Department of Physics
Savitribai Phule Pune University, Pune 411007

Course: Joint IUCAA-SPPU M. Sc. (Physics with Astrophysics) programme

Course Structure and Syllabus for M.Sc (Physics with Astrophysics) 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.

Savitribai Phule Pune University (SPPU) and Inter University Centre for Astronomy and Astrophysics (IUCAA) recognize a growing need for broadly trained students to work on large astronomy/astrophysics projects such as LIGO-India, TMT, SKA, space-based astronomy missions etc. within the country. Both IUCAA and SPPU agree to start a new M. Sc. programme in Physics withAstrophysics. This programme is envisaged to be a flagship Masters' programme in astrophysics to prepare students to undertake research in contemporary astrophysics. The course work in the programme will provide requisite training in physics and astrophysics through courses in theoretical physics and astrophysics, experimental lab work, observational and computational work and projects on current research topics. This will be a standalone programme but utilize the existing physics courses at SPPU.

The curriculum for the M. Sc. (Physics with Astrophysics) 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). 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/Astrophysics 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 scientific and technological concepts of Physics and Astronomy/Astrophysics.
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 Astronomy/Astrophysics.
4. To help students to learn various experimental and computational tools thereby developing analytical abilities to address real world problems.
5. The students of this programme will gain both a solid foundation and practical experience in solving scientific problemswhich should make them very attractive to help fill the growing needs of large astronomy/astrophysics projects.
6. To help students to build-up a progressive and successful career in Astronomy and Astrophysics.

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**
PHY 501 MJ	APPLIED ELECTRONICS	2
PHY 502 MJ	CLASSICAL MECHANICS	2
PHY 503 MJ	QUANTUM MECHANICS-I	2
PHY 504 MJ	MATHEMATICAL METHODS IN PHYSICS	4
PHY 505 MJP	BASIC PHYSICS LABORATORY	4
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
PHY 511 MJ	FUNDAMENTALS OF CLASSICAL MECHANICS	2
PHY 512 MJ	ELEMENTARY FLUID MECHANICS	2
PHY 513 MJ	BASICS OF ELECTRONIC CIRCUIT DESIGN	2
	MAJOR ELECTIVE TOTAL	**4**
PHY 500 RM	RESEARCH METHODOLOGY	4
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**
PHY 551 MJ	STATISTICAL MECHANICS	2
PHY 552 MJ	ELECTRODYNAMICS -I	4
PHY 553 MJ	QUANTUM MECHANICS-II	4
PHY 554 MJP	BASIC PHYSICS LABORATORY	4
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
PHY 561 MJ	ATOMIC AND MOLECULAR PHYSICS	2
PHY 562 MJ	THERMAL PHYSICS	2
PHY 563 MJ	BASICS OF ATOMS AND MOLECULES	2
	MAJOR ELECTIVE TOTAL	**4**
PHY 550 OJT	ON-JOB TRAINING	4
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**
PHYAP 601 MJP	ASTROPHYSICS LAB-I	2
PHYAP 602 MJ	RELATIVISTIC ELECTRODYNAMICS AND RADIATION PROCESSES	4
PHYAP 603 MJ	INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS	4
PHYAP 604 MJ	ASTRONOMY TECHNIQUES	4
	MAJOR CORE TOTAL	**14**
MAJOR ELECTIVE		
Subject Code	**Subject Title**	**Credits**
PHY 602 MJ OR [PHY 625 MJ - 646 MJ]	SOLID STATE PHYSICS **OR** Any two Electives from Annexure-I	4 OR 2+2
	MAJOR ELECTIVE TOTAL	**4**
PHYAP 600 RP	RESEARCH PROJECT-I	4
SEMESTER-III TOTAL		**22**

Please see the Annexure-I for the list of 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**
PHYAP 651 MJP	ASTROPHYSICS LAB-II	2
PHY 652 MJ	NUCLEAR PHYSICS	4
PHYAP 653 MJ	ASTROPHYSICAL DYNAMICS	4
PHYAP 654 MJ	GENERAL RELATIVITY	2
	MAJOR CORE TOTAL	**12**
MAJOR ELECTIVE		
Subject Code	**Subject Title**	**Credits**
PHYAP 656-659 MJ	ELECTIVE	2+2
	MAJOR ELECTIVE TOTAL	**4**
PHYAP 650 RP	RESEARCH PROJECT-II	6
SEMESTER-IV TOTAL		**22**

Please see the Annexure-II for the list of Elective subjects, offered in semester-IV.

T: Theory, P: practical

2 YEARS, 4 SEMESTERS PG Degree (88 Credits)

Annexure-I: (Semester-III)

(Semester-III Physics with Astrophysics)

ELECTIVES SUBJECTS FOR SEMESTER-III [ANY TWO]		
Subject Code	**Subject Title**	**Credits**
PHY 625 MJ	METHODS OF EXPERIMENTAL PHYSICS-I	2
PHY 626 MJ	METHODS OF EXPERIMENTAL PHYSICS-II	2
PHY 627 MJ	X-RAY CRYSTALLOGRAPHY	2
PHY 628 MJ	BIOPHOTONICS	2
PHY 629 MJ	MEDICAL PHYSICS	2
PHY 630 MJ	OPTOELECTRONICS	2
PHY 631 MJ	RADIATION PHYSICS	2
PHY 632 MJ	BASICS OF SEMICONDUCTORS	2
PHY 633 MJ	PHOTODEVICES	2
PHY 634 MJ	RIETVELD ANALYSIS	2
PHY 635 MJ	RADIATION BIOLOGY	2
PHY 636 MJ	PHYSICS OF DIAGNOSTIC INSTRUMENTS	2
PHY 637 MJ	METHODS OF COMPUTATIONAL PHYSICS-I	2
PHY 638 MJ	METHODS OF COMPUTATIONAL PHYSICS-II	2
PHY 639 MJ	SPECIAL TOPICS IN QUANTUM MECHANICS	2
PHY 640 MJ	ADVANCED MATHEMATICAL PHYSICS	2
PHY 641 MJ	QUANTUM MANY BODY THEORY	2
PHY 642 MJ	CLASSICAL FIELD THEORY	2
PHY 643 MJ	RELATIVISTIC QUANTUM MECHANICS	2
PHY 644 MJ	GROUP THEORY IN PHYSICS	2
PHY 645 MJ	ADVANCED STATISTICAL MECHANICS	2
PHY 646 MJ	DENSITY FUNCTIONAL THEORY	2

Annexure-II: (Semester-IV)

(Semester-IV Physics with Astrophysics)

ELECTIVES SUBJECTS FOR SEMESTER-IV [ANY TWO]		
Subject Code	**Subject Title**	**Credits**
PHYAP 656 MJ	COSMOLOGY	2
PHYAP 657 MJ	HIGH ENERGY ASTROPHYSICS	2
PHYAP 658 MJ	FLUIDS & PLASMAS	2
PHYAP 659 MJ	GALAXIES & ISM	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. 4thEdition (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:

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

8. 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.

9. 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: PHYAP 601 MJP	Course Title: Astrophysics Lab-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: PHYAP 602 MJ	Course Title: Relativistic Electrodynamics And Radiation Processes
Credit: 04	

Course Contents

Module-1	Credits: 2	20L , 10 T
	Overview of Special Theory of Relativity, Lorentz Transformations, 4-vectors, Maxwell's equation	
Module-2	Credits: 2	20L, 10 T
	Relativistic formulation, radiation from moving charges, astrophysical radiative processes.	

Learning Outcomes:

Instructional design: Lecture method, Tutorial method,Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Radiative Processes in Astrophysics, G. B. Rybicki & A. P. Lightman, Wiley-VCH; 1st edition (15 May 1985)
2. Landau, Lifshitz - The classical theory of fields (4th, 1994)
3. High Energy Astrophysics, M. S. Longair, Cambridge University Press; 3rd edition 3
4. Theoretical Astrophysics, Vol I: Astrophysical Processes, T. Padmanabhan, Cambridge University Press

Course Information	
Year and Semester: M.Sc-II, Semester-III	Major Core
Course Code: PHYAP 603 MJ	Course Title: Introduction To Astronomy And Astrophysics
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: Lecture method,Tutorial method, 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: PHYAP 604 MJ	Course Title: Astronomy Techniques
Credit: 04	

Course Contents

Module-1	Credits: 2	20 L , 10T
	Celestial mechanics, Optics, telescopes & detectors,	
Module-2	Credits: 2	20 L , 10T
	imaging, spectroscopy and timing, large telescope	

Learning Outcomes:

Instructional design: Lecture method,Tutorial method, Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. C. R. Kitchin: Astrophysical Techniques (Seventh edition, 2021).
2. H. Bradt: Astronomy Methods: A Physical Approach to Astronomical Observations (2004)
3. G. Rieke: Detection of Light: From the Ultraviolet to Submillimeter (2nd Edition, 2002)

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

Course Objectives:

11. To strengthen the basic concepts of Signal Noise and Error Analysis.
12. To be able to understand the details about the Measurements with Photons and various devices, sources.
13. Students will be understanding the various sources, devices used to generate the photon and electrons and to select the required wavelength.
14. 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: PHYAP 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: PHYAP 651 MJP	Course Title: Astrophysics Lab-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 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: PHYAP 653 MJ	Course Title: Astrophysical Dynamics
Credit: 04	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Potentials and orbits, Fluid equations, Hydrostatic equilibrium	
Module-2	Credits: 1	10 L , 5 T
	Flows, Shocks, Turbulence	
Module-3	Credits: 1	10 L , 5 T
	Introduction to plasmas, Magneto Hydro Dynamics, Waves and Instabilities	
Module-4	Credits: 1	10 L , 5 T
	Applications, Boltzmann equation, Jeans' theorem	

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

Instructional design: Lecture method,Tutorial method, Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. The Physics of fluids and plasmas: An introduction for astrophysicists, Arnab Rai Choudhuri, Cambridge University Press, 1998
2. Introduction to plasma physics and controlled fusion: Volume 1: Plasma physics, Francis F. Chen, Plenum Press, 1984, 2nd ed.
3. Galactic dynamics, James Binney, Scott Tremaine, Scott Princeton University Press, 1987, 2008
4. Principles of astrophysical fluid dynamics, Cathie Clarke and Bob Carswell, Cambridge University Press, 2007

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Core
Course Code: PHYAP 654 MJ	Course Title: General Relativity
Credit: 02	

Course Contents

Module-1	Credits: 1	10 L , 5 T
	Stress tensor, Introduction to General Relativity	
Module-2	Credits: 1	10 L , 5 T
	Equivalence principle, Geometric framework	
Module-3	Credits: 1	10 L , 5 T
	Einstein's equation, Solutions and Applications	
Module-4	Credits: 1	10 L , 5 T
	BH, Gravitational waves	

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

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:
1. Descriptive written examinations
2. Assignments

REFERENCES:

1. General Relativity, I. R. Kenyon, Oxford university press.
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: Cambridge university press.

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHYAP 656 MJ	Course Title: Cosmology
Credit: 02	

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Expanding Universe: Cosmological principle, homogeneity and isotropy, maximally symmetric spaces with and without curvature, Friedmann Lemaitre Robertson Walker (FLRW) metric, expansion of the Universe, redshift and distances in an expanding Universe – angular diameter distance, luminosity distance FLRW Dynamics: Einstein tensor of the FLRW metric, Energy-momentum tensor of dust, Friedmann equations, critical density of the Universe, special case solutions, horizons in the Universe, standard model of Cosmology Brief thermal history of the Universe from T = 1 GeV to T = 900 K: number density, energy density, pressure and entropy density of particles in thermal equilibrium, relativistic and nonrelativistic limits, effective number of degrees of freedom and its evolution, particle freeze out, temperature of decoupled relativistic species, cosmic neutrino background, Big Bang nucleosynthesis, Helium abundance, cosmic microwave background (CMB) and discovery of temperature fluctuations	
Module-2	Credits: 1	10 L, 5 T
	Observational evidence for dark matter: Kinematics of galaxies in galaxy clusters, rotation curves of galaxies, growth of structure. Structure Formation: Linear growth of perturbations, Nonlinear evolution of perturbations - Zeldovich approximation, spherical top hat, basic idea of simulation results Brief introduction to physics of galaxy formation Basic discussion of cosmological observations: geometrical probes, CMB anisotropies, late-time cosmic web, intergalactic medium	

Learning Outcomes: Upon completion of the course, the student will have mastered the current understanding of the evolution of our Universe from very early epochs close to the Big Bang up to late times, at small and large scales. The student will be able to calculate various important quantities such as the age of the Universe in different cosmological models, distance-redshift relation for objects at cosmological distances, and will be able to solve the Einstein equations in FLRW spacetimes.

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Introduction to Cosmology, 3rd Edition, J. V. Narlikar, Cambridge University Press
2. The Early Universe: E. Kolb, M. Turner
3. Theoretical Astrophysics, Volume III. Galaxies and Cosmology, T. Padmanabhan, Cambridge University Press
4. Cosmology: J. A. Peacock
5. Physical Cosmology: P. J. E. Peebles

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHYAP 657 MJ	Course Title: High Energy Astrophysics
Credit: 02	

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Introduction to the high-energy sky: Experimental tools for high energy astrophysics, high energy telescopes, high energy sky, X-ray transients Brief review of relevant radiation processes	
Module-2	Credits: 1	10 L, 5 T
	Accretion of plasma: Basics of accretion, Eddington limits, Bondi-Hoyle accretion, Roche lobe geometry in binaries and accretion from a companion star, formation of a disk High Energy sources: Cataclysmic variable stars; supernova explosions and supernova remnants; neutron stars, radio pulsars, X-ray pulsars and magnetars; gamma-ray bursts, X-ray binaries with neutron stars and black holes, active galactic nuclei - basic classification.	

Learning Outcomes: Upon completion of the course, the student will have knowledge of the various components of the high-energy sky and the means to observe them, along with an understanding of the physical mechanisms relevant in producing high energy radiation and particles in various astrophysical compact objects that can be observed in our Galaxy and in the wider cosmos.

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Exploring the X-ray Universe - Frederick D. Sward, Philip A. Charles
2. Introduction to High Energy Astrophysics - Stephan Rosswog, Marcus Brüggen
3. High Energy Astrophysics - Fulvio Melia
4. High Energy Astrophysics - M. S. Longair

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHYAP 658 MJ	Course Title: Fluids & Plasmas
Credit: 02	

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Ideal Fluids: Definition of fluid as continuum, mean free path, collision time, local thermal equilibrium, perfect gas equation of state, convective/Lagrangian derivative, Euler equation, fluid equations in conservation form, vorticity, circulation theorems, Hydrostatic equilibrium of plane parallel atmosphere: isothermal, isentropic; Fluid equations in rotating reference frames Linear Waves and Instability: Sound, Internal gravity, Surface gravity, Schwarzschild criterion for convective instability, Rayleigh-Taylor and Kelvin-Helmholtz instabilities, Jeans instability Non-ideal fluids: Energy equation, Navier-Stokes equations, Boundary layers, Reynolds number, Stokes flow, Molecular origin of viscosity	
Module-2	Credits: 1	10 L, 5 T
	Turbulence: transition to turbulence, homogeneous and isotropic turbulence: Kolmogorov (K41) phenomenology Supersonic Flows: Hydrodynamic shocks, Rankine-Hugoniot jump conditions Plasma: Definitions of cold and warm plasmas, Plasma orbit theory: magnetic mirrors, gradient drift, curvature drift, 2-component plasmas, Debye length, Cold plasma oscillations Kinetic theory: Distribution functions, Vlasov Equation, Landau Damping (collisionless plasma) Magnetohydrodynamics: regime of its validity, induction equation, flux freezing, MHD waves Solar winds: Parker spiral	

Learning Outcomes: Upon completion of the course, the student will have an understanding of the basic principles of fluid dynamics with and without magnetic fields. The student be able to estimate various relevant time scales and length scales in fluid dynamics and will be able to solve the fluid equations under different boundary conditions and analyse them for the presence of shocks, stability, magnetic effects, etc.

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Elementary Fluid Dynamics: D J Acheson
2. Physics of Fluids and Plasmas: A R Choudhuri
3. Fluid Mechanics: Landau & Lifshitz
4. Physics of Plasmas: T J M Boyd & J J Sanderson
5. Introduction to Plasma Physics and Controlled Fusion: F F Chen
6. Magnetohydrodynamics (of Laboratory and Astrophysical Plasmas): H Goedbloed, R Keppens, S Poedts
7. Principles of Astrophysical Fluid Dynamics: C Clarke & B Carswell
8. Astrophysical Flows: J Pringle & A King

Course Information	
Year and Semester: M.Sc-II, Semester-IV	Major Elective
Course Code: PHYAP 659 MJ	Course Title: Galaxies & ISM
Credit: 02	

Course Contents

Module-1	Credits: 1	10 L, 5 T
	Milky Way and its neighbourhood: Basic structure of our Galaxy, solar neighbourhood, Andromeda and their satellites e.g., LMC, SMC Galaxy morphology: Classification of galaxies: spirals, ellipticals, lenticulars, irregulars, dwarfs, peculiar galaxies; Active galactic nuclei, Hubble sequence and Hubble Types; Methods of galaxy classification: visual inspection, colour-based Photometry and Surface Brightness distribution: Basic filter system; photometry; Point spread function; Surface brightness profiles: radial and vertical; colors, colour-bimodality, colour-magnitude diagram Stellar population: Simple stellar population models; mass-to-light ratio estimation; stellar mass estimation Potential of galaxies: Solving Poisson equation for spherical galaxy models; Kuzmin disk and exponential disk models Kinematics: Galaxy spectra; Rotation curve - ionized gas and stellar rotation, cold HI 21 cm, CO rotation; Modelling dark matter profiles; stellar velocity dispersion and its measurement.	
Module-2	Credits: 1	10 L, 5 T
	Interstellar medium (ISM) Overview: Multi-phase structure of ISM Basics of interstellar dust: Extinction and reddening of star light; Galactic reddening correction, extinction curve HII regions: Ionization structure: static; heating and cooling; Nebular diagnostic: BPT diagram; Hot gas: heating and cooling curve HI clouds: Two-phase medium: 21 cm line; HI distribution: in-plane and perpendicular to the plane - bending and breathing waves, corrugation	

Learning Outcomes: Upon completion of the course, the student have a basic understanding of the structure and evolution of galaxies and the ISM which pervades them. The student will be able to distinguish between different physical processes relevant for galaxies based on observations of their morphology and spectra, and also understand the important physical processes occuring in the ISM which are in turn relevant for understanding the formation and evolution of stars and their remnants.

Instructional design: Lecture method, Tutorial method, Seminars

Evaluation Strategies:

1. Descriptive written examinations
2. Assignments

REFERENCES:

1. Galaxies in the Universe: An Introduction: L. S. Sparke, J. S. Gallagher
2. Galactic Astronomy: Binney, Merrifield
3. Theoretical Astrophysics Vol. 3, Galaxies & Cosmology: T. Padmanabhan
4. Galaxy Formation and Evolution: H. Mo, F. van den Bosch, S. D. M. White
5. Galactic Dynamics: Binney, Tremaine
6. Galaxies and cosmology: F. Combes, P. Boisse, A. Mazure, A. Blanchard, M. Seymour
7. Physical Processes in the Interstellar Medium: L. Spitzer Jr.
8. Astrophysics of Gas Nebulae and Active Galactic Nuclei: D. E. Osterbrock, G. J. Ferland
9. Physics of the Interstellar and Intergalactic Medium: B. T. Draine

Course Information	
Year and Semester: M.Sc-II, Semester-IV	
Course Code: PHYAP 650 RP	Course Title: Research Project-II
Credit: 06	