D 3.19	**Minutes of the Meeting of Board of Studies in Portuguese held on 20/04/2018.** The Academic Council did not approve the minutes of the meeting of the Board of Studies in Portuguese held on 20/04/2018. The Chairperson, Board of Studies was requested to take the matter back to the Board of Studies and then place the same before the Academic Council for approval. **(Action: AR-PG)**
D 3.20	**Minutes of the meeting of Board of Studies in Journalism and Mass Communication held on 12/03/2018 and reconvened meeting on 22/03/2018.** The Academic Council approved the minutes of the meeting of the Board of Studies in Journalism and Mass Communication held on 12/03/2018 and the reconvened meeting held on 22/03/2018. **(Action: AR-PG)**
D 3.21	**Minutes of the meeting of Board of Studies in Physics held on 12/04/2018.** The Academic Council approved the minutes of the meeting of the Board of Studies in Physics held on 12/04/2018. **(Action: AR-PG)**
D 3.22	**Minutes of the meeting of Board of Studies in Electronics held on 19th April 2018.** The Academic Council approved the minutes of the Board of Studies in Electronics held on 19th April 2018. **(Action: AR-PG)**
D 3.23	**Minutes of the meeting of Board of Studies in History - PG held on 26th April 2018.** The Academic Council approved the minutes of the meeting of the Board of Studies in History- PG held on 26th April, 2018 with the following suggestions: 1. Course structure to be submitted as an annexure and not in the minutes. 2. The Syllabus for the Goa University Admissions Ranking Test (GU-ART) for 2018-19 to be based on current Goa University TY Syllabus (3 Units) **(Action: AR-PG)**
D 3.24	**Minutes of the meeting of Board of Studies in Sociology held on 27th March 2018.** The Academic Council approved the minutes of the meeting of the Board of Studies in Sociology held on 27th March 2018 with the following suggestions: 1. Compulsory Courses to be changed to Core Courses. 2. Course codes to be corrected. **(Action: AR-PG)**
D 3.25	**Minutes of the meeting of Board of Studies in Hindi held on 28/03/2018.** The Academic Council approved the minutes of the meeting of the Board of Studies in Hindi held on 28/03/2018. The Chairperson, Board of Studies was requested to indicate the number of hours instead of lectures in the Syllabus. **(Action: AR-PG)**
D 3.26	**Minutes of the meeting of Board of Studies in Marathi held on 23rd & 26th April,**

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D 3.21 **Minutes of the meeting of Board of Studies in Physics held on 12/04/2018.**

Part-A

1. Recommendations regarding courses of study in the subject or group of subjects at the Under-graduate level.
   Non-agenda item.

2. Recommendations regarding courses of study in the subject or group of subjects at the Post-graduate level.
   i) M. Sc. Physics course structure is revised as per the revised OA-18 and the same is given in the Appendix A. We have added "A" in the revised paper's code. Annexure I **(refer page no 1021)**
   ii) Revised syllabus is in given in Appendix B.
   iii) Following two new elective papers are recommended.
   a) PHO-315: Nanoscience and Technology
   b) PHO-316: Magnetism in Condensed Matter Physics
   iv) We have dropped elective paper PHO-308: "Acoustics and noise control" because of non-availability of resource person to offer this paper.

Part-B

(i) Scheme of examinations at the under-graduate level

Non-agenda item.

(ii) Scheme of examinations at the post-graduate level

Non-agenda item.

(iii) Panel of examiners for different examinations at post-graduate level

Non-agenda item.

Part-C

(i) Recommendations regarding preparation and publication of selection of reading material in any subject or group of subject and names of persons recommended for appointment to make the selection.

Non-agenda item.

Part-D

Recommendations regarding general academic requirements in the Department of University or affiliated Colleges.

Non-agenda item.

Part-E

(i) Recommendations of text books for the courses of study at the under-graduate level.

Non-agenda item.

(ii) Recommendations of text books for the courses of study at the post-graduate level.

List of Text books and reference books are given course wise at the end of the syllabus in Appendix B.

Part-F

(i) The declaration by the Chairman that the minutes were read out by the Chairman at the meeting itself.

Date: 12th April 2018

(Dr. Ramesh V. Pai)
Signature of the Chairman

Place: Goa University

Part-G

Remarks of the Dean

(i) The minutes are in order

(ii) May be recommended for approval of Academic Council

(iii) Special remarks if any

Date:
Place: Goa University

(Prof. Gaurish M.Naik)
Signature of the Dean

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D 3.22 **Minutes of the meeting of Board of Studies in Electronics held on 19th April 2018.**

Part A

(LXI) Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level:

M. Sc. Physics
Course Structure and List of papers
From academic year 2018-19

Semester I		
Course Code	Course Title	Number of credits
PHC-100*	Bridge course in Mathematical Methods	2
PHC-111	Mathematical Physics	4
PHC-112	Classical Mechanics	4
PHC-113	Electromagnetic Theory	4
PHO-114	Electronics Practical	2
PHO-105	Computer Programming with C	2
PHO-110	Computer Programming in Fortran 95	2
*Not included for the calculation of GPA, but should be completed successfully.		

Semester II		
Course Code	Course Title	Number of credits
PHC-116	Quantum Mechanics – I	4
PHC-117	Basic Electronics	4
PHC-118	Statistical Mechanics	4
PHO-119	General Physics Practical	4

Semester III		
Course Code	Course Title	Number of credits
PHO-301	Summer Fellowships	1
PHC-211	Quantum Mechanics – II	4
PHC-212	Nuclear physics and Elementary Particle Physics	4
PHO-213	Solid State Physics	4
PHO-214	Solid State Physics Practical	4

Semester IV		
Course Code	Course Title	Number of credits
PHO-302	Neutron physics	4
PHO-303	Superconductivity and superfluidity	4
PHO-304	X-ray spectroscopy	4
PHO-305	Electronics practical-II	4
PHO-306	Semiconductor physics	4
PHO-307	Dissertation	8
PHO-309	Physics of non-conventional energy sources	4
PHO-310	Numerical methods and Fortran parallel programming using open mp	4
PHO-311	Phase transitions and critical phenomena	4
PHO-312	Spectroscopic techniques in condensed matter physics	4
PHO-313	Physics of energy materials	4
PHO-314	Documentation using Latex	1
PHO-315	Nanoscience and Technology	4
PHO-316	Magnetism in Condensed Matter Physics	4

Appendix B

Programme: M. Sc. (Physics)
Course Code: PHC-100 **Title of the Course:** Bridge Course in Mathematical Methods
Number of Credits: 2
Effective from AY: 2018-19

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. XI and XII Mathematics text books 3. George B. Arfken and Hans J. Weber , Mathematical methods for Physicists, 7/e Elsevier Inc., 2012.	
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: PHC – 111 **Title of the Course:** Mathematical Physics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied the courses in Physics at F Y B Sc, S Y B Sc and T Y B Sc levels.	
Objective:	To teach theory and problem solving of Mathematics and their applications in Physics.	
Content:	**1. Ordinary Differential Equations** Second order homogeneous and inhomogeneous equation, Wronskian, General Solutions, Ordinary and Singular points, Series Solutions. **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. **3. Linear Vector Spaces** Linear Operators, Matrices, Coordinate Transformations, Eigenvalue Problems, Diagonalization of Matrices, Infinite Dimensional Spaces, Elements of Group Theory. **4. Integral Transforms** Fourier Series, Fourier Transforms, Laplace Transforms, Applications of Integral Transforms. **5. Boundary Value and Initial Value Problems** Vibrating String in one Dimension, Heat Conduction, and Wave Equation.	8 hours 15 hours 7 hours 10 hours 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. J.Mathew and R. L.Walker, Mathematical Methods for Physics, Benjamin Publishers (1973). 3. James W.Brown and Ruei.V.Churchill Complex Variables and Applications, 6th Edition (international) , McGraw - Hill (1996). 4. L.A.Pipes, Applied Mathematics for Engineers and Physicists,3rd Edition, Mcgraw-Hill (1971). 5. W.W.Bell, Special Functions for Scientists and Engineers, D. Van Nostrand Company Ltd (2004). 6. Charlie Harper, Introduction to Mathematical Physics, PHI, . 7. Murray R. Spiegel, Theory and problems in Complex Variables by (Schaum' series) (2009). 8. Murray R. Spiegel, Theory and problems of advanced Mathematics for Engineers and Scientists by (Schaum's series) (1980).	
Learning Outcomes	Understanding the theorems and methods of Mathematics and their application in problems in Physics.	

Programme: M. Sc. (Physics)
Course Code: PHC-112 **Title of the Course:** Classical Mechanics
Number of Credits: 4
Effective from AY: 2018-19

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.	6 hours
	2. Lagrangian Formulation Degrees of Freedom, Generalized Coordinates, Calculus of variations, Hamilton's principle, Euler-Lagrange's equations of motion, Application to non-holonomics systems, Advantages of a variation principle formulation, Conservation theorems and symmetry properties.	8 hours
	3. Rigid Body Dynamics Eulerian angles, Inertia tensor, Angular momentum of rigid body. Free motion of rigid body, Motion of symmetric top.	6 hours
	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.	8 hours
	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 hours
	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.	4 hours
	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.	6 hours
	8. Small Oscillations Simple Harmonic Oscillations, Damped Oscillations, Forced Oscillations without and with damping, Coupled Oscillations.	4 hours
Pedagogy:	Lectures/ tutorials/ term papers/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: PHC-113 **Title of the Course:** Electromagnetic Theory
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied prescribed Physics courses at F. Y. B. Sc., S. Y. B. Sc. and T. Y. B. Sc. levels.	
Objective:	The aim of this course is to provide the students with the fundamental principles of electromagnetic concepts. On completing this course the student shall be able to define and derive expressions for the energy both for the electrostatic and magnetostatic fields, and derive Poyntings theorem and apply it to different problems in Electromagnetics use Maxwells equations wherever required handle different problems in EM wave propagation, Plasma Physics and relativistic electrodynamics. The course will not only enrich the student's knowledge academically but also develop self-discipline and will increase the students imagination and thinking power that will help him in practical world.	
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/seminars/ term papers/assignments/ presentations/ self-study/ 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	On completing this course the student shall be able to define and derive expressions for the energy both for the electrostatic and magnetostatic fields, and derive Poyntings theorem and apply it to different problems in Electromagnetics. Use Maxwell’s equations wherever required handle different problems in EM wave propagation, Plasma Physics and relativistic electrodynamics. The course will not only enrich the student’s knowledge academically but also develop self-discipline and will increase the students imagination and thinking power that will help him in practical world.	

Programme: M. Sc. (Physics)
Course Code:PHO-114 **Title of the Course:** Electronics Practical
Number of Credits: 2
Effective from AY: 2018-19

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 AstableMultivibrator 5. Design and Construction of MonostableMultivibrator 6. Schmitt Trigger circuit and its use as a zero crossing detector and squaring circuit 7. Voltage Regulator (1.2V – 20V, 100mA) 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 (Chua circuit) 12. Series Voltage regulator using transistors 13. J. K. flip-flop counter: Scale of 16 and 10 using IC 14. Adder and Subtractor Circuits (2 experiments)	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).	
Learning Outcome	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: PHO-105 **Title of the Course:** Computer programming with C
Number of Credits: 2
Effective from AY: 2018-19

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. 2. C Fundamentals The C character Set, Identifiers and Keywords, Data types, Constants, variable and Arrays, Declarations, Expressions, Statements, Symbolic Constants 3. Operators and Expressions Arithmetic Operators, Unary Operators, Relational Logical Operators, Assignment Operators, the Conditional Operators, Library Functions. 4. Data Input and Output Preliminaries, Single character input and output, entering Input data, writing output data, Opening and closing data file, format statements. 5. Control Statements Preliminaries, Branching statements, Looping statements, nested control structure, switch, break, continue, go to statements. 6. Functions Defining functions, accessing functions, Passing arguments to a function. 7. Arrays Defining an array, processing an array, passing arrays to functions, multidimensional arrays.	3 hours 4 hours 4 hours 3 hours 4 hours 3 hours 3 hours
Pedagogy:	Lectures/ tutorials/assignments/self-study	
References/Readings	1. Byron Gottfried, Programming with C, Tata Mcgraw-Hill (1996).	
Learning Outcomes	Understand different programming languages in general; Understand C programming language; Understanding how to write and run simple C programs.	

Programme: M. Sc. (Physics)
Course Code: PHO-110 **Title of the Course**: Computer Programming in Fortran 95
Number of Credits: 2
Effective from AY: 2018-19

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 PROGRAMMING 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	6 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	6 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.	6 hours
	4. PROCEDURES Program Units, Introduction to Procedures, Intrinsic 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	6 hours

	.	
Pedagogy:	Lectures/ tutorials/assignments/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: PHC-116 **Title of the Course:** Quantum Mechanics – I
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied prescribed Physics courses at F. Y. B. Sc., S. Y. B. Sc. and T. Y. B. Sc. levels.	
Objective:	Know the historical developments of quantum mechanics and learn the basic properties of quantum world. To develop familiarity with the physical concepts and the mathematical methods of quantum mechanics. Apart from basic concepts it provides qualitative and quantitative knowledge and assessment of different directly solvable problems in quantum mechanics which are directly related to atomic and nuclear level problems.	
Content:	1 **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.	12 hours
	2 **Exactly Solvable Problems** (a) One dimensional potential step and potential barrier, One-dimensional square-well potential of infinite height and finite height, bound states, linear harmonic oscillator. (b) Spherically symmetric potential, orbital angular momentum operator L, eigenvalues and eigenfunctions of L, Spherical harmonics, Hydrogen atom problem.	12 hours
	3. **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.	10 hours
	4 **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.	14 hours
Pedagogy:	lectures/ tutorials/seminars/ term papers/assignments/ presentations/ self-study/ 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, Macmillan India Ltd., Delhi (1999) 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, Prentice Hall, (1994). 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, 4/e, Pearson Education Ltd (2003). 11. Merzbacher Book	
Learning Outcomes	1. The student knows as to why the quantum concepts cannot be applied to macro world. 2. the student comes to know the limitations of classical Physics. 3. The student knows the importance of the concepts and their applications to different areas of quantum world. 4. The student develops skills suitable to formulating ideas for solving physics problems that also helps the growth of self-discipline and work habits useful in academic and real world.	

Programme: M. Sc. (Physics)
Course Code: PHC-117 **Title of the Course:** Basic Electronics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied the courses in Physics at F Y B Sc, S Y B Sc and T Y B Sc levels.	
Objective:	To teach theory, applications and problem solving in Basic Electronics.	
Content:	**1. Network Analysis and Synthesis** Superposition theorem, Maximum power transfer theorem, T and π networks, Lattice Network, Symmetric Network, Positive real functions, Hurwitz polynomials, Synthesis of one port networks, Foster and Cauer forms. **2. Small Signal Amplifiers** Transistor h - parameters, Graphical determination of h - parameters, Small signal model of BJT (analysis of multistage amplifiers) and FET Amplifiers and analysis, Transistor amplifier with Re unbypasssed, High Ri amplifier circuits, Miller's Theorem and Bootstrapped CC amplifier. **3. Power Amplifiers** Large signal amplifiers, Class of operation, Harmonic distortion, class A amplifier with resistive and transformer coupled load, Power efficiency calculations, class B amplifiers, cross over distortion, Complementary symmetry amplifiers. **4. Communication Electronics** Basic principle of amplitude, frequency and phase modulation, simple circuits for amplitude modulation and demodulation, Microwave oscillators.	18 hours 10 hours 10 hours 10 hours
Pedagogy:	Lectures/ tutorials/ or a combination of these. Sessions shall be interactive in nature to enable peer group learning.	
References/Readings	1. J. D. Ryder, Network, Lines and Fields, Prentice -Hall of India Pvt. Ltd., New Delhi (1995). 2. J. D. Ryder, Electronics Fundamentals and Applications, Prentice -Hall of India Pvt. Ltd., New Delhi (1983). 3. Van Valkenburg, Network Synthesis, , Prentice -Hall of India Pvt. Ltd., New Delhi (1984). 4. J.Millman and C.C. Halkias, Integrated Electronics, Analog and Digital Circuits and Systems, McGraw - Hill Book Co. Tokyo (1997). 5. G. Kennedy, Fundamentals of Electronics Communications, Tata McGraw-Hill Book Co. New Delhi (1996). 6. Robert Shrader, Electronic Communication, McGraw-Hill International (1997). 7. D. Ruddy and J. Coolen, Electronic Communication, Prentice -Hall of India Pvt. Ltd., New Delhi (1 997). 8. Robert J. Schoenbeck, Electronic Communications, Modulation & Transmission, Pearson, (1991). 9. T. S. K. V. Iyer Theory & Problems in Circuit Analysis, 4/e, Pearson Education Asia (2003).	

Learning Outcomes	Understanding the theorems and Circuits in Electronics and use them in various applications.	

Programme: M. Sc. (Physics)
Course Code: PHC-118 **Title of the Course:** Statistical Mechanics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Physics or B. Sc. Mathematics. 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. **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. **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. **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. **5. Ideal Fermi Gas** Equation of state of Ideal Fermi Gas, theory of white dwarfs, Landau diamagnetism, DeHass-Van Alphen effect, Pauli paramagnetism. **6. Ideal Bose Gas** Photons, phonons, Bose-Einstein condensation.	10 hours 10 hours 10 hours 6 hours 6 hours 6 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/Readings	1. Statistical Mechanics, Kerson Huang, John Wiley and Sons New Delhi 2000. 2. Fundamentals of Statistical Mechanics, B. B. Laud, New Age International Ltd. New Delhi 1998. 3. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill International 1985. 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: PHO-119 **Title of the Course:** General Physics Practical
Number of Credits: 4
Effective from AY: 2018-19

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	12 hours 72 hours

	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 24. Measurement of Electrical and Thermal Conductivity of metal and Thermal conductivity of Poor conductor	
Pedagogy:	Lectures and Laboratory Experiments.	
References/Readings	1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, Mc Graw 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: PHC-211 Title of the Course: Quantum Mechanics-II
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Physics or B. Sc. Mathematics. It is assumed that students have a basic working knowledge of classical mechanics, mathematical physics.	
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. Identical Particles Symmetrization postulate, connection between spin and statistics, Pauli exclusion principle, wave function for fermions and bosons. Examples: Helium atom, Scattering of identical particles. 2. Perturbation Theory Time-independent perturbation theory, non-degenerate and degenerate cases, applications to simple problems, time dependent perturbation theory, Golden rule for transition probability, application to simple problems. 3. Variational method Upper bounds on the ground state and excited state energies, applications to simple problems. 4. Scattering Theory Schrodinger equation for a free particle in three dimensions, expansion of plane waves in spherical harmonics, scattering by a potential, scattering amplitude and cross-sections, Born approximation, scattering by Yukawa and Coulomb potentials, concept of phase shifts, calculation of phase shifts from potentials, partial wave expansion of scattering amplitude, optic& theorem. 5. 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. .	6 hours 12 hours 6 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/Readings	1. A.K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Macmillan India Ltd., Delhi (1999)	

	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, Prentice Hall, (1994).	
Learning Outcomes	1. Understand time independent perturbation theory and variation methods in quantum mechanics; 2. Understand time dependent perturbation theory in quantum mechanics; 3. Understanding how symmetry of the wave function is important for identical particles 4. Understand scattering problem using quantum mechanical approach. 5. Understand the form and construction of relativistic wave equations.	

Programme: M. Sc. (Physics)
Course Code:PHC-212 **Title of the Course:** Nuclear and Elementary Particle Physics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Familiar with basic quantum mechanics.	
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	5 hours

	formulation, optical model, Direct 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 (1 974). 2. E. Segre, Experimental Nuclear Physics, John Wiley (1 960). 3. V. Devanathan, Nuclear Physics, Alpha Science International Ltd, (2011).	
Learning Outcomes	After passing the course the student should 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: PHO-213 **Title of the Course:** Solid State Physics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied the courses in Physics at F Y B Sc, S Y B Sc and T Y B Sc levels.	
Objective:	To introduce fundamental aspects of solid state physics according to the scheme: chemical bonding, structure, lattice dynamics, electronic, magnetic, dielectric and optical properties.	
Content:	**1. Crystal structure and Crystal Binding** Crystals-Lattice, Bravais lattice, primitive unit cell, seven crystal systems, fourteen Bravais lattices, definitions of directions, coordinates and planes, Simple crystal structures: NaCl, CsCl, diamond, hexagonal close-packed structure, cubic ZnS structure. 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. 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.	13 hours
	2. Free Electron Theory and Energy Bands in solids Free electron theory-Sommerfield model, Electrical conductivity, Experimental electrical resistivity of metals, Heat capacity of electron gas, Experimental heat capacity, Thermal conductivity of metals, motion in magnetic fields Cyclotron frequency, Hall effect, AC conductivity. Energy Spectra in atoms, molecules and solids, Energy Bands in Solids; the Bloch Theorem, Band symmetry in k-space; Brillouin Zones, Number of states in the band, The nearly free electron model, The energy gap and the Bragg reflection, Tight binding model, Metals, insulators and semiconductors, density of states, The Fermi surface, Velocity of Bloch electron, Electron dynamics in an electric field, The dynamical effective mass, Physical origin of effective mass, The hole, Electrical conductivity, Electron dynamics in a magnetic field; cyclotron resonance and Hall effect, Experimental methods of determination of band structure, Limit of band theory; metal-insulator transition.	12 hours
	3. 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, Debye T' law,	7 hours

	Einstein model of the density of states, Thermal conductivity-Thermal resistivity of phonon gas, Umklapp process. **4. Optical and Dielectric Properties** Optical reflectance, Excitons, Raman effect in crystals. Macroscopic electric field, local electric field at atom, dielectric constant and polarizability, Structural Phase transitions, Ferroelectric Crystals and Displacive transition. **5. Magnetic Properties** Langevin Diamagnetism Equation, Quantum Theory of Diamagnetism, Paramagnetism, Quantum Theory of Paramagnetism, Paramagnetic Susceptibility of Conduction electrons, Ferromagnetic Order, Magnon, Ferrimagnetic Order, Antiferromagnetism, Ferromagnetic Domain. **6. 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, Tunneling, Josephson effects High Tc superconductivity.	4 hours 8 hours 4 hours
<u>Pedagogy</u>:	lectures/ tutorials/laboratory work/ project work/ seminars/term papers/assignments/ presentations/ self-study/ Case Studies etc. or a combination of some of these.	
<u>References/Readings</u>	1. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000). 2. C. Kittel, Introduction to Solid State Physics, 7th Edition, John Wiley & Son, Inc. New York (1997). 3. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001). 4. G. Bums, Solid State Physics, Academic press, Inc. London (1985). 5. A. J. Dekker, Solid State Physics, McMillan, India (1985). 6. J. S. Blakemore, W. B. Sauders, Solid State Physics, Philadelphia (1969).	
<u>Learning Outcomes</u>	Student will be experienced with basic theories to understand electrical/thermal/magnetic/dielectric/optical properties of solids.	

Programme: M. Sc. (Physics)
Course Code: PHO-214 **Title of the Course:** Solid State Physics Practical
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Physics. The students have under gone practical courses prescribed at B.Sc. The student knows the criterion of performing experiments and working in a laboratory.	
Objective:	This course aims at developing advance level experimental skills. At the end of this course the student should be in a position to perform the analysis of XRD data, use four probe method of determining resistivity, should know to handle magnetic equipment and measure/determine magnetic properties/constants of magnetic materials, determine thermo power of materials, estimate Hall coefficient of Semiconductors, determine energy band gap of semiconductors, Temperature dependence of resistivity of materials and magneto-resistance of Semiconductors, determine Lande g factor.	
Content:	1. X-Ray Diffraction : XRD of Cubic Material; Powder Pattern and its qualitative and quantitative analysis. 2. Determination of Resistivity and Band Gap of a Semiconductor by Four Probe Method 3. Measurement of Thermoelectric Power 4. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Material by Gouy's Method 5. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Liquid by Quinke's Method 6. Study of Hysteresis of a Ferrite and determination of Curic / Ne'el temperature of a Ring made up of a Ferrite Material. 7. Determination of Lande's Splitting Factor, g, in an organic radical . ESR Spectrum 8. Study of Elastic behaviour of solids using a composite piezoelectric oscillator 9. Determination of Transition Temperature of a Ferroelectric Material Dielectric Constant 10. Measurement of Activation Energy of F-Centres in Alkali Halide Crystals Thermo luminescence 11. Determination of a Hall Coefficient and Nature of a Semiconductor and Mobility of Charge Carriers 12. Frequency dependence of Dielectric constant 13. Energy band gap of material by UV reflectance. 14. IR spectra of material and its analysis. 15. Temperature variation of resistivity of semiconductor material and determination of activation energy. 16. Raman effect – demonstration applied to a particular material. A minimum of 12 experiments are expected to be done by the students.	

Pedagogy:	Practical, tutorials/assignments/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).	
Learning Outcomes	1. Quantitative measurements and evaluations 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.	

Programme: M. Sc. (Physics)
Course Code: PHO-302 **Title of the Course:** Neutron Physics
Number of Credits: 4
Effective from AY: 2018-19

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: 3L Uranium resources and requirements. Isotope separation. (one method). Fuel reprocessing. Storage and disposal of nuclear waste – consideration of different methods.	3 hours
	IX. Nuclear Policy: 2L Elements of India’s Nuclear Policy. Examples of Policy of other countries.	2 hours

	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:		
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: PHO-303 **Title of the Course:** Superconductivity & Superfluidity
Number of Credits: 4
Effective from AY: 2018-19

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. 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, MgB_2 and Iron Arsenide systems, their crystal structure, experimental studies on these materials, Phase diagrams. **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. **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. **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. **3. Bose-Einstein Condensates** Introduction, Bose-Einstein Statistics, Bose-Einstein condensation, BEC in ultra-cold atomic gases.	2 hours 6 hours 22 hours 6 hours 6 hours 6 hours
Pedagogy:	lectures/ tutorials/seminars/term papers/assignments/ presentations/ self-study/ Case Studies 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:PHO-304 **Title of the Course:** X-ray Spectroscopy
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Nil	
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 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 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. 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 12 hours 12 hours 12 hours
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
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	Students are expected to learn the principles of interaction of	

	X-rays with matter; gain knowledge about characteristics of most important X-ray sources (x-ray tubes, synchrotron radiation sources); understand the principles of X-ray diffraction (XRD), X-ray photoemission and X-ray absorption spectroscopy, know the necessary experimental equipment, and understand basic methods for analysis and interpretation of measured spectra, and understand what kind of structural information about the investigated material can be obtained by individual spectroscopic methods.	

Programme: M. Sc. (Physics)
Course Code: PHC-305 **Title of the Course:** Electronic Practical-II
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Should have studied B. Sc. Physics. The students have under gone practical courses prescribed at B.Sc. The student knows the criterion of performing experiments and working in a laboratory.	
Objective:	This course aims at developing advance level experimental skills in Electronics. At the end of this course the student should be in a position to design and construct various operational electronic circuits using advance level electronic components mentioned in the syllabus. The ideas and circuits learned in this course can be extended for various practical applications.	
Content:	1. Study of R-S, D/T, J-K Flip-Flops. 2. Study of counters: Ripple, Mode 3, Mode 5, Mod 7, Mod 9, Mod 12 counters. 3. Study of Shift Register. 4. Study of Binary weighted and R-2R D/A Converter. 5. Study of Random Access Memory (RAM) Read Only Memory. (ROM) 6. Study of A/D Converter. 7. Experiment with Microprocessor 8. Convert BCD in to HEXADECIMPL 9. Design and construction Analog Multiplexer 10. Design and construction of Sample and Hold Circuits 11. Full adder and subtractor 12. Solving of Differential Equation by analog computation using OPAMPS 13. Design and construction of Amplitude modulation and Demodulation Circuit. 14. Design and construction of frequency modulation and demodulation Circuit. 15. Design and construction of variable voltage (0-25V; 1Amp) Regulated power Supply. 16. Design and construction of low voltage SMS power supply. Any **eight** experiments to be completed	
Pedagogy:	Practical, tutorials/assignments/self-study	
References/Readings	1. Charles Roth, Fundamental of Logic Design 4/e: Jaico Publications, New Delhi (2002) 2. M. Morris Mano, Digital Design : Prentice Hall India, New Delhi (2008). 3. Donald Leach, Albert Malvino, Goutam Saha, Digital Principles and Applications, Tata McGraw Hill Education Private limited (2011). 4. Charles H. Roth, Digital System Design using	

	VHDL: Jaico Publishers, New Delhi 5. Stephen Brown, Fundamentals of Digital Logic with VHDL Design: TMH, New Delhi (2009).	
Learning Outcomes	1. Designing of Digital circuits for various types. 2. The basic circuits designed and constructed can be modified to suit different applications. 3. Development of intensive experimental skills in electronics.	

Programme: M. Sc. (Physics)
Course Code: PHO-306 **Title of the Course:** Semiconductor Physics
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Basic knowledge of solid state physics/ solid state chemistry	
Objective:	To introduce basics of semiconductor physics and to make them aware of phenomena of transport in semiconductors and devices based on P-N junctions.	
Content:	1. **Electrons in Solids** Schrodinger equation for electrons; the free electron problem. filling of electronics states: statistics. Cubic lattices, Diamond and zinc blende structures. Metal, Semiconductors and insulators; Fermi levels in metals and semiconductors. 2. **Electrons in Semiconductors** Electrons in a periodic potential, Bandstructures of Ge, Si and GaAs, Mobile carriers: Intrinsic carriers, intrinsic concentration doping: Donors and acceptors; carriers in doped semiconductors. 3. **Carrier Dynamics in Semiconductors** Scattering in semiconductors; Velocity-electric field relations, Very high field transport: breakdown phenamena, Carrier transport by diffusion; Transport by drift and diffusion, Einstein relation, Charge injection and quasi-Femi levels; Charge generation recombination; Optical processes in semiconductors, Nonradiative Recombination, Continuity equation: diffusion length. 4. **Junctions in Semiconductors : P-N Diodes** Unbiased P-N junction., P-N junction under bias., The real diode : consequences of defect, High voltage effects in diodes, Modulation and Switching : AC response.	6 hours 6 hours 6 hours 6 hours
Pedagogy:	Practical, tutorials/assignments/self-study	
References/Readings	1. Semiconductor Devices : basic Principles, Jasprit Singh. (John Wiley & Sons, New York, 2004). 2. Physics of Semiconductors and Their Heterostructures Jasprit Singh (McGraw -Hill, New, York, 1993). 3. Introduction to Semiconductor Materials and Devices , M.S. Tyagi (John Wiley & Sons, New York, 2000). 4. Physics of Semiconductor Devices S. M. Sze (John Wiley & Sons, New York, 1981). 5. Solid State Electronic Devices, B. G. Streetman and S. Banerjee (Prentice Hall, Englewood Cliffe, NJ 1999).	
Learning Outcomes	By the end of the course, students will be able to demonstrate a knowledge and broad understanding of Semiconductor Physics.	

Programme: M. Sc. (Physics)
Course Code: PHO-309 **Title of the Course:** Physics of Non-conventional Energy Sources
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Student should have studied the energy science at B.Sc. level and aware of different types of renewable energy sources and how to harness energy from them.	
Objective:	To develop the awareness among M.Sc. II students about different types of energy sources and their application to solve the present energy crisis and our day to day need of energy. It also helps them to understand the basic physics involved in different ways by which they can extract the energy from wind, ocean, biomass, geothermal, solar energy sources. It also give them basic understanding of fuel cell and hydrogen as an energy source for future generations.	
Content:	1. **An Introduction to Energy Sources** Renewable and non-renewable energy sources, energy consumption Global and National scenarios, Prospects of non-conventional Energy Sources- scope and potential. **Solar radiations** Extra terrestrial radiation, Spectral distribution of solar radiation, Solar constant, Measurement of solar radiations, Solar radiation geometry, Flux on a plane surface, Latitude, Declination angle, Surface azimuth angle, Hour angle, Zenith angle, Solar altitude angle, expression for angle between incident beam and the normal to a plane surface. **Solar energy** Solar thermal power and it's conversion, Solar collectors, Flat plate, Performance analysis of flat plate collector, Solar concentrating collectors, Types of concentrating collectors, Thermodynamic limits to concentration, Cylindrical collectors, Thermal analysis of solar collectors, Tracking CPC and solar swing . Solar thermal energy storage, Different systems, solar pond. Applications: Water heating, Space heating & cooling, Solar distillation, solar pumping, solar cooking, Greenhouses, Solar power plants. **Solar photovoltaic system** Photovoltaic effect, Efficiency of solar cells, Semiconductor materials for solar cells, Solar photovoltaic system, Standards of solar photovoltaic system, Applications of PV system, PV hybrid system. **2. Wind Energy** Principle of wind energy conversion; Betz model, wind mills-horizontal axis and vertical axis, horizontal axis wind turbines,	20 hours 20 hours 8 hours

	their components. Vertical axis- Magnus effect, Madaras & Darrieus turbine. Analysis of aerodynamic forces acting on wind mill blades and estimation of power output. 3. **Energy from Biomass** Photosynthesis, Bio gas production Aerobic and anaerobic bio-conversion process, Raw materials, Properties of bio gas, Producer gas, Biomass conversion technologies, Biogas generation plants, classification, advantages and disadvantages, Fuel properties of bio gas, utilization of biogas. 4. **Geothermal Energy** Structure of earth's interior, geothermal sites, geothermal resources, Principle of working, Estimation and nature of geothermal energy, Types of geothermal stations, advanced concepts, Problems associated with geothermal conversion. 5. **Energy from the ocean** Principle of ocean thermal energy conversion, systems like open cycle, closed cycle, Hybrid cycle, Energy from tides, basic principle of tidal power, single basin and double basin tidal power plants, advantages, limitation and scope of tidal energy. Wave energy conversion machines, power plants based on ocean energy advantages and disadvantages of wave energy. 6. **Fuel Cells** Introduction, Design principle and operation of fuel cell, Types of fuel 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. 7. **Hydrogen Energy** Properties of hydrogen as a source of renewable energy, Hydrogen Production methods, Hydrogen storage, hydrogen transportation, utilization of hydrogen gas as a fuel, hydrogen as alternative fuel for vehicles. Development of hydrogen cartridge.	4 hours 4 hours 6 hours 3 hours 3 hours
<u>Pedagogy</u>:	lectures/ tutorials/laboratory work/ field work/ / project work/viva/ seminars/term papers/assignments/ presentations/ self-study	
<u>Learning Outcomes:</u>	1 General awareness among students regarding energy sector, its scenarios and crisis. 2 How to harness energy from different non-conventional energy sources like sun, wind, geothermal energy, ocean, fuel cell, biomass, hydrogen etc 3 The basic physics and technical intricacies involved in energy extraction from non conventional energy sources.	

	4. Understand the importance of utilizing energy wisely or else to face the dire consequences.	
References/Readings	1. N. K. Bansal, Manfred Kleemann, Michael Meliss, Renewable energy sources and conversion technology, Tata Mc Graw Hill (1990). 2. D.P. Kothari, K. C. Singal, R. Ranjan, Renewable energy resources and emerging technologies, Prentice Hall of India Pvt. Ltd (2011). 3. Rai G.D, Non-Conventional energy Sources, Khanna Publishers (2011). 4. Ashok V. Desai, Nonconventional Energy, New Age International Publishers Ltd (2005). 5. J. Twidell and T. Weir, Renewable Energy Sources, Taylor & Francis (1986). 6. Sukhatme, Solar Energy, Tata McGraw-Hill Education, (1996). 7. B. S. Mangal, Solar Power Engineering, McGraw-Hill Education (India) Pvt Limited, (1999). 8. D. Yogi Goswami, Frank Kreith, Jan F. Kreider, Principles of Solar Energy, Taylor & Francis (2000).	

Programme: M. Sc. (Physics)
Course Code: PHO-310 **Title of the Course:** Numerical Methods and Fortran Parallel Programing using open MP
Number of Credits: 4
Effective from AY: 2018-19

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:PHO-311 **Title of the Course:** Phase Transitions and Critical Phenomena
Number of Credits: 4
Effective from AY: 2018-19

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	4 hours
	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	4 hours
	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.	12hours
	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	12hours
	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	4 hours
	6. Order-disorder phase transitions Order–disorder phenomenology, Mean-field theory of order–disorder phase transitions: the Bragg–Williams model, Computational methods , Beyond Bragg–Williams theory: the	4 hours

	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/assignments. Sessions shall be interactive in nature to enable peer group learning.	
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: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:PHO-312

Title of the Course: Spectroscopic Techniques in Condensed Matter Physics

Number of Credits:4

Effective from AY: 2018-19

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	12 hours

	of NMR (Bloch equations), experimental methods, Chemical shift, Knight shift in metals, spin-lattice relaxation, Applications 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/ term papers/assignments/ presentations/ self-study. Sessions shall be interactive in nature to enable peer group learning.	
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: PHO-313 **Title of the Course:** Physics of Energy Materials
Number of Credits: 4
Effective from AY: 2018-19

Prerequisites for the course:	Student should have basic understanding of the different physical phenomenon in nanotechnology, magnetocaloric effect, plasmonics etc. from B.Sc.(physics) level.	
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. State-of-the-Art of Nanostructures in Solar Energy Research** Introduction, 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. **Metal Oxide Semiconductors and Their Nanocomposites Application towards Photovoltaic and Photocatalytic** Introduction, Metal Oxide Nanostructures for Photovoltaic Applications, TiO2 Nanomaterials and Nanocomposites for the Application of DSSC and Heterostructure Devices, ZnO Nanomaterials and Nanocomposites for the Application of DSSC and Heterostructure Devices, Fabrication of DSSCs with Vertically Aligned TiO2 nanotubes, ZnO Nanorods (NRs) and Graphene Oxide Nanocomposite Based Photoanode, ZnO Nanocomposite for the Heterostructures Devices, Fabrication of Heterostructure Device with Doped ZnO Nanocomposite, Metal Oxide Nanostructures and Nanocomposites for Photocatalytic Application, Future Directions.	14 hours
	3. **Advanced Electronics: Looking beyond Silicon** Introduction, 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. **The Physics of Thermoelectric Energy Conversion** Introduction, 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. **The magnetocaloric effect and its applications** Introduction, Magnetocaloric effect in the phase transition region, Methods of investigation of magnetocaloric	6 hours

	properties, Magnetocaloric effect in different types of materials, Magnetocaloric effect in nanosized materials, Magnetic refrigeration 6. Pl**asmonics: Fundamentals and applications** Introduction, Electromagnetics of metals, Surface Plasmon polaritons at metal/insulator interfaces, localized surface Plasmon, Applications: Transmission of radiation through apertures and films, Spectroscopy and sensing. 7. Fuel Cells: Introduction, Design principle and operation of fuel cell, Types of fuel 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.	6 hours 6 hours
Pedagogy:	lectures/ tutorials /viva/ seminars/ term papers/assignments/ presentations	
Learning Outcomes:	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.	
References/Readings	1. Ashutosh Tiwari, Sergiy Valyukh, Advanced Energy Materials, John Wiley and Sons, 2014. 2. 2 H Julian Goldsmid, The Physics of Thermoelectric Energy Conversion, Morgan & Claypool Publishers, 2017. 3. 3 A.M. Tishin, Y.I. Spichkin, The Magnetocaloric Effect and its Applications, CRC press (Taylor and Francis group), 2016. 4. 4 Stefan A Maier, Plasmonics: fundamentals and application, Springer, 2007. 5. 5 Sam Zhang, Organic nanostructured thin film devices and coatings for clean energy, CRC Press (Taylor and Francis group) 2017. 6. 6 Sam Zhang, Nanostructureed thin films and coatings, CRC Press (Taylor and Francis group), 1ST Edition, 2010. 7. 7 R. Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college Press, 2005. 8. 8 A.S. Bhatia, Nanoscience and carbon nanotubes, Deep and deep publication, 2009. 9. 9 Antonio Dominech Carbo, Electrochemistry of porous materials, CRC Press (Taylor and Francis group) 2010 10. 10 Klimov Vasily, Nano plasmonics, Pan Stanford Publishing, 2014. 11. 11 Ru Eric C.Le, Pablo G. Etchegoin, Principles of surface enhanced raman spectroscopy and related plasmonic effects, Elsevier; 1st Edition, 2009.	

	12. 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. 14. G.D Rai, Non-Conventional energy Sources, Khanna Publishers 2003.	

Programme: M. Sc. (Physics)
Course Code:PHO-314 **Title of the Course:** Documentation using LaTex
Number of Credits: 1
Effective from AY: 2018-19

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	12 hours
Pedagogy:	Lectures / tutorials/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: 2018-19

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. 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 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. Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy 4. **Applications of Nanoscience**	12hours 14hours 12 hours

	Nanomaterials for energy applications, Nanoelectronics, Nanomagnetism and devices, Nanophotonics, Surface plasmons, Nanobio applications, Environmental issues	10 hours
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
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: PHO-316 **Title of the Course:** Magnetism in Condensed Matter Physics
Number of Credits: 4
Effective from AY: 2018-19

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	6hours
	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.	6 hours
	7. **Competing interactions and low dimensionality** Frustration, Spin glasses, Superparamagnetism, One dimensional	4 hours

	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
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.	
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.	