This course aims to introduce the student to topics in Electrostatics, Magnetostatics, Maxwell’s equations and Electromagnetic waves.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Electrostatics: Applications of Gauss law, conductors, Poisson’s and Laplace’s equation, Special Techniques: Generic features of solutions of the Laplace's equations, uniqueness theorems, method of images, boundary value problems, Multipole expansion, Green’s functions Electrostatics in dielectric media: Polarization, Electric field of a polarized material, Electric displacement, Linear dielectrics.	
Module-2	Credits: 1	10 L , 5 T
	Magnetostatics: Biot-Savart law, Lorentz force, div. and curl of magnetic field, Magnetic vector potential, Multipole expansion. Magnetic fields in matter: Magnetization, Magnetic field of magnetized material, linear and non linear media.	
Module-3	Credits: 1	10 L , 5 T
	Electrodynamics: Electromotive force, Electromagnetic induction, Maxwell’s equations, Continuity equation and Poynting theorem, Wave equations for electric and magnetic fields. Vector and scalar potentials, Gauge Transformations : Coulomb Gauge and Lorentz Gauge ,	
Module-4	Credits: 1	10 L , 5 T
	Wave equations: plane waves, Momentum and energy densities associated with electromagnetic wave, Linear, Circular and Elliptic polarizations, Stokes parameters.	

Learning Outcomes: Upon completion of the course, the student will ,
1. have understood the fundamental concepts of electromagnetic theory .
2. have acquired regiourous background to tackle boundary value problems the problems.
3. have thorough knowladge of magnetostatics.
4. be prepared to undertake advanced topics in electrodynamics.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Classical Electrodynamics, J. D. Jackson (John Wiley).
2. Introduction to electrodynamics, D. J. Griffiths (Prentice Hall).
3. Classical theory of fields, L. D. Landau and E. M. Lifshitz Vol-2 (Elsevier).
4. Electrodynamics of continuous media, L. D. Landau and E. M. Lifshitz, Vol-8 (Elsevier)
5. Electrodynamics, A. Somerfield (Academic Press, Freeman and Co.).
6. Classical Electricity and Magnetism, W.K.H. Panofsky and M. Phillips (Addison-Wesley).
7. Feynman Lectures Vol. II. R. P. Feynman, Leighton and Sands (Narosa).
8. Berkeley Series Volume II, E.M.Purcell (McGraw-Hill).
9. Electricity and Magnetism, Reitz, Milford and Christy (Pearson).
10. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa).

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Core
Course Code: PHY 553 MJ	Course Title: Quantum Mechanics-II
Credit: 04	

Course Objectives: Main objective of this course is to introduce to students approximation methods in Quantum mechanics and application of it to atomic spectra and scattering processes.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Addition of angular momenta, Clebsch-Gordan coefficients, Wigner-Eckart theorem (statement). Identical particles: Spin and Statistics. Symmetric and antisymmetric wave functions, Slater determinants and Permanents. Approximation methods: Time-independent perturbation theory. Non-degenerate and degenerate cases.	
Module-2	Credits: 2	20 L , 10 T
	Fine Structure of the Hydrogen atom. Applications such as the Stark effect, Zeeman effect. Variational method and applications such as the Helium Atom. Time-dependent perturbation theory: Interaction picture, Dyson series, Transition probability, Constant perturbation, Fermi's golden rule, Harmonic perturbation, transition probability and interpretation as absorption and emission. Interaction of classical radiation field with matter: Absorption and induced emission, Electric dipole transitions, Selection rules, Decays and lifetime, Transition probability for spontaneous emission. Adiabatic and sudden approximations.	
Module-3	Credits: 1	10 L , 5 T
	Scattering theory: Scattering amplitude, differential scattering cross section and total scattering cross section, the Lippman-Schwinger equation, the Born approximation, Applications and validity of the Born approximation, Optical theorem. Method of partial waves: Partial wave expansion, Unitarity and Phase shifts; Scattering by a perfectly rigid sphere and square well potential.	

Learning Outcomes: Upon completion of the course, the student will

1. understand the formal theory of angular momentum
2. understand the time independent and dependent perturbation theory.
3. understand the quantum mechanical scattering processes
4. be prepared to undertake advanced quantum mechanics/quantum field theory courses

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Mechanics, Cohen-Tannaudji, Din, Laloe Vols. I & II (John Wiley).
2. Modern Quantum Mechanics, J. J. Sakurai (Addison Wesley).
3. Quantum Mechanics, D. J. Griffiths (Pearson Education).
4. Quantum Mechanics, L. I. Schiff (McGraw-Hill).
5. Principles of Quantum Mechanics, R. Shankar, Springer
6. Quantum Physics, S. Gasiorowicz (Wiley International).
7. Quantum Mechanics(Non-Relativistic Theory), L.D. Landau and E.M. Lifshitz (Elsevier).
8. Quantum Mechanics: Fundamentals, K. Gottfried and T-Mow Yan (Springer).
9. Introduction to Quantum Mechanics, L. Pauling and E. B. Wilson (McGraw Hill).
10. Quantum Mechanics, B. Crasemann and J.D. Powel (Addison-Wesley).
11. Quantum Mechanics -Vol. I & II, A.P Messiah (Dover).

12. The Principles of Quantum Mechanics, P. A. M. Dirac (Clarendon Press, Oxford).
13. Quantum Chemistry, I. Levine (Allyn and Bacon).
14. A Modern Approach to Quantum Mechanics, J. Townsend (University Science Books).
15. Essential Quantum Mechanics, G.E. Bowman (Oxford University Press).
16. Quantum Physics, M. Le Bellac (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Core
Course Code: PHY 554 MJP	Course Title: Basic Physics Laboratory
Credit: 04	

Course Objectives:

1. To get trained to perform experiments in Physics.
2. To introduce important experimental techniques.
3. To Collect data and revise an experimental procedure iteratively
4. To develop experimental skills.

Course Contents

	List of experiments	
	The proposed list of the experiments for Basic Physics Laboratory I (Any 12 experiments) 1. Characteristics of operational amplifier 2. UJT and FET characteristics 3. Magnetic Susceptibility 4. Temperature transducer (T to F converter) 5. Thermionic emission 6. Mass Absorption 7. Counting Statistics 8. Zeeman Effect 9. Fabry Perot Interferometer 10. Michelson interferometer 11. Absorption spectra of I_2 molecule 12. Determination of Seebeck coefficient and understanding of Thermocouple working. 13. Recording and analysis of B-H curve 14. Millikan Oil drop method 15. Determination of e/m ratio 16. Franck-Hertz experiment	

Learning Outcomes: Upon completion of the course, the student would

1. learn to formulate hypotheses and devise and perform experiments to test a hypothesis. as individuals and in a team.
2. have gained training in conducting experiments in Physics
3. learn to apply scientific methodologies for problem solving.
4. have learned important techniques in Experimental Physics
5. have developed skills in designing and conducting experiments in Physics

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:
1) Assesment of experimental skills and outcomes
2) Viva-Voce

REFERENCES:

1. Atomic Spectra and Atomic Structure by G. Herzberg, New York Dover Publication.
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, Tata, McGraw-Hill Publishing Company Limited.
3. Electronics Principles, A. P. Malvino, Tata McGraw Hill, New Delhi.
4. Fundamentals of Statistical and Thermal Physics, F. Reif (International Student Ed.) McGraw Hill..
5. Introduction to electrodynamics, D. J. Griffiths, Prentice Hall.
6. Solid State Physics, A. J. Dekkar, Prentice Hall.

7. Fundamentals of Optics, Jenkins and White, McGraw-Hill, International Edition.
8. Physics Lab. Experiments, Jerry D. Wilson, D. C. Heath and Company.
9. Elementary Solid State Physics, M. Ali Omar, (Addision-Wesely).
10. Foundations of Experimental Physics, Shailaja Mahamuni, Deepti Sidhaye, Sulabha Kulkarni, CRC Press.
11. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy. (Wiley Eastern Limited, New Delhi) .

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Core
Course Code: PHY 555 MJP	Course Title: Computer Programming and Numerical Methods
Credit: 04	

Course Objectives:

1. To train the students to gain knowledge on numerical analysis and understand the basics of FORTRAN 90/95 programming language.
2. To introduce important numerical and programming techniques.
3. To develop numerical and algorithmic skills using FORTRAN 90/95 programming language.

Course Contents

	A. Basic Linux commands, text editors and gnuplot (in Lab); FORTAN Commands and Computer basics. B. Exercises for acquaintance (only some experiments are listed here): (Using FORTRAN 90/95): 1. To find the largest or smallest among a set of numbers. 2. To arrange a given set of numbers in ascending/descending order using Bubble sort algorithm. 3. To generate and print first hundred prime numbers. 4. Matrix addition and multiplication using subroutine. 5. Transpose of a square matrix using only one array. 6. Evaluate a polynomial using Horner's method. C. Numerical Methods: 1. Root finding methods (i) Bisection Method (ii) Newton-Raphson Method (iii) Secant method and applications. 2. Regression models: (i) Linear fit, (ii) Spline fit and applications. (a) Fit a given data set as well as find the standard deviation or error. 3. Lagrange Interpolation and Divided difference interpolation and its uses. 5. Numerical differentiation using forward, backward and mean difference method 6. Numerical Integration : (i) Simpson's rule, (ii) Gaussian Quadrature and applications. 7. Numerical solution of a first order differential equation. (Euler's methods) and applications. 8. Solution of simultaneous equations : (i) Gaussian Elimination method and applications. (Note: The course is expected to comprise 20 exercises).	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in numerical analysis and write their own FORTRAN programs.
2. have learned important techniques in numerical and programming techniques
3. have developed numerical and algorithmic skills
4. have developed enough skills to implement knowledge in quickly learning other programming languages.

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies

1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

1. Programming in Fortran 90/95 V. Rajaraman (Prentice-Hall of India).
2. A first course in Computational Physics, 2nd Ed., P. L. DeVries & J. E. Hasbun

(Jones & Bartlett)
3. Computer Oriented Numerical Methods, V. Rajaraman (Prentice Hall of India).
4. Numerical Methods for Scientist and Engineers, H. M. Antia (Tata McGraw Hill).
5. Numerical Methods with Fortran IV case studies, Dorn & McCracken (John Wiley & Sons).
6. Numerical Recipes in FORTRAN (2nd Edn.), W. H. Press, S. A. Teakalsky, W. T. Vellerling, B. P.Flannery (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Elective
Course Code: PHY 560 MJ	Course Title: Essentials of Statistical Physics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of thermodynamics and statistical physics
2. To introduce important techniques that are necessary to build core concepts in statistical physics

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Elementary probability theory: Preliminary concepts, Random walk problem, Binomial distribution, mean values, standard deviation, various moments, Gaussian distribution, Poisson distribution, mean values. Probability density, probability for continuous variables The laws of thermodynamics and their consequences. A brief revision of the laws of thermodynamics. Thermodynamical work for magnetic, dielectric, elastic systems. Legendre transformation, Thermodynamic potentials. Statistical basis of thermodynamics.	
Module-2	Credits: 1	10 L , 5 T
	Elements of ensemble theory. Microcanonical ensemble (MCE). Macroscopic and microscopic states. Classical phase space, Statistical distribution function, Liouville's theorem, Statistical origin of entropy. Central postulates of Statistical Mechanics. Derivation of the laws of thermodynamics from the central postulates. Application to the ideal gas. Quantum states and the phase space. MCE applications: (a) Two level system, (b) Ideal gas. Gibbs paradox and Gibbs correction term.	

Learning Outcomes: Upon completion of the course, the student will

1. understand the application of probability to statistical physics
2. understand the thermodynamic potentials.
3. understand the Microcanonical

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1.Statistical Mechanics, Pathria and Beale (Academic Press).
2.Statistical Mechanics, Huang (Wiley).
3.Statistical Physics of Particles, Kardar (Cambridge University Press).
4.Statistical and Thermal Physics, Gould & Tobochnik (Princeton University Press).
5.An Introduction to Statistical Mechanics and Thermodynamics, Swendsen (Oxford
6.University Press).
7.Thermodynamics and Statistical Mechanics, Greiner, Neise, Stocker, Springer, 2010.
8.Statistical Mechanics, Reif
9. Statistical Physics (Part 1), L.D. Landau and E. M. Lifhsitz (Elsevier)

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Elective
Course Code: PHY 561 MJ	Course Title: Atomic and Molecular Physics
Credit: 02	

Course Objectives:

1. This course is an introduction to atomic and molecular physics in order to understand the atomic structure and atomic spectra as well as molecular structure and molecular spectra.
2. This course of lectures is designed to develop the skills to solve real physical problems using atomic and molecular physics.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Quantum Mechanical model of atom. One electron atoms. Wavefunctions, radial and angular parts. Radial and angular probability densities. Polar plots. Orbital magnetic dipole moments. Stern-Gerlach experiment and electron spin. Spin-orbit interaction and total angular momentum. Hydrogen atom and atomic spectrum – fine structure and hyperfine structure. Zeeman effect. Transition rates and selection rules. Multi-electron atoms. Central field approximation. Hartree-Fock method and self-consistent field (Only results). The ground states of multi-electron atoms. Angular momentum, L-S coupling and J-J coupling, atomic term symbols. Transition rates and selection rules, optical excitations, Zeeman effect, Paschen-Back effect, X-ray line spectra, Molecular structure. Born-Oppenheimer approximation. Valence bond and molecular orbital theories. Molecular orbitals of polyatomic molecules.	

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

1. Explain the atomic spectra of one and two valance electron atoms.
2. To calculate the spectroscopic ground state term symbols for single and multi-electron system.
3. Understand the importance of Pauli's exclusion principle and spectroscopic transition selection rules.
4. Explain the change in behaviour of atoms in external applied electric and magnetic field.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies: Descriptive written examinations, Assignments

REFERENCES:

1. Quantum Physics, Robert Eisberg and Robert Resnick, (John Wiley and Sons).
2. Introduction to Quantum Mechanics – Griffiths (Pearson).
3. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGrawHill Publishing Company Limited)
4. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
5. Perspectives of Modern Physics, Arthur Beiser, (McGraw Hill International Ed.)
6. Physics of Atoms and Molecules, B.H. Bransden and C.J. Joachain (Pearson).
7. The Physics of Atoms and Quanta Introduction to Experiments and Theory Authors: Haken, Hermann, Wolf, Hans Christoph
8. Molecular Spectra and Molecular Structure, Gerhard Herzberg, (D. Van Nostrand Company, Inc.)
9. Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).
10. Molecular Quantum Mechanics, P.W. Atkins and R. Freidman (Oxford University Press)
11. Quantum Chemistry, I. N. Levine (Wiley).
12. Atoms, Molecules and photons by Wolfgang Demtröder, Springer -2005.
13. Physical Chemistry – Atkins and Paula (Freeman).

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Elective
Course Code: PHY 562 MJ	Course Title: Thermal Physics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of thermodynamics
2. To introduce important techniques that are necessary to build core concepts in statistical physics

Course Contents

Module-1	Credits: 1	10 L , 5 T
	A brief revision of the laws of thermodynamics. Thermodynamical work for magnetic, dielectric, elastic systems. Legendre transformation, Thermodynamic potentials. Statistical basis of thermodynamics. Elements of ensemble theory. Microcanonical ensemble. Macroscopic and microscopic states. Classical phase space, Statistical distribution function, Liouville's theorem, Statistical origin of entropy. Application to the ideal gas. Gibbs paradox and Gibbs correction term. Quantum states and the phase space.	
Module-2	Credits: 1	10 L , 5 T
	Canonical ensemble, Partition function and thermodynamic variables, Energy fluctuations. Boltzmann distribution. Applications to the thermodynamics of an ideal gas, Specific heat of solids (classical and Einstein models), and Paramagnetism (Langevin and Brillouin models). Equipartition and virial theorem. Thermodynamics of interacting systems – Van der Waals gas and 1D Ising model.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understand the fundamental concepts of elementary statistical mechanics subject.
2. be prepared to undertake major statistical mechanics course.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Mechanics, Pathria and Beale (Academic Press).
2. Statistical Mechanics, Huang (Wiley).
3. Statistical Physics of Particles, Kardar (Cambridge University Press).
4. Statistical and Thermal Physics, Gould & Tobochnik (Princeton University Press).
5. An Introduction to Statistical Mechanics and Thermodynamics, Swendsen (Oxford
6. University Press).
7. Thermodynamics and Statistical Mechanics, Greiner, Neise, Stocker, Springer, 2010.
8. Statistical Mechanics, Reif
9. Statistical Physics (Part 1), L.D. Landau and E. M. Lifhsitz (Elsevier)

Course Information	
Year and Semester: M.Sc-I, Semester-II	Major Elective
Course Code: PHY 563 MJ	Course Title: Basics of Atoms and Molecules
Credit: 02	

Course Objectives: This course of lectures is designed to develop the skills to solve real physical problems using atomic and molecular physics with the help of quantum mechanics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Revision (Pre-requisites) : Review of models of atom, Quantum mechanics of hydrogen atom, Features of one electron atoms, Magnetic dipole moment, Electron spin and vector atom model, Spin-orbit interaction: Hydrogen fine structure, Identical particles: Pauli's exclusion principle, Multi-electron Atoms: Hartree's field: Atomic ground state and periodic table, Spectroscopic terms: L-S and J-J couplings, Zeeman and Paschen-Back effect, X-ray spectra.	
Module-2	Credits: 1	10 L , 5 T
	Bonds in molecules, ionic bonding, Co-valent bonding valance bond theory, Linear combination of atomic orbitals, covalent bond and valency, limitations of valence bond theory. Molecular orbital approach, Qualitative treatment of H_2^+ and H_2 molecule and discussion of other diatomic molecules. Molecular bonding, Term symbol of the molecular system, electronic configuration of diatomic molecules.	

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

1. Explain the atomic spectra of one and two valance electron atoms.
2. To calculate the spectroscopic ground state term symbols for single and multi-electron system.
3. Understand the importance of Pauli's exclusion principle and spectroscopic transition selection rules.
4. Explain the change in behaviour of atoms in external applied electric and magnetic field.

Explain rotational, vibrational, electronic spectra of molecules.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Physics, Robert Eisberg and Robert Resnick, (John Wiley and Sons).
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGrawHill Publishing Company Limited)
3. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
4. Perspectives of Modern Physics, Arthur Beiser, (McGraw Hill International Ed.)
5. Physics of Atoms and Molecules, B.H. Bransden and C.J. Joachain (Pearson).
6. Molecular Spectra and Molecular Structure, Gerhard Herzberg, (D. Van Nostrand Company, Inc.)
7. Quantum Chemistry, I. N. Levine (Wiley).
8. *Atoms, Molecules and photons by Wolfgang Demtröder, Springer -2005*
9. F. A. Cotton, Chemical application of group theory, Wiley Eastern, 1971
10. M. Mwissbluth, Atoms and Molecules, Academic Press, 1978.

Course Information	
Year and Semester: M.Sc-I, Semester-II	
Course Code: PHY 550 OJT	Course Title: On-Job Training
Credit: 04	

M.Sc-II (Semester-III)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 601 MJP	Course Title: Advanced Physics Laboratory- I
Credit: 02	

Course Objectives:

1. To get trained to perform experiments in Physics.
2. To introduce important experimental techniques.
3. To Collect data and revise an experimental procedure iteratively
4. To develop experimental skills.

Course Contents

	List of experiments	
	Any five experiments from the following List will be offered: 1. Study of Compton scattering. 2. Study of Rutherford scattering. 3. To investigate the characteristics of radiation emitted by bodies at elevated temperatures (Black Body Radiation) and determine the various constants. 4. Determination of lattice constant of given powder sample using X-ray Diffraction method. 5. Effect of Filter on X-ray Diffraction Pattern. 6. Gamma Ray Spectrometry: Understanding the three interactions of γ-rays with matter and determination of resolution of γ-ray spectrometer. 7. Determination of skin depth of aluminium and iron through the measurement of amplitude and phase changes of transmitted low frequency electromagnetic waves. 8. Investigation of propagation of electromagnetic wave through a transmission line and determination of propagation constant under boundary conditions. 9. Investigation of Electron Spin Resonance spectrum for the given DPPH sample and determination of Lande's "g" factor. 10. Investigation of thermoluminescence of X-ray irradiated KCl/KBr single crystal sample and determination of activation energy of thermoluminescence. 11. Determination of band gap of semiconductor from temperature dependence of resistivity using Four Probe Method. 12. Study of Hall Voltage as a function of probe current and magnetic field and determination of Hall Coefficient and carrier concentration in given sample.	

Learning Outcomes: Upon completion of the course, the student would

1. learn to formulate hypotheses and devise and perform experiments to test a hypothesis. as individuals and in a team.
2. have gained training in conducting experiments in Physics
3. learn to apply scientific methodologies for problem solving.
4. have learned important techniques in Experimental Physics
5. have developed skills in designing and conducting experiments in Physics

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

REFERENCES:

1. The Art of Experimental Physics, D. W. Freston, E. R. Dietz, 1991 (John Wiley).
2. Advanced Practical Physics for Students, Worsnop and Flint. (Asia Publishing House).
3. Modern Physics, Arthur Beiser (McGraw-Hill Inc).

Course Information	
Year and Semester : M.Sc-II, Semester-III	Major Core
Course Code: PHY 602 MJ	Course Title: Solid State Physics
Credit: 04	

Course Objectives:

The course deals with introducing the concepts of solid-state physics course to a 2nd-year course in M.Sc in Physics student to employ classical and quantum mechanical theories needed to understand the physical properties of solids. This course is designed to understand the basics of crystallography, the representation of crystal structure, symmetries in solid, X-ray diffraction, Direct and reciprocal space, Brillouin zones, structure determination by diffraction. The course also highlights about lattice vibrations, phonons, heat capacity. To understand the concept of Free electron gas, Fermi-Dirac distribution, electrons in periodic solids, nearly-free-electron model, and energy bands. The course will end by considering the magnetic and dielectric properties of solids with the outline of superconductivity.

Course Contents

Module-1	Crystal Structure and lattice vibrations (Credit:1)	10L, 5T
	Revision of crystal structures : Real lattices, packing fraction, reciprocal lattices, Brillouin zones, Diffraction by crystals - Ewald sphere construction, Geometric structure factor and atomic form factor, concept of electron and neutron scattering. Lattice Dynamics: Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states.	
Module-2	Free Electron and Band Theory of Solids (Credit:1)	10L, 5T
	Free electron theory : Free electrons, density of states, Fermi momentum, Fermi energy and Fermi temperature, Thermal properties of free electron gas, Fermi-Dirac distribution, calculation of electronic contribution to specific heat of metal. Electronic Band Structure in Crystals: Nearly free electron theory. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Tight binding approximation. Band structure (in k-space) of semiconductors crystals – high symmetry points in k-space. Electrons and holes. Effective mass. Hall effect.	
Module-3	Dielectric Properties of Solids (Credit:1)	10L, 5T
	Dielectric Properties of Solids: Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity	
Module-4	Magnetism and Superconductivity (Credit:1)	10L, 5T
	Magnetism in Solids: Diamagnetism – Langevin equation. Pauli paramagnetism in metals. Paramagnetism – Brillouin theory. Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Weiss mean field theory of ferromagnetism. Anti-ferromagnetic and ferromagnetic order. Superconductivity: Zero resistivity and perfect diamagnetism (Meissner effect). Type-I and Type-II superconductors. London equation. Basic thermodynamics. Energy gap. Josephson junctions.	

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

1. Understand crystal structure and direction dependence properties of solids.
2. Explain how diffraction of electromagnetic waves on solid matter can be used to obtain lattice structure.
3. Explain how a lattice vibrates at finite temperature, and how these vibrations determine the heat capacity and conduction.
4. Understand the origin of free electron and concept of band theory of solids.
5. Know the concept of density of states in one, two and three dimensions.
6. Explain simple theories for conduction of heat and electrical current in metals.
7. Classify solid state matter according to their band gaps.
8. Know the basic physics behind dia, para and ferromagnetism.
9. Understand the phenomenon of superconductivity.
10. Know about capacitor behaviour of ferroelectric and piezoelectric ceramics.

Instructional design: 1) Lecture method
2) Tutorial method
3) Seminar/s on renewable energy project case studies

Evaluation Strategies 1) Descriptive written examinations
2) Assignments
3) Seminars, Orals, and Viva

REFERENCES:

1. Solid State Physics, N. W. Ashcroft and N. D. Mermin, (CBS Publishing Asia Ltd.)
2. Introduction to Solid State Physics, C. Kittel, (John Wiley and Sons.)
3. Introductory Solid State Physics, H. P. Myers, (Viva Books Pvt. Ltd.)
4. Solid State Physics, H. Ibach and H. Luth, (Springer-Verlag).
5. Fundamentals of Solid State Physics, J. R. Christman, (John Wiley and Sons.)
6. Solid State Physics, A. J. Dekkar, (Prentice Hall).
7. Solid State Physics, J. J. Quinn and K-Soo Yi (Springer).
8. The Oxford Solid State Basics, Steven H. Simon (Oxford University Press)
9. Solid State Physics, M. A. Wahab (Narosa)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 603 MJ	Course Title: Electrodynamics-II
Credit: 02	

Course Objectives: This course mainly discusses plane waves, propagation of plane waves in vacuum and in matter, wave guides, potetials and dipole radiation.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Reflection and refraction of Electromagnetic waves (normal and oblique incidence), total internal reflection, Propagation of waves in dielectrics, Propagation in conducting medium, Skin depth. Wave guides: TE and TM modes, Modes in a rectangular wave guide.	
Module-2	Credits: 1	10 L , 5 T
	Potentials and fields: Retarded potentials, Lienard-Wiechert potentials of a point charge, Electric and Magnetic dipole radiation, Radiation from an accelerated point charge, Larmor formula, Bremsstarhlung, Synchrotron radiation.	

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

1. understand the theory of reflection and refraction of plane waves and propagation of EM waves in the medium.
2. Understand dipole radiation and radiation from accelerated charge
3. have acquired the problem solving skills to tackle real life problems
4. be prepared to undertake advanced topics in classical field theory.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Classical Electrodynamics, J. D. Jackson (John Wiley).
2. Introduction to electrodynamics, D. J. Griffiths (Prentice Hall).
3. Classical theory of fields, L. D. Landau and E. M. Lifshitz Vol-2 (Elsevier).
4. Electrodynamics of continuous media, L. D. Landau and E. M. Lifshitz, Vol-8 (Elsevier)
5. Electrodynamics, A. Somerfield (Academic Press, Freeman and Co.).
6. Classical Electricity and Magnetism, W.K.H. Panofsky and M. Phillips (Addison-Wesley).
7. Feynman Lectures Vol. II. R. P. Feynman, Leighton and Sands (Narosa).
8. Berkeley Series Volume II, E.M.Purcell (McGraw-Hill).
9. Electricity and Magnetism, Reitz, Milford and Christy (Pearson).
10. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 604 MJ	Course Title: Accelerator Physics-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of particle accelerators and their classification.
2. To introduce important techniques that are necessary to build core concepts in phase stability, emittance for charged particle beams and beam dynamics
3. To develop problem-solving skills with appropriate regior that helps the student to improve their analytical ability in designing and understanding various types of accelerators.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Introduction and classification of particle accelerators. Sector magnets, lines of force and magnetic field index. Edge focusing effects on charged particles in a dipole magnet. Motion of charged particles in electric and magnetic fields. Axial and radial stability of orbits of charged particles in magnetic field, qualitative and quantitative treatment of weak focussing ,transverse and longitudinal oscillations.	
Module-2	Credits: 1	10 L , 5 T
	Phase stability: Principle of phase stability, momentum compaction, analogy of biased pendulum, phase diagram, synchrotron oscillations	
Module-3	Credits: 1	10 L , 5 T
	Emittance and admittance for charged particle beams, matching, measurement of emittance of electron and ion beams.Matrix method of studying orbit stability, Working principle of quadrupole lenses. Low energy d.c. accelerators. Electric lines of force in accelerating column.	
Module-4	Credits: 1	10 L , 5 T
	Basic principle and design details of the following types of accelerators ;Electrostatic, Two stage tandem, cyclotron, Conventional and Race-Track Microtron. High energy ion accelerator-pelletron. Electron synchrotron, synchrotron radiation sources, spectrum of the emitted radiation and their applications.	

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

1) have understood the fundamental concepts of particle accelerators and their operation. Students will also grasp the fundamental principles behind various types of accelerators such as cyclotrons, synchrotrons, and electron synchrotrons.
2) have acquired the problem-solving skills essential to analyze and design particle accelerator systems, Through practical applications and theoretical exercises, students will develop proficiency in solving problems related to accelerator physics.
3) be prepared to undertake advanced topics in accelerator physics and engineering paving the way for further exploration of cutting-edge technologies, novel accelerator designs, and research opportunities This foundation will empower students to contribute to the advancement of particle accelerator science and its applications in various fields.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physics of cyclic accelerators, J. J. Livingood (D. Van Nostrand Co.)
2. Particle Accelerators, J. P. Blewett, (McGraw-Hill Book Co.)

3. Transport of Charged Particle Beams, A. P. Banford (SPON, London).
4. The Microtron, S. P. Kapitza, V. N. Melekhin, (Harwood Academic Publishers).
5. Recirculating, electron accelerators, Roy. E. Rand (Harwood Academic Publishers).
6. Particle accelerators and their uses, W. Scharf (Harwood Academic Publishers).
7. Theory of resonance linear accelerators, I. M. Kapchinsky (Harwood Academic Publishers).
8. Linear Accelerators, P. Lapostole and A. Septier (North Holland)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 604 MJP	Course Title: Accelerator Physics Lab-I
Credit: 02	

Course Objectives:

The aim of the lab course is to provide in hands on experience on various components of accelerators their usefulness, and application.

Course Contents

Module-1	Credits: 2	
	1. Study of characteristics of microwave components (ferrite isolates, directional coupler, magic-T, 90 bent and twist). 2. Measurement of the quality factor Q of a microwave resonator. 3. Electrolytic tank method for plotting equipotentials of an electron gun. 4. Measurement of field index of a double focusing magnet. 5. Cockroft-Walton generator.	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. In depth-understanding different condonements of accelerators, how they ar,e characterised and used.
2. Physics principle about each component through practical experience and measurements.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 605 MJ	Course Title: Advanced Quantum Mechanics-I
Credit: 04	

Course Objectives: In this course students will get introduced to relativistic quantum mechanics, quantization of electromagnetic field and introductory topics in quantum field theory.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Special theory of relativity, Lorentz transformations in covariant notation, Lorentz and Poincare group, Relation between Lorentz group and SL(2,C) group, Poincare group Generators, algebra, Representations of the Lorentz algebra: Scalar, Vector and Spinor representations, Weyl and Dirac spinors, Bilinear covariants. Relativistic wave equations: Klein-Gordon and Dirac equation, Lorentz covariance of Dirac equation, Free particle solutions, Conserved norm, Positive and Negative energy solutions, Covariant normalization and completeness, Spin and helicity, Energy and spin projection operators, Construction of wave packets of positive and negative energy free particle solutions, Gordon decomposition of the vector current, Zitterbewegung and Klein paradox, Bilinear covariants and physical observables, relativistic Hydrogen atom.	
Module-2	Credits: 2	20 L , 10 T
	Classical radiation field, reduction of radiation in a box to an assembly of decoupled simple harmonic oscillators, second quantization, quantization of the electromagnetic field in Coulomb gauge, fluctuations in the quantum fields, time dependent perturbation theory, emission (spontaneous and stimulated) and absorption of radiation (dipole approximation) selection rules, Thomson Scattering, Rayleigh scattering and the Raman effect, Plank's Radiation law. Classical Relativisitic fields: Lagrangian and Action principle, Scalar, Dirac, Weyl fields and vector fields. Symmetries and conservation laws: Noether's theorem, Spacetime and internal symmetries.	

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

1. undertsand relativistic wave equations such as Klein-Gordon, Dirac
2. undertsand the origin of electron spin and its relation to poincare group
3. understand the how special relativity can be consistently incorporated into the framework of quantum mechanics.
4. undertake first course on quantum field theory.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Relativistic Quantum Mechanics, J. Bjorken and S. Drell (McGrew-Hill).
2. Quantum Field Theory, F. Mandl and G. Shaw (J. Wiley & Sons).
3. Advanced Quantum mechanics, J. J. Sakurai (Addison-Wesley).
4. Relativistic Quantum Field Theory, J. Bjorken and S. Drell (McGraw-Hill).
5. An Introduction to Relativistic Quantum Field Theory, S. S. Schweber (Row, Peterson).
6. Quantum Electrodynamics, R. P. Feynman (Benjamin Cummings).
7. Quantum Field Theory, L. Ryder (Academic).
8. Quantum Field Theory, C. Itzykon and J. B. Zuber (McGraw-Hill).
9. The Quantum Theory of Fields, S. Weinberg, Vol. I (Cambridge).
10. An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder (Addison Wesley).
11. Quantum Electrodynamics Ed. J. Schwinger (McGraw-Hill).
12. A Modern Introduction to Quantum Field Theory, M. Maggiore (Oxford University Press).
13. Group theory in Physics, Wu Ki Tung (World Scientific)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 605 MJP	Course Title: Advanced Quantum Mechanics Laboratory-I
Credit: 02	

	List of Experiments	
	1. Reading assignments/problems on introductory group theory 2. Reading assignments/ problems on SO(3) and SU(2) group and its representations 3. Reading assignments/ problems on Lorentz group and its representations 4. Reading assignments/ problems on solutions of Dirac equation in various potentials 5. Any other reading assignments/problems based on PHY-C312	

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 606 MJ	Course Title: Astronomy and Astrophysics-I
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Overview of the universe: interesting astronomy objects: (from planets to large scale structure); length, mass and timescales; physical conditions in different objects; evolution of structures in the universe, redshift. Radiation in different bands; Astronomical Jargon; Astronomical measurements in different bands; Current sensitivities and resolution available. Gravity: Newtonian gravity and basic potential theory; simple orbits kepler's laws and precession, flat rotation curve of galaxies and implications for dark matter; virial theorem and simple applications; role of gravity in different astrophysical systems.	
Module-2	Credits: 1	10 L , 5 T
	Radiative processes: Overview of radiation theory and Larmor formula; Different radiative processes: Thomson and Compton scattering, Bremsstrahlung, Synchrotron [detailed derivations are not expected] radiative equilibrium, Planck spectrum and properties; Line widths and transition rates in QT of radiation; Qualitative description of which radiative processes contribute in which waveband/astrophysical system; Distribution function for photons and its moments; Elementary notion of radiation transport through a slab; Concept of opacities.	
Module-3	Credits: 1	10 L , 5 T
	Gas dynamics: Equations of fluid dynamics; equation of state in different regimes [including degenerate systems]; models for different systems in equilibrium; application to white dwarfs/neutron stars; simple fluid flows including supersonic flow; example of sn explosions and its different phases.	
Module-4	Credits: 1	10 L , 5 T
	Stellar physics: Basic equations of stellar structure; stellar energy sources; qualitative description of numerical solutions for stars of different mass; homologous stellar models; stellar evolution; evolution in the hr-diagram. Galactic physics: Milky Way Galaxy; Spiral and Elliptical galaxies; Galaxies as self gravitating systems; Spiral structure; Supermassive black holes; Active galactic nuclei.	

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Modern Astrophysics, B. W. Carroll and D. A. Ostlie, (Addison -Weseley).
2.The Physical Universe, F. Shu, (University Science Books).
3. The Physics of Astrophysics, Volume I and II, F. Shu, (University Science Books).
4. Theoretical Astrophysics Volumes I, II and III, T. Padmanabhan, (Cambridge Uni. Press).
5. The Physics of Fluids and Plasmas, Arnab Rai Choudhuri, (Cambridge University Press).
6. Astrophysical Concepts, M. Harwitt, (Springer-Verlag).
7. Galactic Astronomy, J. Binney and M. Merrifeld, (Princeton University Press).
8. Galactic Dynamics, J. Binney and S. Tremaine, (Princeton University Press).
9. Quasars and Active Galactic Nuclei, A. K. Kembhavi and J. V. Narlikar, (Cambridge University Press).
10. An Introduction to Active Galactic Nucleii, B. M. Peterson,
11. The Physical Universe : An Introduction to Astronomy. By Frank H. Shu, (University Science Books)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 606 MJP	Course Title: Astronomy and Astrophysics Laboratory-I
Credit: 02	

Course Contents

	List of Experiments	
	List of M.Sc. A & A Experiments : : 1. To estimate the temperature of an artificial star by photometry 2. To study the characteristics of a CCD camera 3. To study the solar limb darkening effect 4. To estimate the relative magnitudes of a group of stars by a CCD camera 5. To study the atmospheric extinction for different colours 6. Differential photometry of a programme star w. r. t. a standard star 7. To study the effective temperature of stars by B-V photometry 8. To estimate the night sky brightness with a photometer 9. Faraday Rotation effect in amorphous glass and crystalline media 10. Beam-pattern of various antenna 11. Muon Physics 12. 21-cm spin-flip line of neutral hydrogen 13. Beam pattern and pointing of a parabolic dish antenna [Out of these there will be 5+5 experiments selected per semester (will have at least 2 Radio and 2 Optical experiments)] Lectures associated with the experiments will be given on a number of topics including: Time and Coordinates; Telescopes; Atmospheric effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry	

REFERENCES:

1. Telescopes and Techniques, C.R.Kitchin, Springer.
2. Observational Astrophysics, R.C. Smith, Cambridge University Press.
3. Detection of Light: from the Ultraviolet to the Submillimetre, G. H. Rieke, Cambridge University Press.
4. Astronomical Observations, G. Walker, Cambridge University Press.
5. Astronomical Photometry, A.A. Henden & R.H. Kaitchuk, Willmann-Bell.
6. Electronic Imaging in Astronomy, I.S. McLean, Wiley-Praxis.
7. An introduction to radio astronomy, B. F. Burke & Francis Graham-Smith, Cambridge University Press
8. Radio Astronomy, John D. Kraus, Cygnus-Quasar Books.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 607 MJ	Course Title: Bioelectronics -I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts in the field of bio-signals. Biological signals are space, time, or space-time records of a biological event such as a beating heart or a contracting muscle. The electrical, chemical, and mechanical activity that occurs during this biological event often produces signals that can be measured and analysed using suitable instruments.
2. To introduce important techniques that are necessary to build core concepts in Bioelectronics with the amphesis on interface of the electronics with the various bio-signals.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in understanding and analyse the bio-signals.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Signals & classification, Biosignals & origin, volume conduction, Origin, Time & frequency domain, characteristics of biosignals such as ECG, EEG, EP, EMG, MEG Signal acquisition & processing basics.	
Module-2	Credits: 1	10 L , 5 T
	Electrode + electrode interface, polarization, Electrode behavior & circuit model, Electrode skin interface, Body surface electrodes, internal electrodes, Microelectrodes, electrode arrays, Displacements, resistive, capacitive, piezoelectric sensors, temperature measurement, fiber- optic sensors, radiation sensors for biomedical uses.	
Module-3	Credits: 1	10 L , 5 T
	Bioelectric amplifiers, Basic requirements, Differential amplifier, Instrumentation amplifier, Integrators, differentiators, active filters, ECG amplifier, right leg driven system, EEG multichannel amplifiers & filters, noise filtering & transient protection, Amplifiers for use with glass electrodes & intracellular electrodes.	
Module-4	Credits: 1	10 L , 5 T
	Stimulators: Constant current & constant voltage stimulator, internal external stimulators Pacemaker types & circuits, Photo-stimulator for vision, Acoustic stimulators for hearing, Wave shaping circuits &waveform generator, Defibrillator, Microschock & Macroschocks	

Learning Outcomes: Upon completion of the course, the student will be able to, measure and analyse electrical bio-signals.

1. have understood the fundamental concepts of bio-signals their origin and control using external stimulus.
2. have acquired the problem-solving skills essential to bio-signals analysis.
3. be prepared to undertake advanced topics in bio-signals subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Principles of Neural Science-Kandel & Schwartz (Elsevier, North Holland).
2. Op-Amps & linear Integrated Circuits-Gaikwad, (EEE Prentice Hall).
3. Biomedical Instrumentation, (EEE Prentice Hall).
4. Introduction to Biomedical Equipment Technology-Carr & Brown (John Wiley & Sons).
5. Design of Microcomputer based medical Inst, Webster & Tompkins (Prentice-Hall).
6. Encyclopedia of Biomed, Inst. Ed. Webster (Wiley).
7. Digital Principles and Applications, Malvino & Leach (Tata McGraw-Hill).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 607 MJP	Course Title: Bioelectronics Laboratory-I
Credit: 02	

Course Contents

	List of experiments	
	The proposed list of the experiments for Bio-Electronics Laboratory-I 1. ECG-Preamplifier-instrumentation amplifier design & testing 2. Active filters for biosignals-design & testing 3. Wave shaping circuits for cardiac pacemaker 4. Recording of action potentials with extra cellular electrodes 5. ECG signal recording with surface electrodes 6. Blood pressure measurement with transducer/pressure differentiation circuits 7. Acoustic impedance measurement 8. Piezo-resistive Strain gauge-and experiments of similar type	

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 608 MJ	Course Title: Biophysics -I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts in the field of biophysics.
2. To introduce important techniques that are necessary to build core concepts in Biophysics with the emphasis on cells and cell mechanics.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in understanding and analyse the biophysics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basics of Biophysics : A) General organization of cells, basic cellular components, cell wall structure and function, cell matrix, cytoskeleton, cell growth and division, cell-cell communication B) Chemical bonding, ionization energy, electron affinity, electron negativity, strong bonds & weak, bond energies with ref. to biomolecules, Interatomic potentials for strong and weak bonds	
Module-2	Credits: 1	10 L , 5 T
	Cellular mechanics & transport: Mechanical Forces, Physical forces, their magnitude at single molecule level e.g. bacterial motor, protein movement, filament growth, chromosomal forces Probability distributions: mean, variance, correlations, brief review of statistical thermodynamics Random walks, Brownian motion, Diffusion equation, friction, Langevin equations, Driven systems Applications to biological systems: molecular motors, polymers, diffusion inside a cell	
Module-3	Credits: 1	10 L , 5 T
	Molecular Biophysics: Amino acids, Protein structure & confirmations, polypeptide chains, potential energy, hydrogen bonding, hydrophobic interactions, disulfide bonds & ways of pairing Protein stability, chemical & surface denaturation, primary structure sequencing of polypeptide, α and β-helix, Ramchandran plot, protein folding & misfolding Types of DNA, properties of DNA & RNA, Nucleotide structure, Base pairing, Transcription & translation, Genetic code Structure & function of water, carbohydrates and Lipids	
Module-4	Credits: 1	10 L , 5 T
	Neurobiophysics: Neuron – structure and function, excitable membrane, Ion channels, Resting membrane potential, Depolarization, Hyper-polarization, Nernst equation, Goldman equation, Passive electrical prop. of neuron, action potential-generation & propogation, Nerve conduction, Cell equivalent circuits, Synaptic Integration & transmission, Voltage clamp technique & H-H equations, coding of sensory information	

Learning Outcomes: Upon completion of the course, the student will be able to, measure and analyse biophysics aspects.

1. have understood the fundamental concepts of biophysics.
2. have acquired the problem-solving skills essential to biophysics.
3. be prepared to undertake advanced topics in bio-physics.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Biology, a human approach, I. W. Sherman and V. G. Sherman (Oxford University Press).
2. Principles of neural science, E. R. Kandel & J. H. Schwatz (Elsevier, North Holland)
3. Neuron to Brain, S. W. Kuffler and J. G. Nichols (Sinacuer Asso. Inc.).
4. The structure and function of proteins, L. Dickerson & J. Geis (Harpes & Row).
5. Biological Physics, Nelson (W.H. Freeman and Company)
6. Biophysics An Introduction, Rodney Cotterill (Wiley)
7. Molecual & Cellualr Biophysics, Mayer & Jackson (Cambridge)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 608 MJP	Course Title: Biophysics Laboratory-I
Credit: 02	

Course Contents

	List of experiments	
	The proposed list of the experiments for Bio-Physics Laboratory-I 1. ECG recording on six leads R-R interval analysis 2. Audiometry 3. Estimation of seed viability by Tetrazonium test 4. Radiation dosimetry 5. Verification of Beer's & Lambert's Law 6. Electrophoresis for protein isolation	

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 609 MJ	Course Title: Chemical Physics-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Group Theory, operators,
2. To introduce important techniques that are necessary to build core concepts in Ligand Fields.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Chemical Physics I.

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Matrix representation of symmetry operations, Representation of a groups, 'Great Orthogonality' theorem, Irreducible representation, Character tables. Representation for Cyclic groups. Group theory and quantum mechanics: Wave functions as bases for irreducible representations, the direct product and its importance in Physics, identifying nonzero matrix elements, spectral transition probabilities. Symmetry Adapted Linear Combinations (SALC), Projection operators, using projection operator to construct SALC. Illustrative examples of SALCs.	
Module-2	Credits: 1	10 L, 5 T
	Molecular orbital (MO) theory and its applications, Hückel approximation, energy level diagrams, symmetry factoring of secular equation, some simple carbocyclic systems, Hybrid orbital and molecular orbitals for AB type molecules. Construct MOs for Naphthalene as an illustrative example.	
Module-3	Credits: 1	10 L , 5 T
	Introduction to ligand fields: The concept and the scope the p and d orbitals, qualitative demonstration of the Ligand field effect, the physical properties by Ligand fields, crystal fields and ligand fields. Quantitative basis of crystal fields: Crystal field theory: the octahedral and tetrahedral crystal field potential. Its effect on d wave functions, evaluation of 10 Dq Atomic Spectroscopy. The free ion, free ion TERMS, Term wave functions, spin orbit coupling. Thermodynamical aspects of ligand field: Crystal field stabilization energy, signatures in other physics properties.	
Module-4	Credits: 1	10 L , 5 T
	Ligand field theory: Splitting of levels and terms in a chemical environment p-octahedral, tetrahedral and others, construction of energy level diagrams, the method of descending symmetry, Tanabe-Sugano diagrams. Free ion in weak crystal fields: effects of cubic crystal field on S, P, D, F, G, H and I terms (to be partly covered in seminars). Thermodynamical aspects of ligand field: Crystal field stabilization energy, signatures in other physics properties.	

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

1. have understood the fundamental concepts of Chemical Physics I.
2. have acquired the problem solving skills essential to Chemical Physics I.
3. be prepared to undertake advanced topics in Chemical Physics II.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Elements of Group Theory for Physicists, A. W. Joshi (Wiley Eastern).
2. Chemical applications of Group Theory, F. A. Cotton (Wiley Eastern Ltd).
3. Introduction to Ligand Fields, B.N. Figgis (Wiley Eastern).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 609 MJP	Course Title: Chemical Physics Laboratory-I
Credit: 02	

Course Objectives:

1. To get trained to perform experiments in Chemical Physics.
2. To introduce important experimental techniques required in Chemical Physics.
3. To Collect data and revise an experimental procedure iteratively

Course Contents

	List of experiments	
	The proposed list of the experiments for Chemical Physics Laboratory I 1. To determine specific rotation of a given solution at different wavelengths (or different solution at a given wavelength). 2. To obtain the crystal field stabilization energy and the value of the crystal field parameter 10 Dq for the given transition metal complexes. 3. To obtain the heat of ligation of the given transition metal complex for the given ligands. 4. To obtain the lattice energy of NaCl by X-ray diffraction and by measuring the heat of dissolution (and using the Born-Haber Cycle). 5. To obtain the ligand field parameter 10 Dq for Cu2+ ions in water and in Ammonia.	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments in Chemical Physics
2. learn to apply scientific methodologies for problem solving.
3. have learned important techniques in Chemical Physics

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:

1) Assessment of experimental skills and outcomes
2) Viva-Voce

References:

1. Elements of Group Theory for Physicists, A. W. Joshi (Wiley Eastern).
2. Chemical applications of Group Theory, F. A. Cotton (Wiley Eastern Ltd).
3. Introduction to Ligand Fields, B.N. Figgis (Wiley Eastern).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 610 MJ	Course Title: Condensed Matter Physics-I
Credit: 04	

Course Objectives: Detailed study of phase transion and critical phenemena, critical exponents, scaling theory, relation betwen critical exponents, Landau theory of phase transition. Detailed theory of dia, para and ferromagnetism, spin wave will be discussed along with Weiss-molecular mean field theory of ferromagnetism.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Magnetism : Paramagnetism and diamagnetism, Larmor diamagnetism, Hund's rules, Pauli paramagnetism. Electrostatic origin of magnetic interaction, magnetic properties of a two-electron system, Heitler-London theory, connection with spin Hamiltonian - Antiferromagnetism. Ferromagnetism : Heisenberg Hamiltonian, Ground state, excited states, Weiss Molecular field theory (mean field), Magnetic resonance.	
Module-2	Credits: 2	20 L , 10 T
	Phase transitions and critical phenomena : phenomenology, critical exponents, Landau mean field theory, scaling hypothesis, relations between exponents, Ising model and transfer matrix method of solution. Bose-Einstein condensation.	

Learning Outcomes: A student of this course is expected to understand extensively the basic as well as the advanced theoretical treatments involved in phase transition and critical phenomena as well as magnetism.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Solid State Physics, N. W. Ashcroft and N. D. Mernin (Holt, Richard & Wilson).
2. Solid State Physics, C. Kittel (Wiley Eastern)
3. Theory of Magnetism, V. 1 and V. 2, D. C. Mattis (Springer).
4. Phase Transition and Critical Phenomena, E. P. Stanley (Oxford University Press, 1971).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 610 MJP	Course Title: Condensed Matter Physics Laboratory-I
Credit: 02	

Course Contents

	List of Experiments	
	Five numerical experiments based on Ising Model. The numerical method to be followed is either classical Monte Carlo method or Transfr Integral method. OR Five numerical experiments using Density Functional method to calculate the electronic structures of certain materials. OR Exercises /Mini projects based on the Condensed Matter – I course. Course Contents	

Course Information	
Year and Semester: MSc II Semester-III	Major Core
Course Code: PHY 611 MJ	Course title: Energy Studies-I
Credit: 04	

Course Objectives: This course aims to introduce the fundamentals of renewable energy sources and awareness about the use of renewable energy to the students. The primary objectives of the study are,

1. To impart knowledge of basic concepts of renewable energy sources and their applications
2. To introduce fundamental laws and principles in various energy conversion of Physics and their applications.
3. To develop research skills, including advanced laboratory techniques, numerical techniques, computer algebra, and interfacing among the students.

Course Contents

Module-1	Credit : 1	10L, 5T
	Global energy scenario, Energy scenario in India, Maharashtra energy scenario, Types of energy sources, Energy security, Future energy options, Primary energy resources, Importance of non-conventional energy sources, Advantages and disadvantages of conventional energy sources, Salient features of non-conventional energy sources Necessity of energy storage, Advantages, and limitations of energy storage, Types of energy storage, Mechanical energy storage, Chemical energy storage, Electromagnetic energy storage, Electrostatic energy storage, Thermal energy storage, Biological energy storage	
Module-2	Credit : 1	10L, 5T
	Applications of solar energy, Solar collectors, Liquid flat plate collectors (Construction, working, efficiency), Solar gadgets based on flat plate collectors (Domestic hot water systems, Industrial solar water heating systems, Power generation using flat plate collectors, Solar refrigeration, Solar heat assisted pump, Solar heating of swimming pool, Solar wax melter), Evacuated tube collectors, Types of evacuated tube collectors (Flat plate type evacuated tube collector, Concentric tube type evacuated tube collector, Flat plate type with heat pipe evacuated tube collector, Transparent insulation honeycomb collectors), Applications of Evacuated tube collectors, Solar air heater, Gadgets based on solar air heaters (Solar dryer, Solar kiln), Solar concentrators (Advantages and limitations of solar concentrator systems, Classification of solar concentrators), Central power receiver system, Solar cookers (Box type solar cooker, Paraboloidal type solar cooker, Heat transfer type solar cooker), Solar still, Solar pond, Solar furnace, Solar greenhouse, Typical winter and summer greenhouses, Solar passive heating and cooling	
Module-3	Credit : 1	10L, 5T
	Semiconductor fundamentals, Solar cell fundamentals, Sand-to-Silicon, Solar cell (Basic structure, Effect of light on a p-n junction, Working of the solar cell, Solar cell equivalent circuit, I-V characteristics of the solar cell, efficiency of the solar cell, Efficiency limits), Solar cell classification, Various types of solar cells (Amorphous silicon solar cells, Copper indium gallium selenide solar cell, Cadmium telluride solar cell, Gallium Arsenide solar cells, Cadmium Sulfide solar cell, Copper Zinc Tin Sulfide solar cell, Organic Photovoltaic Cells/Polymer Solar Cells, Dye-sensitised solar cells, Thermo·Photovoltaics (TPV), Hot carrier solar cells, Balance of system components, Solar PV systems, Solar PV applications	
Module-4	Credit : 1	10L, 5T
	Geothermal energy as a renewable source of energy, Origin of geothermal resources, Types of geothermal resources (Hydrothermal resources, Geopressured resources, Hot dry rock (HDR) resources and Magma resources) Geothermal exploration, Utilization of geothermal energy sources (Non-electric and electric) Hydro geothermal, Geopressured, Geothermal, and Petro geothermal resources, Basics of a geothermal electric power plant, Geothermal heat pump, Heating and cooling using a heat pump, Benefits of geothermal heat pumps, Global status of power generation from	

	geothermal resources, Identification of geothermal resources in India	

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

1. Understand renewable and non-renewable sources of energy.
2. Basics of heat transfer and energy storage systems.
3. Apply the concept and use of knowledge of the renewable energy sources course to real-life problems.
4. Understanding the Physics of renewable energy sources will create a scientific temperament.
5. Students will have hand on experience in theory based on solar conversion systems and their applications, solar photovoltaics, solar thermal energy, geothermal energy, and emerging trends in renewable energy sources.

Instructional design: 1) Lecture method
2) Tutorial method
3) Seminar/s on renewable energy project case studies

Evaluation Strategies 1) Descriptive written examinations
2) Assignments
3) Seminars, Orals, and Viva

Reference Books:

1. Non-Conventional Energy Sources: G. D. Rai, Khanna Publishers (2011)
2. Renewable Energy Sources and Emerging Technologies: D. P. Kothari, K. C. Singal, and Rakesh Ranjan, Prentice Hall of India Pvt. Ltd. (2008)
3. Non-Conventional Energy Resources: B. H. Khan, Tata McGraw Hill Publication (2006)
4. World Energy Resources: Charles E. Brown, Springer Publication (2002)
5. Principles of Solar Energy Conversion: A. W. Culp, McGraw Hill Publication (2001)
6. Solar Energy-Fundamentals and Applications: H. P. Garg and J. Prakash, McGraw Hill (2000)
7. Renewable Energy Sources and Conversion Technology: N. K. Bansal, M. Kleeman, and S. N. Srinivas, Tata Energy Research Institute (TERI), New Delhi (1996)
8. Solar Cells: Operating Principles, Technology, and System Applications: Martin A. Green, Longman Higher Education (1982)
9. Principles of Solar Engineering: F. Kreith and J. F. Kreider, McGraw Hill (1978)
10. Solar Energy-Principles of Thermal Collection and Storage: S. P. Sukhatme, McGraw Hill (1976)
11. Solar Energy Principles of Thermal Collection and Storage: S. P. Sukhatme, Tata McGraw Hill Publication (1976)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 611 MJP	Course Title: Energy Studies Laboratory-I
Credit: 02	

Course Contents

	List of experiments	
	1. Determination of thickness and refractive index of a semiconductor thin film from reflection and transmission data by using UV-Visible spectrophotoscopy. 2. Determination of band gap of a semiconductor thin film from reflection and transmission data by using UV-Visible spectrophotoscopy. 3. To estimate the activation energy of a given semiconductor thin film sample by using thermally stimulated current method. 4. To study the phenomenon of Hall Effect and magneto-resistance. Determination of Hall coefficient and carrier concentration of the given semiconductor sample. 5. Study of I-V characteristics of solar cell/panel (Variation of intensity, Distance between source and solar cell). 6. Study of power versus load characteristics of series and parallel combination solar photovoltaic systems. 7. Estimation of solar constant 8. To evaluate the performance of parallel flow and counter flow heat exchanger.	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 612 MJ	Course title: General Relativity and Black Holes-I
Credit: 04	

Course Objectives: The main objective is to teach the students the physical and mathematical formulation of Einstein's theory of gravitation. Course also include elementary discussion of black hole spacetime.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Tensors Calculus: Brief discussion of Differentiable manifolds, vectors and vector fields, tensor algebra, metric tensor, tensor densities. Special relativity: Lorentz transformations, 4-vectors and tensors, relativistic electrodynamics, accelerated observers and the rindler metric. Scalar field theory and stress tensor. Riemannian geometry: The covariant derivative for vector fields, covariant differentiation along a curve, parallel transport and geodesics, the Riemann curvature tensor and its properties, symmetries and Killing vectors, maximally symmetric spaces.	
Module-2	Credits: 1	10 L , 5 T
	Gravitation: Principle of equivalence and its consequences, principle of general covariance, action formulation of general relativity, Einstein's equation, the Schwarzschild metric, Birkhoff's theorem, experimental tests of general relativity.	
Module-3	Credits: 1	10 L , 5 T
	Schwarzschild black holes, the maximally extended Schwarzschild solution, Penrose diagrams. conserved charges in general relativity, Hamiltonian formulation of general relativity, ADM decomposition of the metric.	

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

1. appriciate and grasp the mathematical foundation of General relativity.
2. Understand principle of equivalence and general covariance.
3. Solve vacuum Einstein's equantion for sphereically symmetric mass distribution.
4. Understand the concept of event horizon and physics of black hole.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Landau and Lifshitz, Classical Theory of Fields, Vol-2, Elsevier .
2. R. Wald, General Relativity (Chicago, 1984).
2. C. Misner, K. Thome and l Wheeler, Gravitation (Freeman, 1973).
3. S. Weinberg, Gravitation and Cosmology (Wiley, 1972).
4. T. Padmanabhan, Gravitation: Foundations and Frontiers (Cambridge 2010)
5. S. Carroll, Spacetimes and Geometry (Addison-Wesley, 2004)
6. S. Chandrasekhar, Mathematical theory of Black holes (Clarendon press 1983).
7. J.B. Hartle, Gravity: An Introduction to Einstein's General Relativity (Addison- Wesley, 2002).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 612 MJP	Course Title: General Relativity and Black Holes Laboratory -I
Credit: 02	

Course Contents

	List of Experiments	
	1. Reading assignments/problems on differential geometry 2. Reading assignments/problems on special relativity 3. Reading assignments/problems on symmetric spaces 4. Reading assignments/problems on Einstein's equations 5. Computational problems, MATHEMATICA programming in general relativity	

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 613 MJ	Course Title: LASER-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of LASER
2. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability related to LASER.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Interaction of radiation with matter : Absorption, Spontaneous and Stimulated Emission, Einstein's Coefficients, Population Inversion, Gain, Absorption Coefficient, Stimulated Cross Section, Threshold Condition for Lasing Action. Two Level (Ammonia maser) Three Level and Four Level Systems, Rate Equations, Threshold Pump Power, Relative Merits and De-merits of Three and Four Level System.	
Module-2	Credits: 1	10 L , 5 T
	Optical Resonators: Resonator Configurations and its Stability, Characteristics of Gaussian Beam, Transverse and Longitudinal Modes, Mode Selection Techniques (at least two techniques in each case), Losses in a Resonator, Mention of hardware design - laser support structure, mirror mounts, optical coating etc.	
Module-3	Credits: 1	10 L , 5 T
	Types of lasers: (A) Gas lasers : Excitation in Gas Discharge via Collisions of 1st and 2nd Kind, Electron Impact Excitation-its cross section, Different Types of Gas Lasers : He-Ne, N2, CO2, Metal Vapor Lasers, Excimer Laser	
Module-4	Credits: 1	10 L , 5 T
	Laser Parameters and their measurement: Near field and Far field regimes, Internal and external parameters in the near and far field, Detectors and their operational mechanism including specific properties like rise time, spectral response etc.	

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

1. have understood the fundamentals of LASER
2. have acquired the problem-solving skills essential to LASER

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

Text Books:

1. Principles of lasers, by Orazio Svelto - Fourth / fifth edition (Plenum Publishing Corporation).
2. Solid state laser engineering, W. Koechner (Springer-Verlag).
3. Principles of Laser and their applications, Callen, O'Shea, Rhodes
4. Laser parameters, Heard

Reference Books:

1. Masers, by A. G. Siegman.
2. Gas lasers, by Garret.
3. Maser Handbook, vol. 1-4, F. T. Arecchi, E. O. Schul Dubois (North Holland).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 613 MJP	Course Title: LASER Laboratory-I
Credit: 02	

Course Objectives:

1. To get trained to perform experiments using LASER.
2. To introduce important experimental techniques related to LASER.

Course Contents

	List of experiments	
	The proposed list of the experiments for Chemical Physics Laboratory I 1. Determine the spot size and hence the divergence of given He-Ne laser 2. Estimate the diameter of the given wires using He-Ne laser 3. Estimate the wavelength of the He-Ne laser using the diffraction pattern formed due to the grooves of a scale. 4. Estimate the E/P ratio of the Excimer laser. Comment on its importance. 5. Determine some of the vibrational bands of the given sample (HDPE) using the IR spectrophotometer. Determine the force constant for the C-C, C-H bonds. 6. Laser induced reactive quenching at the liquid solid interface-study of phase formation by XRD.	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments using LASER
2. learn to apply scientific methodologies for problem solving.

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

References:

1. Principles of lasers, by Orazio Svelto - Fourth / fifth edition (Plenum Publishing Corporation).
2. Solid state laser engineering, W. Koechner (Springer-Verlag).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 614 MJ	Course Title: Materials Science-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Materials Science
2. To understand structure-property relations of different materials

Course Contents

Module-1	Credits: 1	10 L , 5 T
	(A). Introduction and classification of materials: Metals and alloys, Ceramics and glasses, Polymers, etc., a brief introduction to nanomaterials, biomaterials, advance materials, structure–property relationship in materials and modern material needs. (B) Short review of basic structures: Tetrahedral and octahedral voids (sites), their properties and importance, substitutional and interstitial site occupancy, coordination number and Pauling rules, Crystal Structures of metallic alloys, Ceramics, polymers, silicates, composite materials etc. This include structures such as NaCl, CsCl, Rutile, flurite, corrundum, Hexagonal and cubic Zinc Blende, NiAS, Perovskite, Spinel and inverse spinel, Quartz, silicates, glass, polymers etc.	
Module-2	Credits: 1	10 L , 5 T
	(A). Physical Thermodynamics including Laws of thermodynamics, internal energy, heat capacity, enthalpy, concept of entropy, thermal and configurational entropy (with reference to solid solutions), chemical potential, Maxwell’s equations. (B). Phase diagrams of elements (unary systems), Gibb’s phase rule, thermodynamics of phase transitions, Clausius-Clapeyron equation, Nucleation and growth kinetics, solidification, crystallization, and grain growth.	
Module-3	Credits: 1	10 L , 5 T
	(A) Defects in Solids: Point defects (metals and non-metallic crystals), Line defects (edge and screw dislocations, Burger vector, slip and glide motions of dislocations, strain associated with dislocations, dislocations in ionic crystals), Dislocations and stacking faults in bcc, fcc, and hcp crystals, Planar defects (grain boundaries), volume defects (voids), Thermodynamic aspects and impact of defects on physical properties of materials (B) Diffusion in solids: Fick’s laws diffusion, Mechanism of diffusion, Kirkendall Effect, Nernst-Einstein equation, concentration profiles, solution to the Fick’s second law, importance of diffusion for materials synthesis and processing (examples and applications such as oxidation, corrosion, carborization, decarborization, nitridation, etc.)	
Module-4	Credits: 1	10 L , 5 T
	Binary Phase Diagrams: Concepts of solid solubility, Hume-Rothery rules, concept of formation of phase diagrams on basis of entropy and free energy changes for compositions, Phase diagrams of various categories with examples: Binary isomorphous Systems (complete and limited solubility), Interpretation of phase diagrams, Development of microstructures in isomorphous alloys, binary eutectic systems, development of microstructure in eutectic alloys, equilibrium diagrams having intermediate phases or compounds, eutectoid and peritectic reactions, CTT and TTT diagrams and their importance.	

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

1. understand the fundamental concepts of Materials Science subject.
2. develop structure-property relation of materials.
3. synthesize and engineer properties of the materials .

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physical Metallurgy, Vol. I and 2 (Fourth Edition) by R. W. Cahn and P. Hassen (North Holland Publishing Company, New York, Fourth Edition, 1996).
2. Materials Science and Engineering (Sixth Edition) by V. Raghvan (Prentice-Hall Pvt. Ltd., Sixth Edition, 2015).
3. Fundamentals of Materials Science and Engineering (Ninth Edition by, William Callister (John Willey and Sons 2013).
4. Modern Physical Metallurgy (Fourth Edition) by R. E. Smallman (Butterworths, London 1990).
5. Introduction to the Thermodynamics of Materials (Fourth Edition) by David R. Gaskell (Taylor and Francis, New York, 2003).

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 614 MJP	Course Title: Materials Science Laboratory-I
Credit: 02	

	List of experiments	
	The proposed list of the experiments for Materials Science Laboratory-I. Any 5 Experiments out of these will be taken. 1. Cooling curves and Phase diagram of Pb-Sn alloy. 2. Ionic Conductivity. 3. Synthesis of Aluminium thin film by thermal evaporation method. 4. Study of IR spectrum of HCL vapours. 5. Synthesis of Copper thin film by electrochemical method. 6. Synthesis of CNT/RGO thin film by electrophoresis method.	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 615 MJ	Course Title: Nanotechnology-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Nanotechnology I.
2. To introduce important techniques that are necessary to build core concepts in Nanotechnology I.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Nanotechnology I.

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Scientific background and introduction to nanoscience, Historical importance, Relation with material science, Atoms, molecules, assembly, clusters, macromolecules- examples, Assembly of atoms ,Chemical bonds-organic and inorganic nature, Crystal structure, Definition of surface, Surface energy, Defects and dislocations, Particles and defects on the surface, Grain boundaries, Surface to volume ratio, Surface related phenomena-chemical reactivity, Mechanical properties, sintering properties, Hardness, Surface related phenomena- and applications, Volume related phenomena-introduction.	
Module-2	Credits: 1	10 L, 5 T
	Quantum confinements, Bond to band approach, Molecular energy levels, HOMO- LUMO, Approach to band theory of solids- continuum and periodicity, Bohr radius, Electronic density of states, Tight binding approximation, Density functional approach,1D,2D, 3D,0D structures, Effects of quantum confinement in optics, Electronic devices-Semiconductor, Effective mass approximation, Mie theory, scattering, optical properties-colloidal, surface plasmon resonance.	
Module-3	Credits: 1	10 L , 5 T
	Nucleation and growth, Homogeneous and heterogeneous growth, Thermodynamics of growth, Saturation, Supercooling, Gibbs free energy, Wolf construction-faceting, Directional growth, Dendritic growth, 2D growth, 1D growth, Oswald ripening in solution growth, log normal particles size distribution,	
Module-4	Credits: 1	10 L , 5 T
	Synthesis of nanomaterials : Physical, chemical, biological, arc deposition, cluster beam, laser deposition, MBE, MOCVD, glasses, zeolites, polymer, media, chemical, self assembly energy, signatures in other physics properties.	

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

1. have understood the fundamental concepts of Nanotechnology I.
2. have acquired the problem solving skills essential to Nanotechnology I I.
3. be prepared to undertake advanced topics in Nanotechnology I.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physics of Low Dimensional Structures, J. H. Davis (Cambridge Press).
2. Semiconductor Quantum Dots, L. Banjaj and S. W. Koch.
3. Low Dimensional Semiconductors, M. J. Kelly, Clarendon,1955.
4. Characterization of Materials, J. B. Wachtman and Z. H. Kalman, Butterworth Heinmann, USA, 1993.
5. Experimental Physics, Modern Methods, R. A. Dunlop.
6. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F.A. Settle, (CBS Pub.).
7. Phase transformation in Metals by Porter.
8. Nanomaterials Synthesis and Applications: A.S. Edelstein and R.C. Cammarata,
9. Material Science by Ragawan.
10. Progress in Material Science by Gleiter.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 615 MJP	Course Title: Nanotechnology Laboratory-I
Credit: 02	

Course Objectives:
1. To get trained to perform experiments in Nanotechnology.
2. To introduce important experimental techniques required in Nanotechnology.
3. To Collect data and revise an experimental procedure iteratively

Course Contents:

	List of experiments	
	The proposed list of the experiments for Nanotechnology I 1. Synthesis of metal nanoparticles. 2. Synthesis of porous silicon. 3. Absorption by metal nanoparticles. 4. X-ray Diffraction of nanoparticles. 5. Photoluminescence of nanoparticles	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments in Nanotechnology
2. learn to apply scientific methodologies for problem solving.
3. have learned important techniques in Nanotechnology.

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

REFERENCES:

1. Physics of Low Dimensional Structures, J. H. Davis (Cambridge Press).
2. Semiconductor Quantum Dots, L. Banjaj and S. W. Koch.
3. Low Dimensional Semiconductors, M. J. Kelly, Clarendon,1955.
4. Characterization of Materials, J. B. Wachtman and Z. H. Kalman, Butterworth Heinmann, USA, 1993.
5. Experimental Physics, Modern Methods, R. A. Dunlop.
6. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F.A. Settle, (CBS Pub.).
7. Phase transformation in Metals by Porter.
8. Nanomaterials Synthesis and Applications: A.S. Edelstein and R.C. Cammarata,
9. Material Science by Ragawan.
10. Progress in Material Science by Gleiter.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 616 MJ	Course Title: Nonequilibrium Statistical Mechanics-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of nonequilibrium statistical mechanics.
2. To introduce important techniques that are necessary to build core concepts in nonequilibrium systems.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in statistical mechanics of nonequilibrium systems.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Langevin equation. Application to Brownian motion. Time correlation functions. Brownian motion in a heat bath. Heavy mass in a harmonic lattice. Fluctuation-dissipation relations.	
Module-2	Credits: 1	10 L , 5 T
	Markov processes. Continuous Markov processes. Master equations. Chapman-Kolmogorov equation, Kramer-Moyal expansion, forward and backward Kolmogorov equations. Discrete Markov processes. Master equation and its solutions. Detailed balance.	
Module-3	Credits: 1	10 L , 5 T
	Fokker-Plank equation. Diffusion processes. SDE-FPE correspondence, Ornstein-Uhlenbeck distribution. Fluctuation-dissipation relation.	
Module-4	Credits: 1	10 L , 5 T
	Diffusion in unbounded space and in finite regions. Absorbing boundaries. Wiener processes – Brownian motion example. First passage time. Diffusion under external forces. Green-Kubo formulas.	

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

1. understand the fundamental concepts of nonequilibrium statistical mechanics subject.
2. have acquired the problem solving skills essential to nonequilibrium statistical mechanics subject.
3. be prepared to undertake advanced topics in nonequilibrium statistical mechanics.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Physics – II: Nonequilibrium Statisrical Mechanics by M. Toda, R. Kubo, and N. Saito, Springer (1998).
2. Nonequilibrium Statistical Mechanics by R. Zwanzig, Oxford University Press (2001).
3. Elements of Nonequilibrium Statistical Mechanics by V. Balakrishnan, Springer (2021).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 616 MJP	Course Title: Nonequilibrium Statistical Mechanics Laboratory - I
Credit: 02	

Course Objectives:

1. Learning numerical simulation of Langevin dynamics of a particle, Markov processes, diffusion in finite and and unbounded regions.
2. Understanding in depth Chapman-Kolmogorov equation and Ornstein-Uhlenbeck distribution through mini projects.

Course Contents

	List of Experiments	
	1. Langein dynamics of a particle (Simulation). 2. Chapman-Kolmogorov equation (Mini project). 3. Markov process (Simulation). 4. Ornstein-Uhlenbeck distribution (Mini project). 5. Diffusion in unbounded and finite regions, regions with aborbing boundaries (Similation).	

Learning Outcomes: Upon completion of the course, the student would

1. be able to perform numerical simulation of Langevin dynamics of a particle, Markov processes, diffusion in finite and and unbounded regions.
2. Have a detailed understanding of Chapman-Kolmogorov equation and Ornstein-Uhlenbeck distribution.

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies
1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

1. Statistical Physics – II: Nonequilibrium Statisrical Mechanics by M. Toda, R. Kubo, and N. Saito, Springer (1998).
2. Nonequilibrium Statistical Mechanics by R. Zwanzig, Oxford University Press (2001).
3. Elements of Nonequilibrium Statistical Mechanics by V. Balakrishnan, Springer (2021).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 617 MJ	Course Title: Nonlinear Dynamics – I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of differential equations, maps and flows in nonlinear dyanmics.
2. To introduce important techniques that are necessary to build core concepts differential equations, flows and maps in nonlinear dyanmics.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in nonlinear dyanmics.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Ordinary differential equation, linear ODE, S+N decomposition. Linearization of nonlinear equations, stable and unstable manifolds Hortmon Grobman theorem, stable manifold theorem. Flows & maps, Periodic system, Floquet multipliers, Poincare section.Attractors: Types of attractors, strange attractors, stretching and folding, Lorenz and Rossler attractors.	
Module-1	Credits: 2	20 L , 10 T
	Maps : Logistic map, analysis of the logisticmap, period doubling, intermittency Feigenbaum universality circle map, standard map, Henon map. Elements of bifurcation theory, routes to chaos. Characterization of chaotic solutions and attractors, power spectrum, ergodicity, invariant measure, Lyapunov exponent, dimensions and their evaluation, K-entropy and symbolic dynamics.	

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

1. have understood the fundamental concepts of nonlinear dyanmics subject.
2. have acquired the problem solving skills essential to nonlinear dyanmics subject.
3. be prepared to undertake advanced topics in nonlinear dyanmics subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Ordinary Diff. Equations, V. J. Arnold (Springer).
2. Differential Equations, Dynamical Sy stems and an Introduction to Chaos, Hirsch, Smale and Devaney, Academic Press (Elsevier Imprint).
3. Int. to applied nonlinear dynamical systems & Chaos, Wiggins (Springer Verlag).
4. Nonlinear Oscillations, Dynamical Systems and bifurcations of vector fields (Springer Verlag).
5. Guckenheimer and Holmes (Springer Verlag).
6. Chaotic Evolution and Cambridge, D. Ruelle (Uni. Press).
7. Nonlinear Ordinary diff. Eq., Jordan & Smith (Oxford Univ. Press).
8. Nonlinear dynamics & Chaos, Strogatz (Addison Wesley).
9. Chaos and integrability in Nonlinear Dynamics, An introduction, M. Tabor (J. Wiley).
10. Introduction to Dynamics, I. Percival, D. Richards (Cambridge Univ. Press).
11. Chaos in Dynamical System, E. Ott (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 617 MJP	Course Title: Nonlinear Dynamics Laboratory – I
Credit: 02	

Course Objectives:

Generating, analyszing and understanding maps.

Course Contents

	List of Experiments	
	1. Logistic Map : (a) Bifurcation diagram(1 expt.), (b) Lyanpunov exponents (1 expt.), (c) Feigenbaum constants (1 expt.) 2. Circle Map : Arnold tongues (3 expts.) 3. Henon Map : Generate attractor and show self similarity (2 expts.) 4. Lorenz Map : To generate the Lorenz attractor and study no sensitivity to initial condition (12 expts.)	

Learning Outcomes: Upon completion of the course, the student would be able to generate maps, analyze them and understand their physical significance.

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies
1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

1. Ordinary Diff. Equations, V. J. Arnold (Springer).
2. Differential Equations, Dynamical Sy stems and an Introduction to Chaos, Hirsch, Smale and Devaney, Academic Press (Elsevier Imprint).
3. Int. to applied nonlinear dynamical systems & Chaos, Wiggins (Springer Verlag).
4. Nonlinear Oscillations, Dynamical Systems and bifurcations of vector fields (Springer Verlag).
5. Guckenheimer and Holmes (Springer Verlag).
6. Chaotic Evolution and Cambridge, D. Ruelle (Uni. Press).
7. Nonlinear Ordinary diff. Eq., Jordan & Smith (Oxford Univ. Press).
8. Nonlinear dynamics & Chaos, Strogatz (Addison Wesley).
9. Chaos and integrability in Nonlinear Dynamics, An introduction, M. Tabor (J. Wiley).
10. Introduction to Dynamics, I. Percival, D. Richards (Cambridge Univ. Press).
11. Chaos in Dynamical System, E. Ott (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 618 MJ	Course Title: Nuclear Techniques -I
Credit: 04	

Course Objectives:
The aim of the course is to provide in depth knowledge and form a strong conceptual base of the subject. This course will lay down a strong foundation to understand the various basic elements and pre-requisites used in advanced nuclear environment and nuclear instruments.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Interaction of radiation with matter: Origin and basic characterises of X-Rays, beta rays, alpha particles, and gamma-rays. Range –energy relation for beta-rays. Estimation of energies of charged particles from their trajectories in magnetic fields, Interaction of electrons, positrons, heavy ions, gamma rays and neutrons with matter.	
Module-2	Credits: 1	10 L , 5 T
	Radiation detectors: Basic principle of radiation detectors, Gaseous detectors,Ionisation chamber, propotional counter and GM counter, ionization and transport phenomena in gases, avalanche multiplication, cylindrical and multiwire proportional counters, drift chamber, scintillation detectors, general characteristics of organic and inorganic scintillators, detection efficiency for various types of radiations, scintillation detector mounting, photomultiplier gain, stability, semiconductor detectors, basic principle, surface barrier detector, Si(Li), Gel(Li), HPGe and position sensitive detectors.	
Module-3	Credits: 1	10 L , 5 T
	Nuclear Electronics: Pulse processing and related electronics: Preamplifier, amplifier, pulse shaping networks, biased amplifier, pulse stretchers delay lines, discriminator. Pulse height analysis and coincidence technique, D/A, A/D converter, Single channel analyzer, multichannel analyzer, pulse shape discrimination, coincidence units, slow-fast coincidence circuits, anticoincidence circuit.Timing methods and systems: Walk and fitter, time pick off methods, digital timing methods, introduction to CAMAC systems. Multichannel Analyzer Applications of radiation, gamma-ray and neutron radiography.	
Module-4	Credits: 1	10 L , 5 T
	Dosimetry and radiation protection units: Roentgen, RAD, Gray, Sievert, RBE, BED, REM, REP, kerma, Cema, energy deposit and energy imparted, exposure, absorbed dose, equivalent dose, main aims of radiation protection, dose equivalent and quality factor, organ dose, effective dose equivalent effects and dose limits, assessment of exposure from natural man- made sources. Estimation of radiation level near a radioactive source using a radiation detector. Estimation of radiation levels near a radioactive source, working principle of pocket dosimeter	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. Origin of nuclear radiation, their properties and interaction with matter.
2. Different types of nuclear radiation detectors, their categories, basic working principle, constructions and measurement.
3. Transformation of deposited energy by nuclear radiation to measurable signal in electrical or other form. How they are collected and modified, the complete electronics circuits and units after the detector upto the human perceivable unit (like computer screen, counter, recorder etc) .
4. How to quantify the energy deposited by nuclear radiation within materials or human body. What are the standard calibrations and unit, how to the protection is done from nuclear radiations. What are the radiation limits for common person or radiation worker etc.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy (Wiley Eastern Limited).
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).
3. Techniques for nuclear and particle physics, W. R. Len (Springer).
4. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press).
5. Fundamentals of surface and thin film analysis, Leonard C. Feldman and James W. Mayer (North Holland).
6. Introduction to nuclear science and technology, K. Sriram and Y. R. Waghamare (A. M. Wheeler).
8. Nuclear radiation detection, W. J. Price (McGraw-Hill).
9. Alphas, beta and gamma-ray spectroscopy, K. Siegbahn (North Holland, Amsterdam).
11. Introduction to experimental nuclear physics, R. M. Singru (John Wiley and Sons).
12. Radioactive isotopes in biological research, Willaim R. Hendee (John Wiley and Sons).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 618 MJP	Course Title: Nuclear Techniques Laboratory-I
Credit: 02	

Course Objectives:

The aim of the lab course is to provide in hands on experience on various nuclear electronics and instrumentation to have a complete and in-depth understanding of the subject .

Course Contents

Module-1	Credits: 2	
	1. To determine resolving/dead time of a GM counter by double source method. 2. To study Compton scattering using 6.66% MeV gamma-rays. 3. To determine energy resolution ofa Nal(TI) detector and show that it is independent of the gain of the amplifier. 4. To determine energy of a given gamma-ray source by calibration method. 5. To study various operations of 1024 channel analyzer and to calculate energy resolution, energy of gamma ray, area under photopeak etc. 6. To study beta-ray spectrum of Cs-137 source and to calculate binding energy of K-shell electron of Cs-137. 7. To estimate the resolving time (Trr) for a given GM counting system using double source method. (Any five experiments will be covered)	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. In depth-understanding each components of the detectors, signal processing and detection mechanism
2. Basic physics principle behind each detector and its working
3. Radioactivity its level and safety measurements.
4. Basic knowledge about various Nuclear instrumentation.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 619 MJ	Course Title: Physics of Semiconductor Devices-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Basic of Semiconductors and p-n junctions.
2. To introduce important techniques that are necessary to build core concepts in Semiconductor devices and their characterizations and uses.
3. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	-Carrier transport in semiconductors: Valence band model of pure and doped semiconductor, Equilibrium concentration of electrons and holes inside the energy band gap, The Fermi level and energy distribution of carriers inside the bands, temperature dependence of Fermi energy and carrier concentration in an extrinsic semiconductor, Drift, diffusion and injection of carriers; Carrier generation and recombination processes, Carrier lifetime, Relaxation lifetime, Dielectric relaxation lifetime, Recombination of electrons and holes.	
Module-2		10 L , 5 T
	Credits: 1- Properties of semiconductor: Type of semiconductors, direct and indirect band gap semiconductors, measurements of mobility and diffusivity, Optical and thermal properties of some semiconductors, Four –point probe resistivity measurement, Van-der Pauw method, Hall effect, The Haynes-Shockley experiment: Diffusion constant, temperature dependent electrical properties of some semiconductors.	
Module-3	Credits: 1	10 L , 5 T
	-Metal-semiconductor junction: Metal-semiconductor junction, Formation of barriers, Schottkey barriers, Rectifying contacts, Ohmic contacts, Ideal conditions, Depletion layer, Surface/Interface states, Role of interface States in Junction Diodes, Barrier height adjustment, Current transport processes, Tunneling current, Minority carrier injection, MIS tunnel diode, Measurement of barrier height, photoelectric measurements, Activation energy measurements, Capacitance-voltage measurements, applications of M-S junctions	
Module-4	Credits: 1	10 L , 5 T
	-Metal-Insulators-Semiconductor: Metal-Insulators-Semiconductor capacitance, Ideal MIS capacitor, Surface space-charge region, Ideal MIS capacitance curves, Interface traps, measurement of interface traps, oxide charges and work function difference, Carrier transport, Non-equilibrium and avalanche, accumulation and inversion layer thickness, brief about classical and quantum model, dielectric breakdown.	

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

1. have understood the fundamental concepts of Basic of Semiconductors and p-n junctions.
2. have acquired the problem solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about the Semiconductor devices and their characterizations.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. An Introduction to Semiconductor Devices, Donald A. Neamen (McGraw-Hill)
2. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education Inc. 6th Edition)
3. Semiconductor Devices: Physics and Technology, S. M Sze (2nd Edition, John Wiley, New York)
4. Introduction to Semiconductor Materials and Devices, M. S. Tyagi (John Wiley & Sons)
5. Fundamentals of Semiconductor Devices, BL Anderson and RL Anderson (McGraw-Hill Higher Education)
6. Principles of Semiconductor Devices, Sima Dimitrijev (OXFORD UNIVERSITY PRESS)
7. Complete Guide to Semiconductor Devices, K.K. Ng (John Wiley & Sons, Inc., New York 2nd Ed.)
8. Modern Semiconductor Device Physics, S M Sze (John Wiley) (1998)
9. Semiconductor Devices: Basic Principles, Jaspreet Singh (John Wiley & Sons)
10. Semiconductor Device Fundamentals" Robert F., Pierret (Addison-Wesley)
11. Physics of semiconductor devices, Dilip K Roy (Universities press)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 619 MJP	Course Title: Physics of Semiconductor Devices Laboratory -I
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Basic of Semiconductors and p-n junctions.
2. To introduce important techniques that are necessary to build core concepts in Semiconductor devices and their characterizations and uses.
3. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Module-1	Credits: 2	
	1. Fabrication of semiconductor devices (UV-detector, Switches, memory devices, MOS FET's, photovoltaics solar cells, LED's. etc) and basic characterization and/or similar experiments. 2. Fabrication and measurements of p-n MS, MIS, MOS, etc. junctions (structures). 3. Studies on optical properties of semiconductor devices. 4. Calculation of electrical parameters such as swing voltages, threshold voltages, on/off ratios, mobility in linear and saturated regions of MOSFET's. 5. Electric transport properties, Current-Voltage (I-V) measurements on the above prepared semiconductor devices. 6. To study photoelectric properties of the semiconductor devices prepared in SEM III.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understood the fundamental concepts of Basic of Semiconductors and p-n junctions.
2. have acquired the problem solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about the Semiconductor devices and their characterizations.

Instructional design:
1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. An Introduction to Semiconductor Devices, Donald A. Neamen (McGraw-Hill)
2. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education Inc. 6th Edition)
3. Semiconductor Devices: Physics and Technology, S. M Sze (2nd Edition, John Wiley, New York)
4. Introduction to Semiconductor Materials and Devices, M. S. Tyagi (John Wiley & Sons)
5. Fundamentals of Semiconductor Devices, BL Anderson and RL Anderson (McGraw-Hill Higher Education)
6. Principles of Semiconductor Devices, Sima Dimitrijev (OXFORD UNIVERSITY PRESS)
7. Complete Guide to Semiconductor Devices, K.K. Ng (John Wiley & Sons, Inc., New York 2nd Ed.)
8. Modern Semiconductor Device Physics, S M Sze (John Wiley) (1998)
9. Semiconductor Devices: Basic Principles, Jaspreet Singh (John Wiley & Sons)
10. Semiconductor Device Fundamentals" Robert F., Pierret (Addison-Wesley)
11. Physics of semiconductor devices, Dilip K Roy (Universities press)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 620 MJ	Course Title: Plasma Physics and Technology-I
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basic processes in plasmas: Collisions in plasmas, significance of small angle scatterings, ionization, recombination, concepts of diffusion, mobility, ambipolar diffusion. Thermal ionisation and the Saha equation, LTE and equilibrium models.	
Module-2	Credits: 1	10 L , 5 T
	Plasma production: Various plasma production techniques, Electrical breakdown in gases using dc, radio frequency, microwave and high frequency fields, Glow and arc discharge,	
Module-3	Credits: 1	10 L , 5 T
	Plasma diagnostics: Electrical Probes: Probe theory, Langmuir probes, Single and double probe, Emissive probe, magnetic probes, Retarding field analyzer for ion energy analysis, Spectroscopic methods: Spectroscopic diagnostics (Emission spectra), Verification of Atomic Data, Measurements of Particle Densities, Temperature Measurements, Measurements of the Electron Density, Mass spectrometry.	
Module-4	Credits: 1	10 L , 5 T
	Interaction of plasma with material: Constituents of plasma and their energy (i.e. electron, ions, neutrals, heat, electromagnetic radiations). Interaction of electron from plasma with surfaces, Interaction of ions from plasma with surfaces (sputtering mechanism, buried implantation), Interaction of heat with surfaces, Plasma chemistry and physics. Nucleation and growth phenomena , Homogeneous and heterogeneous nucleation , Dusty plasma , Aerosols.	

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

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1) Glow discharge processes (Sputtering and Plasma etching), Brain Chapmn (A Wiley Interscience Publication).
2) Thermal Plasmas: Fundamentals and Applications, Volume 1, Maher I. Boulos, Pierre Fauchais, Emil Pfender (Springer Science+Business Media).
3) Plasma Diagnostics, Holt Greven (North Holand Publishing Company, Amsterdam).
4) Reactions under Plasma Conditions, M. VenuGopalan (Wiley Interscience).
5) Cold Plasma in Materials fabrication: From Fundamental to Applications, Alfred Grillb (IEEE Press).
6) Introduction to Plasma Spectroscopy, Hans-Joachim Kunze (Springer).
7) Plasma Deposition, Treatment, and Etching of Polymers Edited by Riccardo d'Agostino, (ACADEMIC PRESS, INC).

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 620 MJP	Course Title: Plasma Physics and Technology Laboratory- I
Credit: 02	

	List of experiments	
	The proposed list of the experiments for Plasma Physics and Technology Laboratory- I. Any 5 Experiments out of these will be taken. 1. Capacitevely coupled DC plasma reactor, verification of townsend discharge by varying pressure and Voltage. 2. Plasma reactor using AC glow discharge at 50 Hz in capacitively coupled system. Measurements of plasma voltage and plasma current at different voltages . Measurement of plasma power. 3. To study the Inductively coupled plasma devices. Measurement of plasma currents and voltage. 4. Plasma polymerization of poly acrylonitrile nitrile (PPAN). Measurement of physical properties of the plasma polymerized film. 5. Production of microwave plasma in a glass applicator. To study the effect of pressure and microwave power on the plasma glow. 6. Measurement of optical emission spectra from any of plasma devices for any chosen gas in the reactor.	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 621 MJ	Course Title: Quantum Information and Quantum Computation -I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of quantum mechanics.
2. To introduce important techniques that are necessary to build core concepts in quantum information and quantum computation.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in quantum information and quantum computation.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Quantum Mechanics background. Principle of superposition and its implications. Mixed states, Density operators and their properties, state after measurement, convex sets of density operators, evolution of mixed states, random mixtures, Bloch ball and sphere, Density matrix, populations and coherences. Tensor products of state spaces, scalar products, multipartite systems, computational basis, entangled states, operators on tensor product spaces, entangling operators, tensor products of matrices, partial trace and reduced density operators, general,projective and POVM measurements, Schmidt decomposition and purification, EPR and Bell's theorem.	
Module-2	Credits: 2	20 L , 10 T
	Quantum circuits. General description of quantum information processing and the circuit model, single qubit gates, controlled operations, principles of deferred and implicit measurement, universal quantum gates, approximating quantum circuits and proving universality of some set of gates. Approximating general unitary gates, quantum simulation.	
Module-3	Credits: 1	10 L , 5 T
	Quantum algorithms. General characteristics of quantum algorithms, Deutsch/Deutsch-Jozsa algorithms, Bernstein -Vazirani algorithm, Function evaluation and quantum adder Quantum Fourier Transform, Quantum Phase Estimation, Simon's algorithm, Shor algorithm Quantum search (Grover) algorithm.Physical realization of a quantum computer (As chosen by the teacher).	

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

1. have understood the fundamental concepts of quantum information and quantum computation and its technolgical importance.
2. have acquired the problem solving skills essential to quantum information and quantum computation subject.
3. be prepared to undertake advanced topics in quantum computers subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang. Cambridge University Press (2013).
2. Principles of Quantum Computation and Information, G. Benenti, G. Casati and G. Strini World Scientific (2020)
3. The Theory of Quantum Information, J. Watrous, Cambridge University Press (2018).
4. Qauntum Computing: A Gentle Introduction, E. G. Rieffel and W. H. Polak, MIT Press (2014).
5. Lectures Notes on Quantum Computing, J. Presskill. (Available online at theoru.caltech.edu).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 621 MJP	Course Title: Quantum Information and Quantum Computation Laboratory - I
Credit: 02	

Course Objectives:

1. Perform quantum flip game.
2. Construct and test quantum teleportation circuit.
3. Develop and run different quantum algorithms on a quantum computer.

Course Contents

	List of Experiments	
	• Coin Flip Game On a Quantum Circuit • Quantum Teleportation Circuit • Deutsch's Algorithm • Deutsch-Jozsa Algorithm • Bernstein-Vazirani Algorithm	

Learning Outcomes: Upon completion of the course, the student would

1. be able to perform coin flip gam and quantum telepotation on quantum circuit,
2. be able todevelop and run different quantum algorithms on a quantum computer.

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies

1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

Books and References:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang. Cambridge University Press (2013).
2. Principles of Quantum Computation and Information, G. Benenti, G. Casati and G. Strini World Scientific (2020)
3. The Theory of Quantum Information, J. Watrous, Cambridge University Press (2018).
4. Qauntum Computing: A Gentle Introduction, E. G. Rieffel and W. H. Polak, MIT Press (2014).
5. Lectures Notes on Quantum Computing, J. Presskill. (Available online at theoru.caltech.edu).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 622 MJ	Course title: Soft Condensed Matter-I
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Introduction to Soft Matter, Review of concepts of thermal equilibrium, Thermodynamics of solutions, phase separation.	
Module-2	Credits: 1	10 L , 5 T
	Mean Field Theories of phase-transition, Vaan der Waals equation, Critical phenomenon in fluids and Soft Matter systems, Landau Theory of phase transition.	
Module-3	Credits: 1	10 L , 5 T
	Supra-molecular self-assembly in soft-condensed matter. Amphiphilic molecules in solutions – aggregation and phase separation. Micellization process. Bilayers, vesicles and membranes.	
Module-4	Credits: 1	10 L , 5 T
	Liquid crystals. Basic definitions and terminology. Liquid crystal phases and phase transitions. Orientational order and order parameters. Mean-field theories of liquid-crystalline order.	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Soft-Condensed Matter by R. A. L. Jones, (Oxford University Press).
2. Structured Fluids by T. Witten and P. Pincus, (Oxford University Press).
4. Soft Matter Physics: An Introduction by M. Kleman and O. D. Lavrentovich, (Springer).
5. The Colloidal Domain by F. Evans and H. Wennerstrom, (Wiley – VCH).
6. Soft Matter Physics by Masao Doi, (Oxford University Press).
9. An Introduction to Polymer Physics by D. I. Bower, (Cambridge University Press).
10. The Physics of Polymers by G. Strobl, (Springer).
11. Scaling Concepts in Polymer Physics by P. de Gennes, (Cornell University Physics).
12. Liquid Crystals by S. Chandrasekhar, (Cambridge University Press).
13. Intermolecular and surface forces (3rd Ed), Jacob N. Israelachvili (Elsevier).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 622 MJP	Course Title: Soft Condensed Matter Laboratory-I
Credit: 02	

Course Contents

	List of Experiments	
	1. Computer simulation: Random walk 2. Computer simulation: Growth models–Eden, Ballistic Deposition (BD), 3. Diffusion Limited Aggregation (DLA) (any one). 4. Computer simulation: Langmuir Process of Deposition and evaporation (Monte Carlo) 5. Computer simulation: Isotropic-nematic transition of a model liquid crystal (Monte Carlo) 6. Experiment: Study of the Brownian motion of polystyrene bead dispersed in Newtonian liquids. 7.Experiment: Study of the basic micro-rheology from Brownian motion 8. Experiment: Young's wetting on plane surface. (ANY FIVE)	

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 623 MJ	Course Title: Thin Film Physics and Device Technology-I
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of thin film deposition and various measurement techniques to study the various properties.
2. To introduce important techniques that are necessary to build core concepts related to the electrical properties of thin films and the effect of the size of layer on magnetic properties.
3. Various devices will be prepared by different techniques and measured their performance.
4. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Thin Film thickness and deposition rate measurement techniques:- Gravimetric Methods, Optical Methods, Direct Methods, Film Thickness Measurement by Electrical or Magnetic Quantities. Analysis of thin film structure, composition and morphology of thin films, Mechanical properties of thin films: - stress in thin films and adhesion. Optical properties of thin films	
Module-2		10 L , 5 T
	Electrical and magnetic properties of thin films: - Conductivity of continuous and discontinuous thin films, conduction in thin films of metals and insulators, determination of electrical parameters, Hall effect, TEP measurements, Photoconductor, Magnetic film size effect, magnetic thin films for memory applications	
Module-3	Credits: 1	10 L , 5 T
	Applications of thin films: - Antireflection coating, Optoelectronic applications (photon detectors, photovoltaic devices, thin film displays), microelectronic applications (thin film passive components like resistor, capacitor, etc. and thin film active components like thin film diode and thin film transistor)	
Module-4	Credits: 1	10 L , 5 T
	Thin Film Devices: Sensors, Energy conversion (phototelectrolysis, photovoltaics) and energy storage (supercapacitor), Surface engineering applications of thin films (surface passivation, lubricating layer), Miscellaneous Applications (catalysis, biomedical)	

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

1. have understood the fundamental concepts of thin film deposition and various measurement techniques to study the various properties.
2. have acquired the problem solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about the various device preparation by different techniques and measurement of their performance. Semiconductor devices and their characterizations.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Thin Film Materials Stress, Defect Formation and Surface Evolution, I. B. Freund, S. Suresh (Cambridge University Press, 2004)
2. Thin Film Device Applications, K. L. Chopra and I Kaur (Plenum Press, 1983)
3. Thin Film Analysis by X-ray Scattering, M, Birkholz (Wiley, 2006)

4. Active and Passive thin film devices and applications, T.J. Coutts (Academic Press),78.
5. Thin films Solar Cells, K. L. Chopra, S. R. Das (Plenum Press), 1983.
6. Handbook of modern sensors, Jacob Freden (AIP Press 2004)
7. Active and Passive Thin Film Devices, T. J. Coutts (Academic Press, 1978).
8. Light, Water, Hydrogen The Solar Generation of Hydrogen by Water Photo- electrolysis, C. A. Grimes, O. K. Varghese, S. Ranjan (Springer 2008)
9. Energy storage, Robert A Huggins (Springer 2010)
10. Advanced Characterization Techniques for Thin Film Solar Cells, Daniel Abou- Ras, Thomas Kirchartz and Uwe Rau (Wiley 2011)

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHY 623 MJP	Course Title: - Thin Film Physics and Device Technology Laboratory-I
Credit: 02	

	List of experiments	
	The proposed list of the experiments: 1. To study thin film deposition by vacuum evaporation technique. 2. To study thin film deposition by sputtering technique. 3. To study thin film deposition by CVD technique. 4. To study thin film deposition by CBD/electroless technique. 5. To study thin film deposition by electrochemical deposition technique. 6. To study thin film deposition by spin coating technique. To determine thickness of the thin film by different methods.	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: MSc II, Sem III	Major Elective
Course Code: PHY 625 MJ	Course Title: Methods of Experimental Physics-I
Credit: 02	

Course Objectives:
7. To strengthen the basic concepts of Signal Noise and Error Analysis.
8. To be able to understand the details about the Measurements with Photons and various devices, sources.
9. Students will be understanding the various sources, devices used to generate the photon and electrons and to select the required wavelength.
10. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication various devises.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Improvement in Signal to Noise Ratio: Origin of noise, Hardware devices for noise reduction, Filters, Modulation techniques, Lock-in-amplifier, Software methods to reduce noise level, Ensemble averaging, Box car integrator, Fourier transform, and Impedance matching, Shielding and grounding. Error and Statistical Data Handling, Error Determination in physical quantities, Propagation of Error, Quantitative estimation of errors, Weighed average, Statistical handling of data, Distribution of data, Principle of maximum likelihood, Fitting of data, Covariance, Chi square test.	
Module-2		10 L , 5 T
	Measurements with Photons, Sources such as Discharge lamps, Lasers, Synchrotron radiation Dispersion elements or wavelength selectors, Monochromators. Photon detectors, Photodiode, Photomultiplier tube, Charge Couple Device, Fiber Optics, Line Shape in Spectroscopy Measurements with Electrons, Electron gun, Electron lenses, Electron energy analysers and channel plate, channeltron.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understood the fundamental concepts of Signal Noise and Error Analysis.
2. have acquired the problem-solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about various sources, devices used to generate the photon and electrons and to select the required wavelength.

Instructional design:
1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Practical Physics, G. L. Squires (Cambridge University Press, Cambridge)
2. An Introduction to Error Analysis, J.R. Taylor (Oxford University Press, University Science Books).
3. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle (CBS Publishers and Distributers).
4. Instrumental Analysis, D.A. Skoog, F.J. Holler and S.R. Crouch (Cengage Learning).
5. Fundamentals of Molecular Spectroscopy, C.N. Banwell and E.M. McCash (McGraw- Hill International Limited, 4th Edition 1996).

Course Information	
Year and Semester: MSc II, Sem III	Major Elective
Course Code: PHY 626 MJ	Course Title: Methods of Experimental Physics-II
Credit: 02	

Course Objectives:
1. To strengthen the basic concepts of Vacuum Science, various vacuum pumps, and gauges to generate and measure the vacuum.
2. To be able to understand the details to obtain the low-temperature and the measurement of low-temperature.
3. Students will be understanding the working, principle and design of various analytical tools like SQUID, semiconductor devices to measure the low-temperature.
4. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication various devises.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basic Vacuum Science, Basic consideration and units, Ultra-high vacuum system, Gas balance, Rotary vane pump Turbo molecular pump, Diffusion pump, Sorption pump, Getter pump, Sputter ion pump. Measurements of Vacuum Introduction, U tube manometer, McLeod guage, Thermal conductivity guage, Penning guage, Hot cathode ionization gauges, Quadrupole mass spectrometer.	
Module-2		10 L , 5 T
	Obtaining Low Temperature, Magic of latent heat, Superfluidity and liquid He, Dilution refrigerator, Magnetic refrigeration, Overview of modern methods to attain low temperature such as Laser cooling. Low Temperature Thermometry Primary and secondary temperature measurements, Thermometers, Thermoelectric devices, Electrical resistance devices, Semiconductor devices, and use of SQUID (magnetic measurements) to estimate ultra-low temperature.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understood the basic concepts of Vacuum Science, various vacuum pumps, and gauges to generate and measure the vacuum.
2. have acquired the problem-solving skills essential to design and fabrication of low temperature devices.
3. Have understood the details to obtain the low-temperature and the measurement of low-temperature.

Instructional design:
1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Practical Physics, G. L. Squires (Cambridge University Press, Cambridge)
2. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle (CBS Publishers and Distributers).
3. Instrumental Analysis, D.A. Skoog, F.J. Holler and S.R. Crouch (Cengage Learning).
4. Fundamentals of Vacuum Technology, W. Umrath (Leybold Vacuum).
5. Vacuum Technology, A. Roth (North Holland).
6. Vacuum Physics and Techniques, T. A. Delchar, Chapman and Hall
7. Handbook of thin film technology, Maissel and Glang.
8. Matter and Methods at Low Temperature, F. Pobell, (Springer Verlag).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 627 MJ	Course Title: X-Ray Crystallography
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of crystallography
2. To introduce important techniques that are necessary to build core concepts in crystallography
3. To develop problem solving skills with appropriate rigor that helps the student to understand the international tables of crystallography.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Lattice, Unit Cell: primitive and non-primitive, Crystal structure, Symmetry, point groups, space groups, crystallographic symbols, Direction and Plane indexing for cubic and hexagonal crystal structures, Bravais lattice, Understanding Bravais lattice of compound and alloy structures.	
Module-2	Credits: 1	10 L , 5 T
	X-ray diffraction, intensity of XRD peaks, Atomic scattering factor, structure factor, Structure factor calculation for metals, alloys (e.g. CuZn, Cu3Zn, etc.) and compound (e.g. NaCl, CsCl ZnS, BaTiO3, etc.) structures.	

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

1. understand concept of point group, space group.
2. acquire knowledge of space group symbols
3. be prepared to undertake research where crystallographic information is useful.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Fundamentals of Powder Diffraction and Structural Characterization of Materials by Vitalij K. Pecharsky, Peter Y. Zavalij (Springer Publications)
2. Elements of X-ray Diffraction by B. D. Cullity & S. R. Stock, Pearson, 2014
3. The Basics of Crystallography and Diffraction: Fourth Edition by Christopher Hammond, Oxford, 2015.
4. Basic Elements of Crystallography by Teresa Szwacka & Nevill Gonzalez Szwacki, Pan Stanford Publishing 2010.
5. Crystallography applied to solid state physics by A. R. Verma & O N Srivastava, New Age International, 2015.
6. Crystallography an introduction 3rd edition by Walter Borchardt-Ott, Springer, 2011.
7. International Tables for Crystallography Volume A, edited by Theo Hahn (The International Union of Crystallography, Springer Publication)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 628 MJ	Course Title: Biophotonics
Credit: 02	

Course Objectives:
1. To strengthen the basic concepts in the field of Bio-photonics.
2. To introduce important techniques that are necessary to build core concepts in Bio-photonics with the emphasis on bio-photonics fundamentals and applications.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in understanding and analyse systems in the viewpoint of bio-photonics.
4. Biophotonics is a multi-disciplinary area where light-based techniques are used to understand biological mechanisms, diagnose and treat many diseases.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basics of light-matter interactions in biomolecules cells and tissues. Nature of light, Refraction, Reflection, Interference, Diffraction. Intensity, Phase, Polarization, Scattering, Fluorescence, Optical properties of biological materials.	
Module-2	Credits: 1	10 L , 5 T
	Fluorescence-based microscopy, Confocal microscopy, Super-resolution fluorescence microscopy. Deep tissue imaging with multiphoton microscopy Raman imaging (SRS microscopy) Optical tweezers for cells. Lasers for Biophotonics: Endoscopy, Optical Conference Tomography (OCT) Photodynamic therapy LIBS (Laser Induced Breakdown Spectroscopy) for diseases.	

Learning Outcomes: Upon completion of the course, the student will be able to, understand various aspects of bio-photonics.

1. have understood the fundamental concepts of bio-photonics their origin and control using external stimulus.
2. have acquired the problem-solving skills essential to bio-photonics.
3. be prepared to undertake advanced topics in bio-photonics subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Introduction to Biophotonics P.M.Prasad Wiley 2003
2. Laser-Tissue Interactions Munez Springer
3. Introduction to confocal fluorescence microscopy M. Miller SPIE press
4. Quantitative Biomedical Optics J.J.Bigio Sergio Fantini Cambridge University press

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 629 MJ	Course Title: Medical Physics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts in the field of Medical physics.
2. To introduce important techniques that are necessary to build core concepts in Medical physics with the emphasis on Technology.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in understanding and analyse systems related to the medical biophysics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Ionizing/Non-Ionizing Radiations- sources, properties X-rays and interaction with matter, x-ray radiography & tomography, Computer Tomography (CT), Radioactive isotopes, radionuclides applications (RIA)	
Module-2	Credits: 1	10 L , 5 T
	Various types of optical radiations- UV, IR, Lasers, fluence from optical sources. Theory and experimental techniques of laser-tissue interactions. Photothermal, Photochemical and Photoablahen effects, and their applications. Laser in blood flow measurement.	

Learning Outcomes: Upon completion of the course, the student will be able to, handle various medical equipments.

1. have understood the fundamental concepts of medical physics.
2. have acquired the problem-solving skills essential to bio-signals analysis.
3. be prepared to undertake advanced topics in medical physics.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Medical Physics by Cameroon Wiley
2. Medical Physics J.R.Greening North-Holland Pub. Co. New York
3. Laser Tissue Interactions M. H. Neimz Springer Verlag
4. Clinical Biophysics by P.Narayanan, Bhalani Pub.

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 630 MJ	Course Title: Optoelectronics
Credit: 02	

Course Objectives:
1) To strengthen the basic concepts of semiconductor physics and p-n junctions.
2) To introduce important techniques that are necessary to build core concepts in semiconductor devices.
3) To develop problem-solving skills with appropriate rigor that help students improve their analytical ability in optoelectronic devices.
4) To provide students with a strong foundation in optoelectronics, semiconductor physics, and various optoelectronic devices, while also fostering problem-solving skills and analytical abilities to address real-world challenges in the field.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basics of semiconductor and p-n junctions: Type of semiconductors, direct and indirect band gap semiconductors, Electrons and holes in an Intrinsic Semiconductor, Conductivity of semiconductor, carrier concentration in intrinsic semiconductor, donor and acceptor impurities, charge density in a semiconductor, Fermi level in intrinsic and extrinsic semiconductor, diffusion, carrier life time, estimation of carrier concentration, Qualitative theory of the p-n junction, p-n-junction as diode and current flow p-n diode, diode equation, band structure of open circuit and biased p-n junction, I-V characteristics of diode, temperature dependence of p-n characteristics, estimation of width of the depletion region.	
Module-2	Credits: 1	10 L , 5 T
	Semiconductor Devices: Transistor; Energy level diagram of transistor under open circuit and biased condition. Transistor action, base current, emitter current, collector current and their interrelation, Special types of diodes: breakdown diodes, Zener diode, the tunnel diode, p-i-n diode, point contact diode, Schottky diode and their I-V characteristics, Light-Emitting Diodes: Principles, Homojunction and Heterostructure LEDs, LED Materials and Structures, Basic LED Characteristics, LEDs for Optical Fiber Communications	

Learning Outcomes: Upon completion of the course, the student will be able to,
1) have understood the fundamental concepts of semiconductor physics, p-n junctions, and optoelectronic devices.
2) have acquired the problem-solving skills essential to analyze and design semiconductor devices and optoelectronic systems.
3) be prepared to undertake advanced topics in optoelectronics and semiconductor devices.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

Textbooks-
1. Electronics Fundamental and Applications: J D Ryder (John Wiley-Eastern Publication)
2. Integrated Circuits: Milman and Halkias (Prentice-Hall Publications)
3. Introduction to solid state physics- Charles Kitte

Reference books
1. Semiconductor Device Physics and Technology, S M, Zee (Wiley India, 2nd edition, 2002).
2. Solid State Electronic Devices by Ben G. Streetman and Sanjay Kumar Banerjee
3. Optoelectronics and photonics: Principles & Practices, S O Kasap

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 631 MJ	Course Title: Radiation Physics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of nuclear radiation, its origin and radioactivity

2. To introduce important techniques that are necessary to build core concepts of radiation interaction of radiation with matter.

3. To develop problem-solving skills with appropriate regior that helps the student to improve their analytical ability to understand how charged and uncharged radiation deposits energy and how it is quantified.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Classification of radiations, Ionizing and non-ionising radiations, directly and indirectly ionizing radiation, nuclear radiation and their origin, radio-activity fundamental laws, Applications and uses.	
Module-2	Credits: 1	10 L , 5 T
	Interaction of radiation with matter: Basic mechanism and Interaction of electromagnetic radiations with matter, Interaction of charged particles with matter, Interaction of neutral particles with matter, Range –energy relation for beta-rays. Estimation of energies of charged particles from their trajectories in magnetic fields, basic units and measurements.	

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

1. have understood the fundamental concepts of Radiation Physics.
2. have acquired a solid foundation in the principles of radiation and its behavior when interacting with different materials, enabling them to apply this knowledge in real-world scenarios and various scientific and industrial applications.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy (Wiley Eastern Limited).
2. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 632 MJ	Course Title: Basics of Semiconductors
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Basic of Semiconductors and p-n junctions.
2. To introduce important techniques that are necessary to build core concepts in Semiconductor devices and their characterizations and uses.
3. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Electrons and holes in an Intrinsic Semiconductor, Conductivity of semiconductor, carrier concentration in intrinsic semiconductor, donar and acceptor impurities, charge density in a semiconductor, Fermi level in intrinsic and extrinsic semiconductor, diffusion, carrier life time, estimation of carrier concentration, Qualitative theory of the p-n junction, p-n-junction as diode and current flow p-n diode, band structure of open circuit and biased p-n junction, I-V characteristics of diode, temperature dependence of p-n characteristics, diode resistance and diode capacitance, estimation of width of the depletion region.	
Module-2		10 L , 5 T
	Transistor; Energy level diagram of transistor under open circuit and biased condition. Transistor action, base current, emitter current, collector current and their interrelation, Special types of diodes: breakdown diodes, Zener diode, the tunnel diode, p-i-n diode, point contact diode, schottky diode and their I-V characteristics, junction formation and operatory characteristics of UJT, J-FET, MOS FET, Silicon Control Rectifier (SCR).	

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

1. have understood the fundamental concepts of Basic of Semiconductors and p-n junctions.
2. have acquired the problem solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about the Semiconductor devices and their characterizations.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Electronics Fundamental and Applications: J D Ryder, John Wiley-Eastern Publication
2. Integrated Circuits: Milman and Halkias, Prentice-Hall Publications
3. Semiconductor Device Physics and Technology, S M, Zee, Wiley India, 2nd edition, 2002.
4. Introduction to solid state physics- Charles Kittel
5. Semiconductor Device Fundamentals, Robert F. Pierret (Addison-Wesley,1996)
6. Physics of semiconductor devices, Dilip K Roy (Universities Press, 2002).
7. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 633 MJ	Course Title: Photodevices
Credit: 02	

Course Objectives:
1) To strengthen the basic concepts of electronics relevant to photonic devices..
2) To introduce important techniques that are necessary to build core concepts related to Photonic devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Photodiodes, p-i-n and p-n photodiodes, heterojunction photodiode, metal semiconductor photodiode, phototransistors, Gain Bandwidth and Signal to noise ratio, Variation of photo-detectors, Stimulated Emission, Photon Amplification, and Lasers, Stimulated Emission and Population Inversion, Photon Amplification and Laser Principles, Four-Level Laser System, Stimulated Emission and Einstein Coefficients, Emission and Absorption Cross-Sections, Principle of the Laser Diode, Heterostructure Laser Diodes	
Module-2	Credits: 1	10 L , 5 T
	Photovoltaic devices (Solar cells) Basic Principles, Operating Current and Voltage and Fill Factor, Equivalent Circuit of a Solar Cell, Solar Cell Structures and Efficiencies, crystalline Silicon solar cells, thin film solar cells, and multi-junction (tandem solar cells), hybrid solar cells, Dye sensitized solar cells, perovskite solar cells, quantum dot based solar cells. Dark and illuminated characteristics of solar cells, Effect of light intensity on solar cell Parameters (Open circuit voltage, Short circuit current, fill factor, efficiency, etc.), Effect of series and shunt resistance on I-V curves due to defects in materials.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1) have understood the fundamental concepts of Photonic devices.
2) have acquired the problem-solving skills essential to analyze and design photonic devices.
3) be prepared to undertake advanced topics in photonic devices.

Instructional design: Lecture method, Tutorial method , Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

Textbooks-

1. Electronics Fundamental and Applications: J D Ryder (John Wiley-Eastern Publication)
2. Integrated Circuits: Milman and Halkias (Prentice-Hall Publications)
3. Solar photovoltaics: fundamentals, technologies, and applications- Chetan Singh Solanki
4. Solar Energy Fundamentals and Applications, H. P. Garg and Satya Prakash (Tata McGraw Hill, 1997)

Reference books-

1. Semiconductor Device Physics and Technology, S M, Zee (Wiley India, 2nd edition, 2002).
2. Solid State Electronic Devices by Ben G. Streetman and Sanjay Kumar Banerjee
3. Optoelectronics and photonics: Principles & Practices, S O Kasap

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 634 MJ	Course Title: Rietveld Analysis
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Rietveld Analysis
2. To introduce important techniques that are necessary to build core concepts in Rietveld Analysis
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in XRD analysis.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Revision of crystallography, space group, .cif file, interaction of x-rays with matter, x-ray diffraction, structure factor, intensity calculations for different metallic and ceramic structures	
Module-2	Credits: 1	10 L , 5 T
	Introduction to Rietveld method, mathematical aspects of Rietvield refinement, Rietveld analysis of XRD patterns with ample examples	

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

1. understand different between bulk and surface of the materials.
2. acquire knowledge of surface process and their measurements
3. be prepared to undertake research where surface properties are important in deciding applications.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Fundamentals of Powder Diffraction and Structural Characterization of Materials by Vitalij K. Pecharsky, Peter Y. Zavalij (Springer Publications)
2. The Rietveld Method, edited by R. A. Young, (International Union of Crystallography Monographs on Crystallography, Oxford Science Publications)
3. Powder Diffraction: The Rietveld Method and the Two Stage Method to Determine and Refine Crystal Structures from Powder Diffraction Data by Georg Will (Springer Publications)
4. Rietveld Refinement Practical Powder Diffraction Pattern Analysis using TOPAS by Robert E. Dinnebier, Andreas Leineweber, John S.O. Evans (de Gruyter publications)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 635 MJ	Course Title: Radiation Biology
Credit: 02	

Course Objectives:
1. To strengthen the basic concepts biological effects of ionizing radiation.
2. To introduce important techniques that are necessary to build core concepts of radiation interaction of radiation with matter.
3. To develop problem-solving skills with appropriate regior that helps the student to improve their analytical ability to understand how radiation affects interacts different parts of human body, how it is quantified, how radiations are used for therapeutic applications

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Introduction to nuclear radiations, biological cells, tissues and organs, effect of radiation on cell, dna damage and repair, dna damage. dna repair, cellular effects of radiation, concept of cell death, cell survival curves, dose deposition characteristics: linear energy transfer. determination of relative biological effectiveness. Biological effects of acute exposure of radiation. Radiation quantities and units.	
Module-2	Credits: 1	10 L , 5 T
	Radiation effects and timescales, biological properties of ionizing radiation, types of ionizing radiation. molecular effects of radiation and their modifiers role of oxygen, bystander effects, the dose rate effect and the concept of repeat treatments , the basic linear–quadratic model, modification to the linear–quadratic model for radionuclide therapies, quantitative intercomparison of different treatment types, cellular recovery processes , consequence of radionuclide heterogeneity.	

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

1) have understood the fundamental concepts of nuclear radiations, cellular responses, DNA damage and repair, and dose deposition characteristics.
2) have acquired the problem-solving skills essential to enabling them to evaluate cellular survival, dose rate effects, and treatment strategies in various scenarios.
3) be prepared to undertake advanced topics possessing a solid foundation to explore specialized areas such as radionuclide therapies, radiation oncology, and further research in the broader domain of radiation science.

Instructional design: Lecture method, Tutorial method , Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Radioactive isotopes in biological research, Willaim R. Hendee (John Wiley and Sons)
2. Nuclear Medicine Physics, A handbook for teachers and students D.L. Bailey J.L. Humm A. Todd-Pokropek A. van Aswegen, Published by International Atomic Energy Agency, Viena 2014.
3. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 636 MJ	Course Title: Physics of Diagnostic Instruments
Credit: 02	

Course Objectives:
1. To strengthen the basic concepts of biopotential measurements and their origin along with imaging techniques
To introduce important techniques that are necessary to build core concepts of diagnostic instruments its electronics, signal processing and instrumentation.
2. To develop problem-solving skills with appropriate regior that helps the student to improve their analytical knowledge for various diagnostic instruments.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Biopotential Measurements Origin of biopotential, surface potential, volume conduction, skin impedance, bioelectrode tissue interfaces. Bio amplifiers and filters, signal acquisition and display, signal averaging. ECG, EEG, EP, ERG signal recording and time domain analysis, artifacts.	
Module-2	Credits: 1	10 L , 5 T
	Imaging techniques X-ray imaging and CT-Scan Properties of x-ray, x-ray production, x-ray therapy CAT scan Magnetic Resonance Imaging, Basic MMR components, Image reconstruction. Basics of positron emission tomography. Nuclear Medicine & Imaging System	

Learning Outcomes: Upon completion of the course, the student will be able to,
1) have understood the fundamental concepts of biopotential measurements, bioelectrode tissue interfaces, imaging modalities such as X-ray, CT-Scan, MRI, and positron emission tomography. They will also grasp the principles of signal acquisition, amplification, filtering, and display in biomedical instrumentation.

2) have acquired the problem-solving skills essential to enabling them to identify artifacts, perform time domain analysis of ECG, EEG, EP, ERG signals, and reconstruct medical images using MRI.

3) be prepared to undertake advanced topics in laying a solid foundation to explore specialized areas such as nuclear medicine, image processing, and further research in the broader domain of biomedical instrumentation and imaging.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Medical Instrumentation by J.G.Webster, Wiley
2. Introduction to Biomedical Equipment Technology by J.Carr and J.M. Brown Pearson Education Publication
3. Handbook of Biomedical Instrumentation by R. S. Khandpur, Tata McGraw Hill Pub. Co.

Course Information	
Year and Semester: M.Sc-II Semester-III	Major Elective
Course Code: PHY 637 MJ	Course Title: Methods of Computational Physics-I
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of numerical methods of solutions of differential equations, applications of random numbers, Monte Carlo methods in computational physics.
2. To introduce important techniques that are necessary to build core concepts in numerical methods of solutions of differential equations, applications of random numbers, Monte Carlo methods.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in differntial equations and Monte Carlo methods.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Numerical Methods : Solution of differential equations – initial value problems and boundary value problems. Runge-Kutta method and Numerov method.	
Module-2	Credits: 1	10 L , 5 T
	Random numbers. Uniform random number generators. Various tests for random numbers. Applications of random numbers – random walks, definite integrals by Monte Carlo method. Importance sampling Monte Carlo method.	

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

1. have understood the fundamental concepts of differntial equations and Monte Carlo methods.
2. have acquired the problem solving skills essential to differntial equations and Monte Carlo methods.
3. be prepared to undertake advanced topics in differntial equations and Monte Carlo methods in computational physics.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. An Introduction to Computer Simulation Methods, Gould, Tobochnik & Christian (Pearson).
2. A first course in Computational Physics, Paul L. DeVries (John Wiley & Sons).
3. Monte Carlo Methods, M. H. Kalos and P. A. Whitelock (John Wiley & Sons).
4. Understanding Molecular Simulation, Daan Frenkel and B. Smit (Academic Press).
5. Computational Physics, J. M. Thijssen (Cambridge University Press).
6. A Guide to Monte Carlo Simulations in Statistical Physics, Landau & Binder (Cambridge University Press).
7. Statistical Mechanics - Algorithms and Computations, Krauth (Oxford University Press).
8. Molecular Dynamics Simulation, Haile (Wiley Professional).

Course Information	
Year and Semester: M.Sc-II Semester-III	Major Elective
Course Code: PHY 638 MJ	Course Title: Methods of Computational Physics-II
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of computational physics.
2. To introduce important techniques that are necessary to build core concepts in computational physics.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in computational physics..

Course Contents

	Module 1 is compulsory. Among modules 2 to 7, any one should be offered depending on the instructor.	
Module-1	Credits: 1	10 L , 5 T
	Metropolis Monte Carlo integration. Application to evaluation of averages in equilibrium thermal systems (canonical ensemble). Ising model and Lenard Jones fluids.	
Module-2	Credits: 1	10 L , 5 T
	Classical Molecular Dynamics simulation. Applications to systems of few bodies and many bodies. Lennard-Jones fluids at thermal equilibrium.	
Module-3	Credits: 1	10 L , 5 T
	Hubbard model : Motivation, Representation of Sz basis, Generation of basis states, Construction of Hamiltonian. Exact diagonalization, Calculation of correlation function.	
Module-4	Credits: 1	10 L , 5 T
	Lanczos method and applications to tight binding Hamiltonians, Calculation of spectral properties.	
Module-5	Credits: 1	10 L , 5 T
	Numerical solution of Schrödinger equation for spherically symmetric potentials - scattering states, Calculation of phase shifts, Resonance.	
Module-6	Credits: 1	10 L , 5 T
	Quantum Monte Carlo, Variational Monte Carlo, Diffusion Monte Carlo.	
Module-7	Credits: 1	10 L , 5 T
	Electrons in Periodic Potential, Calculation of band structure using plane wave methods.	

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

1. have understood the fundamental concepts of computationa physics subject.
2. have acquired the problem solving skills essential to computationa physics subject.
3. be prepared to undertake advanced topics in computationa physics subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. An Introduction to Computer Simulation Methods, Gould, Tobochnik & Christian (Pearson).
2. A first course in Computational Physics, Paul L. DeVries (John Wiley & Sons).
3. Monte Carlo Methods, M. H. Kalos and P. A. Whitelock (John Wiley & Sons).
4. Understanding Molecular Simulation, Daan Frenkel and B. Smit (Academic Press).

5. Computational Physics, J. M. Thijssen (Cambridge University Press).
6. A Guide to Monte Carlo Simulations in Statistical Physics, Landau & Binder (Cambridge University Press).
7. Statistical Mechanics - Algorithms and Computations, Krauth (Oxford University Press).
8. Molecular Dynamics Simulation, Haile (Wiley Professional).

Course Information	
Year and Semester: M.Sc-II Semester-III	Major Elective
Course Code: PHY 639 MJ	Course Title: Special Topics in Quantum Mechanics
Credit: 02	

Course Objectives: This course gives a deeper look into quantum mechanics. Powerful techniques of group representation theory is used to study topic such as symmetries in quantum mechanics. The students will also be introduced to formal theory of quantum mechanical scattering.

Course Contents:

Module-1	Credits: 1	10 L , 5 T
	Symmetries in Quantum Mechanics: Conservation laws and degeneracies, rotations in quantum mechanics, SO(3) and SU(2) group and Euler rotations, general theory of addition of angular momenta, tensor operators. Discrete symmetries – Space inversion, intrinsic parity. Time reversal, anti-linear, anti-unitary operators. Some applications to atomic physics.	
Module-2	Credits: 1	10 L , 5 T
	Advanced topics in approximation methods: Details of WKB method. Applications of time dependent perturbation theory: Photoelectric effect, ionization of H-atom. Collision theory: Green's function and propagator, free particle propagator, application to scattering, scattering matrix, analytical properties of S-matrix and dispersion relations, scattering of identical particles.	

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

1. understand symmetries in quantum mechanics and its application to atomic physics
2. implement Green's function techniques to quantum mechanical scattering.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Modern Quantum Mechanics, J. J. Sakurai (Addison Wesley).
2. Quantum Mechanics, L. I. Schiff (McGraw-Hill).
3. Quantum Mechanics(Non-Relativistic Theory), L.D. Landau and E.M. Lifshitz (Elsevier).
4. Quantum Mechanics, Cohen-Tannaudji, Din, Laloe Vols. I & II (John Wiley).
5. Quantum Mechanics: Fundamentals, K. Gottfried and T-Mow Yan (Springer). Collision Theory, M.
6. L. Goldberger and K. M. Watson (Dover Publications).
7. Angular Momentum in Quantum Mechanics, A. R. Edmonds (Princeton University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 640 MJ	Course Title: Advanced Mathematical Physics
Credit: 02	

Course Objectives: This course is devoted to the study of differential equations and Sturm - Liouville systems and their applications to physics. Special functions which appear frequently in physics are studied. Throughout the course the emphasis is on the contour integrals and other techniques in complex analysis such as method of steepest decent.

Course Contents

Module-1	Credits: 2	20L , 10 T
	Principal value integrals and Dispersion relations, Evaluation of integrals involving multivalued functions, Contour integral representations for special functions, etc. Differential Equations: Differential operators, boundary conditions, adjoint and self-adjoint differential operators, Sturm-Liouville systems and orthogonal polynomials, Expansion in terms of eigenfunctions, Special functions as Complete orthogonal sets of functions, Infinite dimensional vector spaces Green's function: Green's function for second order ordinary differential equations and some applications	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. apply theory of contour integration to special functions and differential equations.
2. understand application of Sturm-Liouville theory to boundary value problems in physics
3. use Green's functions to solve partial differential equations.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Mathematics of Classical and Quantum Physics, Byron and Fuller (Dover).
2. Mathematics for Physicists, Dennery & Krzywicki (Dover).
3. Mathematical Physics, S. Hassani (Springer).
4. Complex variables, Ablowitz and Fokas (Cambridge Univ. Press).
5. Complex analysis, Ahlfors (Springer).
6. Mathematical Methods of Physics, Tulsi Dass and Sharma (University. Press).
7. Functions in Mathematical Physics, Smith & Spain (Van Nost. Reinhold).
8. Differential Equations With Applications, G. Simmons (Pearson Education)

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 641 MJ	Course Title: Quantum Many Body Theory
Credit: 02	

Course Objectives: This course teaches the student concept of second quantitation and its application to condensed matter systems.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Quantum Many body Theory: Harmonic oscillators and phonons, Second quantization for particles. Degenrate electron gas using second quantization	
Module-2	Credits: 1	10 L , 5 T
	The Hartree and Hartree-Fock approximation, dielectric theory and screening, Thomas Fermi theory, Lindhard theory, Friedel Oscillation, electron phonon interaction, effective electron phonon- resistivity of metals. Hubbard Model.	

Learning Outcomes: Upon completion of the course, the student will be able to understand second quantization, Fock spaces and its applications in Hubbard model.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Theory of Solids, C. Kittel (Wiley).
2. Solid State Physics, N.W. Ashcroft & N.D. Mermin (Holt, Reinhart and Winston).
3. Many-particle physics, G.D. Mahan (Plenum Press).
4. Quantum theory of many-particle systems, A.L. Fetter and J.D. Walecka (Dover).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 642 MJ	Course Title: Classical Field Theory
Credit: 02	

Course Contents

Module-1	Credits: 1	10L , 5T
	Continuous systems and fields: descrete to contunuous system, Eular-Lagrange equations for string, membrane. Lagrangian formulation of classical fields, symmatries and Noether theorem, Energy-momentum tensor Brief review of special relativity, 4-vectors and tensors action for relativistic free particle. Relativistic fields: Lagrnagian for Klein-Gordon field, symmetries and conserved charges, complex Klein-Gordon field theory, propagation, advanced and retarded Green's functions.	
Module-1	Credits: 1	10L , 5T
	Maxwell's field theory in covariant formulation, motion of charged particle in EM field, principle of minimal coupling , Maxwell's theory as a classical field theory, spacetime symmetries of Maxwell's theory, Energy-momentum tensor. Gauge invariance, principle of minimal coupling, classical scalar electrodynamics. Noether theorem for Gauge symmetries and its consequences. Hamiltoniam formulation of Maxwell's theory, brief discussion of Dirac contraint analysis, Gauge symmtries and constraints.	

Learning Outcomes:

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Classical theory of fields, L. D. Landau and E. M. Lifshitz Vol-2 (Elsevier).
2. Electrodynamics And Classical Theory Of Fields & Particles, A. Barut, Dover (1980).
3. Classical Mechanics, H. Goldstein, C. Poole, J. Safko, 3rd Ed, Addison Wesley (2000).
4. Classical Field Theory, F. Scheck, Springer (2011).
5. Classical Field Theory, H. Nastase, Cambridge University Press (2019).
6. Introduction to Classical Field Theory, C. Torre, lecture notes https://digitalcommons.usu.edu/lib_mono/3

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 643 MJ	Course Title: Relativistic Quantum Mechanics
Credit: 02	

Course Objectives: In this course students are introduced to quantum mechanics of relativistic particles. Course mainly focuses on solving relativistic wave equations such as Klein-Gordon equation and Dirac equation.

Course Contents

Module-1	Credits: 1	10L , 5 T
	Special theory of relativity: Einstein's Postulates, Lorentz Transformations, Relativistic Energy and Momentum. Relativistic Electrodynamics: Field strength tensor and its properties, Maxwell's equations in covariant formalism, Gauge transformations – coulomb and Lorentz gauge. Lorentz and Poincare group, Poincare group Generators, algebra, Representations of the Lorentz algebra: Scalar, Vector and Spinor representations, Weyl and Dirac spinors, Dirac Bilinear covariants.	
Module-1	Credits: 1	10L , 5 T
	Relativistic wave equations: Klein-Gordon and Dirac equation, Lorentz covariance of Dirac equation, Free particle solutions, Conserved norm, Positive and Negative energy solutions, Covariant normalization and completeness, Spin and helicity, Energy and spin projection operators, Construction of wave packets of positive and negative energy free particle solutions, Gordon decomposition of the vector current, Zitterbewegung and Klein paradox, relativistic Hydrogen atom.	

Learning Outcomes: Upon completion of the course, the student will be able to
1. learn how the relationship between special relativity and intrinsic spin.
2. how to solve Klein-Gordon equation with and without electromagnetic coupling.
3. solve Dirac equation the presence of electromagnetic field.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:
1. Relativistic Quantum Mechanics, J. Bjorken and S. Drell (McGrew-Hill).
2. Quantum Field Theory, F. Mandl and G. Shaw (J. Wiley & Sons).
3. Advanced Quantum mechanics, J. J. Sakurai (Addison-Wesley).
4. Quantum Field Theory, L. Ryder (Academic).
5. Quantum Field Theory, C. Itzykon and J. B. Zuber (McGraw-Hill).

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 644 MJ	Course Title: Group Theory in Physics
Credit: 02	

Course Objectives: This course is a brief introduction to group theory and its applications to physics. Fundamental concepts in representation theory and its role in atomic physics and relativistic physics is covered.

Course Contents

Module-1	Credits: 1	10L , 5T
	Basic definitions of groups and some simple examples, Group Representations, irreducible representations, Unitary representations, Schur's Lemmas. Simple applications of groups and representations.	
Module-2	Credits: 1	10L , 5T
	Continuous group: SO(3) and SU(2) groups their representations, appliations in quantum mechanics. Lorentz group and its representations	

Learning Outcomes: Upon completion of the course, the student will be able to understand group representation theory and its role in physical problems.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Group, Representations and Physics, H. F. Jones; CRC Press; 2 edition (January 1, 1998).
2. Group Theory in Physics, W. K. Tung ; World Scientific Publishing Company (1985).
3. Group Theory and Its Application to Physical Problems, M. Hamermesh; Dover Publications; Reprint edition (December 1, 1989).
4. Group Theory and Physics, S. Sternberg; Cambridge University Press (September 29, 1995).
5. Lie Groups, Lie Algebras, and Representations: An Elementary Introduction, B. Hall;

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 645 MJ	Course Title: Advanced Statistical Mechanics
Credit: 02	

Course Contents

Module-1	Credits: 1	10L , 5T
	Spin Models : Application of Transfer Matrix methods. Techniques of High Temperature and Low temperature expansion methods in Ising spin model.Langevin equation. Application to Brownian motion, Fluctuation-dissipation relations.	
Module-1	Credits: 1	10L , 5T
	Stochastic Processes, Markov processes. Continuous Markov processes. Master equations. Chapman-Kolmogorov equation, Kramer-Moyal expansion, forward and backward Kolmogorov equations. Discrete Markov processes. Master equation and its solutions. Fokker-Planck equation. Diffusion processes	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Physics – II: Nonequilibrium Statisrical Mechanics by M. Toda, R. Kubo, and N. Saito, Springer (1998).
2. Nonequilibrium Statistical Mechanics by R. Zwanzig, Oxford University Press (2001).
3. Elements of Nonequilibrium Statistical Mechanics by V. Balakrishnan, Springer (2021).
4. Statistical Mechanics of Particles by Mehran Kardar

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Elective
Course Code: PHY 646 MJ	Course Title: Density Functional Theory
Credit: 02	

Course Objectives:
1. To introduce students to the most widely used method to theoretically study interacting electrons.
2. To enable the students to understand the experimentally observed properties of materials at the fundamental level.

Course Contents

Module-1	Credits: 1	10L , 5T
Calculus of Variation Fundamentals of Density Functional Theory (DFT)	Functionals, Some simple variational problems, Variation of a Functional and necessary condition for an Extremum, Functional Derivative, Euler-Lagrange Equation. Hohenberg-Kohn Theorems and their proofs, Adiabatic approximation, Energy functional and variational equations, Self-consistent fields.	
Module-1I	Credits: 1	10L , 5T
Kohn-Sham Theory Exchange-Correlation Energy Functional Extension of DFT	Practical implementation of Density functional theory for a simulated non-interacting system. Approximations to E_{xc} : Local densty aproximation, Genralized gradient approximation and beyond, their advantages and limitations, Correlation energy, Exchange-correlation hole, Silf-interaction correction, Hellmann-Feynman theorem and Virial theorem. Introduction to DFT at non-zero temperatures and for excited states.	

Learning Outcomes: Upon completion of the course, the student will be able to
1. take up computational studies of materials at different length scales
2. read and understand reseach papers published for materials' properties using DFT.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Density Functional Theory of Atoms and Molecules by Robert G. Parr and Weitao Tang, Oxford University Press, NY, 1989, ISBN : 0-19-504279-4
2. Theory and Computational Methods by Jorge Kohanoff, Cambridge University Pree, UK, 2006, ISBN-13 : 978-0-521-81591-8, ISBN-10 : 0-521-81591-6
3. Lectures on Methods of Electronic Structure Calculations, Vijay Kumar, Ole K Anderson, Abhijit Mookerjee (Eds.), World Scientific, Singapore, 1994, ISBN : 981-02-1485-5

Course Information	
Year and Semester: M.Sc-II, Semester-III	
Course Code: PHY 600 RP	Course Title: Research Project-I
Credit: 04	

M.Sc-II (Semester-IV)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 651 MJP	Course Title: Advanced Physics Laboratory- II
Credit: 02	

Course Objectives:

1. To get trained to perform experiments in Physics.
2. To introduce important experimental techniques.
3. To Collect data and revise an experimental procedure iteratively
4. To develop experimental skills.

Course Contents

	List of experiments	
	Any five experiments (Not conducted in PHY-CP300) from the following List will be offered: 1. Study of Compton scattering. 2. Study of Rutherford scattering. 3. To investigate the characteristics of radiation emitted by bodies at elevated temperatures (Black Body Radiation) and determine the various constants. 4. Determination of lattice constant of given powder sample using X-ray Diffraction method. 5. Effect of Filter on X-ray Diffraction Pattern. 6. Gamma Ray Spectrometry: Understanding the three interactions of γ-rays with matter and determination of resolution of γ-ray spectrometer. 7. Determination of skin depth of aluminium and iron through the measurement of amplitude and phase changes of transmitted low frequency electromagnetic waves. 8. Investigation of propagation of electromagnetic wave through a transmission line and determination of propagation constant under boundary conditions. 9. Investigation of Electron Spin Resonance spectrum for the given DPPH sample and determination of Lande's "g" factor. 10. Investigation of thermoluminescence of X-ray irradiated KCl/KBr single crystal sample and determination of activation energy of thermoluminescence. 11. Determination of band gap of semiconductor from temperature dependence of resistivity using Four Probe Method. 12. Study of Hall Voltage as a function of probe current and magnetic field and determination of Hall Coefficient and carrier concentration in given sample.	

Learning Outcomes: Upon completion of the course, the student would

1. learn to formulate hypotheses and devise and perform experiments to test a hypothesis. as individuals and in a team.
2. have gained training in conducting experiments in Physics
3. learn to apply scientific methodologies for problem solving.
4. have learned important techniques in Experimental Physics
5. have developed skills in designing and conducting experiments in Physics

Instructional design:
1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

REFERENCES:

1. The Art of Experimental Physics, D. W. Freston, E. R. Dietz, 1991 (John Wiley).
2. Advanced Practical Physics for Students, Worsnop and Flint. (Asia Publishing House).
3. Modern Physics, Arthur Beiser (McGraw-Hill Inc).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 652 MJ	Course Title: Nuclear Physics
Credit: 04	

Course Objectives:

The aim of the course is to systematically enhance the basic understanding, knowledge, and concepts of the subject. To lay down a strong foundation for advanced studies in particle physics and beyond. Provoke innovative thinking.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	General properties of nuclei, Radioactive decay and Radiation detectors: Nuclear mass, mass defect, binding energy, nuclear radius, angular momentum, magnetic dipole moment and electric quadrupole moment. Basic theory of Alpha, Beta and Gamma-Rays decay. Radioactivity and units of radiation. Interactions of charged particles and gamma-rays with matter. Basic working principle of radiation detectors with details of proportional counter, NaI(Tl) and semiconductor detectors.	
Module-2	Credits: 1	10 L , 5 T
	Nature and properties of nuclear force. Deuteron problem, Electromagnetic, weak and hadronic interactions. Low energy n-p and n-n scattering, Phase shift and scattering cross section. Q-value and threshold energy of nuclear reactions. Neutron and charged particle induced nuclear reactions, cross section of a nuclear reaction. Compound nucleus formation, nuclear fission and fusion reactions.	
Module-3	Credits: 1	10 L , 5 T
	Liquid drop model and Empirical mass formula. Shell Model with details of Magic numbers, Nuclear Energy levels and their pplications. Collective Model. Nuclear fission and fusion reactions. Fissile and fissionable nuclei. Classification of nuclear reactors and electric power delivered.	
Module-4	Credits: 1	10 L , 5 T
	Classification of elementary particles, their masses, spin parity,and life-time. Additive quantum numbers such as strangeness, isospin, baryon number, hyper charge,etc. Classification of quarks, their masses and spins. Quark contents of particles. C.T.P invariances. Parity non conservation in weak interactions, etc. Gell-Mann-Nishijima formula.	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. General static and dynamical properties of nuclei
2. Basic quantum mechanical theory behind alpha, beta, and gamma decay.
3. About nuclear forces through simplest nuclei (deuteron) and through nucleon-nucleon scattering experiments.
4. Different models and theories to explain various properties governed by nuclei.
5. Nuclear radiation interaction with matters, different nuclear detectors, accelerators, and application of nuclear radiations.
6. Introduction to elementary particles and information on current research in the area.

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Concepts of Nuclear Physics, B.L. Cohen (Tata McGraw Hill).
2. Subatomic Physics, Frauenfelder and Henley (Prentice-Hall).
3. Nuclear Physics. Irving Kaplan (Addison-Wesley Publishing Company. Inc.).
4. Theoretical Nuclear Physics, John Markus Blatt and Victor Weisskopf (Dover Publication, Inc.).
5. Introductory Nuclear Physics, Kenneth S. Krane (Wiley India Pvt. Ltd.)
6. Modern Atomic and Nuclear Physics, Fujia Yang and J.H.Hamilton (McGraw Hill International Editions).
7. Atomic and Nuclear Physics, Shatendra Sharma (Pearson).
8. Nuclear Physics An Introduction, S. B. Patel (New Age International Limited).
9. Introduction to Nuclear Science and Technology, K. S. Ram and Y. R. Waghmare (A.H. wheeler & Co.Ltd).
10. Nuclei and Particles: In Introduction to nuclear and Sub-Atomic Physics, Emilo Segre (W.A. Benjamin Inc.).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 653 MJ	Course Title: Accelerator Physics-II
Credit: 04	

Course Objectives:
The aim of the course is to provide in depth knowledge and form a strong conceptual base of the subject. This course will lay down a strong foundation to understand the various basic elements and pre-requisites used in advanced nuclear environment and nuclear instruments.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Electric and magnetic lenses for focusing charged particles.Concept of weak and strong focusing in accelerators.Air-core magnetic lenses for focusing electrons.Measurement of charged particle beam profile. Measurement of electron and ion beam energies. Study of focusing properties of a pair of quadrupole lenses. High voltage pulse forming electronic systems for accelerator.	
Module-2	Credits: 1	10 L , 5 T
	Equation for describing trajectories of charged vparticles. Linear machine lattices, Hamiltonian formulation, linear machine imperfections, storage ring physics. Techniques for extraction of electron beam from the booster electron accelerator.	
Module-3	Credits: 1	10 L , 5 T
	Sources of particle beams, electron gun, ion sources. Techniques for producing pulsed charged particle beams.Basic working principle of pulsed transformers. Induction coil for measurement of pulsed current. Applications of accelerators with special emphasis on industrial and medical fields.	
Module-4	Credits: 1	10 L , 5 T
	Design of dipole, quadrupole magnets and its applications in beam optics. Structures of the R.F. cavities used in particle accelerators. Electric fields in the cavity. Mechanism of particle acceleration in a cavity. Range of frequencies in cavities used for electron and ion accelerations.	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. Origin of nuclear radiation, their properties and interaction with matter.
2. Different types of nuclear radiation detectors, their categories, basic working principle, constructions and measurement.
3. Transformation of deposited energy by nuclear radiation to measurable signal in electrical or other form. How they are collected and modified, the complete electronics circuits and units after the detector upto the human perceivable unit (like computer screen, counter, recorder etc) .
4. How to quantify the energy deposited by nuclear radiation within materials or human body. What are the standard calibrations and unit, how to the protection is done from nuclear radiations. What are the radiation limits for common person or radiation worker etc.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physics of cyclic accelerators, J. J. Livingood (D. Van Nostrand Co.)
2. Particle Accelerators, J. P. Blewett (McGraw-Hill Book Co.)
3. Transport of Charged Particle Beams, A. P. Banford (SPON, London).
4. The Microtron, S. P. Kapitza, V. N. Melekhin (Harwood Academic Publishers).
5. Recirculating, electron accelerators, Roy. E. Rand (Harwood Academic Publishers).
6. Particle accelerators and their uses, W. Scharf (Harwood Academic Publishers).
7. Theory of resonance linear accelerators, I. M. Kapchinsky (Harwood Academic Publishers).
8. Linear Accelerators, P. Lapostole and A. Septier (North Holland)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 653 MJP	Course Title: Accelerator Physics Laboratory-II
Credit: 02	

Course Objectives:
The aim of the lab course is to provide in hands on experience on various components of accelerators their usefulness, and application.

Course Contents

	List of Experiments	
	1. I/V characteristics of R.F. ion source. 2. Measurement of peak and average current of a beam delivered by an accelerator. 3. Measurement of radiation level around an accelerator using pocket doesimeter. 4. Characteristics of pulse modulator used in accelerators. 5. Study of quadrupole lenses OR similar experiments will be provided.	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. In depth-understanding different components of accelerators, how they are characterised and used.
2. Physics principle about each component through practical experience and measurements.
3. Basic knowledge about various Nuclear instrumentation.
4. Safety precaution while handling high voltages and using accelerator systems.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 654 MJ	Course Title: Advanced Quantum Mechanics-II
Credit: 04	

Course Objectives: This is an introductory course on Quantum Field theory. Quantum Field theory is one of the foundational fields in Theoretical High Energy physics. The aim of this course is to introduce the mathematical formalisms of quantum fields and their applications to relativistic scattering processes.

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Canonical quantization of free fields: Scalar field, Radiation field, Dirac field, Feynmann propagator. Discrete symmetries: parity, charge conjugation and time reversal. Interacting fields : Relativistically covariant Lagrangians for various interactions, coupling of Maxwell field with Dirac field, Gauge invariance, covariant derivative.	
Module-2	Credits: 1	20 L , 10 T
	Perturbation theory: Interaction picture, Time evolution and S-matrix, Decay rates and cross sections, Scalar and spinor electrodynamics, Elementary processes and Diagrams, Feynman rules for diagrams. Cross section and Decay rate calculations: Applications to elementary processes such as Mott scattering, Bhabha scattering, pair annihilation, Compton effect, etc. Radiative corrections: LSZ reduction Electron propagator, vertex function, one-loop renormalization, Lamb shift, self energy. Renormalization, regularization and power counting.	

Learning Outcomes: Upon completion of the course, the student will be able to undertand the quantization of free fields, the quantization of interacting field theories such as QED and Scalar electrodynamics. After doing this course students will be prepared to for advanced courses such as Quantum Chromodynamics , string theory.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Relativistic Quantum Mechanics, J. Bjorken and S. Drell (McGrew-Hill).
2. Quantum Field Theory, F. Mandl and G. Shaw (J. Wiley & Sons).
3. Advanced Quantum mechanics, J. J. Sakurai (Addison-Wesley).
4. Relativistic Quantum Field Theory, J. Bjorken and S. Drell (McGraw-Hill).
5. An Introduction to Relativistic Quantum Field Theory, S. S. Schweber (Row, Peterson).
6. Quantum Electrodynamics, R. P. Feynman (Benjamin Cummings).
7. Quantum Field Theory, L. Ryder (Academic Press).
8. Quantum Field Theory, C. Itzykon and J. B. Zuber (McGraw-Hill).
9. The Quantum Theory of Fields, S. Weinberg, Vol. I (Cambridge).
10. An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder (Addison Wesley).
11. Quantum Electrodynamics Ed. J. Schwinger (McGraw-Hill).
12. A Modern Introduction to Quantum Field Theory, M. Maggiore (Oxford University Press).
13. Field Theory: A Modern Primer, Frontiers in Physics, P. Ramond (Westview press).
14. Group theory in Physics, Wu Ki Tung (World Scientific).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 654 MJP	Course Title: Advanced Quantum Mechanics Laboratory - II
Credit: 02	

Course Contents

	List of Experiments	
	1. Reading assignments/problems on unitary representations of Poincare group 2. Reading assignments/problems on Many-body theory 3. Reading assignments/problems on path integral methods 4. Reading assignments/problems on Casimir effect 5. Any other reading assignments/problems based on PHY-CT412	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 655 MJ	Course Title: Astronomy and Astrophysics-II
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Overview of Special Relativity, spacetime diagrams, Lorentz metric, light cones, electrodynamics in 4 dimensional language. Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of spacetime. Geometrical Framework Of General Relativity: Curved spaces, tensor algebra, metric, affine connection, covariant derivatives, physics in curved spacetime, curvature – Riemann tensor, Bianchi identities, action principle, Einstein's field equations, energy momentum tensors, energy-momentum tensor for a perfect fluid, connection with Newton's theory.	
Module-2	Credits: 1	10 L , 5 T
	Solutions To Einstein's Equations And Their Properties: Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles. The three classical tests of GR, black holes, event horizon – one way membranes, gravitational waves.	
Module-3		10 L , 5 T
	Cosmological Models: Cosmological principle, Robertson-Walker metric, cosmological redshift, Hubble's law, observable quantities – luminosity and angular diameter distances. Dynamics of Friedmann- Robertson-Walker models: Solutions of Einstein's equations for closed, open, and flat universes.	
Module-4		10 L , 5 T
	Physical Cosmology And The Early Universe: Thermal history of the universe: Temperature-redshift relation, distribution functions in the early universe – relativistic and non-relativistic limits. Decoupling of neutrinos and the relic neutrino background – nucleosynthesis – decoupling of matter and radiation; Cosmic microwave background radiation – inflation – origin and growth of density perturbations.	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. General Relativity and Cosmology, J. V. Narlikar, Delhi: Macmillan Company of India Ltd.
2 .Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford : Pergamon Press.
3 .First Course in General Relativity, B. F. Schutz, Cambridge University Press.
4 .Introduction to Cosmology, J. V. Narlikar, Cambridge University Press.
5 .Structure Formation in the Universe. T. Padmanabhan, Cambridge University Press.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 655 MJP	Course Title: Astronomy and Astrophysics Laboratory-II
Credit: 02	

Course Contents

	List of Experiments	
	List of M.Sc. A & A Experiments : : 1. To estimate the temperature of an artificial star by photometry 2. To study the characteristics of a CCD camera 3. To study the solar limb darkening effect 4. To estimate the relative magnitudes of a group of stars by a CCD camera 5. To study the atmospheric extinction for different colours 6. Differential photometry of a programme star w. r. t. a standard star 7. To study the effective temperature of stars by B-V photometry 8. To estimate the night sky brightness with a photometer 9. Faraday Rotation effect in amorphous glass and crystalline media 10. Beam-pattern of various antenna 11. Muon Physics 12. 21-cm spin-flip line of neutral hydrogen 13. Beam pattern and pointing of a parabolic dish antenna [Out of these there will be 5+5 experiments selected per semester (will have at least 2 Radio and 2 Optical experiments)] Lectures associated with the experiments will be given on a number of topics including: Time and Coordinates; Telescopes; Atmospheric effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry	

REFERENCES:

1. Telescopes and Techniques, C.R.Kitchin, Springer.
2. Observational Astrophysics, R.C. Smith, Cambridge University Press.
3. Detection of Light: from the Ultraviolet to the Submillimetre, G. H. Rieke, Cambridge University Press.
4. Astronomical Observations, G. Walker, Cambridge University Press
5. Astronomical Photometry, A.A. Henden & R.H. Kaitchuk, Willmann-Bell.
6. Electronic Imaging in Astronomy, I.S. McLean, Wiley-Praxis.
7. An introduction to radio astronomy, B. F. Burke & Francis Graham-Smith, Cambridge University Press.
8. Radio Astronomy, John D. Kraus, Cygnus-Quasar Books.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 656 MJ	Course Title: Bioelectronics -II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts in the field of bio-signals. Biological signals are space, time, or space-time records of a biological event such as a beating heart or a contracting muscle. The electrical, chemical, and mechanical activity that occurs during this biological event often produces signals that can be measured and analysed using suitable instruments.
2. To introduce important techniques that are necessary to build core concepts in Bioelectronics with the amphesis on interface of the electronics with the various bio-signals.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in understanding and analyse the bio-signals.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basics of Biosignal Analysis Continuous discrete signals, classification of biosignals, random processes and random signal characterization (statistical averages, probability distribution functions Gaussian process) Sampling, Aliasing Quantization, D to A converters, A to D converters, Laboratory interface, programmed data transfer, interrupt driven data transfer, Direct memory access data transfer continuous sampling to disc, selection of lab. Interface interfacing micro computers/PC to standard biomedical instruments.	
Module-2	Credits: 1	10 L , 5 T
	Frequency Domain analysis, representation and properties of FT (convolution theorem, FT of periodic, periodic signals) DET, FFT, power spectral density function auto correlation, Cross- correlation power spectral density function.	
Module-3	Credits: 1	10 L , 5 T
	Special techniques for biosignal analysis, Heart rate variability (HRV), Arrthymia analyzer, Power spectra of EEG, EMG, signals, Averaging of Evoked potential, Real time system for ECG & EMG with DSP hardware, Patient monitoring system,Neurophotonics system.	
Module-4	Credits: 1	10 L , 5 T
	Linear systems: Modeling of physiological systems, system identification, transfer function sensory receptors. Current techniques in biosignal analysis, Neural networks application for biosignal classification, multiresolution analysis of biosignal using wavelet trasform.	

Learning Outcomes: Upon completion of the course, the student will be able to, measure and analyse electrical bio-signals.
1. have understood the fundamental concepts of bio-signals their origin and control using external stimulus.
2. have acquired the problem-solving skills essential to bio-signals analysis.
3. be prepared to undertake advanced topics in bio-signals subject.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Principles of Neural Science-Kandel & Schwartz (Elsevier, North Holland).
2. Op-Amps & linear Integrated Circuits-Gaikwad, (EEE Prentice Hall).
3. Biomedical Instrumentation, (EEE Prentice Hall).
4. Introduction to Biomedical Equipment Technology-Carr & Brown (John Wiley & Sons).
5. Design of Microcomputer based medical Inst, Webster & Tompkins (Prentice-Hall).
6. Encyclopedia of Biomed, Inst. Ed. Webster (Wiley).
7. Digital Principles and Applications, Malvino & Leach (Tata McGraw-Hill).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 656 MJP	Course Title: Bioelectronics Laboratory-II
Credit: 02	

	List of experiments	
	1. Fourier analysis of biopotentials. 2. Nerve conduction velocity measurement. 3. R-R interval analysis of ECG under various conditions. 4. Spike train analysis (are, entropy, autocorrelation, CNSS-correlation). 5. Signal conversion (ADC) & sample & hold circuit. 6. Digital filter design-finite impulse response & IIR filters and similar experiments in digital Signal processing. (Any Five per Semester)	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 657 MJ	Course Title: Biophysics -II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts in the field of biophysics.
2. To introduce important techniques that are necessary to build core concepts in Biophysics with the emphasis on cells and cell mechanics.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in understanding and analyse the biophysics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Bioenergetics: Reversible & Irreversible Thermodynamics, Free energy, Helmoltz free energy, Gibbs free energy, Redox potentials, Photosynthetic pathways (Photosystem I & II), Thermodynamics in photosynthesis, thermoluminescence & glow curves in photosynthesis Energy consumption, Respiration, ATP synthesis, Chemoenergetics (oxidative phosphorylation)	
Module-2	Credits: 1	10 L , 5 T
	Neurobiophysics: A)Biophysics of Mechanoreception- structure of ear, Auditory transduction, frequency analysis Biophysics of photoreception – structure of eye, photoreceptors, visual perception, visual pathways- parvo & magnocellular, Receptive field, responces from photoreceptors, LGN & visual cortex, simple, complex, Hypercomplex cells, Blob cells B) Origin of EEG and its significance, Auditory, Visual and Somatosensory evoked potentials C) Memory & Learning by Neurons, Brain areas & Cognitive functions	
Module-3	Credit:1	10 L , 5 T
	Techniques and Methods in Biophysics Centrifugation, chromatography & electrophoresis, Absorption spectroscopy, IR & Raman spectroscopy for biomolecules, NMR spectroscopy for proteins Scanning Tunnelling Microscopy, Atomic force microscopy for biomolecules & cells Optical Tweezers- basics & application for piconewton force measurement Patch clamping technique	
Module-4	Credits: 1	10 L , 5 T
	Radiation Biophysics: Ionizing radiation, Interaction of radiation with cells & biological systems, measurement of radiation (Dosimetry), radioactive isotopes and medical applications, Biological effects of radiation, radiation protection & therapy Laser radiation & cell-tissue interactions Lasers and phototherapy	

Learning Outcomes: Upon completion of the course, the student will be able to, measure and analyse biophysics aspects.

1. have understood the fundamental concepts of biophysics.
2. have acquired the problem-solving skills essential to biophysics.
3. be prepared to undertake advanced topics in bio-physics.

Instructional design:

1. Lecture method

2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Biophysics, P.Narayanan (Bhalani Publication)
2. From Neurons To Brain, Stephen W. Kuffler & John G.Micholls (Sinaeur Associates Inc Publishers)
3. Methods in Modern Biophysics, Bengt Nolhrg (Springer)
4. Clinical Biophysics: Principle & Techniques, P.Narayanan (Bhalani Publishing House)
5. Biological Physics, Phillip Melion (W.H. Freeman and Company)
6. Radiation Biophysics, Edward L.Alpen (Prenhce Hall Series)
7. Modelling Biological System, James W. Haefner (Springer)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 657 MJP	Course Title: Biophysics Laboratory-II
Credit: 02	

	List of experiments	
	1) Recording and analysis of Visual Evoked Potential 2) Mechanotrasnconduction in insect leg & recording of action potentials 3) Fourier analysis of biopotentials 4) Chlorophyll absorption and fluorescence spectra 5) Protein structure and Sequence alignment using software tools	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 658 MJ	Course Title: Chemical Physics-II
Credit: 04	

Course Objectives:
1. To strengthen the basic concepts of Hybridization, Electronic Spectra
2. To introduce important techniques that are necessary to build core concepts in Ligand Fields.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Chemical Physics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Hybridization schemes for sigma and pi bonding hybrid orbitals as LCAO, MO theory for ABn type molecules, the relationship of the molecular orbital and the hybridization treatments, molecular orbitals for regular octahedral and tetrahedral molecules.	
Module-2	Credits: 1	10 L , 5 T
	Electronic spectra of complex ions: selection rules and bandwidths, band intensities, spin- orbit coupling departure form cubic symmetry (Jahn-Taller effect), band shapes spectra in solids, spectra of aqueous solution of metals ions, band assignments, spectra of spin free transition metal ligand octahedral complexes, spectra of spin paired transition metal ligand octahedral complexes, spectra of distorted octahedral complexes, spectra of tetrahedral complexes, the spectro-chemical and nephelauxetic series, charge transfer spectra.	
Module-3	Credits: 1	10 L , 5 T
	Magnetic properties of complex ions: magnetic susceptibility, the magnetic properties of free ions, quenching of orbital angular momentum by ligand field, the magnetic properties of A, E and T terms, the magnetic of complexes with A and E ground terms and T ground terms. Experimental methods for magnetic measurements (Susceptibility, Magnetization, ESR, NMR in brief).	
Module-4	Credits: 1	10 L , 5 T
	Molecular vibrations: Group theoretical analysis of various modes of vibration of molecules, IR and Raman active modes, F and G matrices (introduction only). R and Raman spectroscopy): Experimental details, Analysis of IR and Raman Spectra of simple molecules. Discussion of Raman Spectra of novel materials such as Graphene, Carbon nanotubes etc.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understood the fundamental concepts of Chemical Physics II
2. have acquired the problem-solving skills essential to Chemical Physics II

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Chemical applications of group theory, F. A. Cotton (Wiley Eastern Ltd. New Delhi, 1989.)
2. Introduction to Ligand fields, B.N. Figgis (Wiley Eastern Ltd. New Delhi, 1976).
3. Magnetism and Transition metal complexes, F. E. Mabbs, D. J. Machin (Chapman and Hall, London, 1973).
4. Introduction to Ligand field theory, C. J, Ballhausen (McGraw Hill, New York, 1962).
5. Symmetry and Spectroscopy, D. C. Harris and M. D. Berrtolucci (Oxford University Press, Oxford, 1978)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 658 MJP	Course Title: Chemical Physics Laboratory-II
Credit: 02	

Course Objectives:
1. To get trained to perform experiments in Chemical Physics.
2. To introduce important experimental techniques required in Chemical Physics.
3. To Collect data and revise an experimental procedure iteratively

Course Contents

	List of experiments	
	The proposed list of the experiments for Chemical Physics Laboratory II 1. To obtain electronic spectra of transition metal octahedral complexes in water and obtain 10 Dq. And B for the metal ions (equivalent to 2 expts.) 2. To obtain electronic spectra of transition metal tetrahedral complexes and obtain 10 Dq and B for the metal ions (equivalent to 2 expts). 3. To obtain vibrational spectra of Carbon Tetrachloride (vapours) and ammonia (gas) and study the vibrational modes. 4. To obtain Raman Spectra of some novel materials such as Graphene and interpret the results.	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments in Chemical Physics
2. learn to apply scientific methodologies for problem solving.
3. have learned important techniques in Chemical Physics

Instructional design:
1. Lecture method
2. Laboratory sessions
3. Seminars

Evaluation Strategies:
1. Assessment of experimental skills and outcomes
2. Viva-Voce

REFERENCES:

1. Chemical applications of group theory, F. A. Cotton (Wiley Eastern Ltd. New Delhi, 1989.)
2. Introduction to Ligand fields, B.N. Figgis (Wiley Eastern Ltd. New Delhi, 1976).
3. Magnetism and Transition metal complexes, F. E. Mabbs, D. J. Machin (Chapman and Hall, London, 1973).
4. Introduction to Ligand field theory, C. J, Ballhausen (McGraw Hill, New York, 1962).
5. Symmetry and Spectroscopy, D. C. Harris and M. D. Berrtolucci (Oxford University Press, Oxford, 1978)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 659 MJ	Course Title: Condensed Matter Physics-II
Credit: 04	

Quantization of lattice vibrations, Second Quantization methods for many-body system and its use for studying degenerate electron gas, electron-phonon interaction and BCS theory of superconductivty, Hartree- and Hartree-Fock theory, dielectric theory and screening, London and Ginzburg-Landau theory of superconductivity will be discussed in detail.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Harmonic oscillators and phonons, Second quantization for particles. Electron Gas: the Hartree-Fock approximation, dielectric theory and screening, Thomas Fermi theory, Lindhard theory, Friedel Oscillation, electron phonon interaction, effective electron phonon- resistivity of metals. Density functional theory: Hohenberg-Kohn theorem, Kohn-Sham theory, Local density approximation.	
Module-2	Credits: 1	10 L , 5 T
	Superconductivity: Phenomenology, London theory, Ginzburg-Landau theory, BCS theory, high temperature superconductor. Superfluidity: Phenomenology, two fluid model, Landau's theory, superfluid velocity, superfluid flow, excited states.	

Learning Outcomes: A student of this course is expected to learn use of quantum many-body theory techniques to study advanced quantum theory of solids and also several mean-field theories of solids.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Superconducitivity of Metals and Alloys, P.de Gennes (Benjamin).
2. Superfluidity, Vol. 1 & 2, F. London (Dover).
3. Density Functional Theory, R.G. Par and W.T.Yang (Oxford).
4. Quantum Theory of Solids, C. Kittel (Wiley).
5. Solid State Physics, N.W. Ashcroft & N.D. Mermin (Holt, Reinhart and Winston).
6. Many-particle physics, G.D. Mahan (Plenum Press).
7. Quantum theory of many-particle systems, A.L. Fetter and J.D. Walecka (Dover).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 659 MJP	Course Title: Condensed Matter Physics Laboratory-II
Credit: 02	

Course Contents

	List of Experiments	
	Five numerical experiments based on the Hubbard Model. The numerical method to be followed is either Quantum Monte Carlo method or Numerical Exact Diagonalization method. OR Excercises/Mini projects based on the Condensed Matter – II course.	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 660 MJ	Course Title: Energy Studies-II
Credit: 04	

Course Objectives: This course aims to introduce the fundamentals of renewable energy sources and awareness about the use of renewable energy to the students. The primary objectives of the study are,

1. Acquire a comprehensive understanding of different renewable energy sources, including wind, hydrogen, ocean, and bioenergy.
2. Familiarize themselves with the technological aspects of renewable energy systems and their applications in practical scenarios.
3. Analyze the advantages, limitations, and sustainability aspects of each renewable energy source.
4. Gain insights into the integration of renewable energy into the existing energy infrastructure and its role in achieving global energy sustainability goals.
5. Develop critical thinking and problem-solving skills to address real-world challenges in the renewable energy sector.

Course Contents

Module-1	Credits :1	10L, 5T
	1. Introduction to Wind Energy - Global energy scenario and the role of renewable energy sources. - Wind energy's contribution to the sustainable energy landscape. - Advantages and challenges of harnessing wind energy. - Wind resource assessment and site selection for wind farms. 2. Wind Turbine Technology - Basics of wind turbine operation and components. - Types of wind turbines (horizontal axis, vertical axis) and their applications. - Aerodynamics of wind turbine blades and efficiency optimization. - Wind turbine control systems and grid integration. 3. Wind Energy Conversion Systems - Overview of wind energy conversion systems. - Direct mechanical energy conversion (windmills and water pumping). - Indirect electrical energy conversion using generators. - Power electronics and grid-connected wind farms. 4. Wind Energy Applications - Onshore and offshore wind energy projects. - Small-scale wind turbines for residential and remote areas. - Wind energy in rural electrification and community-based projects. - Wind energy policies, incentives, and market trends.	
Module-2	Credits :1	10L, 5T
	1. Introduction to Hydrogen Energy - Properties of hydrogen as an energy carrier. - Hydrogen production methods (steam methane reforming, electrolysis, biomass). - Environmental impact and sustainability of hydrogen production. 2. Fuel Cell Technology - Fundamentals of fuel cell operation and types (PEMFC, SOFC, AFC, etc.). - Electrochemical reactions in fuel cells and efficiency considerations.	

	- Fuel cell components and stack design. - Applications of fuel cells in stationary and transportation sectors. 3. Hydrogen Storage and Infrastructure - Methods of hydrogen storage (compressed gas, liquid hydrogen, metal hydrides). - Hydrogen infrastructure development and challenges. - Hydrogen safety and regulations. 4. Integration of Hydrogen in Energy Systems - Role of hydrogen in energy storage and grid balancing. - Hybrid energy systems with hydrogen integration. - Hydrogen as a means of decarbonizing various sectors.	
Module-3	Credits :1	10L, 5T
	1. Introduction to Ocean Energy - Overview of ocean energy resources (tidal, wave, ocean thermal, and current). - Global potential and significance of ocean energy. - Environmental impacts and sustainability considerations. 2. Tidal and Wave Energy Conversion - Tidal energy generation methods (barrages, tidal stream turbines, tidal lagoons). - Wave energy conversion technologies (point absorbers, oscillating water columns, etc.). - Challenges and advancements in tidal and wave energy projects. 3. Ocean Thermal Energy Conversion (OTEC) - Principles of OTEC and open/closed cycle systems. - Utilizing temperature gradients for power generation. - OTEC applications and potential in tropical regions. 4. Ocean Energy Integration and Future Trends - Grid integration of ocean energy systems. - Emerging technologies and research in ocean energy. - Policy and regulatory aspects of ocean energy projects.	
Module-4	Credits :1	10L, 5T
	1. Introduction to Bio Energy - Overview of biomass resources (agricultural residues, forestry waste, organic matter). - Bioenergy conversion pathways (thermal, biochemical, and biofuels). - Environmental impacts and sustainability considerations. 2. Biomass-to-Energy Conversion Technologies - Biomass combustion for heat and power generation. - Anaerobic digestion and biogas production. - Bioethanol and biodiesel production processes. 3. Bioenergy Applications - Use of biogas for electricity generation and cooking. - Biofuels in transportation and their role in decarbonization. - Biomass co-firing in conventional power plants.	

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

1. Understand renewable and non-renewable sources of energy.

2. Basics of heat transfer and energy storage systems.

3. Apply the concept and use of knowledge of the renewable energy sources course to real-life problems.

4. Understanding the Physics of renewable energy sources will create a scientific temperament.

5. Students will have hand on experience in theory based on solar conversion systems and their applications, solar photovoltaics, solar thermal energy, geothermal energy, and emerging trends in renewable energy sources.

Instructional design: 1. Lecture method
2. Tutorial method
3. Seminar/s on renewable energy project case studies

Evaluation Strategies 1. Descriptive written examinations
2. Assignments
3. Seminars, Orals, and Viva

Reference Books:

1) Climatological and Solar Data for India, Seshadri (Sarita Prakashan, 1969).

2) Solar Energy Utilization: G. D. Rai (Khanna Publishers, 1996).

3) Energy Technology: S. Rao and B. B. Parulekar (Khanna Publishers, 1995).

4) Terrestrial Solar Photovoltaics: Tapan Bhattacharya (Namsa Publication House, New Delhi, 1998).

5) Solar Cells-Operating Principles, Technology and System Applications, Martin A.Green (Prentice Inc., U.S.A.).

6) Solar Thermal Engineering: J. A. Duffie (Academic Press).

7) Renewable Energy Sources and Conversion Technology, N. K. Bansal, M. Kleeman and S. N. Srinivas (Tata Energy Research Institute, New Delhi, 1996).

8) Fundamentals of Solar Cells, F. A. Faherenbruch and R. H. Bube (Academic Priess).

9) Biomass Energy systems, Venkata Ramala and S. N. Srinivas (Tata Energy Research Institue, New Delhi, 1996).

10) Thin Film Solar Cells, K. L. Chopra and S. R. Das (Plenum Press, 1983).

11) Solar Hydrogen Energy Systems, T. Ohta (Pergamon Press, 1979).

12) Hydrogen Technology for Energy, D. A. Maths (Noyes Data Corp.,1976).

13) Handbook-Batteries and Fuel Cell, Linden (McGraw Hill, 1984).

14) Wind Energy Conversion Systems, L. L. Freris (Prentice Hall, 1990).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 660 MJP	Course Title: Energy Studies Laboratory-II
Credit: 02	

Course Contents

	List of experiments	
	1. Determination of calorific value of wood/cow dung using bomb calorimeter. 2. Performance evaluation of solar still. 3. Performance evaluation of flat plate collector. 4. Performance evaluation of evacuated tube collector. 5. Performance evaluation of box type solar cooker. 6. Performance evaluation of parabolidal type solar cooker. 7. To measure the intensity of solar radiation using Pyranometer and solar intensity meter (Suryamapi) and to estimation of standard deviation. 8. Study of domestic/industry electricity bill	

Evaluation Strategies:

1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 661 MJ	Course title: General Relativity and Black Holes-II
Credit: 04	

Course Objectives: In this course consists of advanced concepts in general relativity. The emphasis is given to detailed study of black holes. Student is also introduced to gravitational waves.

Course Contents

Module-1	Credits: 1	10 L , 5T
	Linearised Gravity and Gravitational Waves: linearised Einstein equations, gauge invariance and coordinate choices, gravitational wave solutions, production of gravitational waves, energy loss due to gravitational radiation, detection of gravitational waves.	
Module-2	Credits: 2	20 L , 10T
	Other Black holes solutions: Kerr-Newman family of 4-dimensional black holes, black holes in Einstein-Maxwell theory – Reissner-Nordstrom solution. Mass, Charge, and Spin, Komar integrals. Horizons: Killing Horizons, event horizons of stationary black holes, surface gravity, null congruences, Vaidya metrics: trapped surfaces, apparent horizon, horizons in the collapsing thin light shell geometry, horizons in Oppenheimer-Snyder collapse	
Module-3	Credits: 1	10 L , 5 T
	Anti-de Sitter Spaces: Global (and Static) coordinates, conformal coordinates, conformal boundary, isotropic (spatially conformally flat) coordinates, de sitter slicing coordinates, anti-de sitter slicing coordinates; Black holes in AdS space: BTZ solution and its properties	

Learning Outcomes: Upon completion of the course, the student will

1. have detailed understanding of black holes
2. have acquired exposure to gravitational waves
3. be able to understand Anti de-Sitter black holes.
4. be able to dive into research areas related to gauge/gravity duality, string theory and cosmology

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Landau and Lifshitz, Classical Theory of Fields, Vol-2, Elsevier .
2. R. Wald, General Relativity (Chicago, 1984).
2. C. Misner, K. Thome and l Wheeler, Gravitation (Freeman, 1973).
3. S. Weinberg, Gravitation and Cosmology (Wiley, 1972).
4. T. Padmanabhan, Gravitation: Foundations and Frontiers (Cambridge 2010)
5. S. Carroll, Spacetimes and Geometry (Addison-Wesley, 2004)
6. S. Chandrasekhar, Mathematical theory of Black holes (Clarendon press 1983).
7. J.B. Hartle, Gravity: An Introduction to Einstein's General Relativity (Addison- Wesley, 2002).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 661 MJP	Course Title: General Relativity and Black Holes Laboratory-II
Credit: 02	

Course Contents

	List of Experiments	
	1. Reading assignments/problems/mini project on black holes 2. Reading assignments/problems/mini project on Penrose diagrams 3. Reading assignments/problems/mini project on AdS spaces 4. Reading assignments/problems/mini project on Linearised Gravity 5. Computational problems, MATHEMATICA programming in general relativity	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 662 MJ	Course Title: LASER-II
Credit: 04	

Course Objectives:

1. To learn the basic concepts of LASER.
2. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability related to LASER.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Optically pumped laser systems:- Optical sources, projection geometries, power supply Ruby laser, Nd: YAG laser, Nd:glass Laser Amplifiers for these lasers, their characteristics	
Module-2	Credits: 1	10 L , 5 T
	Q-switches-pulse reflection mode- Multiple-pulsing in slow Q-switches. Pulse transmission mode Q-switching- Mode locking-active and passive techniques Passive mode locking using dye cell, Distributed Feedback Lasers (and its importance for short pulse generation) semiconductor lasers, colour center laser.	
Module-3	Credits: 1	10 L , 5 T
	Non-linear optics: interaction of radiation with matter, optical susceptibility, propagation of E-M radiation in a medium/non- linear medium, S.H. generation, T.H. generation, wave mixing optical parametric oscillation, non-linear materials.	
Module-4	Credits: 1	10 L , 5 T
	Laser applications: (i) Holography, (ii) Optical communications / optical fiber (iii) Laser spectroscopy (iv) Material processing, welding cutting etc. (v) Medical applications, (vi) Doppler free two photon absorption, (viii) Isotope separation.	

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

1. have understood the fundamentals of LASER
2. have acquired the problem-solving skills essential to LASER

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Laser in Industry, by S.S. Charschan, (Vol Nostrand, 1972).
2. Solid State Laser Engineering, by Walter Koechner, (Springer-Verlag, 1976).
3. Applied non-linear optics, by Fzernik and J. Midwinte, (John Wiley, 1973).
4. Laser Handbook, Vol.1-4, edt. By F.T. Arechi, E.O. Schul Dobois, (North Holland, 1973).
5. Industrial Application of lasers, by John F. Ready (Elsevier Inc.)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 662 MJP	Course Title: LASER Laboratory-II
Credit: 02	

Course Objectives:
1. To get trained to perform experiments using LASER.
2. To introduce important experimental techniques related to LASER.

Course Contents

	List of experiments	
	The proposed list of the experiments for Chemical Physics Laboratory I 1. Relative intensity in different diffraction orders. 2. Estimation of band gap of ZnO by UV-Visible spectroscopy 3. Study of Relaxation oscillation in solid state lasers 4. Study of oscillator and amplifier systems of Nd: YAG laser, 5. Estimation of gain factor 6. To study magneto-optic rotation and magneto-optic modulation	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments using LASER
2. learn to apply scientific methodologies for problem solving.

Instructional design:
1. Lecture method
2. Laboratory sessions
3. Seminars

Evaluation Strategies:
1. Assessment of experimental skills and outcomes
2. Viva-Voce

References:

1. Laser in Industry, by S.S. Charschan, (Vol Nostrand, 1972).
2. Solid State Laser Engineering, by Walter Koechner, (Springer-Verlag, 1976).
3. Applied non-linear optics, by Fzernik and J. Midwinte, (John Wiley, 1973).
4. Laser Handbook, Vol.1-4, edt. By F.T. Arechi, E.O. Schul Dobois, (North Holland, 1973).
5. Industrial Application of lasers, by John F. Ready (Elsevier Inc.)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 663 MJ	Course Title: Materials Science -II
Credit: 04	

Course Objectives:

1. To strengthen the understanding and measurements of materials properties of Materials Science
2. To synthesize materials of desired properties

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Mechanical response of Materials: Elasticity, model of elastic response, inelasticity, viscoelasticity, stress-strain curves, concept of various mechanical properties such as Young modulus, shear modulus, shear strength yield strength, hardness, toughness, ductility, toughness, brittleness, stiffness, Frenkel model, Peierls-Nabarro relation, Plastic deformation, importance of dislocation movements, sessile dislocations, relation of slip process and crystal structures, Creep, Fatigue in materials, Fracture, Strengthening of materials.	
Module-2	Credits: 1	10 L , 5 T
	Electrical properties and its measurements: Metals - Electrical resistivity of metals and commercial alloys, their applications. Semiconductors - Electrical conductivity of intrinsic and extrinsic semiconductors, temperature and charge carrier concentration dependence, practical aspects of doping in semiconductors, electrical conduction in ionic materials, electrical properties of polymers. Dielectric materials - Peizoelectricc, Pyroelectric and Ferroelectric materials their characteristics and applications (examples illustrating the occurrence of Pyro/Piezo/Ferro-electric properties).	
Module-3	Credits: 1	10 L , 5 T
	Magnetic and optical properties and their measurements: Examples of Diamagnetic, Paramagnetc, Ferromagnetic, Ferri- and Antiferrimagntic materials (explanation of their corresponding magnetic behaviour), Soft and hard magnetic materials. Magnetic storage. Optical Properties: Interaction of visible radiation with materials, Photoconductivity, Optical Fibers, types and applications in communication. Various applications based on optical properties of materials (explanation of their corresponding optical behaviour)	
Module-4	Credits: 1	10 L , 5 T
	Materials Synthesis: Concept of equilibrium and nonequilibrium processing and their importance in materials science. Synthesis of Bulk materials: Metallic and non-metallic, Ceramics and other materials. Compaction, sintering, calcination, vitrification reactions with examples. Laboratory scale synthesis routes - Solid state reaction, solgel, and combustion synthesis methods. Thin Films and surface processing: (a) Ion beam processing, features of ion induced phenomenon (low and high energy) (b) Laser processing - Pulsed and CW laser processing, various types of processing, concepts Laser annealing, alloying, laser deposition etc. with examples.	

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

1. understand the different materials properties.
2. know principles and applications of different materials properties .
3. synthesize and engineer properties of the materials.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physical Metallurgy, Vol. I and 2 by R. W. Cahn and P. Hassen (North Holland Publishing Company, New York, 1983).
2. Materials Science and Engineering, V. Raghvan, (Prentice-Hall Pvt. Ltd., 1989).
3. Fundamentals of Materials Science and Engineering, William Callister (John Willey and Sons).
4. Encyclopedia in Materials Characterization: Surfaces, Interfaces, Thin Films Editors: C.Richard Brundle and Charles A. Evans (Jr. Butterworth-Heinemann publishers, Singapore).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 663 MJP	Course Title: Materials Science Laboratory-II
Credit: 02	

	List of experiments	
	The proposed list of the experiments for Materials Science Laboratory-II. Any 5 Experiments out of these will be taken. 1. Morphological investigations using Scanning Electron Microscopy (SEM). 2. Structural investigations using Raman Spectroscopy. 3. Study of optical properties of semiconducting nanostructures using Photoluminescence 4. Photoluminescence Spectroscopy (PL). 5. Study of magnetic properties using Vibrating Sample Magnetometer (VSM). 6. Study of Magnetostriction of Ferrite materials.	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 664 MJ	Course Title: Nanotechnology-II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Nanotechnology II.
2. To introduce important techniques that are necessary to build core concepts in Nanotechnology II.
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Nanotechnology II.

Course Contents

Module-1	Credits: 1	10 L, 5 T
	SPECIAL MATERIALS AND THEIR CHARACTERIZATION Special Nanomaterials: Graphene, MoS2, CNT, C60, nanorods, nano-porous materials. Clusters. Fullerens,semiconductor and metal clusters. Data analysis of nanostructure material using spectroscopic and microscopic technique: SEM, TEM, AFM, MFM, SNOM, Confocal Microscope, Uv-Vis, Raman, XPS, SAXS.	
Module-2	Credits: 1	10 L, 5 T
	THE SCIENCE OF MINIATURIZATION -Top Down Approach of Nanomaterials Synthesis : Moore's Laws (1,2,&3) and technology' Roadmap– clean rooms Processing Methods: - Cleaning – Oxidation – Lithography – Etching- – CVD - Diffusion – Ion implantation – metallization – state of the art CMOS architectures Photolithography Overview – Critical Dimension – Overall Resolution – Line- Width – Lithographic Sensitivity and Intrinsic Resist Sensitivity (Photochemical Quantum Efficiency) – Resist Profiles – Contrast and Experimental Determination of Lithographic Sensitivity – Resolution in Photolithography – Photolithography Resolution Enhancement Technology Conventional lithography and its limitations. Lithography using scanning probes, soft lithography.	
Module-3	Credits: 1	10 L , 5 T
	SPINTRONICS-Analysis of spintronic materials : GMR and CMR, DMS materials. Photonic band gap materials. Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization - Giant tunneling using MgO tunnel barriers - Tunnel-based spin injectors - Spin injection and spin transport in hybrid nanostructures - spin filters -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS -Field Sensors - Multiferro electric sensors- Spintronic Biosensors.	
Module-4	Credits: 1	10 L , 5 T
	NANOELECTRONIC DEVICES-Electronic transport in 1,2 and 3 dimensions- Quantum confinement - energy subbands - Effective mass - Drude conduction - mean free path in 3D - ballistic conduction - phase coherence length - quantized conductance - Buttiker-Landauer formula- electron transport in pn junctions - short channel NanoTransistor –MOSFETs - Advanced MOSFETs – CMOS devics.	

Learning Outcomes:

Upon completion of the course, the student will be able to,

1. have understood the fundamental concepts of Nanotechnology II.
2. have acquired the problem solving skills essential to Nanotechnology II.
3. be prepared to undertake advanced topics in Nanotechnology II.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Dots, L. Jacak, P. Hawrylak, A. Wojs (Springer, 1997).
2. Optical Properties of Semiconductor Nanocrystals, S. V. Gaponenko (Cambridge Press,97).
3. Physics and Applications of Semiconductor Microstructures, M. Jaros. (Clarendon).
4. Nanoparticles and Nanostructured Films, J. H. Fendler (ed.) (Wiley-VCH, 1998).
5. Nanostructured Materials and Nanotechnology, H. S. Nalwa (Ed.) (Academic Press, 2002).
6. Nanotechnology, G. Timp, Maple-Vail (Book Man. Group, USA, 1999).
7. Characterization of Materials, J B. Wachtman and Z. H. Kalma (Butterworth- Heinmann, USA,93)
8. Nanotechnology, G. Timp, Maple-Vail (Book Man. Group, USA, 1999).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 664 MJP	Course Title: Nanotechnology Laboratory-II
Credit: 02	

Course Objectives:
1. To get trained to perform experiments in Nanotechnology.
2. To introduce important experimental techniques required in Nanotechnology.
3. To Collect data and revise an experimental procedure iteratively

Course Contents:

	List of experiments	
	The proposed list of the experiments for Nanotechnology II 1. Alloy nanoparticles using ball milling and X-ray Diffraction of alloy. 2. Granular thin film deposition and SEM+EDAX analysis of thin films. 3. Magnetoresistance Analysis. 4. Lithography	

Learning Outcomes: Upon completion of the course, the student would

1. have gained training in conducting experiments in Nanotechnology
2. learn to apply scientific methodologies for problem solving.
3. have learned important techniques in Nanotechnology.

Instructional design:
1. Lecture method
2. Laboratory sessions
3. Seminars

Evaluation Strategies:
1. Assessment of experimental skills and outcomes
2. Viva-Voce

REFERENCES:

1. Quantum Dots, L. Jacak, P. Hawrylak, A. Wojs (Springer, 1997).
2. Optical Properties of Semiconductor Nanocrystals, S. V. Gaponenko (Cambridge Press,97).
3. Physics and Applications of Semiconductor Microstructures, M. Jaros. (Clarendon).
4. Nanoparticles and Nanostructured Films, J. H. Fendler (ed.) (Wiley-VCH, 1998).
5. Nanostructured Materials and Nanotechnology, H. S. Nalwa (Ed.) (Academic Press, 2002).
6. Nanotechnology, G. Timp, Maple-Vail (Book Man. Group, USA, 1999).
7. Characterization of Materials, J B. Wachtman and Z. H. Kalma (Butterworth- Heinmann, USA,93)
8. Nanotechnology, G. Timp, Maple-Vail (Book Man. Group, USA, 1999).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 665 MJ	Course Title: Nonequilibrium Statistical Mechanics-II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of nonequilibrium and far from equilibrium statistical mechanics.
2. To introduce important techniques that are necessary to build core concepts in nonequilibrium and far from equilibrium systems.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in statistical mechanics of nonequilibrium systems and and far from equilibrium systems.

Course Contents

Module-1	Credits: 2	20 L , 5 T
	Classical linear response theory. Relaxation and resonance absorption. Linear irreversible processes. Debye relaxation. NMR. Static response to external force. Dynamic response to external force. Kubo formula. Symmetry and dispersion relations. Fluctuation-dissipation theorem. Density response, conduction and diffsuion. Response to thermal internal forces. Onsager postulate.	
Module-2	Credits: 1	10 L , 5 T
	Boltzman equation. H-theorem. Detailed balance and equilibrium idstribution. Collision invariants. Boltzmann equation close to equilibrium. Collision integral. Single relaxation time approximation. Relaxation of a non-uniform distribution.	
Module-3	Credits: 1	10 L , 5 T
	Far from equilibrium systems. Stability of systems of nonlinear differential equations. Limit cycles, bifurcations. Prey-predator ecologies. Far from equilibrium systems. Pattern formation. Turing reaction-diffusion mechanism. Patterns in 1D and 2D. Travelling waves. Applications to BZ chemical clock, chemotaxis and mammalian coat patterns.	

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

1. understand the fundamental concepts of nonequilibrium and and far from equilibrium statistical mechanics subject.
2. have acquired the problem solving skills essential to nonequilibrium and and far from equilibrium statistical mechanics subject.
3. be prepared to undertake advanced topics in nonequilibrium and and far from equilibrium statistical mechanics.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Physics – II: Nonequilibrium Statisrical Mechanics by M. Toda, R. Kubo, and N. Saito, Springer (1998).
2. Nonequilibrium Statistical Mechanics by R. Zwanzig, Oxford University Press (2001).
3. Elements of Nonequilibrium Statistical Mechanics by V. Balakrishnan, Springer (2021).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 665 MJP	Course Title: Nonequilibrium Statistical Mechanics Laboratory- II
Credit: 02	

Course Objectives:

1. To understand in depth resonance absorption, Boltzman equation, prey-predator dynamics through mini projects.
2. Perform numerical simulation of reaction-diffusion process and dynamics of model system chemotactic particles.

Course Contents

	List of Experiments	
	1. Resonance absorption (Mini project). 2. Boltzman equation close to equilibrium (Mini project). 3. Prey-pedator population dynamics (Mini project). 4. Reaction-diffusion process (Simulation). 5. Dynamics of model system of chemotactic particles (Simulation).	

Learning Outcomes: Upon completion of the course, the student would

1. have detailed understanding of resonance absorption, Boltzman equation, and prey-predator dynamics.
2. be able to simulate and analyze reaction-diffusion process and dynamics of model system chemotactic particles.

Instructional design:

1) Lecture method
2) Laboratory sessions
3) Seminars

Evaluation Strategies

1) Assesment of numerical and programming skills and outcomes
2) Viva-Voce

REFERENCES:

1. Statistical Physics – II: Nonequilibrium Statisrical Mechanics by M. Toda, R. Kubo, and N. Saito, Springer (1998).
2. Nonequilibrium Statistical Mechanics by R. Zwanzig, Oxford University Press (2001).
3. Elements of Nonequilibrium Statistical Mechanics by V. Balakrishnan, Springer (2021).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 666 MJ	Course Title: Nonlinear Dyamics – II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of nonlinear dynamics.
2. To introduce important techniques that are necessary to build core concepts of maps and bifurcation theory.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in maps and bifurcation theory.

Course Contents

Module-1	Credits: 2	20 L , 5 T
	Hamiltonian systems Introduction : Hamiltonian phase flow and integral invariants, canonical formalism, Hamilton-Jacobi methods, Generating functions, integrable systems, Liouville Arnold integrability Central force problem, Harmonic oscillators, Toda chain, action variables. Perturbation Theory : Adiabatic invariance, Averaging KAM theorem Resonances, variational calculation of Tori, Stochastic motion, Diffusion. Other area preserving systems: Maps Baker's transformation, Cat map, Symbolic synamics.	
Module-1	Credits: 2	20 L , 5 T
	Any one of the following topics : 1. Quantum Mechanical Systmes : Chaotic behavior of quantum systems, level spacing and statistics of random matrices, kicked oscillator. 2. Ergodic properties of physical systems: Birkhoff, Hopf and mean ergodic theorems (no proof), Metric transitivity, mixing, k-systems, C-systems, Ergodic invariants, Sinai billiards, stadium problem.	

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

1. have understood the fundamental concepts of nonlinear dynamics subject.
2. have acquired the problem solving skills essential to nonlinear dynamics subject.
3. be prepared to undertake advanced topics in nonlinear dynamics subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Ordinary Diff. Equations, V. J. Arnold (Springer).
2. Differential Equations, Dynamical Sy stems and an Introduction to Chaos, Hirsch, Smale and Devaney, Academic Press (Elsevier Imprint).
3. Int. to applied nonlinear dynamical systems & Chaos, Wiggins (Springer Verlag).
4. Nonlinear Oscillations, Dynamical Systems and bifurcations of vector fields (Springer Verlag).
5. Guckenheimer and Holmes (Springer Verlag).
6. Chaotic Evolution and Cambridge, D. Ruelle (Uni. Press).
7. Nonlinear Ordinary diff. Eq., Jordan & Smith (Oxford Univ. Press).
8. Nonlinear dynamics & Chaos, Strogatz (Addison Wesley).
9. Chaos and integrability in Nonlinear Dynamics, An introduction, M. Tabor (J. Wiley).
10. Introduction to Dynamics, I. Percival, D. Richards (Cambridge Univ. Press).
11. Chaos in Dynamical System, E. Ott (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 666 MJP	Course Title: Nonlinear Dynamics Laboratory- II
Credit: 02	

Course Objectives:

To evaluate the dimension of fractal objects,Grassberger -Procaccia algorithm, analyze simple pendulum with elliptic functions.

Course Contents

	List of Experiments	
	Computational experiments/exercises/mini/project. 1. Symplectic integrators, Fermi pasta problem. 2. Study of Henon-Heiles system. 3. Study of parametric resonances. 4. Coupled map lattice systems. 5. Analysis of the Lorenz system.	

Learning Outcomes: Upon completion of the course, the student would
be able to evaluate the dimension of fractal objects,Grassberger -Procaccia algorithm, analyze simple pendulum with elliptic functions.

Instructional design:
1. Lecture method
2. Laboratory sessions
3. Seminars

Evaluation Strategies
1. Assesment of numerical and programming skills and outcomes
2. Viva-Voce

REFERENCES:

1. Ordinary Diff. Equations, V. J. Arnold (Springer).
2. Differential Equations, Dynamical Sy stems and an Introduction to Chaos, Hirsch, Smale and Devaney, Academic Press (Elsevier Imprint).
3. Int. to applied nonlinear dynamical systems & Chaos, Wiggins (Springer Verlag).
4. Nonlinear Oscillations, Dynamical Systems and bifurcations of vector fields (Springer Verlag).
5. Guckenheimer and Holmes (Springer Verlag).
6. Chaotic Evolution and Cambridge, D. Ruelle (Uni. Press).
7. Nonlinear Ordinary diff. Eq., Jordan & Smith (Oxford Univ. Press).
8. Nonlinear dynamics & Chaos, Strogatz (Addison Wesley).
9. Chaos and integrability in Nonlinear Dynamics, An introduction, M. Tabor (J. Wiley).
10. Introduction to Dynamics, I. Percival, D. Richards (Cambridge Univ. Press).
11. Chaos in Dynamical System, E. Ott (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 667 MJ	Course Title: Nuclear Techniques -II
Credit: 04	

Course Objectives:
The course aims to provide in-depth knowledge and form a strong conceptual base of the subject. This course will lay down a strong foundation to understand the various basic elements and pre-requisites used in advanced nuclear environment and nuclear instruments.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Neutron Sources and Reactors: Reactor neutron sources, radioactivity based neutron sources and laboratory neutron sources, Thermal and fast neutron detectors, basics of fission and fusion as a source of nuclear energy, production of radioisotopes. Reactor operation, Power reactors.	
Module-2	Credits: 1	10 L , 5 T
	Measurement of Lifetime and Nuclear Levels: Basic concepts of half life, mean lifetime of radioactive nuclei. Excited states of nuclei; Measurement of lifetime of the nuclear excited states, covering range from picoseconds to years using techniques such as recoil distance, delayed coincidence, activity measurement and others. Measurement of beta-beta and beta- gamma coincidence. Study of angular co-relation between the gamma-rays emitted from Co-60 source.	
Module-3	Credits: 1	10 L , 5 T
	Nuclear Spectroscopy: Basic principles and applications of (i) Mössbauer effect. (ii) Positron annihilation and (iii) perturbed Angular co-relation (iv) Beta-ray orange spectrometer. Iron and air core magnetic spectrometers, mass and energy resolution, and transmission efficiency for the above spectrometers.	
Module-4	Credits: 1	10 L , 5 T
	Applications: Elemental analysis by neutron activation method, proton induced X-ray Emission, Nuclear Reaction analysis, Elastic recoil detection analysis method. Measurement of thermal and fast neutron flux and cross-section by activation method. Practical uses of radioisotopes, Radioactive waste disposal, applications of radioisotopes in medical field, industries and agriculture .dating of archaeological and other ancient object, Carbon-14 and potassium-argon dating 39,40 method trace element studies, radiotherapy for cancer treatment.	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. About special nuclear particle viz. neutrons. How they are produced naturally and artificially. Their untilization in production of various isotopes for medical or other applications.
2. The various requirement of nuclear reactions, specific instruments used for specific nuclear reaction, their detailed measurement set-up and calculation of lifetime and reaction cross-section.
3. Different Nuclear spectroscopies used for analysis, in general used for physics or related areas of research.
4. Applications of nuclear radiations and methods used in gereneral other than nuclear like material science, geo-science, acheology, medical, medicine etc.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Nuclear radiation detectors, S. S. Kapoor and V. S. Ramamurthy (Wiley Eastern Limited, New Delhi).
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).
3. Techniques for nuclear and particle physics, W. R. Leo (Springer).
4. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press, New Delhi).
5. Fundamentals of surface and thin analysis, Leonard C. Feldman and James W. Mayer (North Holland, New York).
6. Introduction to nuclear science and technology, K. Sriram and Y. R. Waghamare (A. M. Wheeler).
7. Nuclear radiation detection, W. J. Price (McGraw-Hill, New York).
8. Alpha, beta and gamma-ray spectroscopy, K. Siegbahn (North Holland, Amsterdam).
9. Introduction to experimental nuclear physics, R. M. Singru (John Wiley and Sons).
10. Radioactive isotopes in biological research, William R. Hendee (John Wiley and Sons).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 667 MJP	Course Title: Nuclear Techniques Laboratory-II
Credit: 02	

Course Objectives:
The aim of the lab course is to provide in hands on experience on various nuclear electronics and instrumentation to have a complete and in-depth understanding of the subject .

Course Contents

	List of Experiments	
	1. To make a short lived isotope Using 14 MeV neutrons and measure its half life time. 2. To determine resolving time of a coincidence using chance coincidence technique. 3. To determine activity of a given gamma-ray source using radiation monitor. 4. Measurement of neutron flux using activation method. 5. To measure efficiency and energy resolution of a HPGe detector 6. To study different pulse shaping circuits for > T, = T, < T conditions and combination of differentiation and integration for 'n' number of networks. 7. To study designing of a D/A converter using R-2R ladder network. 8. Obtain Fermi-Kurie plot and estimate the end point energy of beta particle emitted from Cs-137 using beta ray spectrometer. 9. i) To verify inverse square law of radiation in air ii) To estimate mass absorption coefficient for a given concrete brick and iii) Calculate the time and minimum permissible dose per week for which the student can work in the laboratory using Cs-137 source and radiation survey meter. 10. Measurement of half life of a given radioactive material (MnO_2) induced by thermal neutrons. Also, estimate the flux of the Cf-252 neutron source 11. To determine the mass absorption coefficient for mica, aluminum, copper and estimate the end point energy using different radioactive sources, such as Sr90, Sr90-Y90, Ra226, etc. 12. Design study of different modes of scalar using IC 7490 and observe the output of an 13. oscilloscope. (Any five experiments will be covered)	

Learning Outcomes: Upon completion of the course, the student will be able to understand,

1. In depth-understanding each components of the detectors, signal processing and detection mechanism
2. Basic physics principle behind each detector and its working
3. Radioactivity its level and safety measurements.
4. Basic knowledge about various Nuclear instrumentation.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 668 MJ	Course Title: Physics of Semiconductor Devices-II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of Basic of Semiconductors sensors, photodetectors.
2. To introduce important techniques for the development of various electronic devices like, FET, JFET, MOSFET, etc an d their characteristics.
3. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Optoelectronic and Sensor devices: Photodiodes, p-i-n and p-n photodiodes, heterojunction photodiode, metal semiconductor photodiode, Phototransistors, Gain Bandwidth and Signal to noise ratio, Variation of photo-detectors, Light emitting diodes, Thermistors, Diode- thermal sensors, Transistor thermal sensors, mechanical sensors, Strain gauge, piezoelectric strain gauge, inter-digital transducer capacitor sensor, Magnetic sensors, Hall plate, magnetoresistor, Chemical sensors, metal oxide sensors,	
Module-2	Credits: 1	10 L , 5 T
	Transistor based devices: Fabrication of field effect transistors, Transistor as an amplifier, High frequency transistor behavior, Thin film transistor architectures, Concept of Integration and planar technology, Basic device characteristics, Junction field effect transistor (JFET) Metal-semiconductor FET, Metal-insulator FET, MOS Field effect transistor, and output and transfer characteristics, Mobility model, short channel MOSFET I-V characteristics, control of threshold voltage, sub threshold characteristics	
Module-3	Credits: 1	10 L , 5 T
	- Photvoltaic devices (Solar cells): Spectral distribution of solar radiation, photovoltaic effect, types of solar cells, solar constant, absorption of solar radiation in the atmosphere, crystalline Silicon solar cells, thin film solar cells, and multi-junction (tandem solar cells), hybrid solar cells, Dye sensitized solar cells, perovskite solar cells, quantum dot based solar cells. Dark and illuminated characteristics of solar cells, Effect of light intensity on solar cell parameters(Open circuit voltage, Short circuit current, fill factor, efficiency, etc.), Effect of series and shunt resistance on I-V curves due to defects in materials.	
Module-4	Credits: 1	10 L , 5 T
	- Integrated Circuit (IC) Technology: The integrated circuit approach, A short summary of the planar technology, Pattern generation and photomask making, Photolithography, Epitaxy, Oxidation, diffusion, and ion implantation, metallization and interconnections, encapsulation and circuit testing.	

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

1. have understood the fundamental concepts of Basic of Semiconductors, semiconductors sensors, photodetectors
2. have acquired the important techniques for the development of various electronic devices like, FET, JFET, MOSFET, etc an d their characteristics.
3. be prepared to undertake advanced topics about the Semiconductor devices and their characterizations.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:
1. An Introduction to Semiconductor Devices, Donald A. Neamen (McGraw-Hill)
2. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education Inc. 6th Edition)
3. Semiconductor Devices: Physics and Technology, S. M Sze (2nd Edition, John Wiley, New York)
4. Introduction to Semiconductor Materials and Devices, M. S. Tyagi (John Wiley & Sons)
5. Fundamentals of Semiconductor Devices, BL Anderson and RL Anderson (McGraw-Hill Higher Education)
6. Principles of Semiconductor Devices, Sima Dimitrijev (OXFORD UNIVERSITY PRESS)
7. Complete Guide to Semiconductor Devices, K.K. Ng (John Wiley & Sons, Inc., New York 2nd Ed.)
8. Modern Semiconductor Device Physics, S M Sze (John Wiley) (1998)
9. Semiconductor Devices: Basic Principles, Jaspreet Singh (John Wiley & Sons)
10. Semiconductor Device Fundamentals" Robert F., Pierret (Addison-Wesley)
11. Physics of semiconductor devices, Dilip K Roy (Universities press

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 668 MJP	Course Title: Physics of Semiconductor Devices Laboratory- II
Credit: 02	

	List of experiments	
	1. Frequency dependent Capacitance-Voltage measurements on above prepared semiconductor devices (Flat band potential, Dielectric constant, Carrier concentration, etc.) 2. Studies on optoelectronic properties (dark and illuminated J-V characteristics) photovoltaic devices. 3. The effect of intensity of light and light soaking on the photovoltaic devices. 4. Preparation of IR detector devices and their characterization under Dark and IR light source.	

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 669 MJ	Course Title: Plasma Physics and Technology-II
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Cold Plasma Reactors: Plasma systems, DC reactor, RF reactor, microwave reactor, ECR plasma reactor, Magnetically enhanced reactor, Plasma Enhanced Chemical Vapour Deposition and reactors , Reactor clusters, Merits and de-merits of plasma techniques : Case study (RF & ECR plasma).	
Module-2	Credits: 1	10 L , 5 T
	Applications of Cold plasma: Plasma polymerization, Plasma etching, Plasma enhanced chemical vapor deposition, hallow cathode discharge for thin film deposition, Examples: Polymer thin films, deposition of amorphous Si, polymer thin film for passivation, discuss the process operative in each case. Ion sources using ECR and RF plasma devices , Inductively coupled plasma for elemental analysis, Plasma ashing , surface cleaning, space application, Plasma display devices , Various other applications.	
Module-3	Credits: 1	10 L , 5 T
	Thermal plasma Reactors: Thermal plasma interaction with matter, Plasma reactors viz. DC arc plasma, Plasma torches, Transferred and non-Transferred arc plasma torches, RF Plasma torches and based reactors, Laser plasma reactors .	
Module-4	Credits: 1	10 L , 5 T
	Applications of thermal plasmas: Thermal plasma assisted melting, evaporation and condensation, Nucleation and growth phenomena in thermal plasma reactors , Nano-material synthesis, Plasma spray coating, plasma spherodisation, plasma cutting & welding.	

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

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1) Glow discharge processes (Sputtering and Plasma etching), Brain Chapmn (A Wiley Interscience Publication).
2) Thermal Plasmas: Fundamentals and Applications, Volume 1, Maher I. Boulos, Pierre Fauchais, Emil Pfender (Springer Science+Business Media).
3) Plasma Diagnostics, Holt Greven (North Holand Publishing Company, Amsterdam).
4) Reactions under Plasma Conditions, M. VenuGopalan (Wiley Interscience).
5) Cold Plasma in Materials fabrication: From Fundamental to Applications, Alfred Grillb (IEEE Press).
6) Introduction to Plasma Spectroscopy, Hans-Joachim Kunze (Springer).
7) Plasma Deposition, Treatment, and Etching of Polymers Edited by Riccardo d'Agostino, (ACADEMIC PRESS, INC).

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 669 MJP	Course Title: Plasma Physics and Technology Laboratory- II
Credit: 02	

	List of experiments	
	The proposed list of the experiments for Plasma Phtysics and Technology Laboratory- II. Any 5 Experiments out of these will be taken. 1. Production and study of open arc thermal plasma. Measurement of current, Voltage and power. Study of evaporation rate of anode. 2. Production and study of transferred arc torch operated thermal plasma and generation of Nano-particles of Metal and Metal oxide 3. Production and study microwave excited Electron Cyclotron Resonance plasma and study its properties. 4. Spectroscopic investigation of thermal plasma and calculate the electron temperature using Bolzman plots. 5. Thermal plasma for alloy preparation 6. Cold plasma for etching application 7. Cold plasma for thin film deposition 8. Cold plasma for polymer surface modification 9. Atmospheric plasma for the degradation of organic pollutants. 10. Study of dielectric barrier discharge (DBD) plasma	

Evaluation Strategies:
1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 670 MJ	Course Title: Quantum Information and Quantum Computation -II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of quantum mechanics.
2. To introduce important techniques that are necessary to build core concepts in quantum information and quantum computation.
3. To develop problem solving skills with appropriate regior that helps the student to improve their analytical ability in quantum information and quantum computation.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Quantum noise and quantum operations, Evolution of open quantum systems. decoherence, linearity and complete positivity of quantum channels (superoperators), quantum channels as POVM, Kraus Representation Theorem, maximum number of Kraus operators, maximum dimension of environmental state space, number of real parameters to specify a superoperator.	
Module-2	Credits: 2	10 L , 5 T
	Quantum channels for a single qubit: bit-flip,phase-flip,bit-phase-flip. Distance measures for quantum information. trace distance, fidelity and their properties (chapter 9, NC) Uhlmann's theorem.	
Module-3	Credits: 1	10 L , 5 T
	Quantum error correction, various kinds of errors in quantum computation, three qubit bit flip and phase flip codes, Shor code, quantum Hamming bound, five qubit code, classical linear codes, CSS code, stabilizer codes, fault tolerant quantum computation.	
Module-4	Credits: 1	10 L , 5 T
	Entropy and information. Shenon entropy, data processing inequality, Von-neumann entropy, quantum relative entropy, concavity, entropy of mixed states, strong subadditivity. Quantum information. Schumacher's quantum noiseless channel coding theorem, Holevo bound, classical information over noisy quantum channel, HSW theorem, entanglement as physical resource.	

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

1. have understood the fundamental concepts of quantum information and quantum computation and its technolgical importance.
2. have acquired the problem solving skills essential to quantum information and quantum computation subject.
3. be prepared to undertake advanced topics in quantum computers subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang. Cambridge University Press (2013).
2. Principles of Quantum Computation and Information, G. Benenti, G. Casati and G. Strini World Scientific (2020)
3. The Theory of Quantum Information, J. Watrous, Cambridge University Press (2018).
4. Qauntum Computing: A Gentle Introduction, E. G. Rieffel and W. H. Polak, MIT Press (2014).
5. Lectures Notes on Quantum Computing, J. Presskill. (Available online at theoru.caltech.edu).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 670 MJP	Course Title: Quantum Information and Quantum Computation Laboratory - II
Credit: 02	

Course Objectives:

1. Perform quantum fourier transform on a quantum circuit.
2. Construct and test quantum phase estimation circuit and quantum error estimation circuit.
3. Develop and run Grover's algorithm and Simons algorithm on a quantum computer.

Course Contents

	List of Experiments	
	1. Quantum Fourier Transform 2. Quantum Phase Estimation Circuit 3. Quantum Error Correction Circuit 4. Grover's Algorithm 5. Simon's Algorithm	

Learning Outcomes: Upon completion of the course, the student would

1. be able to Perform quantum fourier transform on a quantum circuit
2. be able to construct and test quantum phase estimation circuit and quantum error estimation circuit, and develop and run Grover's algorithm and Simons algorithm on a quantum computer.

Instructional design:
1. Lecture method
2. Laboratory sessions
3. Seminars

Evaluation Strategies
1. Assesment of numerical and programming skills and outcomes
2. Viva-Voce

REFERENCES:

Books and References:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang. Cambridge University Press (2013).
2. Principles of Quantum Computation and Information, G. Benenti, G. Casati and G. Strini World Scientific (2020)
3. The Theory of Quantum Information, J. Watrous, Cambridge University Press (2018).
4. Qauntum Computing: A Gentle Introduction, E. G. Rieffel and W. H. Polak, MIT Press (2014).
5. Lectures Notes on Quantum Computing, J. Presskill. (Available online at theoru.caltech.edu).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 671 MJ	Course title: Soft Condensed Matter-II
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Brownian Motion and thermal fluctuations : Brownian Motion of free particles, Langevin equation, Einstein Relation, Brownian motion in potential field, Fluctuation dissipation Theorem.	
Module-2	Credits: 1	10 L , 5 T
	Colloidal dispersions. Stability and phase behaviour of colloidal systems. DLVO theory.	
Module-3	Credits: 1	10 L , 5 T
	Polymer physics. Basic definitions and terminology. Statistical properties of polymer chains. The ideal chain and the Gaussian chain. Excluded volume effect. Lattice theory of polymer solutions. Mean field approximation. Polymer dynamics.	
Module-4	Credits: 1	10 L , 5 T
	Non-Equilibrium Systems: Any two topic from the following: (i) Physics of Active systems (ii) Growth models (iii) Capillarity and Wetting phenomenon.	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Soft-Condensed Matter by R. A. L. Jones (Oxford University Press).
2. Structured Fluids by T. Witten and P. Pincus (Oxford University Press).
4. Soft Matter Physics: An Introduction by M. Kleman and O. D. Lavrentovich (Springer).
5. The Colloidal Domain by F. Evans and H. Wennerstrom (Wiley –VCH).
6. Soft Matter Physics by Masao Doi (Oxford University Press).
9. An Introduction to Polymer Physics by D. I. Bower (Cambridge University Press).
10. The Physics of Polymers by G. Strobl (Springer).
11. Scaling Concepts in Polymer Physics by P. de Gennes (Cornell University Physics).
12. Liquid Crystals by S. Chandrasekhar (Cambridge University Press).
13. Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls and Waves, by Pierre-Gilles de Gennes, Françoise Brochard-Wyart, and David Quéré (Springer)
14. Inter-molecular and surface forces (3rd Ed), Jacob N. Israelachvili (Elsevier)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 671 MJP	Course Title: Soft Condensed Matter Laboratory-II
Credit: 02	

Course Contents

	List of Experiments	
	1. Computer simulation: structure and dynamics in model active matter (Monte Carlo) 2. Computer simulation: structure of model driven matter (Monte Carlo) 3. Computer simulation: Lattice gas model of fluid flow. 4. Computer simulation: Self-assembly of model amphiphiles. 5. Simulation of Diffusion of fractal particle in continuum 6. Fractal dimension of a DLA and similar fractal clusters 7. Experiment: Stability of colloidal suspensions, flocculation. 8. Experiment: Isotropic to nematic transition in liquid crystals. 9. Experiment: Viscous fingering / Fractal growth (any one). 10. Experiment: Rheological study of suspensions/polymer solution (any one). 11. Experiment: Avalanches in a sand pile.	

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 672 MJ	Course Title: Thin Film Physics and Device Technology-II
Credit: 04	

Course Objectives:

1. To strengthen the basic concepts of thin film deposition and various measurement techniques to study the various properties.
2. To introduce important techniques that are necessary to build core concepts related to the electrical properties of thin films and the effect of the size of layer on magnetic properties.
3. Various devices will be prepared by different techniques and measured their performance.
4. To develop problem solving skills with appropriate region that helps the student to improve their analytical ability in essential to design and fabrication of semiconductor devices.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Thin Film thickness and deposition rate measurement techniques:- Gravimetric Methods, Optical Methods, Direct Methods, Film Thickness Measurement by Electrical or Magnetic Quantities. Analysis of thin film structure, composition and morphology of thin films, Mechanical properties of thin films: - stress in thin films and adhesion. Optical properties of thin films	
Module-2		10 L , 5 T
	Electrical and magnetic properties of thin films: - Conductivity of continuous and discontinuous thin films, conduction in thin films of metals and insulators, determination of electrical parameters, Hall effect, TEP measurements, Photoconductor, Magnetic film size effect, magnetic thin films for memory applications.	
Module-3	Credits: 1	10 L , 5 T
	Applications of thin films: - Antireflection coating, Optoelectronic applications (photon detectors, photovoltaic devices, thin film displays), microelectronic applications (thin film passive components like resistor, capacitor, etc. and thin film active components like thin film diode and thin film transistor),	
Module-4	Credits: 1	10 L , 5 T
	Thin Film Devices: Sensors, Energy conversion (phototelectrolysis, photovoltaics) and energy storage (supercapacitor), Surface engineering applications of thin films (surface passivation, lubricating layer), Miscellaneous Applications (catalysis, biomedical)	

Learning Outcomes:

Upon completion of the course, the student will be able to,

1. have understood the fundamental concepts of thin film deposition and various measurement techniques to study the various properties.
2. have acquired the problem solving skills essential to design and fabrication of semiconductor devices.
3. be prepared to undertake advanced topics about the various device preparation by different techniques and measurement of their performance. Semiconductor devices and their characterizations.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Thin Film Materials Stress, Defect Formation and Surface Evolution, I. B. Freund, S. Suresh (Cambridge University Press, 2004)
2. Thin Film Device Applications, K. L. Chopra and I Kaur (Plenum Press, 1983)
3. Thin Film Analysis by X-ray Scattering, M, Birkholz (Wiley, 2006)
4. Active and Passive thin film devices and applications, T.J. Coutts (Academic Press),78.
5. Thin films Solar Cells, K. L. Chopra, S. R. Das (Plenum Press), 1983.
6. Handbook of modern sensors, Jacob Freden (AIP Press 2004)
7. Active and Passive Thin Film Devices, T. J. Coutts (Academic Press, 1978).
8. Light, Water, Hydrogen The Solar Generation of Hydrogen by Water Photo- electrolysis, C. A. Grimes, O. K. Varghese, S. Ranjan (Springer 2008)
9. Energy storage, Robert A Huggins (Springer 2010)
10. Advanced Characterization Techniques for Thin Film Solar Cells, Daniel Abou- Ras, Thomas Kirchartz and Uwe Rau (Wiley 2011)

COURSE INFORMATION	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHY 672 MJP	Course Title: - Thin Film Physics and Device Technology Laboratory-II
Credit: 02	

	List of experiments	
	The proposed list of the experiments: 1.Determination of band gap/carrier concentration of thin films using optical method. 2. To study electrical properties of thin films of metals and oxides. 3. To study photoconductivity/electrochromism of thin films. 4.To find out type of conductivity of thin film using TEP. 5.To study properties of gas/UV sensors. 6.To study phototelectrolysis of thin films. 7.To study thin film as a supercapacitor. (Any five)	

Evaluation Strategies:

1) Assessment of experimental skills and outcomes
2) Viva-Voce

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 675 MJ	Course Title: Atomic Spectroscopy
Credit: 02	

Course Contents

Module-1	Credits: 2	20 L , 10 T
	General remarks: physical constants, unit and conversion factor, origin of emission/absorption spectra, regions of spectrum, representation of spectra, basic elements of practical spectroscopy, signal-to-noise ratio, line width and intensity of spectral transition. The simplest line spectra and the elements of atomic theory, multiplet structure of line spectra and electron spin, the building-up principle and the periodic system of the elements, finer details of atomic spectra, hyperfine structure of spectral line, Hydrogen spectra atomic spectra and pauli exclusion principle: central field approximation (only remarks), hartree's self-consistent field (only remarks). Exclusion principle, ground state of atom, term symbol : l-s and j –j coupling, spectra of alkali elements, spectra of alkaline earth elements and complex spectra, hyperfine structure and spectral lines, x-ray spectra. X-ray photoelectron spectroscopy	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Atomic Spectra and Atomic Structure by G. Herzberg, New York Dover Publication 1944
2. Atomic Spectra and Radiative Transitions by Igor I. Sobelman, Springer series on Atoms and Plasmas 1991
3. Molecular Spectra and molecular structure Volume I, II, III, G. Herzberg, D. Van Nostrand Company Inc. , 1963.
4. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particle, Robert Eisberg and Robert Resnick, John Wiley and Sons
5. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, Tata, McGraw-Hill Publishing Company Limited.
6. Atoms, Molecules and photons by Wolfgang Demtröder, Springer -2005.
7. Molecular Structure and Spectroscopy, by G Aruldhas , PHI Learning Pvt. Ltd. New Delhi, 2008.
8. Atomic and Molecular Spectroscopy : Basic Aspects and Practical applications, by Sune Svanberg, Forth edition, Springer, 2003.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 676 MJ	Course Title: Molecular Spectroscopy
Credit: 02	

Course Contents

Module-1	Credits: 2	20 L , 10 T
	observed molecular spectra (experimental details and special features in different spectral regions). Separation of nuclear and electronic motion. Rigid and non rigid rotation of linear, symmetric, asymmetric top rotators, harmonic and anharmonic vibrations, vibrational rotational interaction in simple cases. Electronic states and transitions. Coupling of rotational and electronic motion in diatomic molecules. Molecular spectra, frank condon principle, fluorescence and phosphorescence. Optical spectroscopy: Light source, spectral resolution instruments, detectors, optical components and materials, optical methods and chemical analysis: beer lambert law, atomic absorption spectroscopy, atomic emission spectroscopy, fluorescence spectroscopy, methods of atomization.	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Atomic Spectra and Atomic Structure by G. Herzberg, New York Dover Publication 1944
2. Atomic Spectra and Radiative Transitions by Igor I. Sobelman, Springer series on Atoms and Plasmas 1991
3. Molecular Spectra and molecular structure Volume I, II, III, G. Herzberg, D. Van Nostrand Company Inc. , 1963.
4. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particle, Robert Eisberg and Robert Resnick, John Wiley and Sons
5. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, Tata, McGraw-Hill Publishing Company Limited.
6. Atoms, Molecules and photons by Wolfgang Demtröder, Springer -2005.
7. Molecular Structure and Spectroscopy, by G Aruldhas , PHI Learning Pvt. Ltd. New Delhi, 2008.
8. Atomic and Molecular Spectroscopy : Basic Aspects and Practical applications, by Sune Svanberg, Forth edition, Springer, 2003.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 677 MJ	Course Title: Plasma Physics
Credit: 02	

Course Contents

Module-1	Credits: 2	20 L , 10 T
	Introduction to Plasma Definition of Plasma: the fourth state of matter, collective behavior, charge neutrality, space and time scales. Concept of plasma temperature, Debye length, plasma frequency, plasma parameters. Debye shielding, plasma sheath and dielectric properties, Plasma potential, Transport properties of plasma, plasma in nature, laboratory plasmas, classification of plasma (thermal and non-thermal plasmas), laser produced plasmas. Plasma Reactors Cold Plasma: Plasma systems, DC reactor, RF reactor, microwave reactor, ECR plasma reactor, Magnetically enhanced reactor. Thermal Plasma: Thermal plasma interaction with matter, Plasma reactors viz. DC arc plasma, Plasma torches, Transferred and non-Transferred arc plasma torches, RF Plasma torches and based reactors. Applications of Plasma.	

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Glow discharge processes (Sputtering and Plasma etching) : by Brain Chapmn, A Wiley Interscience Publication, NY, (1980).
2. Thermal Plasmas: Fundamentals and Applications, Volume 1: by Maher I. Boulos, Pierre Fauchais, Emil Pfender, Springer Science+Business Media New York (1994).
3. Plasma Diagnostics: Holt Greven, North Holand Publishing Company, Amsterdam, (1968).
4. Reactions under Plasma Conditions: by M. VenuGopalan, Wiley Interscience, (NY), London (1971)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 678 MJ	Course Title: Energy Storage Devices
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Energy Storage Device System.

2. To introduce important techniques that are necessary to build core concepts to explore how energy storage devices integrate with different energy systems.

3. To develop problem solving skills with appropriate rigour that helps the student to improve their analytical ability in designing energy storage projects, evaluating feasibility, estimating costs, and managing the implementation of energy storage systems.

Course Contents

Module-1	Credits: 1 Introduction of Energy Storage Device	10 L , 5 T
	Necessity of energy storage, types of energy storage, comparison of energy storage technologies. Fundamental concept of batteries, measuring of battery performance, charging and discharging, power density, energy density, and safety issues. Types of batteries: Lead Acid, Nickel -Cadmium, Zinc Manganese dioxide, Li-ion batteries, Mathematical Modelling for Lead Acid Batteries, Flow Batteries.	
Module-2	Credits: 1 Working, Principle and Applications	10 L , 5 T
	Flywheel, Super capacitors, Principles & Methods, Applications, Compressed air Energy storage, Concept of Hybrid Storage, Pumped Hydro Storage, Applications.	

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

1. have understood the fundamental concepts of Energy Storage Device System subject.
2. have acquired the problem-solving skills essential to analyse the appropriate storage technologies for different applications for energy storage Device system subject.
3. be prepared to undertake advanced topics in Model battery storage system subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1) Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.

2) A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN – 13:9789380090122), 2011.

3) Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010.

4) Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) – A National Laboratory of the U.S. Department of Energy – Technical Report NREL/ TP6A2-47187, January 2010.

5) Ibrahim Dincer and Mark A. Rosen, Thermal Energy Storage Systems and Applications, John Wiley & Sons, 3rd Edition, 2021.

6) Ru-shi Liu, Lei Zhang and Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2nd Volume set, 2012.

7) James Larminie and Andrew Dicks, Fuel cell systems Explained, Wiley publications, 3rd Edition, 2018

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 679 MJ	Course Title: Ferroelectrics and Magnetism
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Ferroelectrics and Magnetism
2. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Ferroelectrics and Magnetism

Course Contents:

Module-1	Credits: 1	10 L, 5 T
	Dielectric material: Basic theory of electronic polarizability and ionic polarizability, spontaneous polarization, Polarization versus electric field hysteresis, Frequency dependent polarization, Piezoelectricity An introduction to relaxor ferroelectricity. Perovskite crystal structure, Ferroelectric phases and domains, Curie Weiss behavior, Diffuse phase transition, Physics of Relaxor ferroelectricity, Application of ferroelectricity.	
Module-2	Credits: 1	10 L, 5 T
	Magnetic Properties and magnetic materials: Diamagnetism, Van Vleck paramagnetism Quantum theory of paramagnetism and Ferromagnetism, Temperature dependence spontaneous magnetization, magnetic domain, hysteresis, Exchange interaction. Molecular field theory (Weiss law). Technological application of magnetic materials & multilayer in memory device, sensors, magnetic bubbles Phenomenological theories of magnetic order- Interaction of atomic spins at large distance, molecular field theory, Spin waves, Ising model, Magnetic phase transition.	

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

1. have understood the fundamental concepts of Ferroelectrics and Magnetism.
2. have acquired the problem-solving skills essential to Ferroelectrics and Magnetism.
3. be prepared to undertake advanced topics in Ferroelectrics and Magnetism.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

Essential Reading

1. Kenji Uchino, Ferroelectric Devices, Marcel, Dekker, Inc., New York.
2. Adrianus J. Dekker, Solid State Physics, Prentice-Hall India (Specially for Ferroelectricity)
3. Charles Kittel, Introduction to Solid State Physics, John Wiley & Sons, Inc., New York
4. B. D. Cullity, C. D. Graham, Introduction to Magnetic Materials, Wiley-IEEE Press
5. N. W. Ashcroft and N.D. Mermin, Solid State Physics by, Harcourt College Publishers
6. Nicola A. Spaldin, Magnetic Materials: Fundamentals and Applications (2nd Edition), Cambridge University Press, New York.

Supplementary Reading

1. S. Blundell, Magnetism in condensed matter, Oxford University Press, New York
2. M. E. Lines and A. M. Glass, Principle and Applications of Ferroelectrics and Related Materials, Clarndon Press, Oxford, New York.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 680 MJ	Course Title: Functional Materials
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Functional Materials
2. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Functional Materials

Course Contents:

Module-1	Credits: 1	10 L, 5 T
	Introduction: Definition of functional materials, Different types of functional materials; Use of functionalities of materials in fabricating devices, Causes for observed functionality in a material; Functionality arising due to (i) electronic, (ii) spin, and (iii) ionic degrees of freedom; Exploitation of combined effects in designing new functional materials. Functionality driven by electronic degrees of freedom: Atoms and crystalline solids; electronic states of atoms and crystalline solids; Formation of bands in crystalline solids; Band dispersions; Density of states; Metals, semiconductors and insulators; Direct and indirect band gap semiconductors; Formation of impurity bands in the p-type and n-type semiconductors; Electrons effective mass in a semiconductor; Transport and optical properties of a semiconductor; Opto-electronic materials.	
Module-2	Credits: 1	10 L, 5 T
	Functionality driven by spin degrees of freedom: Revision of magnetization of a solid; Diamagnetic, paramagnetic, ferromagnetic and anti- ferromagnetic materials; Different kind of antiferromagnetic structures; Exchange interaction; Determination of magnetic transition temperature using mean-field theory; Formation of domain wall in ferromagnetic material; Soft and hard ferromagnets; Giant and colossal magnetoresistance materials. Functionality driven by ionic degrees of freedom: Polarization of a material; Paraelectric, ferroelectric, antiferroelectric, piezoelectric, and pyroelectric materials; formation of domain wall in ferroelectric material; Magnetoelectric and Multiferroic materials.	

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

1. have understood the fundamental concepts of Functional Materials.
2. have acquired the problem-solving skills essential to Functional Materials.
3. be prepared to undertake advanced topics in Functional Materials.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Solid State Physics by N. W. Ashcroft and N.D. Mermin, Harcourt College Publishers.
2. The Physics of Semiconductors: An Introduction Including Devices and Nanophysics by Marius Grundmann, Springer Berlin Heidelberg New York.
3. Electronic Structure: Basic Theory and Practical Methods by R. M. Martin, Cambridge University Press.
4. Multiferroicity: the coupling between magnetic and polarization orders by K.F. Wang, J. M. Liu, and Z. F. Ren, Advances in Physics 58, 321 (2009).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 681 MJ	Course Title: Microscopy
Credit: 02	

Course Objectives:

This course covers the learning outcomes of understanding the fundamentals and principles of microscopy. It will cover the basic principles and techniques of optical and electron (scanning electron) microscopy. Students will learn how to use the optical and electron microscopes as characterization tools in various applications in materials and life sciences. The teaching method includes theoretical explanations (class room teaching) and practical demonstrations, wherever possible. This course is proposed for individuals interested in gaining foundational knowledge in microscopy.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Optical Microscopy – Fundamentals of optics, Optical microscope and its instrumental details, resolution, types of optical microscopes, their instrumental details and working principles, image formation - phase contrast, differential interference contrast, applications, sample preparation, merits and demerits.	
Module-1		10 L , 5 T
	Electron Microscopy (Scanning Electron Microscope – SEM) – Need of electron microscope, advantages of electrons (electron beam) as input source for microscopy, block diagram of SEM and its working principle, image formation, applications, sample preparation, merits and demerits.	

Instructional design: Lecture method, Tutorial method , Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. ‘Introduction to Optical Microscopy (2nd Edition)’, Jerome Mertz, Cambridge University Press.
2. ‘A Practical Guide to Optical Microscopy’, John Girkin, Routledge, Taylor and Francis Group.
3. Fundamentals of light microscopy and electronic imaging' Douglas B. Murphy, 2001, Wiley- Liss, Inc. USA.
4. ‘Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM’R. F. Egerton, Springer Nature Publishing.
5. ‘The Principles and Practice of Electron Microscopy’, Ian M Watt, Cambridge University Press.
6. 'Encyclopedia of Materials Characterization, Surfaces, Interfaces, Thin Films,' Editors C. Richard Brundle, Charles A. Evans, Jr., Shaun Wilson, Butterworth-Heinemann, Boston, USA

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 682 MJ	Course Title: Physics of Nuclear Medicine
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of nuclear radiation, its origin, and radiation interaction with materials with special emphasis on human organs and tissues.
2. To introduce important techniques that are necessary to build core concepts in the use of radiation in nuclear medicines and imaging purposes.
3. To develop problem-solving skills with appropriate regior that helps the student to improve their analytical ability in nuclear radiation, nuclear medicine and imaging.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Classification of radiations, Ionizing and non-ionising radiations, directly and indirectly ionizing radiation, nuclear radiation and their origin, fundamental laws of radioactivity, Units and measurements, artificial production of radionuclides.	
Module-2	Credits: 1	10 L , 5 T
	Functional measurements in nuclear medicine: non-imaging measurements, renal function measurements, 14c breath tests, imaging measurements, thyroid, renal function, lung function, gastric function, and cardiac function. Quantitative nuclear medicine: planar whole-body biodistribution measurements, quantitation in emission tomography, region of interest, use of standard, partial volume effect and the recovery coefficient, quantitative assessment, estimation of activity, evaluation of image quality	

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

1. have understood the fundamental concepts of the Physics of Nuclear Medicine.
2. have acquired the problem-solving skills essential to nuclear radiation, nuclear medicines and nuclear imaging subject.
3. be prepared to undertake advanced topics in nuclear medicine subject.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Radioactive isotopes in biological research, Willaim R. Hendee (John Wiley and Sons)
2. Nuclear Medicine Physics, A handbook for teachers and students D.L. Bailey J.L. Humm A. Todd-Pokropek A. van Aswegen, Published by International Atomic Energy Agency, Viena 2014.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 683 MJ	Course Title: Solar Energy Materials
Credit: 02	

Course Objectives:
1. To strengthen the basic concepts of Solar Energy Materials.
2. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in Solar Energy Materials.

Course Contents:

Module-1	Credits: 1	10 L, 5 T
	Energy and its sources, introduction to solar energy, energy band diagram, classification of semiconductors, electrons and holes, densities of electron and holes, direct and indirect band gap semiconductors, location of fermi levels in doped semiconductors, charge carrier generation and recombination in semiconductors, p-n junction diode, p-n junction model, diode equation, principle of solar energy conversion, working principle of solar cell, I-V characteristics of solar cell, equivalent model of solar cell.	
Module-2	Credits: 1	10 L, 5 T
	Thin film solar cells, solar cell devices and parameters, efficiency losses, Solar PV technologies, generation-I technologies- mono silicon and poly silicon solar cells, GaAs solar cells, generation-II technologies-CdTe cells, CIGS solar cells, CIGS multijunction solar cells, amorphous silicon solar cells, generation-III technologies- organic solar cells, dye -sensitized solar cells, : Perovskite Solar Cells, Fabrication of perovskite solar cells, Photophysics in perovskite solar cells and CZTS solar cells, multijunction tandem solar cells.	

Learning Outcomes: Upon completion of the course, the student will be able to,
1. have understood the fundamental concepts of Solar Energy Materials.
2. have acquired the problem-solving skills essential to Solar Energy Materials.
3. be prepared to undertake advanced topics in Solar Energy Materials.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Solar cells, operating principles technology and system applications, Prentice Hall (1982) USA, Martin A. Green.
2. Optoelectronics and photonics, S O Kasap
3. Introduction to solid state physics- Charles Kittel
4. Solar photovoltaics: fundamentals, technologes, and applications- Chetan Singh Solanki
5. Solar Energy Fundamentals and Applications, H. P. Garg and Satya Prakash (Tata McGraw Hill, 1997).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 684 MJ	Course Title: Basics of Accelerator Physics
Credit: 02	

Course Objectives:

1. To provide students with a comprehensive understanding of accelerator physics and particle accelerators, covering fundamental concepts such as magnetic fields, charged particle motion, orbit stability, and focusing techniques.
2. To equip students with problem-solving skills essential for analyzing and designing accelerator systems, including particle beam sources, stability considerations, and optimization techniques.
3. To prepare students for advanced topics in accelerator physics and engineering, enabling them to explore cutting-edge technologies, novel accelerator designs, and potential research opportunities in diverse fields such as synchrotron radiation and high-energy ion accelerators.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Introduction and classification of particle accelerators. Sector magnets, lines of force and magnetic field index. Edge focusing effects on charged particles in a dipole magnet. Motion of charged particles in electric and magnetic fields. Axial and radial stability of orbits of charged particles in magnetic field. Electric and magnetic lenses for focusing charged particles.	
Module-2	Credits: 1	10 L , 5 T
	Basic principle and design details of the following types of accelerators, particle beams sources like electron gun, ion sources etc. Electrostatic, Two stage tandem, cyclotron, Conventional and Race-Track Microtron. High energy ion accelerator-pelletron, synchrotron radiation sources, applications of accelerators.	

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

1) Gain a comprehensive understanding of accelerator physics and particle accelerators, covering fundamental concepts, magnetic fields, charged particle motion, orbit stability, and focusing techniques.
2) Develop problem-solving skills essential for analyzing and designing accelerator systems, including particle beam sources, stability considerations, and optimization techniques.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Physics of cyclic accelerators, J. J. Livingood (D. Van Nostrand Co.)
2. Particle Accelerators, J. P. Blewett, (McGraw-Hill Book Co.)
3. Transport of Charged Particle Beams, A. P. Banford (SPON, London).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 685 MJ	Course Title: Spintronics
Credit: 02	

Course Objectives:

1. To provide students with a comprehensive understanding of the fundamental concepts of spintronics.
2. To understanding the fundamental physics of spintronics, students will be introduced to essential techniques used in spintronics research.
3. To develop problem-solving skills with appropriate rigor that helps the student to improve their analytical ability in in the exciting field of spintronics.
4. By the end of the course, students should be able to grasp the significance of electron spin manipulation, analyse spintronic phenomena in materials, and identify potential applications in various fields.
5. Understanding Spintronics will enable students to contribute to advancements in technology, computing, and information processing in the emerging era of spin-based electronics.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	GMR, Datta-Das, Spin relaxation, Spin injection, Spin detection Pauli equation, Spin-Orbit coupling, Zeeman splitting, Current density, Magnetization, Bloch states with SO coupling, Electronic structure of GaAs, Dresselhaus and Rashba spin splitting, Optical orientation and spin pumping, Stern-Gerlach experiments with electron spins, Detection of free electron spin Bloch equations, T_1 and T_2 times, Elliot-Yafet mechanism with phonons, Dyakonov-Perel, Bir-Aronov-Pikus, hyperfine coupling mechanisms, density matrix, pure and mixed states, spin kinetic equation, motional narrowing Spin-polarized transport, Electrochemical potential, Spin accumulation, Spin diffusion, FN junction, Rashba formalism of linear spin injection, Equivalent circuit model, Silsbee-Johnson spin-charge coupling Datta-Das spin-FET, P-N junctions, Magnetic bipolar diode, Magnetic bipolar transistor, Magnetic tunneling devices	
Module-2	Credits: 1	10 L , 5 T
	Quantum vs. semiclassical transport, Weak and strong localization, Mesoscopic fluctuations, Quantum point contact, Quantum Hall bar, Aharonov-Bohm rings Quantum spin-polarized transport, Pure spin currents, Spin-orbit interaction in semiconductors, Spectral problem of the Rashba Hamiltonian, Geometric spin phases, Diluted magnetic semiconductors Tight-binding Hamiltonian, Mesoscopic Kubo vs. Landauer formula, Scattering approach to spin-charge quantum transport, Real-space Green functions Spin current density matrix, Two-level system decoherence, T_2 and T^*_2 times: True vs. false vs. fake decoherence, Entanglement and quantum teleportation, Spin-orbit entanglement, D'yakonov-Perel' mechanism in confined systems Non-ballistic Datta-Das spin-FET, Aharonov-Casher mesoscopic rings, Spin Hall bars, Spin qubits.	

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

1) Have a thorough understanding of the fundamental concepts of Spintronics, including the principles of spin generation, spin manipulation, and spin transport in materials.
2) Acquire essential problem-solving skills related to Spintronics, enabling them to analyze and interpret spintronic phenomena in materials and devices.
3) Be well-prepared to delve into advanced topics and research areas within Spintronics, with the ability to identify potential applications in various fields such as technology, computing, and information processing.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. "Spintronics: Fundamentals and Applications" by I. Žutić, J. Fabian, and S. D. Sarma.
2. "Spintronics: A Spin-Based Electronics Vision for the Future" by S. A. Wolf, D. D. Awschalom, R. A. Buhrman, J. M. Daughton, S. von Molnár, M. L. Roukes, A. Y. Chtchelkanova, and D. M. Treger
3. "Spin Hall effects" by J. Sinova, S. O. Valenzuela, J. Wunderlich, C. H. Back, and T. Jungwirth
4. "Semiconductor spintronics" by F. Jaroslav, A. Matos-Abiague, C. Ertler, P. Stano, and I. Žutić.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 686 MJ	Course Title: Surface Physics
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of surface physics
2. To introduce important techniques that are necessary to build core concepts in surface physics
3. To develop problem solving skills with appropriate rigor that helps the student to improve their analytical ability in surface characterizations.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Surface structures, low and high index surfaces, surface energy, surface adsorption, surface diffusion, reconstruction, surface reactivity	
Module-2	Credits: 1	10 L , 5 T
	Surface Probe techniques: UHV, scanning probe techniques, LEED, electron spectroscopy (XPS, AES, UPS), vibrational spectroscopy, etc. application of surface studies in catalysis, nanoscience, etc.	

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

1. understand different between bulk and surface of the materials.
2. acquire knowledge of surface process and their measurements
3. be prepared to undertake research where surface properties are important in deciding applications.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Surfaces by Gary Attard and Colin Barnes (oxford Publications)
2. Introduction to Surface Physics by M. Prutton, Clarendon Press, Oxford 1998.
3. Surface Science Foundations of Catalysis and Nanoscience by Kurt W. Kolasinski (Wiley Publications)
4. Springer Handbook of Surface Science Edited by Rocca, Rahman and Vattuone (Springer Publications)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 687 MJ	Course Title: Vacuum Technology
Credit: 02	

Course Objectives:

1. To strengthen the basic concepts of Vacuum Science, various vacuum pumps, and gauges to generate and measure the vacuum.
2. To introduce important high vacuum machines, design and function and handling to perform the various expt.
3. To develop problem solving skills with appropriate region that helps the student to improve their thinking to develop the indigenous high vacuum systems, such as RF and DC sputtering, thermal evaporation, pulsed laser depositions, etc.

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Basic terms and concepts in vacuum technology, Maxwell's distribution of velocities, Ideal gas laws, Mean free path, Viscosity of gases, flow of gases through tubes- Knudsen number, Types of flow and conductance and impedance, Vacuum pumps- Rotary vane (oil) pump, The molecular drag pump (Turbomolecular pump), Diffusion pump, , Getter pump and Getter ion pump, Sputter ion pump, Sorption pump, Cryopump.	
Module-2		10 L , 5 T
	Measurements of Vacuum- Fundamentals of low-pressure measurement, Absolute gauges- U tube manometer, McLeod gauge, Thermal conductivity gauge, Penning gauge, Hot cathode ionization gauge, Monopole, Quadrupole mass spectrometer, Vacuum system design, Application of vacuum technology for coating techniques, Vacuum coating technique, Coating sources, Thermal evaporators (boats, wires etc.), Electron beam evaporators (electron guns), Cathode sputtering, Chemical vapor deposition, Coating of parts, Web coating, Optical coatings, Glass coating etc.	

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

1. have understood the fundamental concepts of Vacuum Science, various vacuum pumps, and gauges to generate and measure the vacuum.
2. gain the knowledge about high vacuum machines, design and function and handling to perform the various expt.
3. have acquired the problem solving skills essential to design and develop the indigenous high vacuum systems, such as RF and DC sputtering, thermal evaporation, pulsed laser depositions, etc.

Instructional design:

1. Lecture method- Blackboard teaching, animation of the concepts, videos related to the topics on PPTs.
2. Tutorial method- A separate batches of at most 15 students will be made to solve the numerical problems, and some topics related to the subject.
3. Seminars- Every week the seminar on the topics covered in class room teaching and tutorial will be arranged as a part of the assignment.

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Fundamentals of Vacuum Technology, W. Umrath (Leybold Vacuum).
2. Vacuum Technology, A. Roth (North Holland).
3. Vacuum Physics and Techniques, T. A. Delchar, Chapman and Hall
4. Handbook of thin film technology, Maissel and Glang.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 688 MJ	Course Title: Computational Materials Modelling
Credit: 02	

Course Objectives:
1. To enable the students to undersand the elecronic tsructure of materials ranging from atms to solids.
2. To train the students to compute simple materials' properties.

Course Contents

Module-1	Credits: 1	10L , 5T
Theory of electronic structure	Introduction to different methods of electronic structure calculations for atoms, molecules, solids and nanostructures, Basis sets, Psedopotentials.	
Module-1	Credits: 1	10L , 5T
Practical implementation in program	Implementation of the plane-wave psedoptentail method in the open-source computer program Quantum Espresso and studies of some typical systems	

Learning Outcomes: Upon completion of the course, the student will be able to
1. Understand properties of systems ranging from simple multi-electron atoms to solid systems calculated using density functional theory.
2. Interpret the experimental findings of materials properties in terms of underlying physics and chemistry of materials.
3. Read and understand research papers that report results of materials modeling.
4. Perform basic calculations with an open-source DFT code.

Instructional design:
1. Lecture method
2. Tutorial method along with demonstartions in the computer laboratory
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Condensed Matter Physics by Michael P. Marder
   John-Wiley & Sons, 2000, ISBN : 0-471-17779-2
2. Elementary Electronic Structure by Walter A. Harrison
   World Scientific, Singaore, 2004, ISBN : 981-238-707-2 (Hard cover), 981-238-708-0 (Paperback)
3. Band Theory and Electronic Properties of Solids by John Singleton
   Oxford University Press, Great Britain, 2001, ISBN : 978-0-19850-6447 (Paperback),
   978-0-19850-6454 (Hard cover)
4. Computational Physics by J. M. Thijssen
   Cambridge University Press, UK, 1999 ISBN : 0-521-57304-1(Hard cover), 0-521-57588-5 (Paperback)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 689 MJ	Course Title: Physics of Driven Systems
Credit: 02	

Course Contents

Module-1	Credits: 1	10L , 5T
	Introduction to driven system, Review of concepts Statistical Mechanics , Random walk problem, and Brownian Motion.	
Module-1	Credits: 1	10L , 5T
	Driven lattice gas modeling approach, Lattice gas models and their application in physics, Growth Processes, Monte-Carlo simulation techniques, Introduction to Active Hydrodynamics.	

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

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Statistical Mechanics of Particles by Mehran Kardar, Cambridge Press.
2. Stochastic Processes in Physics and Chemistry, Van Kampen, North Holland Personal Library
3. Soft Matter Physics by Masao Doi, Oxford University Press.
4. Elements of Non-Equilibrium Statistical Mechanics, V.Balakrishnan. Springer Press
5 Fluid Mechanics, Landau and Lifshitz

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 690 MJ	Course Title: Path Integral Methods
Credit: 02	

Course Objectives: Path integrals provides an alternative description to operator formalism in quantum mechanics. Objective of this course is introduce to studetns basic formalism and imporatant applications of it.

Course Contents:

Module-1	Credits: 1	10L , 5T
	Path integral: General formalism, Construction of the path integral, Functional integrals and Gaussian integrals, Applications to free particle and harmonic oscillator problem. Path integral and statistical mechanics, Euclidean path integral, Generating functions and correlation functions. Nonlinear Path integrals: Quartic potentials, Semiclassical approximation, Effective actions.	
Module-1	Credits: 1	10L , 5T
	Instantons and tunneling, Tunneling in a dissipative environment. Path integrals for fields: Free scalar field, integraction scalar field, Grassman variables and spinor fields Path integral and topological effects: Path integral for spin, other applications.	

Learning Outcomes: Upon completion of the course a student is expected to understand the path integral quantization of free particle and harmonic oscillator, correlation functions , Instantons and tunneling, path integrals for field theory. This course is pivotal for the students who wish to undertake Advanced quantum field theory and statistical field theory.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Quantum Mechanics and Path integrals, R. P. Feynman and A.R. Hibbs (Dover publications).
2. Techniques and Applications of Path Integration, L.S. Schulman (Dover Publications).
3. Path integrals and quantum processes, M. Swanson (Dover publications).
4. Field Theory: A Modern Primer, Frontiers in Physics, P. Ramond (Westview press).
5. Field theory: A Path Integral Approach, Ashok Das (World Scientific).
6. Path Integrals in Quantum MechanicsStatistics, Polymer Physics and Financial Markets, H. Kleinert (World Scientific).
7. Stiatistical Field Theory, G. Mussardo, (Osford University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 691 MJ	Course Title: Renormalization Group and Critical Phenomenon
Credit: 02	

Course Contents

Module-1	Credits: 2	20L ,10T
	Phase transition, order parameter, critical exponents, scale invariance, scaling hypothesis, relation between critical exponents, Block spin, Kadanoff block spin construction, block spin transformation, real space renormalization group transformation, RG flow and fixed point analysis, calculations of critical exponents, example of one-dimensional Ising model.	

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Phase transition and Crtical Phenomena, Eugene Stanley (Oxford University Press).
2. Statistical Mechnics, K. Huang (Willey).
3. Statistical Physics: Statics, Dynamics And Renormalization, L. P. Kadanoff, (World Scientific, 2000)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 692 MJ	Course Title: Solitons and Integrable Systems
Credit: 02	

Course Objectives: Detailed discussions on various nonlinear differential equations and their applications in physical systems, one soliton and many soliton solutions, Backlund transformation, Painleve analysis, Inverse scattering method.

Course Contents

Module-1	Credits: 2	20L , 10T
	Wave equations that exhibit solitons: KdV equation, sine-Gordon equation, nonlinear-Schrodinger equation, nonlinear lattice equation – Toda lattice, etc. and their applications in physics. Elementary soliton calculations: one soliton solution and two-soliton solution of KdV equations and sine-Gordon equation, constants of motion and infinite conservation laws, linear stability analysis of the soliton soluton, Backlund and auto-Backlund transformations for integrable hierarchies, KdV as integrable Hamiltonian system, inverse scattering method for soliton solutions.	

Learning Outcomes: Upon completion of the course a student of this course is expected to learn about integrability properties of the nonlinear differential equations and obtaining soliton solutions of the integrable nonlinear differential equations using various techniques.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Solitons: An introduction, P.G. Derazin and R.S. Johnson (Cambridge University Press).

2.Solitons, Nonlinear Evolution equations and inverse scattering, M.J. Ablowitz and P.A.Clearkson (Cambridge University Press).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 693 MJ	Course Title: Topology and Differential Geometry
Credit: 02	

Course Objectives: This course introduces to students Topology and Differential geometry. These are essential tools for the student motivated towards pursuing his/her career in theoretical physics.

Course Contents

Module-1	Credits: 1	10L , 5T
	Topological spaces: definition of topological spaces, Subspace topology, Open and closed sets, limit points and closure, continuous mappings, homeomorphisms, product topology, Metric topology, topological groups. Connectedness and compactness: connected spaces, connected sets in the real line, compact spaces, compact sets in the real line. Fundamental groups: Paths and loops, homotopy of paths and loops, First fundamental group, fundamental group of R^n, S^n, punctured plane, S^2 with anti-podal points identified (RP2) etc, simple applications.	
Module-1	Credits: 1	10L , 5T
	Differential Geometry: Manifolds: definition, differentiable manifolds, differentiation of functions on manifolds, orientability. Calculus on manifolds: vectors and vector fields, tangent and cotangent spaces. Differential forms: definition and properties, exterior derivatives, exterior algebra, Lie derivative, Integration of differential forms, Stokes theorem. Riemannian geometry: Frames, connections, curvature and torsion, volume form, Hodge star operation and Laplacian of forms. Simple applications.	

Learning Outcomes: Upon completion of the course, the student will be able grasp elementary aspects of topology and differential geometry. The course will be beneficial for the students who wish to study Gauge theory, gravity, string theory and some areas of condensed matter physics.

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Topology, J. Munkres (Pearson Education).
2. Real Mathematical Analysis, C.C. Pugh (Springer).
3. Basic Topology, M.A. Armstrong (Springer).
4. Topology without Tears, S. Morris, (Lecture note, available at https://www.topologywithouttears.net)
5. Lectures on Advanced Mathematical Methods for Physicists, S. Mukhi and N. Mukunda (World Scientific).
6. Algebraic Topology, E. H. Spanier (Springer).
7. Topology and Geometry for Physicists, C. Nash and S. Sen (Dover).
8. Geometrical Methods of Mathematical Physics, B. Schutz (Cambridge University Press).
9. Geometry, Topology and Physics, M. Nakahara (CRC Press).
10. The Geometry of Physics: An Introduction, T. Frankel (Cambridge University Press).
11. Lectures on Differential Geometry, S. Sternberg (American Mathematical Society).
12. Differential Geometry and Lie Groups for Physicists, M. Fecko (Cambridge University Press).
13. Mathematical Methods of Classical Mechanics, V. I. Arnold, K. Vogtmann and A. Weinstein (Springer).

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 694 MJ	Course Title: Physics in curved Spacetime
Credit: 02	

Course Contents

Module-1	Credits: 2	20L , 10T
	Tensor analysis: 4-vectors and tensors on manifold, tensor algebra, metric tensor, tensor densities, operations with tensors Riemannian geometry: Parallel transport, the covariant derivative for tensor fields, geodesics, Riemann curvature tensor and its properties	

Learning Outcomes: Upon completion of the course, the student will be able to understand basics topic in curved spacetime and Reimannian geometry .

Instructional design:
1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Landau and Lifshitz, Classical Theory of Fields, Vol-2, Elsevier .
2. C. Misner, K. Thome and l Wheeler, Gravitation (Freeman, 1973).
3. S. Weinberg, Gravitation and Cosmology (Wiley, 1972).
4. S. Carroll, Spacetimes and Geometry (Addison-Wesley, 2004)

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 695 MJ	Course Title: Introduction to Conformal Field Theory
Credit: 02	

Course Objectives: This course is designed for the students motivated in pursuing theior research in theoretical high energy physics, condensed matter physics and statistical mechanics. Course discusses conformal invariance, conformal group and its representations. Emphasis is given to two dimensional conformal field theories.

Course Contents

Module-1	Credits: 2	20L , 10T
	Conformal Invariance: Conformal group in d-dimensions and generators. Tracelessness of energy-momentum tensor. Conformal invariance in two dimesions: Conformal transformations in 2-dimensions, global conformal transformations, The Witt and Virasoro algebras and thjeir representations. Primary fields and radial quantization. The stress-energy tensor and an introduction to OPEs, Highest weight states and unitarity bounds, Ward identities. Exmaples of simple CFTs: free bosons and fermions.	

Learning Outcomes: Upon completion of the course, the student will be able to understand basics topic in conformal field theory and its applications.

Instructional design:

1. Lecture method
2. Tutorial method
3. Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Conformal Field Theory, P. Di Francesco, P. Mathleu, D. Senechal, (Springer 1997).
2. Conformal Field Theory, S. Ketov (World Scientefic 1995)
3. Introduction to Conformal Field Theory: With Applications to String Theory,
4. R. Blumenhagen, E. Plauschinn, Lect. Notes Phys. 779, (Springer, Berlin Heidelberg 2009).
5. Applied Conformal Field Theory, P. Ginsparg, Les Houches, Session, XLIX, 1988.
6. Fields, Strings and Critical Phenomena, (Elsevier Science Publishers, B.V., 1989), Lecture notes are available at [arxiv:9108028v2 [hep-th]].
7. A.N. Schellekens "Introduction to Conformal Field Theory"
8. J. Bagger "Basic Conformal Field Theory"
9. M. Gaberdiel "An Introduction to Conformal Field Theory"

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHY 696 MJ	Course Title: Advanced Microscopy
Credit: 02	

Course Objectives:

Course Contents

Module-1	Credits: 1	10 L , 5 T
Module-1		10 L , 5 T

Instructional design: Lecture method, Tutorial method , Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

Course Information	
Year and Semester: M.Sc-II, Semester-IV	
Course Code: PHY 650 RP	Course Title: Research Project-II
Credit: 06	