Department of Physics, Goa University introduces specializations for its M.Sc. Physics programme from 2020 – 2021.
The three specializations are:

1. Solid State Physics
2. Computational Physics
3. Biophysics

Students being admitted for the academic year 2020 – 2021 will be offered first two specializations at the end of their first semester while Biophysics will be offered from 2021 – 2022.

The new course structure and syllabi of different compulsory (C) and optional (O) papers is given below.
Each course has unique course code PHXY-nnn where,
X = G/S/C/B – General (common for all specializations)/ Solid State Physics/Computational Physics/ Biophysics
Y = C/O – Compulsory/ Optional
nnn = three digit identification number also indicating level of a course.

Course Structure and List of papers

Course Code	Course Title	Number of credits
Semester I		
PHGC-100*	Bridge course in Mathematical Methods	2
PHGC-101	Mathematical Physics	4
PHGC-102	Classical Mechanics	4
PHGC-103	Electromagnetic Theory	4
Optional courses (any two)		
PHGO-110	Computer Programming in Fortran 95	2
PHGO-111	Computer Programming with C	2
PHGO-112	Electronics Practical	2
PHGO-113	Mini project	2
*Not included for the calculation of GPA, but should be completed successfully.		
Semester II		
Course Code	Course Title	Number of credits
PHGC-106	Quantum Mechanics	4
PHGC-107	Electronics	4
PHGC-108	Statistical Mechanics	4
Optional courses (any one)		
PHGO-119	General Physics Practical	4
PHGO-120	Methods of Experimental Physics	4
Semester III		
Course Code	Course Title	Number of credits
PHGO-301	Summer Fellowships	2
Solid State Physics		
PHSC-201	Structure, Lattice and Thermal Properties of Solids	3
PHSC-202	Band Theory and Electronic Properties of Solids	3
PHSC-203	Magnetic, Superconducting and Optical Properties of Solids	2
Optional courses (any two)		
PHGO-212	Nuclear physics and Elementary Particle Physics	4
PHGO-213	Laser Physics and its applications	4
PHSO-214	Solid State Physics Practical	4
Computational Physics		
PHCC-221	Advanced Quantum Mechanics	3
PHCC-222	Advanced Statistical Mechanics	3
PHCC-223	Numerical Techniques	2
Optional courses (any two)		
PHGO-212	Nuclear and Elementary Particle Physics	4
PHGO-213	Laser Physics and its applications	4
PHCO-234	Numerical Techniques Practical	4

Biophysics		
PHBC-200*	Introduction to Biology and Biophysics	4
PHBC-241	Molecular Biophysics	4
PHBC-242	Methods in Biophysics	4
Optional courses (any two)		
PHBO-251	Solid State and Biomaterials	4
PHGO-213	Laser Physics and its applications	4
PHBO-252	Biophysics Practical	4
*Not included for the calculation of GPA, but should be completed successfully.		
Semester IV		
Course Code	Course Title	Number of credits
PHGO-311	Dissertation	8
PHSO-302	Neutron Physics	4
PHSO-303	Superconductivity and Superfluidity	4
PHSO-304	X-ray spectroscopy	4
PHSO-310	Numerical methods and Fortran parallel programming using open mp	4
PHSO-311	Phase transitions and Critical Phenomena	4
PHSO-312	Spectroscopic techniques in Condensed Matter Physics	4
PHSO-313	Physics of Energy materials	4
PHSO-314	Documentation using Latex	2
PHSO-315	Nanoscience and Technology	4
PHSO-316	Magnetism in Condensed Matter Physics	4
PHSO-317	Introduction to Crystallography and X-ray Diffraction	4
PHBO-321	Neurobiology and Neurophysics	4
PHBO-322	Radiation Physics and its applications	4
PHCO-341		
PHCO-342		

Programme: M. Sc. (Physics)

Course Code: PHGC-100 **Title of the Course:** Bridge Course in Mathematical Methods
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	NIL	
Objectives:	This course develops problem solving capabilities of students. It also helps to revise and understand the concepts based on Integration, differentiation and such other basic topics of mathematics, which are useful in solving problems based on Physics.	
Content:	**1. Preliminary Calculus** Differentiation from first principles; products; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz' theorem; special points of a function; theorems of differentiation, Integration from first principles; the inverse of differentiation; integration by inspection; sinusoidal functions; logarithmic integration; integration using partial fractions; substitution method; integration by parts; reduction formulae; infinite improper integrals; plane polar coordinates; integral inequalities; applications of integration	8 hours
	2. Partial Differentiation Definition of partial derivative; the total differential and total derivative; Exact and inexact differentials; Useful theorems of partial differentiation; the chain rule; Change of variables; Taylor's theorem for many variable functions; Stationary values of many variable functions; Stationary variables under constraints; Thermodynamic relations; Differentiation of integrals	4 hours
	3. Series and Limits Series; Summation of series (arithmetic, geometric); convergence of infinite series; Operations with series; Power series; Taylor series; Evaluation of limits.	4 hours
	4. Vector Algebra Scalars and vectors; Addition and subtraction of vectors; Multiplication by a scalar; Basis vectors and components; Magnitude of a vector; Multiplication of vectors; Equation of lines and planes; Using vectors to find distances; Reciprocal vectors.	4 hours
	5. Ordinary differential equations Linear equations with constant coefficients; Linear equations with variable coefficients; General ordinary differential equations.	4 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/Readings	1. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and engineering, Cambridge University Press, Cambridge UK (Reprint 2002). 2. George B. Arfken and Hans J. Weber, Mathematical methods	

	for Physicists, 7/e Elsevier Inc., 2012. 3. Mathematics text books of XI and XII Science prescribed by NTSE/CBSE/Goa Board.	
Learning Outcomes	1. Conceptual understanding of the meaning of the differentiation, partial differentiation, integration, ODE (Ordinary differential equations) and its application to solve the problems based on physics. 2. Understand the vector algebra, series and its application in solving the problems in physics and day to day life.	

Programme: M.Sc. (Physics)
Course Code: PHGC – 101 **Title of the Course:** Mathematical Physics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have studied the courses in Physics at graduation level.	
Objective:	Students will get exposed to necessary mathematical skills that are essential to understand different phenomena in physics. The course also helps students to understand the theoretical background of other core courses in physics.	
Content:	**1. Ordinary Differential Equations** Second order homogeneous and inhomogeneous equation, Wronskian, General Solutions, Ordinary and Singular points, Series Solutions. Polynomial solutions, Legendre's equation, Bessel's equation, Gamma function	11 hours
	2.Functions of Complex Variable Limits, Continuity, Analyticity of Functions of a Complex Variable, Taylor and Laurent Series, Isolated and Essential Singularities, Branch Cuts, Cauchy Formula, Contour Integration, Application of Residue Theorem.	12 hours
	3. Linear Vector Spaces Linear Operators, Matrices, Coordinate Transformations, Eigenvalue Problems, Diagonalization of Matrices, Infinite Dimensional Spaces, Elements of Group Theory.	7 hours
	4. Integral Transforms Fourier Series, Fourier Transforms, Laplace Transforms, Applications of Integral Transforms.	10 hours
	5. Boundary Value and Initial Value Problems Vibrating String in one Dimension, Heat Conduction, and Wave Equation.	8 hours
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. George B. Arfken and Hans J. Weber, Mathematical methods for Physicists, 7/e Elsevier Inc., 2012. 2. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and engineering, Cambridge University Press, Cambridge UK (Reprint 2002) 3. J. Mathew and R. L. Walker, Mathematical Methods for Physics, Benjamin Publishers (1973). 4. James W. Brown and R. V. Churchill Complex Variables and Applications, 6th Edition (international), McGraw - Hill (1996). 5. L. A. Pipes, Applied Mathematics for Engineers and Physicists, 3rd Edition, McGraw-Hill (1971). 6. W. W. Bell, Special Functions for Scientists and Engineers, D. Van Nostrand Company Ltd (2004). 7. Charlie Harper, Introduction to Mathematical Physics, PHI. 8. Murray R. Spiegel, Theory and problems in Complex Variables by (Schaum' series) (2009). 9. Murray R. Spiegel, Theory and problems of advanced Mathematics for Engineers and Scientists by (Schaum's	

	series) (1980).	
Learning Outcomes	1. Develop sufficient mathematical skills and apply them in other courses of physics. 2. Develop understanding of the mathematical background of various concepts in physics.	

Programme: M. Sc. (Physics)
Course Code: PHGC-102 **Title of the Course:** Classical Mechanics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have studied basic courses in mechanics in B.Sc. and Mathematics.	
Objective:	This course is aimed at understanding intermediate to advanced classical mechanics and to build the necessary framework for other topics that requires classical mechanics such as quantum mechanics, statistical mechanics and electromagnetism.	
Content:	**1. Newton's Laws of Motion** Mechanics of a single particle, Mechanics of a system particles, Constraints and their classification, Principle of virtual work, D'Alembert's principle. **2. Lagrangian Formulation** Degrees of Freedom, Generalized Coordinates, Calculus of variations, Hamilton's principle, Euler-Lagrange's equations of motion, Application to non-holonomic systems, Advantages of a variational principle formulation, Conservation theorems and symmetry properties. **3. Rigid Body Dynamics** Eulerian angles, Inertia tensor, Angular momentum of rigid body. Free motion of rigid body, Motion of symmetric top. **4. Hamilton's equation of motion** Legendre transformation and the Hamilton equations of motion, cyclic coordinates and conservation theorems, Routh's procedure and oscillation about steady motion, Derivation of Hamilton's equations from a variational principle, Principle of least action. **5. Canonical Transformations** Equations of canonical transformations, Examples of canonical transformations, Poisson brackets and other canonical invariants, Equations of motion, Infinitesimal canonical transformation theorems in Poisson bracket formulation, Angular momentum, Poisson brackets relations, Lagrange brackets. **6. Hamilton - Jacobi Theory** H-J equation for Hamilton's principal function, Harmonic oscillator problems, H -J equation for characteristic function, Action angle, Kepler's problem. **7. Two-body Central Force Problem** Equations of motion and first integrals, Classification of orbits, virial theorem, Differential equation and integrable power law potentials, Kepler's problem. **8. Small Oscillations** Simple Harmonic Oscillations, Damped Oscillations, Forced Oscillations without and with damping, Coupled Oscillations.	6 hours 8 hours 6 hours 8 hours 6 hours 4 hours 6 hours 4 hours

Pedagogy:	Lectures/ tutorials/ assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. H. Goldstein, Classical Mechanics; McMillan, Bombay.1998. 2. N. C. Rana, and P. S. Joag; Classical Mechanics, Tata Mcgraw-Hill;1991. 3. J. C. Upadhyaya, Classical Mechanics, Himalaya, Publishing House, Mumbai;1991. 4. P. V. Panat; Classical Mechanics; Alpha Science International Ltd; 2004. 5. M. G. Calkin, Lagrangian and Hamiltonian Mechanics, World Scientific, 1996.	
Learning Outcomes	1. Study basic principles of classical mechanics. 2. Apply different techniques to solve mechanical problems.	

Programme: M. Sc. (Physics)
Course Code: PHGC-103 **Title of the Course:** Electromagnetic Theory
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have studied electrostatics and magnetostatics at the graduation level.	
Objective:	The aim of this course is to develop understanding of time varying scalar and vector electromagnetic fields and relativity. To inculcate fundamental concepts related to electromagnetic waves, their transmission via wave guides, radiation and plasma.	
Content:	**1. Maxwells Equations:** Displacement current, Maxwell's equations, Vector and Scalar potentials, Gauge transformation, Lorentz and Coulomb gauge, Poynting's theorem, Conservation of energy and momentum for charged particles and fields.	8 hours
	2. Electromagnetic Waves Plane electromagnetic waves and their propagation in non- conducting and conducting media, Frequency dispersion in conductors	7 hours
	3. Electromagnetic Radiation Retarded Potentials, Fields and radiation by localized dipole, Lienerd Weichert potentials, Power radiated by an accelerated charge.	8 hours
	4. Physics of Plasmas Electrical neutrality in a plasma, Particle orbits and drift motion in a plasma, Magnetic mirrors, The hydro-magnetic equations, The pinch effect, Plasma oscillations and wave motion, Reflection from a plasma (ionosphere).	7 hours
	5. Wave Guides Propagation of Waves between conduction planes, Wave guides in arbitrary cross-section, Wave -guides in Rectangular Cross-section, Coaxial Wave guide, Resonant Cavities, Dielectric wave guides.	8 hours
	6. Relativistic Electrodynamics Lorentz transformation as four dimensional orthogonal transformation, Lorentz matrix, four vectors in mechanics and electrodynamics, Lorentz covariance of Maxwell equations, field tensor, transformation of fields, field due to a point charge in uniform motion.	10 hours
Pedagogy:	Lectures/ tutorials/ assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	**Text Books / References:** 1. J. B. Marion, Classical Electromagnetic Radiation, Academic Press, New York (1980). 2. J. R. Reitz and F. J. Milford, Foundations of Electromagnetic theory, Addison – Welsey, Reading	

	(1960). 3. B. B. Laud, Electromagneties, Wiley Eastern Ltd., New Delhi (1983). 4. S. P. Puri, Classical Electrodynamics, Tata McGraw-FEII Publishing Co. Ltd. New Delhi (1997). 5. David J. Griffiths, Introduction to Electrodynamics, Prentice - Hall of India Pvt. Ltd., New Delhi (1995). 6. J. D. Jackson, Classical Electrodynamics, Wiley, New York (1995). 7. W. H. Panofsky and M. Philips, Classical Electricity and Magnetism, Addison-Wesley Publication, 1962.	
Learning Outcomes	1. Apply Maxwell's equations and their application to time-harmonic fields, boundary conditions, wave equations, and Poynting's power-balance theorem. 2. Describe the properties of plane waves in unbounded space, and understand such concepts as wavelength, phase velocity, and attenuation.	

Programme: M. Sc. (Physics)
Course Code: PHGO-110 **Title of the Course**: Computer Programming in Fortran 95
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	This course develops concepts of computer programming in general and introduces programming language FORTRAN 94.	
Content:	**1. Fundamentals of Computer Programing** Programming Languages, Fortran Evolution, Character Set, Intrinsic Types, Numeric Storage, Literal Constants, Names, Significance of Blanks, Implicit Typing, Numeric and Logical Type Declarations, Character Declarations, Initialisation, Constants (Parameters), Comments, Continuation lines, Expressions, Assignment, Intrinsic Numeric Operations, Relational and Intrinsic Logical Operators, Intrinsic Character Operations, Operator Precedence, Mixed Type Numeric Expressions, Mixed Type Assignment, Integer Division, Formatting input and output, WRITE Statement, READ Statement, Prompting for Input, Reading and writing to a file, How to Write a Computer Program, Statement Ordering, Compiling and Running the Program, Practical Exercise 1	12 hours
	2. Logical Operations and Control Constructs Relational Operators, Intrinsic Logical Operations, Operator Precedence, Control Flow, IF Statement, IF ... THEN ... ELSE Construct, IF ... THEN ELSEIF Construct, Nested and Named IF Constructs, SELECT CASE Construct, The DO construct, Conditional Exit Loop, Conditional Cycle Loops, Named and Nested Loops, Indexed DO Loops, Practical Exercise 2	12 hours
	3. Arrays Declarations, Array Element Ordering, Array Sections, Array Conformance, Array Syntax, Whole Array Expressions, WHERE statement and construct, COUNT, SUM, MOD, MINVAL, MAXVAL, MINLOC and MAXLOC functions, Array I/O, The TRANSPOSE Intrinsic Function, Array Constructors, The RESHAPE Intrinsic Function, Named Array Constants, Allocatable Arrays, Deallocating Arrays, Vector and Matrix Multiplication, Practical Exercise 3.	12 hours
	4. Procedures Program Units, Introduction to Procedures, Intrinsic	12 hours

	Procedures, Intrinsic statement Mathematical Intrinsic Function Summary, Numeric Intrinsic Function Summary, Character Intrinsic Function Summary, Main Program Syntax, Functions, Subroutine and Functions, Practical Exercise 4	
Pedagogy:	Lectures/ Laboratory work/self-study	
References/Readings	1. V. Rajaraman, Computer Programming in FORTRAN 90 and 95, Prentice-Hall of India, New Delhi 1999. 2. Martin Counihan, Fortran 95, UCL Press Limited University College London (1996). 3. Stephen Chapman, Fortran 95/2003: for Scientists and Engineers, McGraw-Hill (2007).	
Learning Outcomes	1. Understand different programming languages in general; 2. Understand FORTRAN programming language; 3. Understanding how to write and run simple FORTRAN programs.	

Programme: M. Sc. (Physics)
Course Code: PHGO-111 **Title of the Course:** Computer programming with C
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	This course develops concepts of computer programming in general and introduces programming language C.	
Content:	**1. Introductory Concepts** Introduction to computers, Introduction to Linux OS, Linux basics, Introduction to C, Writing a C Program, Compiling and Executing the Program, Error Diagnostics, Some simple C Programs, Desirable Program Characteristics.	6 hours
	2. C Fundamentals The C character set, Identifiers and Keywords, Data types, Constants, variable and Arrays, Declarations, Expressions, Statements, Symbolic Constants	8 hours
	3. Operators and Expressions Arithmetic Operators, Unary Operators, Relational Logical Operators, Assignment Operators, the Conditional Operators, Library Functions.	8 hours
	4. Data Input and Output Preliminaries, Single character input and output, entering Input data, writing output data, Opening and closing data file, format statements.	6 hours
	5. Control Statements Preliminaries, Branching statements, Looping statements, nested control structure, switch, break, continue, go to statements.	8 hours
	6. Functions Defining functions, accessing functions, Passing arguments to a function.	6 hours
	7. Arrays Defining an array, processing an array, passing arrays to functions, multidimensional arrays.	6 hours
Pedagogy:	Lectures/ Laboratory work/self-study	
References/Readings	1. Byron Gottfried, Programming with C, Tata McGraw- Hill (1996).	
Learning Outcomes	1. Understand different programming languages in general; Understand C programming language; 2. Understanding how to write and run simple C programs.	

Programme: M. Sc. (Physics)
Course Code: PHGO-112 **Title of the Course:** Electronics Practical
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	This course provides laboratory training in designing, and constructing electronics circuits commonly used in a Physics laboratory.	
Content:	Experiments are to be performed on following topics (minimum 8) with emphasis on designing and constructing the circuit on a bread board. 1. Operational Amplifier parameters 2. Design and Construction of Wien Bridge Oscillator 3. Design and Construction of phase shift oscillator 4. Design and Construction of Astable Multivibrator 5. Design and Construction of Monostable Multivibrator 6. Schmitt Trigger circuit and its use as a zero crossing detector and squaring circuit 7. Voltage Regulator 8. Constant Current Source 9. Design and Construction of DC differential amplifier using op-amps 10. Design and Construction of Function generator 11. Design and construction of Negative nonlinear resistor 12. J. K. flip-flop counter: Scale of 16 and 10 using IC 13. Adder and Subtractor Circuits	48 hours
Pedagogy:	Laboratory Experiments	
References/Readings	1. J. Millman and C. C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems, Mc Graw Hill International Student Ed. (1972). 2. LM317 – 3 Terminal Adjustable Voltage regulator datasheet Rev. X, Texas Instruments 3. Wikibooks – Negative resistance, Negative differential resistance. https://en.wikibooks.org/wiki/Circuit_Idea 4. D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications, Tata Mc Graw Hill 7e (2011).	

<u>Learning Outcome</u>	1. The student should be able to prepare for laboratory work, by reading from books / laboratory manual / datasheet. 2. Should be able to design and construct electronic circuits by identifying and fetching different components. 3. Should be able to record observations from different measuring instruments and record them neatly. 4. Plot graphs and analyse the results. 5. Demonstrate the ability to maintain a laboratory notebook. 6. Prepare lab reports in standard scientific format.	

Programme: M. Sc. (Physics)
Course Code: PHGO-113 **Title of the Course**: Mini project
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Interest in designing and building electronic circuits by soldering	
Objective:	This course develops skills for designing and building laboratory equipment commonly used in Physics Laboratory.	
Content:	Design and Construct any one of the following instruments on a printed circuit board, make it work and pack it in a box. 1. Constant current source 2. Function Generator 3. Lock-in Amplifier 4. DC differential amplifier 5. Laboratory Power supply	48 hours
Pedagogy:	Laboratory work and self-study	
References/Readings	1. R. Srinivasan, K. R. Priolkar and T. G. Ramesh Experiments in Physics - Laboratory Manual, Indian Academy of Sciences 2017. 2. J. Millman and C. C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems, Mc Graw Hill International Student Ed. (1972).	
Learning Outcomes	1. To design and build simple laboratory instruments and understand their working. 2. To carry out minor repairs necessary in a laboratory.	

Programme: M. Sc. (Physics)
Course Code: PHGC-106 **Title of the Course:** Quantum Mechanics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Studied Physics, including an introductory course on Quantum Mechanics at graduate level	
Objective:	1. To develop basic formalisms of non-relativistic Quantum Mechanics. 2. To illustrate the concepts for analyzation of simple quantum mechanical systems	
Content:	**Schrodinger's Equation and Hermitian operators** (a) Time-dependent Schrodinger equation, continuity equation, expectation values, Ehrenfest's theorems, time-independent Schrodinger equation and stationary states. (b) Hermitian operators, eigenvalues and eigenstates of Hermitian operators, momentum eigenfunctions, orthogonality and completeness of wave functions, Computability and compatibility of observables, parity operation.	6 hours
	The Schrodinger equation in three dimensions Separation of the Schrodinger equation in Cartesian coordinates, Central potential, separation of the Schrodinger equation in spherical polar coordinates, The free particle, The three-dimensional square well potential, The hydrogen atom, The three-dimensional isotropic oscillator.	10 hours
	Vector space formulation of quantum mechanics Dirac Notation, representation of states and observables, bra and ket vectors, linear operators, relation with wave mechanics, algebra of Hermitian operators, matrix representation, unitary operators, Schrodinger and Heisenberg representations, linear harmonic oscillator problem by operator method.	4 hours
	Angular Momentum theory Angular Rotations in Classical and Quantum Mechanics, Rotational Symmetry and conservation of angular momentum, Treatment of general angular momentum by operator method, eigenvalues and eigenvectors, Eigen values and eigenfunctions of L^2 and L_z operators, ladder operators L^+ and L^-, spin angular momentum, algebra of Pauli matrices, Pauli representation of angular momentum operators. Addition of two angular momenta, spin-orbit interaction, Clebsch Gordon coefficients.	8 hours
	Approximation methods for stationary problems Time-independent perturbation theory for a non-degenerate energy level, Time-independent perturbation theory for a degenerate energy level, The variational method, The WKB approximation.	6 hours
	Approximation methods for time-dependent problems	6 hours

	Time-dependent perturbation theory, General features, Time-independent perturbation, periodic perturbation, The adiabatic approximation, The sudden approximation **Quantum Collision Theory** Scattering experiments and cross-sections, potential scattering and general features, the method of partial waves, Application of the partial-wave method, the integral equation of potential scattering, The Born approximation, Collision between identical particles, Collision involving composite systems.	8 hours
Pedagogy:	lectures/ tutorials/ assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	**Text Books / References** 1. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2004) 2. P. M. Mathew and K. Venkatesan, A Text Book of Quantum Mechanics, 2/e, Tata McGraw Hill (2017) 3. L. I. Schiff and Jayendra Bandhyopadhyay, Quantum Mechanics, 4/e, McGraw-Hill (2017). 4. V. K. Thankappan, New Age International Publishers (2012)). 5. V. Devanathan, Quantum Mechanics, 2/e Narosa Publishing House (2015). 6. David J. Griffiths, Introduction to Quantum Mechanics 2/e, Cambridge India, (2016). 7. J. J. Sakurai Modern Quantum mechanics, Addition-Wesley Publishing Company, (1994). 8. R. Eisberg and R. Resnick, Quantum Physics of atoms, molecules, solids, nuclear and particles, 2/e, John Wiley and Sons, (1985). 9. W. Greiner, Introductory Quantum mechanics, Springer Publication, (2001). 10. R. L. Liboff, Introductory Quantum Mechanics, 4e, Pearson Education Ltd (2003). 11. Nouredine Zettili, Quantum Mechanics: Concepts and Applications 2/e, Wiley India (2016)	
Learning Outcomes	1. Students will be able to solve wave equations for simple three dimensional system 2. Students will have the knowledge and skills to describe the structure of the hydrogen atom and show an understanding of quantisation of angular momentum and spin as well as the rules for quantisation and addition of these. 3. Students will learn the concepts of approximation methods for solving Schrodinger equations 4. Students will gain the knowledge about fundamental scattering of quantum particles.	

Programme: M. Sc. (Physics)
Course Code: PHGC-107 **Title of the Course:** Electronics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have studied the Electronics courses in Physics at graduation level.	
Objective:	The aim of the course is to introduce students to wide range of electronic circuits and their applications in Physics such as OP-AMPs. They also get basic understanding of opto-electronic devices, modulation, signals, microprocessor and memories.	
Content:	1. **OP-AMP Applications** OP-AMPS with negative feedback, Voltage controlled voltage source (VCVS), Current controlled voltage source (ICVS), Voltage controlled current source (VCIS), Current controlled current source (ICIS), Inverting and noninverting amplifier circuits, Open-loop frequency and phase response, Closed-loop frequency response, Differential amplifier, Instrumentation amplifier, DC and AC amplifiers, Summing, scaling and averaging amplifier, Voltage to current converter, Current to voltage converter.	12 hours
	2. **Opto-electronic devices** Radiative and non-radiative transitions, Characteristics of LED, Photoconductor, Photo diode, Photo transistor, Photo detector, Solar cell, Semiconductor laser; Optical fiber, Optical fiber waveguides, Fundamentals of optical communication	12 hours
	3. **Communication Electronics** Analog and digital signals, Modulation, Types of modulation, Basic principles of amplitude, frequency and phase modulation, Simple circuits for amplitude modulation and demodulation, Digital modulation and demodulation, Microwave Oscillators, Cavity resonators, Standing wave detector.	12 hours
	4. **Digital Electronics** Types of signals, Digital signal processing (DSP) basics, A/D and D/A conversion methods, DSP applications; Introduction to Microprocessors, Elements of 8-bit Microprocessors (INTEL 8085); Memory and storage, RAM, ROM, PROM and EPROM, Flash memories, Magnetic and optical storage.	12 hours
Pedagogy:	Lectures/tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings -	1. Millman, J. and Halkias, C. C., Integrated Electronics, Analog and Digital Circuits and Systems, McGraw – Hill Book Co. Tokyo (1997) 2. Boylestad, R. L. and Nashelsky L., Electronic Devices & Circuit Theory, XI Edn. Prentice-Hall of India (2015). 3. Floyd, T. L., Electronic Devices, V Edn. Pearson Education Asia (2001). 4. Gayakwad, R, A., Op-Amps and Linear Integrated Circuits, IV Edn. Prentice-Hall of India (2002).	

	5. Chen, Chin-Lin, Elements of Optoelectronics and Fiber Optics, McGraw-Hill Book Co. New Delhi (2014). 6. Kennedy, G., Electronics Communication Systems, IV Edn, Tata McGraw-Hill Book Co. New Delhi (2003). 7. Shrader, R., Electronic Communication, Glencoe Division of MacMillan (1993). 8. Kasap, S. O., Optoelectronics and Photonics: Principles and Practices, Dorling Kindersley India (2009) 9. Floyd, T. L., Digital Fundamentals, VII Edn. Pearson Education (2002). 10. Smith, S. W., Digital Signal Processing, Elsevier India (2006).	
Learning Outcomes:	1. Understanding the principles and circuits in electronics and use them in various applications. 2. Students acquire knowledge about working principles of opto-electronic devices and communication electronics. 3. Students get exposure to microprocessor and memory devices.	

Programme: M. Sc. (Physics)

Course Code: PHGC-108 **Title of the Course:** Statistical Mechanics

Number of Credits: 4

Effective from AY: 2021-22

Prerequisites for the course:	Should have studied Physics or Mathematics at graduation level. It is assumed that students have a basic working knowledge of classical and quantum mechanics, including Hamiltonian formulation and density matrices.	
Objective:	This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, microcanonical, canonical and grant canonical ensembles; the methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases.	
Content:	**1. Kinetic Theory and Equilibrium state of Dilute Gas** Formulation of problem, binary collisions, Boltzmann transport equation, Boltzmann's H theorem, Maxwell-Boltzmann distribution, Method of the most probable distribution, analysis of the H theorem, recurrence and reversal paradoxes, Validity of the Boltzmann transport equation.	10 hours
	2. Classical Statistical Mechanics Review of laws of thermodynamics, Entropy, Thermodynamic Potentials, Postulate of Classical Statistical Mechanics, Microcanonical ensemble, derivation of thermodynamics, equipartition theorem, Classical ideal gas, Gibbs paradox.	10 hours
	3. Canonical and Grand Canonical Ensembles Canonical ensemble, energy fluctuations in canonical ensemble, grand canonical ensemble, density fluctuations in grand canonical ensembles, equivalence of canonical and grand canonical ensembles, behaviour of W(N), meaning of Maxwell construction.	10 hours
	4. Quantum Statistical Mechanics Postulates of quantum statistical mechanics, density matrix, ensembles in quantum mechanics, third law of thermodynamics, ideal gases in microcanonical and grand canonical ensembles, foundations of statistical mechanics.	6 hours
	5. Ideal Fermi Gas Equation of state of Ideal Fermi Gas, theory of white dwarfs, Landau diamagnetism, deHass-Van Alphen effect, Pauli paramagnetism.	6 hours
	6. Ideal Bose Gas Photons, phonons, Bose-Einstein condensation.	6 hours
Pedagogy:	Lectures/ tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. Statistical Mechanics, Kerson Huang, 2/e, Wiley India 2008.	

	2. Fundamentals of Statistical Mechanics, B. B. Laud, New Age International Ltd. New Delhi 1998. 3. Fundamentals of Statistical and Thermal Physics, F. Reif, Waveland Press 2009. 4. Statistical Mechanics L. D. Landau and E. M. Lifshitz, Pergamon Press 1969. 5. Statistical Physics, R. P. Feynmann, The Benjamin Cummings Publishing Co 1981. 6. Introduction to Statistical Physics, S. K. Sinha, Narosa Publishing House, New Delhi 2007. 7. Statistical Physics, Tony Guenault, New Age International Ltd. New Delhi 2007. 8. Francis W. Sears , Gerhard Salinger, Thermodynamics, Kinetic Theory, and Statistical Thermodynamics, Addison-Wesley Principles of Physics Series, 1975.	
Learning Outcomes	1. Explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics. 2. Apply the principles of statistical mechanics to selected problems. 3. Apply techniques from statistical mechanics to a range of situations.	

Programme: M. Sc. (Physics)
Course Code: PHGO-119 **Title of the Course:** General Physics Practical
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	This course provides laboratory training in performing experiments that verify important physical laws and using modern and novel techniques of measurements.	
Content:	Short Lecture Course on – Theory of errors, Treatment of Errors of observation, linear least squares fitting and Data analysis. The experiments on the following topics (any 12) are to be performed with emphasis on the estimation and calculation of errors. 1. Types of Statistical Distributions 2. Analysis of Sodium Spectrum – Quantum defect and Effective quantum number 3. Michelson Interferometer/Fabry-Perot Interferometer 4. Diffraction experiments using laser– single slit, double slit, grating 5. Polarization experiments using laser –linearly and elliptically polarized light 6. Statistical Distribution of radioactive decay 7. Verification of Inverse Square Law using GM counter 8. Linear Absorption Coefficient of Aluminium using GM counter 9. Verification of Debye Relaxation Law and measurement of thermal relaxation of serial light bulb 10. Thermal diffusivity of Brass 11. Thermometry – measurement of thermoemf of Iron-Copper (Fe-Cu) thermocouple as a function of temperature and verification of law of intermediate metals 12. Calibration of Lock-in Amplifier 13. Measurement of mutual inductance of a coil using lock-in amplifier 14. Measurement of low resistance using lock-in amplifier 15. X-ray Emission – characteristics lines of a W target 16. Experiments using Strain Gauge 17. Ultrasonic Interferometer 18. Nonlinear dynamics – Feigenbaum circuit 19. Nonlinear dynamics – Chua's circuit 20. Verification of Percolation phenomena 21. Measurement of electrical resistance of Ni wire to verify para to ferromagnetic phase transition 22. Measurement of electrical resistance of NiTi based shape memory alloy 23. Measurement of Young's modulus of Brass by Flexural vibrations	12 hours 72 hours

Pedagogy:	Lectures and Laboratory Experiments.	
References/Readings	1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, McGraw Hill (Indian Edition) 2015. 2. R. Srinivasan, K. R. Priolkar and T. G. Ramesh, A Manual on Experiments in Physics, Indian Academy of Sciences, 2018.	
Learning Outcomes	1. Employ proper techniques when making scientific measurements 2. Demonstrate the ability to use selected pieces of measuring devices including the multimeter, oscilloscope, and AC and DC power supplies 3. Demonstrate the ability to use the computer as a data analysis tool 4. Demonstrate the ability to maintain a laboratory notebook 5. Apply the appropriate physics to the physical situation presented 6. Quantitatively analyze experimental data 7. Estimate and translate errors and report quantities up to last significant digit 8. Formulate and report scientific conclusions based on data analysis 9. Prepare lab reports in standard scientific format	

Programme: M. Sc. (Physics)
Course Code: PHGO-120 **Title of the Course:** Methods of Experimental Physics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	This course seeks to develop understanding of principles of measurement of various fundamental quantities in a Physics laboratory.	
Content:	**1. Measurement of temperature** Thermocouple, diode and semiconductor sensors, RTD, pyrometer, Langmuir probes, **2. Measurement of resistance** Two probe measurement and four probe measurement using constant current source and constant voltage source, Lock-in amp, discharge of capacitance **3. Measurement of capacitance** RC circuit, DC bridges, AC Bridges **4. Measurement of radiation** GM counter, ionization chambers, scintillation detector, solid state detectors, CCD detectors **5. Measurement of magnetic flux** Force methods, induction methods (including SQUID), Hall probe, indirect methods (MOKE) **6. Measurement of frequency** Resonance methods 7. **Estimation of errors in measurement.** Precision and accuracy, estimation of errors, propagation of errors, general formula, least square fitting, non-linear least square	8 hours 8 hours 8 hours 10 hours 10 hours 8 hours 8 hours
Pedagogy:	Lectures and Laboratory Experiments.	
References/Readings	1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, McGraw Hill (Indian Edition) 2015. 2. R. Srinivasan, K. R. Priolkar and T. G. Ramesh, A Manual on Experiments in Physics, Indian Academy of Sciences, 2018.	
Learning Outcomes	1. Understand the advantages and disadvantages of using a technique or probe for making scientific measurements. 2. Demonstrate the ability to use selected pieces of measuring devices. 3. Estimate and translate errors and report quantities up to last significant digit	

Programme: M. Sc. (Physics)
Course Code: PHGO-212 **Title of the Course:** Nuclear and Elementary Particle Physics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	PHGC-106	
Objective:	To introduce students to the fundamental principles and concepts governing nuclear and particle physics and have a working knowledge of their application to real-life problems.	
Content:	**1. Basic Properties of Nuclei:** Nuclear mass, charge and radius, Nuclear spin, Parity Statistics, magnetic and electric quadrupole moments	6 hours
	2. Nuclear Models: a. Liquid Drop model, Weizsacker's mass formula, mass parabolas b. Nuclear shell model. Energy levels in a three dimensional harmonic oscillator well potential, spin orbit interaction, prediction of magic numbers, ground state spins and parities, magnetic moments, Schmidt lines, Nuclear quadrupole moments c. Collective Model, Bohr-Mottelson theory of surface vibrations and rotations of nuclei, Excitation spectra of deformed nuclei, Nilsson model	11hours
	3. Nuclear Transformations: a. Alpha decay, Barrier penetration problem. Gamow's theory of Alpha decay, Geiger-Nuttal law, Alpha spectra and nuclear energy levels b. Gama transitions, multipole radiations, Quantum theory of the transition probability, selection rules, Angular correlation, Calculations of transition rates and comparison with experiments, internal conversion c. Beta Decay, Experiments in beta spectra, neutrino hypothesis, Fermi's theory of beta decay, Kurie plots, ft values, Allowed and forbidden transitions, selection rules, electron capture, parity violation in beta decay, experimental verification, measurement of neutrino helicity	10hours
	4. Two-Body Problem: Properties of deuteron Theory of the ground state of deuteron, Magnetic moment and electric quadrupole moment of deuteron, tensor force, theory of nucleon-nucleon scattering at low energy, phase shift and scattering length, effective range theory, experimental determination of low energy parameters, nature of nuclear forces, Wigner, Heisenberg and Majorana exchange forces, Meson theory of nuclear force	11hours
	5. Nuclear Reactions: Cross-sections, principles of detailed balance, Bohrs theory of compound nucleus, resonances and Breit-Wigner Single level formulation, optical model, Direct	5 hours

	reaction, Nuclear fission **6. Elementary Particles:** Classification of elementary particles, Baryons, Mesons and Leptons, Strong, weak and electromagnetic interactions, Isobaric spin, strangeness and parity, elementary particles reactions and decays, Resonances, Eightfold way, Quark model	5 hours
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. H. Enge, Introduction to Nuclear Physics, Addison-Wesley (1974). 2. E. Segre, Experimental Nuclear Physics, John Wiley (1960). 3. V. Devanathan, Nuclear Physics, Alpha Science International Ltd, (2011). 4. S. N. Ghoshal, Nuclear Physics, S. Chand and Co. (2019)	
Learning Outcomes	Student will be able to 1. Apply the models describing the basic nucleon and nuclear properties. 2. Describe the properties of strong and weak interaction. 3. Explain the different forms of radioactivity and account for their occurrence. 4. Classify elementary particles and nuclear states in terms of their quantum numbers.	

Programme: M. Sc. (Physics)
Course Code: PHGO-213 **Title of the Course:** Laser Physics and its applications
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Student should have basic knowledge of Atomic Physics and Lasers	
Objective:	1. To develop understanding of construction and operation of different Laser systems. 2. To understand advances in laser physics and its applications	
Content:	**Introduction to LASER:** Definition, brief history of Lasers, Unique Properties of laser, Coherence, fundamental wave properties of light: interaction of light with materials and quantum properties of light: Particle nature of light, discrete energy levels, radiative transitions and emission line width, energy levels and radiative properties of molecules, liquids and solids, radiation and thermal equilibrium- absorption and stimulated emission, Laser Safety: Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard ANSI	12 hours
	Laser Amplifiers and Resonators: Conditions for producing a laser – population inversions, Gain and gain saturation, Development and growth of laser beam, Laser oscillation above threshold, Requirements for obtaining population inversion, laser pumping requirements and techniques. laser cavity modes: longitudinal and Transverse, Stable laser resonators and Gaussian beams, Special laser cavities and cavity effects: unstable resonators, Q switching, gain switching, mode- locking, pulse shortening techniques (self-phase modulation, using group velocity dispersion, with gratings or prisms), ultrashort - pulsed laser and amplifier system, Ring lasers, Cavities for producing spectral narrowing of laser output.	12 hours
	Laser systems He -Ne laser, Ar ion laser, Molecular Gas lasers: CO2 laser, Excimer lasers, Laser systems involving high-density gain media: Organic dye lasers, solid state lasers: Ruby laser, Nd-YAG and glass lasers.	12 hours
	Applications of Laser: Engineering Applications of Lasers, Applications in communication, LIDAR, Medical Applications, Laser Cooling and Trapping of Atoms,	12 hours
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.	
References/Readings	1. Laser fundamentals, second edition William T. Silfvast, Cambridge publication, 2004 2. Laser electronics, third edition, Joseph T. Verdeyen, Prentice Hall series, 1994.	

	3. Basics of laser physics, second edition, Karl F. Renk, Springer, 2012. 4. Laser Physics and application, Tarasov. L, Mir Publication, 1987. 5. Laser application, William V. Smith, Artech House Publishers, 1970. 6. Lasers: Fundamentals and Applications (Graduate Texts in Physics), second edition, K. Thyagarajan, Ajoy Ghatak, Springer publication, 2012. 7. Principles of Lasers, O. Svelto, Springer 2004 8. Laser Physics, Simon Hooker and Colin Webb, Oxford, 2010.	
Learning Outcomes:	1. Student will understand the basic principle and operation of different types of Lasers. 2. Student will get exposure to applications of Lasers in different fields.	

Programme: M. Sc. (Physics) (Solid State Physics)
Course Code: PHSC-201 **Title of the Course:** Structure, Lattice and Thermal Properties of Solids
Number of Credits: 3
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-101	
Objective:	1. To introduce fundamental concepts of solids like crystalline order, symmetry in solids, simple crystal structures and their properties. 2. To acquaint with the concept of reciprocal lattice and its importance in structure determination using x-rays. 3. To introduce different types of crystal bindings and elastic properties of solids. 4. To familiarize the concept of lattice vibration and their role in thermal properties of solids.	
Content:	**Crystal Structure** Crystals - Lattice, Bravais lattice, primitive unit cell, symmetry of molecules and crystals, symmetry operations and symmetry elements, Lattices in one, two and three dimensions, Space groups, definitions of directions, coordinates and planes. Simple crystal structures: NaCl, CsCl, diamond, hexagonal close-packed structure, cubic ZnS structure and their properties, Non ideal crystal structures – random stacking and polytypism Reciprocal Lattice - Diffraction of waves by crystals, Bragg law, Scattered wave amplitude - Fourier analysis, reciprocal lattice vectors, diffraction conditions, Laue equations, Brillouin zones, Geometric structure factor, Atomic Structure factor Point Defects General Thermodynamic Features, Color centres, Line Defects: Dislocations	15 hours
	Crystal Binding and Elastic Constants Crystals of inert gases - Van der Waals - London interaction, repulsive interaction, equilibrium lattice constants, cohesive energy, Ionic Crystals - Electrostatic or Madelung Energy, evaluation of Madelung constant, covalent crystals, bonding in metals and Hydrogen bonds, Atomic Radii, Analysis of elastic strains, elastic compliance and stiffness constants, elastic waves in cubic crystals	9 hours
	Thermal Properties Vibrations of a one -dimensional monatomic lattice, first Brillouin zone, group velocity, long wavelength limit, derivation of force constant from experiment. Vibrations of a one dimensional diatomic lattice. Quantization of elastic waves, phonon momentum, Inelastic scattering by Phonons, Phonon Heat capacity, Planck distribution, normal mode enumeration, density of states in one dimension, density of states in three dimensions Debye model for density of states,	12 hours

	Debye T^3 law, Einstein model of the density of states, Thermal conductivity - Thermal resistivity of phonon gas, Umklapp process	
Pedagogy:	Lectures/ tutorials/ assignments. Sessions will be interactive in nature to enable peer group learning.	
References/Readings	1. Introduction to Solid State Physics, C. Kittel, Wiley India (2019) 2. Elementary Solid State Physics; Principles and Applications, M. A. Omar Addison Wesley (2000) 3. Solid State Physics, Niel W. Ashcroft, N. David Mermin, Harcourt Asia Pte Ltd. (2001) 4. Solid State Physics, G. Bums, Academic press, Inc. London (1985) 5. Solid State Physics, A. J. Dekker, McMillan, India (1985) 6. Solid State Physics, J. S. Blakemore, W. B. Sauders, Philadelphia (1969)	
Learning Outcomes:	1. Student will understand the fundamental aspects related to structure of solids, lattice symmetry, and structure determination. 2. Student will be exposed to various aspects of crystal binding and the elastic properties of solids 3. Student will recognize the idea of vibrating lattice, its quantization and the role of phonons in thermal properties of solid.	

Programme: M. Sc. (Physics) (Solid State Physics)
Course Code: PHSC-202 **Title of the Course:** Band Theory and Electronic Properties of Solids
Number of Credits: 3
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-106 and PHGC-108	
Objective:	1. To introduce the concept of formation of electronic bands in solids. 2. To acquaint with techniques associated with measurement of band structure. 3. To present the effect of band structure on electronic transport properties of solids.	
Content:	**Metals: Drude and Sommerfeld models** Free electron theory – Drude model - assumptions, failures of Drude model, Sommerfeld model, Successes and failures of the Sommerfeld model, Electrical conductivity, Experimental electrical resistivity of metals, Heat capacity of electron gas, Experimental heat capacity.	6 hours
	Nearly Free electron model Periodic potential, Born – von Karman boundary conditions, Schrodinger equation in a periodic potential, Bloch's theorem, Electronic band structure, single electron energy state, degenerate electron levels, Consequences of the nearly free electron model, Fermi surface.	6 hours
	Tight binding model Band arising from a single electronic level, electronic wavefunctions, General points about the formation of tight binding bands, Group I and II metals, Group IV elements, transition metals, comparison of tight binding and nearly free electron band structure, crystal momentum, effective mass, holes.	6 hours
	Semiconductors and Insulators Band structure of Si and Ge, Band structure of direct gap III-V and II-VI semiconductors, Optical absorption and excitons, Thermal population of bands in semiconductors, Intrinsic carrier density, Impurities and extrinsic carrier density, degenerate semiconductors.	6 hours
	Measurement of Band structure Lorentz force and orbits, Landau levels, electronic density of states in a magnetic field, quantum oscillatory phenomena, de Hass – van Alphen effect, Cyclotron resonance, interband magneto optics, electron spectroscopy – angle resolved photoelectron spectroscopy, Some case studies – Copper, Sr_2RuO_4 .	6 hours
	Transport Properties Thermal and electrical conductivity of metals, electron-electron scattering – Fermi liquid behaviour, Electrical conductivity of semiconductors, Disordered systems and hopping conduction, Hall effect, magnetoresistance in metals, magnetophonon effect, magnetoresistance in two	6 hours

	dimensional systems, quantum Hall effect, fractional quantum Hall effect.	
Pedagogy:	Lectures/ tutorials /assignments. Sessions will be interactive in nature to enable peer group learning.	
References/Readings	1. Band theory and Eletronic Properties of Solids, J. Singleton, Oxford University Press, (2014) 2. Introduction to Solid State Physics, C. Kittel, Wiley India (2019) 3. Solid State Physics, Niel W. Ashcroft, N. David Mermin, Harcourt Asia Pte Ltd. (2001) 4. Elementary Solid State Physics; Principles and Applications, M. A. Omar Addison Wesley (2000)	
Learning Outcomes:	1. Student will understand formation of bands, their importance in classification of solids and theoretical models of calculation of band structure. 2. Student will get familiarized with some the techniques of band structure measurement. 3. Student will comprehend the effect of band structure on electronic transport properties of solids.	

Programme: M. Sc. (Physics) (Solid State Physics)
Course Code: PHSC-203 **Title of the Course:** Magnetic, Superconducting and Optical Properties of Solids
Number of Credits: 3
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-106 and PHGC-108	
Objective:	1. To introduce students to different types of magnetic order in solids. 2. To present to the students' fundamentals of superconductivity. 3. To acquaint the students with optical and dielectric properties of solids.	
Content:	**Magnetic Properties** Magnetic moments, Quantum mechanics of spin, Atom in mangetic field, Magnetic susceptibility, Diamagnetism, Paramagnetism, Semiclassical treatment, Quantum Theory of Paramagnetism, Hund's Rules, Crystal field, Paramagnetic Susceptibility of Conduction electrons, Van Vleck paramagnetism, Adiabatic demagnetization Ferromagnetism, The Weiss model of a ferromagnet, Origin of molecular field, Magnons, Domains, Antiferromagnetism, Neel's theory, Ferrimagnetism	12 hours
	Superconductivity Experimental survey- Occurrence of Superconductivity, Destruction of superconductivity by magnetic fields, Meissner effect, Heat capacity, Energy gap, microwave and infrared properties, Isotope Effect Theoretical Survey - Thermodynamics of the transition, London equation, Coherence length, BCS theory, Flux quantization, Type II superconductors, Tunnelling, Josephson effects, High Tc superconductivity (introduction)	6 hours
	Optical and Dielectric Properties Macroscopic electric field, local electric field at atom, dielectric constant and polarizability, Complex dielectric constant, Classical theory of electronic polarization and optical absorption, Structural Phase transitions, Ferroelectric Crystals and Displacive transitions Optical reflectance, Excitons, Raman effect in crystals. Luminescence and Luminescence centres	6 hours
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.	
References/Readings	1. Introduction to Solid State Physics, C. Kittel, Wiley India (2019) 2. Elementary Solid State Physics; Principles and Applications, M. A. Omar Addison Wesley (2000) 3. Solid State Physics, Niel W. Ashcroft, N. David Mermin, Harcourt Asia Pte Ltd. (2001) 4. Solid State Physics, A. J. Dekker, McMillan, India (1985) 5. Solid State Physics, J. S. Blakemore, W. B. Sauders,	

	Philadelphia (1969)	
Learning Outcomes:	1. Student will recognize diverse types of magnetic orders in solids. 2. Students will be conversant with different contributions to the dielectric and optical properties of the lattice. 3. Student will be familiar with basics of superconductivity phenomenon and its theory.	

Programme: M. Sc. (Physics)(Solid State Physics)
Course Code: PHSO-214 **Title of the Course:** Solid State Physics Practical
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGO-119/PHGO-120	
Objective:	This course aims at developing advanced level experimental skills and competence in the analysis of experimental data on structural, magnetic, transport and optical properties of solids and relate them to different physical concepts studied in the theory courses, PHSC-201, PHSC-202 and PHSC-203.	
Content:	1. X-ray diffraction: Analysis of diffraction patterns of cubic crystal structures to determine their lattice constant, intensity ratios, and lattice type 2. Measurement of dispersion relation of monoatomic and diatomic lattices using electrical equivalent circuits. 3. Measurement of Resistivity of a metal and a Semiconductor by Four Probe Method 4. Measurement of Thermoelectric Power of a metal 5. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Material by Gouy's Method. 6. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Liquid by Quinke's Method. 7. Study of Hysteresis loop of magnetic materials. 8. Determination of Lande's Splitting Factor, g, in an organic radical. 9. Study of Elastic behaviour of solids using a composite piezoelectric oscillator 10. Measurement as well as determination of Transition Temperature of a Ferroelectric Material Dielectric Constant and understanding failure of mean field theory 11. Measurement of Activation Energy of F-Centres in Alkali Halide Crystals Thermo luminescence 12. Determination of a Hall Coefficient and Nature of a Semiconductor and Mobility of Charge Carriers 13. Analysis of frequency dependence of Dielectric constant of a material. 14. Study of optical properties of a material - absorption, excitation and emission spectra. 15. Measurement of thermal conductivity of a good and poor thermal conductor. 16. Raman effect – demonstration applied to a particular material. A minimum of 10 experiments are expected to be done by the students.	96 hours
Pedagogy:	Laboratory experiments, self-study	

References/Readings	1. Experimental Manuals assigned to each experiment. 2. C. Kittel, Introduction to Solid State Physics, 7th Edition, John Wiley & Son, Inc. New York (1997). 3. B.L. Worsnop & H.T. Flint, Advanced Practical Physics for Students, (1927). 4. A. J. Dekker, Solid State Physics, McMillan, India (1985). 5. Jerry D. Wilson, Physics Lab. Experiments 7/e, D. C. Heath and Company (2009).	6.
Learning Outcomes	1. Quantitative measurements and evaluation of various properties and constants introduced in the theory courses of Physics. 2. Verification of different laws and concepts learned in the theory courses of Physics 3. Development of fine and intensive experimental skills. 4. Interpreting results, error analysis, writing reports, analyzing data.	5.

Programme: M. Sc. (Physics)(Computational Physics)
Course Code: PHCC-221 **Title of the Course:** Advanced Quantum Mechanics
Number of Credits: 3
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-106	
Objective:	To introduce advanced topics in the field of quantum mechanics such as many-body systems, relativistic wave equations and relativistic fields	
Content:	**Second Quantization** Identical Particles, Many-Particle States, and Permutation Symmetry, Completely Symmetric and Antisymmetric States, Bosons: States, Fock Space, Creation and Annihilation Operators, The Particle-Number Operator, General Single- and Many-Particle Operators, Fermions: States, Fock Space, Creation and Annihilation Operators, Single- and Many-Particle Operators, Field Operators: Transformations Between Different Basis Systems, Field Operators, Field Equations, Momentum Representation: Momentum Eigen functions and the Hamiltonian, Fourier Transformation of the Density, The Inclusion of Spin.	8 hours
	Spin-1/2 Fermions Noninteracting Fermions, The Fermi Sphere, Excitations, Single-Particle Correlation Function, Pair Distribution Function, Density Correlation Functions, and Structure Factor, Ground State Energy and Elementary Theory of the Electron Gas, Hamiltonian, Ground State Energy, in the Hartree–Fock Approximation, Modification of Electron Energy Levels due to the Coulomb Interaction, Hartree–Fock Equations for Atoms.	6 hours
	Bosons Free Bosons, Pair Distribution Function for Free Bosons, Two-Particle States of Bosons, Weakly Interacting, Dilute Bose Gas, Quantum Fluids and Bose–Einstein Condensation, Bogoliubov Theory of the Weakly Interacting Bose Gas, Superfluidity.	6 hours
	Relativistic Wave Equations Klein-Gordon equation, Plane wave solution, charge and current densities, hydrogen atom. Dirac equation, algebra of Dirac matrices, covariance of Dirac equation, plane wave solutions, equation in an electromagnetic field. Properties of Dirac electron. The spin of the Dirac particle, Magnetic dipole moment of electron, Velocity operator, Expectation value of the velocity. Parity, Charge conjugation and time reversal operations, Parity operation, Charge conjugation, a time reversal operation. Dirac's hole theory, Feynmann's theory of Positrons.	8 hours
	Quantization of Fields and Radiation Theory Wave equation for a field, Conjugate field momentum, Hamiltonian, density conservation laws, quantum condition	8 hours

	and quantization of scalar field, quantization of complex scalar and Schrodinger fields, Quantization of electromagnetic fields, Interaction of radiation with matter spontaneous and induced emission, Thomson scattering, cross-section for photoelectric effect, Heisenberg-Kramer formula, Rayleigh and Raman scattering. Quantization of Schrodinger field by anticommutator, Atomic level shift, Lamb shift.	
<u>Pedagogy</u>:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.	
<u>References/Readings</u>	1. Franz Schwabl, Advanced Quantum mechanics, Springer (2005) 2. J. J. Sakurai, Advanced Quantum mechanics, Addison-Wesley (1967) 3. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson (2004) 4. S. N. Biswas, Quantum Mechanics, Books and Allied Pvt. Ltd. (2015) 5. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2004)	
<u>Learning Outcomes:</u>	1. In the first unit students will learn the formalism of second quantization and its application to the most important problems of weakly interacting electron gas and Bose gases. 2. In the second unit students will learn about the Klein-Gordon and Dirac equation, and their important aspects. 3. In the third unit students will learn about quantization of Klein-Gordon, Dirac and radiation fields	

Programme: M. Sc. (Physics) (Computational Physics)
Course Code: PHCC-222 **Title of the Course:** Advanced Statistical Mechanics
Number of Credits: 3
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-106 and PHGC-108	
Objective:	To introduce advanced statistical methods and phenomena in many-body systems.	
Content:	**Phase Transition and Critical Phenomena** First and second order transitions, critical phenomena, morphology, fluctuation and correlation and response, Critical exponents, scaling inequalities, how to study critical phenomena	7 hours
	Models and Universality Ising models and its ground state, Ising models and its applications, other models and their ground states, Universality in different models	4 hours
	Mean Field theory Mean field theory for fluids, critical exponent of a fluid system, Mean field theory for magnetic systems, Mean field equation of state and its solution, Mean field critical exponents, correlation length and correlation function, Bethe approximation, Bethe approximation for 2D Ising model, Landau theory of Phase transition, Critical exponents from Landau theory.	6 hours
	Transfer Matrix method Transfer matrix and 1D Ising model, Determination of magnetization, susceptibility, specific heat and correlation length. Spin-1 Ising model and potts model, 2D Ising model	3 hours
	Series expansion method (Perturbation method) High temperature expansion and id Ising model, High and low temperature expansions for 2D Ising model, Duality and critical temperature, approximation techniques	3 hours
	Monte Carlo method (Numerical method) Ensemble average in Monte Carlo method, Ergodicity, Detailed balance and Metropolis algorithm, Monte Carlo Simulation for 2D Ising model, Measurements and errors.	7 hours
	Scaling and renormalization Homogeneous function, Homogeneity of free energy and scaling, Renormalization group, Renormalization Group, Renormalization operation, Free energy function and correlation length, Critical exponents, fixed point and universality.	6 hours
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.	
References/Readings	1. R. K. Pathria and P. D. Beale, *Statistical Mechanics* , (Elsevier, London, 2011). 2. L. D. Landau and E. M. Lifshitz: Statistical Physics, Third Edition, Part 1: Volume 5 (Course of Theoretical Physics, Volume 5)	

	3. J. M. Yeomans, Statistical Mechanics of Phase Transitions, (Oxford University Press, New York, 1994). 4. H. E. Stanley, Introduction to Phase Transitions and Critical Phenomena, (Oxford University Press, New York, 1987) 5. P. M. Chaikin and T. C. Lubensky: Principles of Condensed Matter Physics, Cambridge (2013) 6. S. B. Santra and P. Ray, Statistical Mechanics and Critical Phenomena: A brief overview, in Computational Statistical Physics, edited by S. B. Santra and P. Ray, (Hindustan Book Agency, New Delhi, 2011).	
Learning Outcomes:	Students will be able to learn Physics of phases and phase transitions, critical phenomena, elementary excitations, models, and Monte Carlo method etc.	

Programme: M. Sc. (Physics)(Computational Physics)
Course Code: PHCC-223 **Title of the Course:** Numerical Techniques for Physics
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGC-100, PHGC-101	
Objective:	To introduce the methods of solving mathematical problems that occur in physics using numerical techniques.	
Content:	**Root Finding and Nonlinear Sets of Equations** Introduction, Bracketing and Bisection, Secant Method, False Position Method, and Ridders' Method, Van Wijngaarden-Dekker-Brent Method, Newton-Raphson Method Using Derivative, Roots of Polynomials, Newton-Raphson Method for Nonlinear Systems of Equations, Globally Convergent Methods for Nonlinear Systems of Equations	4 hours
	Minimization or Maximization of Functions Introduction, Initially Bracketing a Minimum, Golden Section Search in One Dimension, Parabolic Interpolation and Brent's Method in One Dimension, One-Dimensional Search with First Derivatives, Downhill Simplex Method in Multidimensions, Line Methods in Multidimensions, Direction Set (Powell's) Methods in Multidimensions, Conjugate Gradient Methods in Multidimensions, Quasi-Newton or Variable Metric Methods in Multidimensions, Linear Programming: The Simplex Method, Linear Programming: Interior-Point Methods, Simulated Annealing Methods, Dynamic Programming	5 hours
	Modelling of Data Introduction, Least Squares as a Maximum Likelihood Estimator, Fitting Data to a Straight Line, Straight-Line Data with Errors in Both Coordinates, General Linear Least Squares Nonlinear Models, Confidence Limits on Estimated Model Parameters, Robust Estimation, Markov Chain Monte Carlo, Gaussian Process Regression	5 hours
	Interpolation and Numerical Differentiation Introduction, Polynomial Interpolation, Error in Polynomial Interpolation, Estimating derivatives and Richardson Extrapolation	5 hours
	Integration of Ordinary Differential Equations Introduction, Runge-Kutta Method, Adaptive Step size Control for Runge-Kutta, Richardson Extrapolation and the Bulirsch-Stoer Method, Second-Order Conservative Equations, Stiff Sets of Equations, Multistep, Multi value, and Predictor-Corrector Methods, Stochastic Simulation of Chemical Reaction Networks.	5 hours
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.	

References/Readings	1. W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, Numerical Recipes: The Art of Scientific Computing (Cambridge University Press) 2. W. Cheney, D. Kincaid, Numerical Mathematics and Computing, (Thomson Higher Education, USA) 3. A. L. Gercia, Numerical methods for Physics (CreateSpace Independent Publishing, 2015) 4. Computational Physics, Koonin & Meredith	
Learning Outcomes:	Students will learn basic algorithms, advanced, and cutting edge numerical techniques used in Computational Physics.	

Programme: M. Sc. (Physics)(Computational Physics)
Course Code: PHCO-234 **Title of the Course:** Numerical Techniques Practicals
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have attended PHGO-110/PHGO-111	
Objective:	To apply numerical methods for solving mathematical problems that occur in physics	
Content:	1. Finding Errors: its sources, propagation and analysis 2. Find Roots of functions: bisection, Newton-Raphson, secant method, fixed-point iteration, applications 3. Solution of Linear equations: Gauss and Gauss-Jordan elimination, Gauss-Seidel, LU decomposition; 4. Eigenvalue Problems 5. Least square fitting of functions 6. Interpolation 7. Numerical differentiation 8. Numerical integration 9. Solutions of ODE by initial value problems, Euler's method, second and fourth order Runge-Kutta methods 10. Boundary value problems by finite difference method. 11. Monte Carlo simulation	96 hours
Pedagogy:	Lectures/Laboratory practicals. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, Numerical Recipes: The Art of Scientific Computing (Cambridge University Press) 2. W. Cheney, D. Kincaid, Numerical Mathematics and Computing, (Thomson Higher Education, USA) 3. A. L. Gercia, Numerical methods for Physics (CreateSpace Independent Publishing, 2015) 4. Computational Physics, Koonin & Meredith 5. Computational Physics/Scientific Computing by Konstantinos Anagnostopoulos 6. William H. Press, Brian P. Flannery, Saul A. Teukolsky, William T. Vetterling: Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 2002	
Learning Outcomes:	Students will learn basic algorithms, advanced, and cutting edge numerical techniques used in Computational Physics.	

Programme: M.Sc (Physics)(Biophysics)
Course Code: PHBC-200 **Title of the Course: Introduction to Biology and Biophysics**
Number of Credits: 4
Effective from AY: 2020-21

Prerequisites for the course:	Understanding of basic concepts in biology, chemistry and physics	
Objective:	This is a bridge course for the students for introducing them to the concepts in biology and biophysics.	
Content:	**Introduction to Biology** Origin and evolution of life, prokaryotic cells, photosynthesis, eukaryotic cells, elementary building blocks of life	6 hours
	Biochemistry I Chemical components of the cell, energy, catalysis and biosynthesis, cellular membranes, transport across membranes, energy generation in cells, cytoskeletons, cell division,	16 hours
	Biochemistry II Proteins-structure and function, DNA, RNA and chromosomes, Genes, genetics, carbohydrates, lipids and enzymes	16 hours
	Biophysics Biological motion, free energy transduction, chemochemical machines, pumps and motors as chemochemcial machines, flux force dependence, molecular motors, mechanochemistry of molecular motors, biomolecular forces, biomechanics of muscle contraction and cardiovascular system.	10 hours
Pedagogy:	Lectures/Assignments/Self Study Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. The Cell: A Molecular Approach, Geoffrey M. Cooper and Robert E. Hausman, Seventh Edition, Oxford University Press (2018). 2. Essential Cell Biology, Bruce Alberts, Dennis Bray, Karen Hopkin, Alexander D. Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter, Fourth Edition Garland Science (2013). 3. Molecular Biology, David Clark Nanette Pazdernik Michelle McGehee, Third Edition, Elsevier (2019). 4. Introduction to Molecular Biophysics, Jack A Tuszynski and Michal Kurzynski, First Edition, CRC Press, (2003). 5. Biophysics: An Introduction, Rodney Cotterill, Wiley (2002). 6. Applied Biophysics, A Molecular Approach for Physical Scientist, Thomas A Weigh, First Edition, Wiley, (2007). 7. Molecular & Cellular Biophysics, Mayer & Jackson, Cambridge Press (2006).	

Learning Outcomes:	1. The students will be familiarized with the basic concepts of molecular biophysics 2. The students will have gained sufficient knowledge in the structure and functioning of molecular processes 3. The students will be exposed to the recent developments in biomechanics and molecular motion.	

Programme: M.Sc (Physics)(Biophysics)
Course Code: PHBC-241 **Title of the Course: Molecular Biophysics**
Number of Credits: 4
Effective from AY: 2020-21

Prerequisites for the course:	PHBC-200	
Objective:	This course is intended to enrich the students with the basics of molecular biophysics. The students will learn about the different physical process occurring in biological systems.	
Content:	**Cellular Biophysics** General organization of the cell, Structure of biomolecules, cellular mechanics and transport, Chemical bonding, ionization energy, electron affinity, electron negativity, strong bonds and weak, bond energies in biomolecules, Interatomic potentials for strong and weak bonds, cellular mechanics, transport mechanism	6 hours
	Structure of Proteins, DNA and Enzymes Kinetics Basics aspects of protein structure, Polypeptide chain geometrics, estimates of potential energy, results of potential energy calculations, hydrogen bonding, hydrophobic & hydrophilic interactions and water as universal solvent in biological systems, Primary structure sequencing of polypeptide, haemoglobin, homologies in proteins, Secondary structure alpha and beta conformation, collagen structure, stability of alpha helix, Ramchandran plot, Tertiary structure, structure of myoglobin and hemoglobin, Quaternary structure, symmetry consideration, Analysis of subunits and chain arrangement of subunits, stability of globular quaternary structure. Protein folding rules, pathways and kinetics Nucleic acids, purines and pyrimides, double helical structure of DNA, polymorphism of DNA, RNA structure, thermodynamics of DNA supercoiling, chromosome structure Enzymes, enzyme kinetics, Michaelis-Menten equation, Inhibitors, kinetics of competitive, non-competitive and uncompetitive inhibitors	16 hours
	Membrane Biophysics Fundamental aspects of biological membrane, Various membrane models, Carbohydrate, Lipids & Proteins, Components of cell membrane, Composition of biological membranes- lipid molecules, proteins, glycoprotein, membrane, skeletons, forms of lipids and proteins, electrical properties of lipids and proteins, principles of membrane organization & stability, Biogenesis of cell membrane, Molecular motion in membrane & membrane fluidity, Protein lipid interactions, Electric properties of membranes: electric double layer, Poisson-Boltzmann theory of electric double layer, Gouy-Chapman model of electric double layer, free energy of	16 hours

	electric double layer, bonds and adhesion of electrified molecules on the surface of a membrane, Hodgkin Huxley equation, membrane impedance, Zeta, Stern & total electrochemical potential, Helmholtz-Smoluchowski equation; it's correction by Debye-Huckle theory, transmembrane potential & it's measurement by microelectrodes. Neurobiophysics Transport across membranes: diffusion and osmosis, Selectivity & ion specificity of biomembrane, Ion channel structure and gating function, Ion channel types and characterization, transport of macromolecules with & without vesiculation & by intermediate mechanism, Transport and communication between cells and organelles. **Molecular biomechanics** Biological motion, free energy transduction, chemochemical machines, pumps and motors as chemochemcial machines, flux force dependence, molecular motors, mechanochemistry of molecular motors, biomolecular forces, biomechanics of muscle contraction and cardiovascular system.	10 hours
Pedagogy:	Lectures/ Tutorials/Assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. Introduction to Molecular Biophysics, Jack A Tuszynski and Michal Kurzynski First Edition, CRC Press (2003). 2. Biophysics: An Introduction, Rodney Cotterill, Wiley (2002). 3. Applied Biophysics, A Molecular Approach for Physical Scientist, Thomas A Weigh Wiley (2007). 4. Molecular & Cellular Biophysics, Mayer & Jackson, Cambridge (2006). 5. Biophysics, Vasantha Pattabhi and N. Goutham First Edition, Narosa (2002). 6. Biomembrane structure and Function, Ed. Chapman D., Macmillan, (1983). 7. Introduction to Biological Membrane, Jain R K, John Wiley& Sons (1988). 8. Text Book of Physiology, Guyton & Hall, 12th Edition, Elsevier (2010). 9. Molecular motors, Schliwa, Wiley-VCH Verlag GmbH & Co (2003).	
Learning Outcomes:	1. The students will be familiarized with the basic concepts of molecular biophysics. 2. The students will have gained sufficient knowledge in the structure and functioning of molecular processes. 3. The students will be exposed to the recent developments in biomechanics and molecular motion.	

Programme: M.Sc (Physics)(Biophysics)
Course Code: PHBC-242 **Title of the Course: Methods in Biophysics**
Number of Credits: 4
Effective from AY: 2020-21

Prerequisites for the course:	PHBC-200	
Objective:	The aim of course is introduced various experimental techniques used in biophysical systems. The student will learn about the basic and advanced characterization tools for biophysics.	
Content:	**Separation techniques I** Electrokinetics methods: electrophoresis, electrophoretic mobility (EPM), factors affecting EPM, Paper, PAGE, SDS-PAGE, Disc gel, gradient gel, electrophoresis of nucleic acid and its application, Pulse field electrophoresis, single cell gel electrophoresis, Isolectrophoresis, preparative electrophoresis, 2-D gel electrophoresis, Capillary, Iso-Electric focusing, applications in biology and medicine. Chromatography, TLC, adsorption, partition, ion exchange, gel filtration, affinity and FPLC, GLC,	12 hours
	Separation techniques II HPLC: mobile phase systems, modes of operations, application, Hydrodynamics method: fundamental principles' Centrifugation: principle, preparative centrifuge, analytical, ultracentrifuge, sedimentation and diffusion, Ultracentrifugation and their applications in molecular weight, size determination. Viscosity and its application, dialysis, solvent fractionation, isoelectric precipitation,	12 hours
	Spectroscopic methods Principles of spectroscopic techniques, Ultraviolet-visible spectroscopy, circular dichroism and optical rotatory dispersion, fluorescence spectroscopy, infrared spectroscopy, Raman spectroscopy, Atomic Absorption spectroscopy- Inductively coupled plasma atomic emission spectrophotometry. Electron spin resonance, Nuclear Spin resonance, X-ray spectroscopy	12 hours
	Microscopic Techniques Principle, instrumentation and application of optical microscopy, image formation, magnification, resolving power. optimum resolution, image defects, different types of Microscopy: Dark field, Phase contrast, polarization microscopy, Interference microscopy, Fluorescence microscopy, Electron microscopy: Electron guns, Electron lens, electrostatic focusing, magnetic focusing, SEM, STEM, Atomic force microscopy.	12 hours
Pedagogy:	Lectures/Tutorials/Assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. Methods in Molecular Biophysics, Igor N S, N Zaccai & J Zaccai, First Edition, Cambridge (2007). 2. Principle of Biochemistry, D Voet, J Voet and CW Pratt, Third Edition, John Wiley and Sons, (2008). 3. DNA Cloning, Grover Vol. I, II, III, First Edition, Oxford (1987).	

	4. Biophysics Vasantha Pattabhi and N. Goutham, First Edition, Narosa (2002). 5. Advanced Methods in Protein Microsequencing, Wittmann, First Edition, Springer (1986). 6. Fundamentals of Molecular Spectroscopy, Banwell, Fourth Edition, McGraw Hill (1994). 7. Essential Biophysics, Narayanan First Edition, New Age Publications (2000). 8. Handbook of Molecular Biophysics (Methods & Application) Henrik G Bohr, First Edition, Wiley (2009).	
Learning Outcomes:	1. The students will be familiarized with the basic experimental techniques used in biophysics. 2. The students will expand their knowledge on various spectroscopic and microscopic methods in characterization.	

Programme: M.Sc (Physics)(Biophysics)
Course Code: PHBO-251 **Title of the Course: Solid state and Biomaterials**
Number of Credits: 4
Effective from AY: 2020-21

Prerequisites for the course:	PHBC-200	
Objective:	This course is intended to introduce the concepts in biomaterials. The students will have a good understanding of the different bio materials and their properties. A brief introduction to new and advanced materials for biological applications will also be covered in the course.	
Content:	**Introduction to Solid State** Types of bonds, Crystal structure, Phase changes, crystal imperfections, defects and dislocations, non-crystalline solids, surface energy, contact angle, surface tension, Types of materials-ceramics, metals, semiconductors, polymers, composites, Impact of biomaterials	12 hours
	Properties of Materials Mechanical properties-elasticity, stress, strain, tensile strength, plastic deformation, hardness, thermal properties, optical properties,	12 hours
	Biomaterials I Introduction to biomaterials, property requirements for biomaterials, concept of biocompatibility, structure of cells and biological tissues, cell material interaction and response to foreign bodies, histocompatibility, genotoxicity.	12 hours
	Biomaterials II Important biometallic alloys: Ti-based, stainless steels, Co-Cr-Mo alloys, Nitinol, Tantalum and magnesium, Bioinert, Bioactive and bioresorbable ceramics, Processing and properties of different bioceramic materials silicates, aluminates, Zirconia, hydroxyapatite tricalcium phosphatecalcium sulfate, bioactive glasses, Synthesis of biocompatible coatings on structural implant materials, Microstructure and properties of glass-ceramics, common biocompatible polymers and their properties, biodegradable polymers, Natural biomaterials, design concept of developing new materials for bioimplant applications, Nanobiomaterials	12 hours
Pedagogy:	Lectures/Tutorials/Assignments Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. Biomaterials Science: An introduction to Materials in Medicine, Edited by Ratner, Hoffman, Schoet and Lemons, Third Edition, Elsevier Academic Press (2012). 2. Introduction to Biomaterials: Basic Theory with Engineering Applications, Mauli Agrawal, Ong, Appleford and G. Mani, First Edition, Cambridge Press, (2013).	

	3. Biomaterials Science and Biocompatability, Fredrick H. Silver and David L. Christiansen, Piscataway, First Edition, Springer (1999). 4. Biomaterials: An Introduction, John B Park and Roderik S Lakes, Third Edition, Springer, (2007). 5. Nanobiomaterials: Classification, Fabrication and Biomedical Applications, Ed: Wang, M. Ramalingam, X. Kong L. Zhao, First Edition, Wiley (2018). 6. Nanobiomaterials, Roger Narayan, First Edition, Elsevier (2017).	
Learning Outcomes:	1. The students will be familiarized with the basic types of materials and their properties. 2. The students will have gained sufficient knowledge in the biomaterials and their applications. 3. The students will be exposed to the recent developments in biomaterial engineering and nanobiomaterials.	

Programme: M.Sc (Physics)
Course Code: PHBO-252 **Title of the Course: Biophysics Practical**
Number of Credits: 4
Effective from AY: 2020-21

Prerequisites for the course:	PHBC-200, basic knowledge in experimental techniques in chemistry and biology	
Objective:	This laboratory course is intended to provide basic laboratory training in the experiments in biophysics. Important biophysical phenomena will be tested and studied. The experiments will start from familiarization of basic characterization tools and protocols followed by advanced experiments.	
Content:	Short lectures on general protocols of biophysics experiments. The following experiments are to be performed/demonstrated: Experiments to be performed 1. Microscopic techniques: The study of biological samples/cells using fluorescence /DIC microscopy 2. Protein-protein interactions using spectroscopy (fluorescence/UV visible) techniques 3. Study of DNA-Protein interaction using fluourimetry 4. Study of fluorescence sensitivity and quenching, fluorescence recovery after photobleaching (FRAP) 5. PAGE and SDS PAGE Demonstrations 6. Classification of gram –ve & +ve organisms, observe cell growth/ survival by colony forming assay, estimation of cell viability by dye exclusion and colony formation assay, observe cell death by physical and chemical agents 7. Preparation of buffers and pH analysis 8. Determination of the titration curve of Proteins, amino acids & calculation of the pKa values 9. Isolation of Proteins- Casein from milk, Hb from RBC. 10. Study of interaction of acridine orange with DNA 11. Enzyme Assays (LKH, beta galactosidase, acid phosphatase, arginase, Succinic De –hydrogenase): Time, Temp, enzyme concentration, cofactors. LKH: Km & Vmax Demonstrations via online videos (to be discussed) 12. Gel filtrations chromatography 13. DEAE cellulose chromatography of DNA	

	14. Study of phase transition of membrane phospholipids and Study of the membrane potential using fluorescence spectroscopy. 15. To study the charge characteristics of cells through micro Electrophoresis 16. Osmolarity: Determination of osmotic pressure of salts. 17. Study of diffusion of biomolecules/ions (Fick's Law)	
Pedagogy:	Laboratory work, Presentations, demonstrations.	
References/Readings	1. Introduction to Experimental Biophysics: Biological Methods for Physical Scientists, Jay Nadeau, CRC Press (2012). 2. Introduction to Practical Biochemistry, Plummer, D. T. 3rd edition. McGraw-Hill Publishing Co. (1987). 3. Basic Methods for the Biochemical Lab, Holtzhauer, M. 1st English edition. Springer (2006). 4. Experimental techniques in bacterial genetics, Stanley R. Maloy, John and Bartlett (1989).	
Learning Outcomes:	1. The students will be familiarized with the basic experimental methods in biophysics. 2. The students will have gained sufficient knowledge in the various characterization and spectroscopic tools. 3. This course will also enable the students to have an understanding of some of the advanced techniques in experimental biophysics	

Programme: M. Sc. (Physics)
Course Code: PHSO-302 **Title of the Course:** Neutron Physics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have basic knowledge of electrodynamics, thermodynamics and quantum mechanics, and solid state physics	
Objective:	To develop the equations that describe the neutron population in a critical nuclear reactor; calculation of critical size with and without a reflector blanket; kinetics of the reactor including all factors affecting criticality during operation; description of reactor types; radiation dose units; reactor economics; fuel reprocessing and radioactive waste disposal.	
Content:	**I. Interaction of Neutrons with Matter:** Interaction of neutrons with matter, cross-section and variation with neutron energy. Neutron flux. Maxwellian distribution. Fissile and fertile materials. Chain reaction and neutron life cycle. Fermi four factor formula keff.	5 hours
	II. Neutron Diffusion: Diffusion theory approximation, derivation of diffusion equation. Neutron balance and critical equation. Boundary conditions and extrapolation distance. Diffusion length and its measurement.	6 hours
	III. Slowing down of Neutrons: Slowing down length, lethargy, slowing down in a mixture. Moderations. Slowing down models.	8 hours
	IV. Calculation of Critical Size of Reactors: Critical equation. One group model, four factor formula and calculation of parameters. Critical size of sphere and cylinder. Effect of reflector.	5 hours
	V. Power Operation: Reactor kinetics, mean neutron lifetime. The "In-Hour" equation and stable reactor period. Reactivity changes due to temperature. Fission product poisoning. Fuel burn-up. Measurement or reactor power and period.	11 hours
	VI. Reactor Types and Economics: Descriptions of MAGNOX, CANDU, fast reactor. Calculation of total generation cost. Comparison with economics of oil fired plant. Influence of economics on nuclear plant design.	5 hours
	VII. Radiological Protection: Units of radiation and radioactivity. Concept and derivation of safe working levels. Monitoring instruments and methods.	3 hours
	VIII. Reactor Fuels and Materials: Uranium resources and requirements. Isotope separation. (one method). Fuel reprocessing. Storage and disposal of	3 hours

	nuclear waste – consideration of different methods. **IX. Nuclear Policy**: Elements of India's Nuclear Policy. Examples of Policy of other countries. **X. Field trip** to a nuclear establishment such as the Dhruva Reactor, Bhabha Atomic Research Centre, Mumbai or Kaiga Nuclear Plant, Karwar or any other nuclear reactor establishment which gives permission for the visit of students accompanied by the teacher(s) of the course. The visit is to be organized with the aim of helping students better understand and appreciate the layout and complexity of a nuclear reactor. The assessment of the student's understanding is to be done through an essay on a choice of topics relevant to the particular nuclear establishment that is visited. It shall be considered as a compulsory Intra Semester Assessment of the course.	
Pedagogy:	Lectures, Tutorials, Field trip	
References/Readings	1. S. Glasstone and A. Sesonske, Nuclear Reactor Engineering , Van Nostrand Reinhold Co., (1963). 2. E. E. Lewis, Fundamentals of Nuclear Reactor Physics, Elsevier (2008). 3. Safe Handling of Radioisotopes (Safety Series no. 1) (1958). 4. Atomic Energy Waste. Editor E. Glueckauf, (Butterworths) (1961).	
Learning Outcomes	Familiarity with the main features of a nuclear reactor and conditions that determine its criticality. Awareness of the many uses of neutrons and radioactive materials.	

Programme: M. Sc. (Physics)
Course Code: PHSO-303 **Title of the Course:** Superconductivity & Superfluidity
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Should have basic knowledge of electrodynamics, thermodynamics and quantum mechanics, and solid state physics	
Objective:	To introduce an up-to-date experimental progresses and theories of superconductivity and superfluidity	
Content:	**SUPERCONDUCTIVITY:** **1. Basic Experimental Aspects** Introduction, Conduction in metals, Zero-resistivity, Meissner- Ochsenfeld effect, Perfect diamagnetism, Type-I and type-II superconductors, Application of low and high temperature superconductors.	2 hours
	2. Superconducting Materials Classical Superconductors: Elemental superconductors, superconducting compounds and alloys, A15 compounds, Chevrel phase compounds and their crystal structure, experimental studies on these materials, Phase diagrams. High-temperature Superconductors: La-Ba-Cu-0 systems, Y-Ba- Cu-0 systems, Bi-Sr-Ca-Cu-0 systems, Ti-Sr-Ca-Cu-0 systems, superconductivity in rare-earth and actinide compounds, organic superconductors, MgB2 and Iron Arsenide systems, their crystal structure, experimental studies on these materials, Phase diagrams.	6 hours
	3. Theoretical Aspects Phenomenological theories: Thermodynamics of superconducting transition, expressions for critical temperature T_C, critical field H_C London's theory, Pippard non-local theory, Ginzburg-Landau Theory. Microscopic theory: BCS theory, the electron-phonon interaction, the Cooper pair formation, BCS ground state, Consequences of the BCS theory and comparison with experimental results, Coherence of the BCS ground state and the Meissner-Ochsenfeld effect. Possible Mechanisms of high T_C Superconductors: Hubbard- Model, the Resonating valence Bond (RVB) model, Spin fluctuation model.	22 hours
	SUPERFLUIDITY: **1. Superfluid Helium-4** Introduction, Classical and quantum fluids, the macroscopic wave function, Superfluid properties of He II, Flow quantization and vortices, the momentum distribution, quasiparticle excitations.	6 hours
	2. Superfluid Helium-3 Introduction, The Fermi liquid normal state of ^{3}He, the pairing interaction in liquid ^{3}He, Superfluid phases of ^{3}He.	6 hours
	3. Bose-Einstein Condensates Introduction, Bose-Einstein Statistics, Bose-Einstein condensation, BEC in ultra-cold atomic gases.	6 hours

Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. James F. Annett, "Superconductivity, Superfluids and Condensates", Oxford Series in Condensed Matter Physics (2004). 2. J.B. Ketterson and S.N. Song, Superconductivity, Cambridge Univ. Press (1999). 3. M. Tinkham, Introduction to Superconductivity, McGraw Hill (1996). 4. C. Kittel, "Introduction to Solid State Physics", Wiley, Eight Ed. (1997). 5. H. Ibach and H. Luth, " Solid State Physics", Springer (2012).	
Learning Outcomes	Student will be experienced with 1. All superconducting materials. 2. theories on conventional superconductors 3. Possible mechanism of unconventional superconductors 4. BEC and superfluidity	

Programme: M. Sc. (Physics)
Course Code: PHSO-304 **Title of the Course:** X-ray Spectroscopy
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Solid State Physics/Chemistry and Electromagnetic waves	
Objective:	To introduce to students various techniques in x-ray spectroscopy using synchrotron radiation and its applications to condensed matter physics, chemistry and material science.	
Content:	1. **X-rays: Sources and Interaction with matter** X-rays: Waves and photons, Scattering, Absorption, Refraction and Reflection. X-ray tubes, Synchrotron radiation, Bending magnet sources, Undulator radiation, Wiggler radiation. X-ray detection	12 hours
	2. **Scattering of X-Rays** Scattering from an electron, scattering from an atom, scattering from a molecule, scattering from liquids and glasses, Small angle X-ray scattering, scattering from a crystal, Debye-Waller factor, measured intensity from a crystallite	12 hours
	3. **X-ray Absorption** Absorption coefficient, absorption edge, Definition: x-ray absorption fine structure (XAFS), x-ray absorption near edge structure (XANES), extended x-ray absorption fine structure (EXAFS), History, Theory of XAFS, XAFS Experiment, Beamline and optics, Data acquisition, treatment and modelling, XANES as fingerprint technique, x-ray magnetic circular dichroism.	12 hours
	4. **Photoelectron Spectroscopy** Photoelectric Effect, History of x-ray photoelectron spectroscopy (XPS), Theoretical model – three step model, Instrumentation, The electron mean free path, Auger electrons, Core level binding energies in atoms, molecules and solids, Final state effects, Valence band in solids, Band structure, Angle resolved photoelectron spectroscopy (ARPES), Inverse photoelectron spectroscopy.	12 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	Jens Als-Nielsen and Des Mc Morrow, Elements of Modern X-ray Physics, 2nd Edition, Wiley 2011. B. D. Cullity, Elements of X-ray Diffraction, Addision Wesley Publishing Company Inc. Grant Bunker, Introduction to XAFS, Cambridge University Press, 2010.	

	Stefan Hufner, Photoelectron Spectroscopy, Principles and Applications, Springer 2003	
Learning Outcomes	1. Students are expected to learn the principles of interaction of X-rays with matter; 2. Gain knowledge about characteristics of most important X-ray sources (x-ray tubes, synchrotron radiation sources); 3. Understand the principles of X-ray diffraction (XRD), X-ray photoemission and X-ray absorption spectroscopy, know the necessary experimental equipment, 4. Understand basic methods for analysis and interpretation of measured spectra, 5. Understand the kind of structural information about the investigated material can be obtained by individual spectroscopic methods.	

Programme: M. Sc. (Physics)
Course Code: PHSO-310 **Title of the Course:** Numerical Methods and Fortran Parallel Programing using open MP

Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of FORTRAN Programming Language	
Objective:	This course is designed to familiarize students with numerical methods and parallel programming.	
Content:	1. Computations and basics of open MP Introduction to scientific computations and FORTRAN parallel Programing using Open MP. 2. Introduction to numerical methods Round-off and truncation errors. 3. Solving nonlinear algebraic equations, Bisection method; Regula Falsi method Newton-Raphson and Secant methods. 4. Solving systems of linear algebraic equations Gaussian elimination method; Gaussian elimination with pivoting, LU Decomposition method, Inverse matrix algebra. Eigenvalues and eigenvectors. 5. Curve fitting and interpolation Linear least-squares regression; Linearized nonlinear regression models. Interpolation techniques. 6. Numerical integration and differentiation, Trapezoidal and Simpson's rules, Gauss quadrature Multiple integrals. Finite differences, difference formulas Differentiation using Lagrange polynomials. 7. Ordinary differential equations, Euler's Method, Modified Euler's method. Runge-Kutta methods Multiple-step methods; Predictor-corrector methods. Systems of first-order equations	24 hours 2 hours 4 hours 4 hours 4 hours 5 hours 5 hours
Pedagogy:	Lectures / laboratory/tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. V. Rajaraman, Computer Programming in FORTRAN 90 and 95, Prentice-Hall of India, New Delhi 1999. 2. Martin Counihan, Fortran 95, UCL Press Limited University College London (1996). 3. Stephen Chapman, Fortran 95/2003: for Scientists and Engineers, McGraw-Hill (2007). 4. Jain M., Numerical Methods for Scientific and Engineering computation, Wiley Eastern Limited (1995). 5. Xavier C., FORTRAN 77 and numerical methods New Delhi New Age International 2003 6. William H. Press et.al., Numerical Recipes in C, New Delhi Cambridge University Press 2005. 7. Open MP user guide at http://openmp.org/wp/resources/#Tutorials	
Learning Outcomes	1. Understanding of numerical methods to solve linear and non-linear algebraic equations; 2. Understanding of eigenvalue problems; 3. Understanding of Parallel computing	

Programme: M. Sc. (Physics)
Course Code: PHSO-311 **Title of the Course:** Phase Transitions and Critical Phenomena
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Thermodynamics and Statistical Mechanics	
Objective:	This course is designed to familiarize students with general and specific aspects of phase transitions, teach them the concept of symmetry and spontaneous breaking thereof and theoretical understanding within the realm of Landau's mean field theory.	
Content:	1. Phenomenology of phase transitions The role of symmetry and the onset of order, switching of the degree of order, Example of atomic site ordering, Ferroelectric phase transitions, how to observe a phase transition, Order of a phase transition, General aspects of the thermodynamics of a phase transition, Seeds of a theoretical model, Examples 2. Magnetic phase transitions Macroscopic and microscopic views of magnetism, Non-interacting atoms in a magnetic field: paramagnetism, interacting atoms in a magnetic field: ferromagnetism, Critical exponents revisited, Successes and failures of the mean-field model 3. Landau theory Introduction, Quantification of the free energy, Results for second-order phase transitions, Field-dependence of the order parameter at the transition temperature, Taking account of spatial variations, Validity of Landau theory, Ferromagnetism, the mean-field approximation, and Landau theory, First-order phase transitions, The case when the free energy is allowed to have odd-order terms, Tricritical phase transitions. Examples like phase transitions and elastic strain, ferroelectric phase transition, superfluid Mott insulator phase transition. 4. The role of symmetry Introduction to Symmetry, Point group symmetry operations, Space group symmetry operations, Groups and their representations, Symmetry of the order parameter, Symmetry of the spontaneous strain, Group-subgroup relationships across phase transitions 5. Soft modes and displacive phase transitions Displacive phase transitions, Phenomenology of the soft mode model of displacive phase transitions, Lattice dynamics theory of the soft mode, Lattice dynamical theory of the low-temperature phase, Phase transitions, soft modes, and structure flexibility: the Rigid Unit Mode model 6. Order-disorder phase transitions	4 hours 4 hours 12hours 12hours 4 hours 4 hours

	Order–disorder phenomenology, Mean-field theory of order–disorder phase transitions: Bragg–Williams model, Computational methods, Beyond Bragg– Williams theory: the Cluster Variation Method 7. Critical point phenomena The Widom scaling hypothesis: relationships between critical exponents, Introduction to the renormalisation group, Deriving the Widom scaling hypothesis, A sketched example: the 1D Ising model 8. Reconstructive Phase transitions Introduction and definition, Examples, Thermodynamics of reconstructive Phase transitions	4 hours 4 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. Binney, J. J., N. J. Dowrick, A. J. Fisher, and M. E. J. Newman, The theory of critical phenomena: An introduction to the renormalisation group. Oxford: Clarendon Press, (1992). 2. Blundell, S., Magnetism in condensed matter. Oxford: Oxford University Press, (2001). 3. Burns, G. and A. M. Glazer, Space groups for solid state scientists, third edition. Waltham: Academic Press, (2013). 4. Dove, M. T. Structure and dynamics. Oxford: Oxford University Press, (2003). 5. Goldenfeld, N., Lectures on phase transitions and the renormalisation group. Reading, MA: Addison-Wesley, (1992). 6. Muller, U. Symmetry relationships between crystal structures. Oxford: Oxford University Press, (2013). 7. Nishimori, H. and G. Ortiz, Elements of phase transitions and critical phenomena. Oxford: Oxford University Press, (2011). 8. Salje, E. K. H., Phase transitions in ferroelastic and co-elastic crystals, Student Edition, Cambridge University Press, (1993). 9. Tol´edano, J.-C. and P. Tol´edano, The Landau theory of phase transitions. Singapore: World Scientific, (1987). 10. Yeomans, J. M. Statistical mechanics of phase transitions. Oxford: Clarendon Press, (1992).	
Learning Outcome	The student is expected to obtain considerable insight into various types of phase transitions, and their classification; identify phase transition and how these can be described theoretically using Landau mean field theory	

Programme: M. Sc. (Physics)
Course Code: PHSO-312 **Title of the Course:** Spectroscopic Techniques in Condensed Matter Physics

Number of Credits:4
Effective from AY: 2021-22

Prerequisites for the course:	Should have studied courses in classical mechanics, electromagnetism, elementary quantum mechanics and nuclear physics.	
Objective:	To introduce different spectroscopic techniques that can be used for characterization of materials, especially in condensed matter.	
Content:	**1. Electronic Spectroscopy** Electromagnetic radiation, Absorption and Emission of radiation, Line width and its broadening mechanisms, One- electron and two-electron atoms: spectrum of hydrogen, helium and alkali atoms; Many electron atoms: Hund's rule, L-S and j-j coupling, Spectroscopic terms, Lande interval rule; Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects, electron spin resonance spectroscopy, Hyperfine structure and isotope shift, selection rules; Lamb shift, Spontaneous and stimulated emissions, Einstein coefficients, Introduction to lasers and laser spectroscopy	10 hours
	2. Molecular Spectroscopy Microwave spectroscopy, Infrared spectroscopy, the vibrating diatomic molecule – simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator, Interaction of rotation and vibrations, the vibrations of polyatomic molecules, Raman spectroscopy– Electronic spectra of diatomic molecules – Born-Oppenheimer approximation, vibrational coarse structure – progressions. Intensity of vibrational transitions – the Franck-Condon principle. Optical absorption: Free carrier absorption-optical transition between bands-direct, and indirect-excitons, Luminescence in crystal - excitation and emission - decay mechanism, Fluorescence, Phosphorescence, Crystal Field Theory, Spectroscopy of transition metals complexes.	14 hours
	3. X-rays: Sources and Interaction with matter X-rays: Waves and photons, Scattering, Absorption, Refraction and Reflection. X-ray tubes, Synchrotron radiation, Bending magnet sources, Undulator radiation, Wiggler radiation. X-ray detection	12 hours
	4. Nuclear Spectroscopy Nuclear Magnetic Resonance:Principles, Classical treatment of NMR (Bloch equations), experimental methods, Chemical shift, Knight shift in metals, spin-lattice relaxation, Applications	12 hours

	Mossbauer Spectroscopy: Principles, The Debye-Waller Factor, Mossbauer Sources and Experimental Apparatus, Isomer Shifts, Electric quadrupole interaction, Magnetic Dipole Interaction, Quadratic Doppler effect, Results of Mossbauer spectroscopy.	
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. B. H. Bransden and C. J. Joachain; Physics of Atoms and Molecules; Pearson; 2008/2nd Ed.. 2. C. N. Banwell and E. M. McCash; Fundamentals of Molecular Spectroscopy, Tata McGraw;2004/4thEd. 3. H. E. White; Introduction to Atomic Spectra; Tata McGraw Hill; 1934. 4. K. Thayagarajan and A.K Ghatak; Lasers Theory and Applications; Macmillan (Tata McGraw Hill) 1995. 5. D. Satyanarayana; Handbook of Molecular Spectroscopy; I K International Publishing House, 2015, 1st edition 6. J. Als-Nielsen, D. McMorrow; Elements of Modern X-ray Physics; Wiley; 2011. 7. G. Schatz and A. Weidinger; Nuclear condensed matter physics: nuclear methods and applications; John Wiley; 1997. 8. H. Kuzmany; Solid-state spectroscopy; Springer; 2009. 9. A. H. Kitai; Solid State Luminescence; Chapman and Hall London; 1993. 10. Luminescence of Solids edited by D. R. Vij, Plenum Press, New York, 1998.	
Learning Outcomes	1. Explain different spectroscopic techniques 2. Better understanding of atomic and molecular physics 3. Apply the techniques in experimental characterisation of materials.	

Programme: M. Sc. (Physics)
Course Code: PHSO-313 **Title of the Course:** Physics of Energy Materials
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Solid State Physics and thermodynamics	
Objective:	1. Is to develop the understanding of different energy materials properties, their synthesis and how to make use of them for energy extraction 2. Student should understand the basic principle of different energy extraction phenomenon.	
Content:	**1. Materials for Solar Energy applications** Motivations for Solar Energy, Nanostructures and Different Synthesis Techniques, Nanomaterials for Solar Cells Applications, Advanced Nanostructures for Technological Applications, Theory and Future Trends in Solar Cells.	4 hours
	2. Photovoltaic and Photocatalytic Materials Photovoltaics, Metal oxide nanostructures and nanocomposites for photovoltaic applications (TiO_2 and ZnO based DSSC and heterostructure devices), Fabrication of heterostructure devices with doped nanocomposites, Photocatalysis, Metal oxide nanostructures and nanocomposites for photocatalytic application, Future directions.	14 hours
	3. Advanced Electronics: Looking beyond Silicon Limitations of Silicon-Based Technology, Need for Carbon-Based Electronics Technology, Carbon Family, Electronic Structure of Graphene and CNT, Synthesis of CNTs, Carbon Nanotube Devices, Advantages of CNT-Based Devices, Issues with Carbon-Based Electronics.	6 hours
	4. Thermoelectric Materials The Seebeck and Peltier effects, thermoelectric figure of merit, Measuring the thermoelectric properties, Heat conduction by the crystal lattice, Materials for Peltier cooling, Generator materials, Thermoelectric refrigerators and generators.	6 hours
	5. Magnetocaloric Mateirals Thermodynamics of Magnetocaloric effect, Methods of investigation of magnetocaloric properties, Magnetocaloric effect in different types of materials, Magnetocaloric effect in nanosized materials, Magnetic refrigeration	6 hours
	6. Pl**asmonic Materials** Electromagnetics of metals, Surface Plasmon polaritons at metal/insulator interfaces, localized surface Plasmon, Applications: Transmission of radiation through apertures and films, Spectroscopy and sensing.	6 hours
	7. Fuel Cells Design principle and operation of fuel cell, Types of fuel	6 hours

	cells, conversion efficiency of fuel cell, application of fuel cells. Efficiency of fuel cells, operating characteristics of fuel cells, Advantages and future potential of fuel cells.	
<u>Pedagogy</u>:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
<u>References/Readings</u>	1. Ashutosh Tiwari, Sergiy Valyukh, Advanced Energy Materials, John Wiley and Sons, 2014. 2. H Julian Goldsmid, The Physics of Thermoelectric Energy Conversion, Morgan & Claypool Publishers, 2017. 3. A.M. Tishin, Y.I. Spichkin, The Magnetocaloric Effect and its Applications, CRC press (Taylor and Francis group), 2016. 4. Stefan A Maier, Plasmonics: fundamentals and application, Springer, 2007. 5. Sam Zhang, Organic nanostructured thin film devices and coatings for clean energy, CRC Press (Taylor and Francis group) 2017. 6. Sam Zhang, Nanostructureed thin films and coatings, CRC Press (Taylor and Francis group), 1ST Edition, 2010. 7. R. Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college Press, 2005. 8. A.S. Bhatia, Nanoscience and carbon nanotubes, Deep and deep publication, 2009. 9. Antonio Dominech Carbo, Electrochemistry of porous materials, CRC Press (Taylor and Francis group) 2010 10. Klimov Vasily, Nano plasmonics, Pan Stanford Publishing, 2014. 11. Ru Eric C.Le, Pablo G. Etchegoin, Principles of surface enhanced raman spectroscopy and related plasmonic effects, Elsevier; 1st Edition, 2009. 12. Tsukerman Igor, Computational methods for nanoscale applications, Springer, 2008. 13. John Twidell, Tony Weir, Renewable Energy Sources, Taylor and Francis group, 2nd Edition, 2006. 14. G.D Rai, Non-Conventional energy Sources, Khanna Publishers 2003.	
<u>Learning Outcomes:</u>	Student will understand how to synthesis different energy materials (nanomaterials and bulk) and how to make use of them for diverse energy applications Student will understand the basic principle of operation of all energy extraction devices and manipulate it to get better efficiency.	

Programme: M. Sc. (Physics)
Course Code:PHO-314 **Title of the Course:** Documentation using LaTex
Number of Credits: 2
Effective from AY: 2021-22

Prerequisites for the course:	Nil	
Objective:	LaTeX is a high-quality typesetting system; it includes features designed for the production of technical and scientific documentation. LaTeX is the de facto standard for the communication and publication of scientific documents. LaTeX is available as free software. Objective of this course is to introduce the basics of how LaTeX works, how to install LaTex and Tex editor TeXstudio, explain how to get started, and go through lots of examples.	
Content:	Course Contents: In this course we will cover: ● Setting up a LaTeX Document ● Typesetting Text ● Handling LaTeX Errors ● Typesetting Equations ● Using LaTeX Packages ● Structured Documents ● Sections, Labels and Cross-References ● Figures and Tables in LaTeX ● Automatic Bibliographies with BibTeX ● Useful LaTeX Packages and Online Resource ● LaTeX Presentations with Beamer	24 hours
Pedagogy:	Lectures/ self-study/ assignments. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. Leslie Lamport, LaTeX: A document preparation system, User's guide and reference manual, Addison Wesley, 1994. 2. Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle, Chris Rowley, The LaTeX Companion, 2nd edition (TTCT series), Addison-Wesley Professional, 2004.	
Learning Outcomes	Students are expected to learn how to write a scientific document, presentation, scientific report, dissertation etc. in LaTex.	

Programme: M. Sc. (Physics)
Course Code:PHO-315 **Title of the Course:** Nanoscience and Technology
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Solid State Physics / Solid State Chemistry	
Objective:	This course is designed to familiarize students with general and specific aspects of magnetic interaction in condensed matter and methods of magnetic measurements.	
Content:	**1. Nanostructures and Nanomaterials** Introduction to Nanoscience, Physics and Chemistry of solid surfaces, Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement size, Fick's Law-mechanisms of diffusion - Kirkendall effect - surface defects in nanomaterials - effect of microstructure on surface defects - interfacial energy, Classifications of nanomaterials Nanoparticles through homogeneous and heterogeneous nucleation-Growth controlled by surface and diffusion process- Oswald ripening process - influence of reducing agents-solid state phase segregation- Mechanisms of phase transformation- grain growth and sintering precipitation in solid solution- Hume Rothery rule.	12hours
	2. **Synthesis and Applications of Nanomaterials** Top down and bottom up approaches–Mechanical alloying and mechanical ball milling Mechanical and chemical process, Inert gas condensation technique – Arc plasma and laser ablation. Sol gel processing-Solvothermal, hydrothermal, precipitation, Spray pyrolysis, Electro spraying and spin coating routes, Self-assembly, self-assembled monolayers (SAMs). Langmuir-Blodgett (LB) films, micro emulsion polymerization- templated synthesis, pulsed electrochemical deposition Vapor deposition and different types of epitaxial growth techniques (CVD,MOCVD, MBE,ALD)- pulsed laser deposition, Magnetron sputtering - lithography :Photo/UV/EB/FIB techniques, Dip pen nanolithography, Etching process :Dry and Wet etching, micro contact printing , Application of nanomaterials in physics, chemistry and biological sciences	14hours
	3. Characterization Techniques in Nanotechnology Optical microscopy: Use of polarized light microscopy – Phase contrast microcopy – Interference Microscopy – hot stage microscopy – surface morphology – Introduction toconfocal microscopy.	12 hours

	Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy 4. **Applications of Nanoscience** Nanomaterials for energy applications, Nanoelectronics, Nanomagnetism and devices, Nanophotonics, Surface plasmons, Nanobio applications, Environmental issues	10 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. G. Cao, ―Nanostructures & Nanomaterials: Synthesis, Properties & Applications Imperial College Press, 2004. 2. Murthy. B. S., Textbook of nanoscience and nanotechnology, University Press 3. L. Novotny and B. Hecht, Principles of nano-optics, Cambridge University Press, 2009. 4. M. Baker et al., ―Lithographic pattern formation via metastable state rare gas atomic beam, Nanotechnology 15, 1356, 2004. 5. H. Schift et al., ―Fabrication of polymer photonic crystals using nanoimprint lithography, Nanotechnology 16, 261, 2005. 6. R.D. Piner, ―Dip-Pen‖ Nanolithography, Science 283, 661, 1999. 7. W.L.Barnes et. al., Nature 424, 825, 2003. 8. Heinz Raether, Surface Plasmons on Smooth and Rough Surfaces and on Gratings Springer Tracts in Modern Physics, Vol. 111, Springer Berlin 1988. 9. Plasmonics: Fundamentals and Applications, Stefan Maier, Springer 2007.	
Learning Objectives	1. Gain knowledge in Nanoscience and Nanotechnology 2. Understand various techniques in cutting-edge science 3. Apply the knowledge in nanoscience in research based situations	

Programme: M. Sc. (Physics)
Course Code: PHSO-316 **Title of the Course:** Magnetism in Condensed Matter Physics
Number of Credits: 4
Effective from AY: 2021-22

Prerequisites for the course:	Basic knowledge of Solid State Physics / Solid State Chemistry	
Objective:	This course is designed to familiarize students with general and specific aspects of magnetic interaction in condensed matter and methods of magnetic measurements.	
Content:	1. **Magnetic Moments** Magnetic moments and angular momentum, Precessional motion, Bohr Magneton, Magnetization and field, Classical Mechanics and magnetic moments, Quantum mechanical treatment, Spin	4 hours
	2. **Isolated magnetic moments** An atom in magnetic field, Magnetic susceptibility, Diamagnetism, Paramagnetism – semiclassical treatment, Brillouin function, van-Vleck paramagnetism, The ground state of an ion, Hund's rules, Adiabatic demagnetization, Nuclear spin, hyperfine structure, Origin of crystal field, orbital quenching, Jahn-Teller effect	6 hours
	3. **Magnetic Interactions** Dipolar interactions, Exchange interactions – origin, direct and indirect exchange, Indirect exchange in ionic solids, indirect exchange in metals, Double exchange, Anisotropic exchange, Continuum approximation	8 hours
	4. **Order and Magnetic Structures** Ferromagnetism – Weiss model, Magnetic susceptibility, The effect of magnetic field, Origin of the molecular field Antiferromagnetism – Weiss model, Magnetic susceptibility, magnetic field effects, types of antiferromagnetic order Ferrimagnetism, Helical order, Spin glasses, Nuclear ordering Measurement of magnetic order – magnetization and magnetic susceptibility, Neutron scattering, other techniques	8 hours
	5. **Order and broken symmetry** Broken symmetry, Landau theory of ferromagnetism, Heisenber and Ising models (1D and 2D), Consequences of broken symmetry, Phase transitions, Rigidity, Excitations – magnons, Domains, Domain walls, Magnetocrystalline anisotropy, Domain wall width, Magnetization process, Obesrvation of domain wall, small magnetic particles, Stoner-Wohlfarth model, Soft and hard materials	6 hours

	6. Magnetism in metals Pauli paramagnetism, spontaneously spin-split bands, spin-density functional theory, Landau levels, Landau diamagnetism, Magnetism of electron gas – paramagnetic response, diamagnetic response, RKKY interactions, Excitations in the electron gas, Spin-density waves, Kondo effect. 7. **Competing interactions and low dimensionality** Frustration, Spin glasses, Superparamagnetism, One dimensional and two dimensional magnets – spin chainsmSpinons Haldane chains, Spin-Peierls transitions, spin ladders, Magnetoresistance, Magneto-optics **8. Experimental Methods** Magnetic fields, Atomic scale magnetism, Domain scale measurements, Bulk magnetism measurements, Magnetic resonance techniques – ESR, NMR, Mossbauer, X-rays and magnetism.	6 hours 4 hours 6 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. Stephen Blundell, Magnetism in Condensed Matter, Oxford University Press 2001. 2. J. M. D. Coey, Magnetism and magnetic materials, Cambridge University Press, 2010. 3. D. C. Mattis, Theory of Magnetism, Springer Verlag, 1981.	
Learning Outcomes	The student is expected to acquire basic understanding of Magnetism and magnetic interactions in solids. Distinguish between different types of magnetic order and magnetically frustrated states. Have basic knowledge of different experimental methods of measuring magnetization at bulk, domain size and atomic level.	

Programme: M. Sc. (Physics)
Course Code: PHSO317 **Title of the Course:** Introduction to Crystallography and X-ray Diffraction
Number of Credits: 4
Effective from AY: 2019-20

Prerequisites for the course:	Basic knowledge of Solid State Physics / Solid State Chemistry	
Objective:	This course is designed to familiarize students with general aspects of crystal symmetry and X-ray scattering methods. Students also get an exposure to solving crystal structure from single crystal and powder X-ray data and use them in characterization of materials.	
Content:	**1. Introduction to Symmetry and Crystal Structures** Unit cell, Symmetry elements and their operations, Screw axes and glide planes, Crystal systems, 1D, 2D and 3D lattices, Bravais lattice, Point groups and their representations, Crystal classes, Herrmann-Mauguin and Schoenflies nomenclature of point groups, Group-subgroup-supergroup relationships, Stereographic projections, Laue symmetry, Space groups, Equivalent points, General and special positions, Deriving general positions of space groups, Wyckoff notations, Shifting of origin in lattice, Miller indices, Crystal directions and planes, Real space vs reciprocal lattice, Close packed structures, Octahedral and tetrahedral sites, Linear density and planar density, Miller–Bravais indices for hexagonal systems, Asymmetric unit, Concept of Z and Z′, Metric matrix, Deriving bond length and bond angles, Crystal density, Quasicrystals and their importance	12 hours
	2. X-ray Scattering and Structure Factors Generation of X-rays, White and Characteristic X-rays, Laboratory and synchrotron X-ray sources and their properties, Coherent and incoherent scattering, Scattering of X-rays by an electron, atom and crystal, Atomic scattering factor, Structure factor, Fourier transform, Electron density, Laue's equations, Bragg's law, Ewald's sphere, Limiting sphere and reflecting sphere, Bragg's law in reciprocal space, Systematic absences, Deriving conditions for systematic absences, X-ray detectors, Laue method, L-P corrections, Temperature factors, Absorption and extinction of X-rays, Friedel's law, Anomalous scattering, Absolute configuration determination, Phase problem in crystallography, Solution to the phase problem, Direct method, Patterson method, ∇ F synthesis	12 hours
	3. Single Crystal X-ray Diffraction (SCXRD) Method Pros and cons of single crystal and powder X-ray diffraction, Single crystal growth and selection, Indexing of crystals, Data collection, Data reduction, Space group determination, Structure solution and refinement, Parameters/constraints/restraints, Anisotropic displacement	8 hours

	parameters (ADPs), Reliable (R) factor, Twining, Treatment of disordered structures, Introduction structure refinement software: OLEX2 and WinGX, Crystal structure analysis, CIF preparation, Validation of structures, Example: X-ray data of aspirin and $KHSO_4$ **4. Powder X-ray Diffraction (PXRD) Method** Importance of PXRD method, Background of methodology, Geometrical basis of PXRD, Indexing powder pattern, Rietveld refinement using FullProf, Identification of unknown/new phases, Applications: Particle size and strain determination, Example: PXRD of CeO_2 **5. Total X-ray Scattering and Pair Distribution Function (PDF) Analysis** Short and long range order, Structure of non-crystalline, disordered solids and nanocrystals, Local structure, Bragg and diffuse scattering concepts, atomic scattering amplitude, Debye's scattering intensity, Total scattering structure function, atomic PDF, Structure and reaction mechanism, Examples: Pt and WO_3 nanoparticles	8 hours 8 hours
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.	
References/Readings	1. Fundamentals of Crystallography, C. Giacovazzo, Oxford Science Publications, 2011. 2. X-ray Structure Determination: A Practical Guide, G. H. Stout and L. H. Jensen, John Wiley and Sons, New York, 1989. 3. Elements of X-ray Diffraction, B.D.Cullity and S. R. Stock, 3rd edition, Pearson Education, 2014. 4. The Basics of Crystallography and Diffraction, C. Hammond, Oxford Science Publications, 2015. 5. Crystal Structure Determination, W. Massa, Springer, 2000. 6. The Rietveld Method, R. A. Young, Oxford University Press, 1993. 7. Structure Determination from Powder Diffraction Data, W. I. F. David, Oxford Science Publications, 2006. 8. Underneath the Bragg Peaks: Structural Analysis of Complex Materials, T. Egami and S. J. L. Billinge, Pergamon Materials Series, Volume 16, 2012	
Learning Outcomes:	1. The student acquires a basic understanding of crystallography and X-ray scattering methods in the solid state. 2. Have basic knowledge of single crystal, powder X-ray diffraction and PDF methods. 3. Able to use X-ray scattering methods as an experimental tool for materials characterization.	