	Mahatma Gandhi University **School of Pure and Applied Physics** **Programme Specific Outcomes**

Programme Specific Outcomes (PSO)

PSO 1: Acquire adequate knowledge in physics which make students able to understand, remember, analyse, evaluate and interpret the world around in a scientific way

PSO 2: Students are expected to develop problem-solving ability

PSO 3: Develop **s**kills to implement innovative and advanced ideas/ techniques via collaborative, multidisciplinary means

PSO 4: Students are expected to have an outlook rooted in human and ethical values

PSO 5: Students will learn to communicate effectively and hence network with scholars/educational institutions, collaborate and work in teams / lead teams

PSO 6: Students will acquire a positive attitude towards learning which engenders lifelong personal and professional development.

PSO 7: Students will be able to realize and analyse the world they live in, in a scientific and creative way and thereby make attempts for improving the quality of life of all

SCHOOL OF PURE & APPLIED PHYSICS

Scheme for M.Sc. Degree Course

(Effective from 2021 admissions, Evaluation will be based on CSS regulation 2020)

COURSE CODE	**NAME OF COURSE**	**CREDITS**
SEMESTER- I		
PHM21C01	BASIC ELECTRONICS	4
PHM21C02	MATHEMATICAL PHYSICS-I	4
PHM21C03	CLASSICAL MECHANICS	4
PHM21C04	CLASSICAL ELECTRODYNAMICS	4
PHM21C05*	PRACTICAL-I	4
	Total	20
SEMESTER- II		
PHM21C06	QUANTUM MECHANICS-I	4
PHM21C07	MATHEMATICAL PHYSICS-II	4
PHM21C08	STATISTICAL PHYSICS	4
PHM21C09	SOLID STATE PHYSICS	4
PHM21C10*	PRACTICAL-II	4
	Total	20
SEMESTER- III		
PHM21C11	QUANTUM MECHANICS-II	4
PHM21C12	COMPUTATIONAL METHODS IN PHYSICS	4
PHM21C13	LASERS AND SPECTROSCOPY	4
PHM21C14*	ADVANCED PRACTICAL -I	2
PHM21Exx@	ELECTIVE-I	4
SCMYROyy#	OPEN COURSE	4
	Total	22
SEMESTER- IV		
PHM21C15	NUCLEAR AND PARTICLE PHYSICS	4
PHM21C16*	ADVANCED PRACTICAL -II	2
PHM21Exx	ELECTIVE-II	4
PHM21Exx	ELECTIVE-III	4
PHM21C17	PROJECT	8
	Total	22
	Grand Total	84

@PHM21Exx represents elective course with course codes - PHM21E01 to PHM21E15
#SCMYROyy represents Open Course (SC-School Code, M - program, YR - Year, Oyy - course number)
*Syllabus will be decided by the faculty council based on the availability of experimental facilities

SCHOOL OF PURE & APPLIED PHYSICS

Subject Codes of Elective Courses

(Effective from 2021 admissions)

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ELECTIVE COURSES		
COURSE CODE	**NAME OF COURSE**	**CREDITS**
PHM21E01	BASIC ASTRONOMY	4
PHM21E02	STARS GALAXIES AND COSMOLOGY	4
PHM21E03	APPLIED PHOTONICS	4
PHM21E04	NANOPHOTONICS	4
PHM21E05	X-RAY CRYSTALLOGRAPHY	4
PHM21E06	PHYSICS OF NANOMATERIALS	4
PHM21E07	NANOSCIENCE AND NANOSTRCTURED MATERIALS	4
PHM21E08	PHYSICS OF SEMICONDUCTOR MATERIALS	4
PHM21E09	PHYSICS AND APPLICATIONS OF SEMICONDUCTOR DEVICES	4
PHM21E10	X-RAY CHARACTERISATION METHODS	4
PHM21E11	FUNDAMENTALS OF PLASMA PHYSICS	4
PHM21E12	ADVANCED SOLID STATE PHYSICS	4
PHM21E13	ADVANCED OPTICS	4
PHM21E14	NONLINEAR OPTICS AND ADVANCED LASER SYSTEMS	4
PHM21E15	ADVANCED MATERIAL CHARACTERIZATION METHODS	4
PHM21E16	MATERIALS SCIENCE	4
PHM21E17	MATERIALS PHYSICS	4
PHM21E18	QUANTUM FIELD THEORY	4
	OPEN COURSE	
PHM21O01	INTRODUCTION TO MATHEMATICAL SCIENCE	4

Course Name	**Basic Electronics**					
Course Code	PHM21C01					
Course Summary & Justification	The course comprises the theory and applications of analog and digital electronics. Students are introduced to circuit designing and analysis approaches in detail. Electronic devices are so much a part of our daily lives. The field of electronics is very diverse with lot many applications and a lot many career opportunities. This course of 'Basic Electronics' equips students with the necessary knowledge and skills to design, develop and operate different kinds of electronics systems.					
Semester	1					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about electricity, passive and active electric components and electric circuits.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Make a better understanding of the basics of electronic components and circuits	U	1
2	Distinguish/analyse the types of electronic circuits	An	1,2
3	Design various analog and digital circuits for an expected output	C	2
4	Construct simple devices using the designed circuits for a specific application	C	2
5	Develop, at least conceptually, a new electronic product	C	2,3,7
**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*			

COURSE CONTENT

Content	CO	Hours
Unit I- Analog Integrated Circuits (18 Hrs) Introduction to analog integrated circuits, Introduction to operational amplifiers, Characteristics of Op-Amp, Characteristics of an ideal Op-Amp, Open-Loop Op-Amp configurations: differential, inverting and non-inverting amplifiers, Closed-Loop Op-Amp configurations: positive and negative feedback amplifiers, Negative feedback Op-Amp configurations: voltage-series/noninverting, voltage-shunt/inverting and differential amplifiers, Characteristics of a practical Op-Amp: total output offset voltage, frequency response, Compensating networks, Parameter evaluation for DC and AC applications of operational amplifiers	**1-4**	**18**
Unit II- Analog Integrated Circuit Applications (20 Hrs) DC and AC amplifier, Summing, scaling and averaging amplifiers, Instrumentation amplifier, Differential input and differential output amplifier, Voltage-to-current converter: with floating and grounded loads, Current-to-voltage converter, Integration amplifier, Differentiation amplifier, Filters: first, second and higher-order filters, low-pass, high-pass, band-pass, band- reject and all-pass filters, Oscillators: phase-shift, Wien bridge and quadrature oscillators, Wave generators: square, triangular and saw tooth wave generators, Voltage-controlled oscillator, Comparators: Schmitt trigger, Voltage limiters, Clippers and clampers, Absolute value output circuit, Peak detector, Sample-and-hold circuit, The 555 timer: monostable and astable multivibrators, Phase-locked loops	**1-5**	**18**
Unit III-Digital Integrated Circuits and Applications (18 Hrs) Introductory concepts of digital systems, Binary logic, Logic gates, Logic circuits, Binary number system, Boolean algebra, Standard forms of Boolean expressions, Introduction to digital integrated circuits, Analysis and simplification of logic circuits using Boolean algebra and Karnaugh maps, Combinational logic circuits: binary adders, decoders, encoders, multiplexers, demultiplexers, parity generators and checkers, comparators, Sequential logic circuits: Flip-flops: RS, D, JK Shift registers: serial and parallel transfer, Counters: asynchronous and synchronous, up and down counters, Microprocessor architecture and Microcomputer system design	**1-4**	**18**
Unit IV-Communication Electronics(16 Hrs) Amplitude modulation, Single side band techniques- balanced modulator, phase shift method, Radio receivers-superheterodyne receiver, AM receiver, detection and AGC, Frequency modulation-theory and generation, FM receiver, Pulse communication, Types of modulation-PAM, PWM, PPM, PCM, Digital communication- error detection and correction, Frequency and time division multiplexing	**1-4**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Op-amps and Linear Integrated Circuits, Ramakant. A. Gayakwad.
2. Digital Logic and Computer Design, M Morris Mano.
3. Electronic Communication Systems, Kennedy and Davis.

SUGGESTED READINGS

1. Integrated Electronics, Jacob Millman and C.C. Halkias.
2. Digital Principles and Applications, Donald P Leach, Albert Paul Malvino and Goutam Saha.
3. Electronic Communications, Roody & Coolen.

Course Name	**Mathematical Physics I**
Type of Course	Core
Course Code	PHM21C02
Course Summary & Justification	The course comprises the theory and formulate techniques of defining real systems and solving advanced level problems Mathematics is not only to solve the scientific problem but it is a need for day to day life. But the course we offer is Advanced Course on Mathematics which specifically for the need of understanding the natural dynamics.
Semester	1

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, Collaborative learning, Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about numbers, addition & division, subtraction & multiplication					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understands the concepts of physical quantities, Concept of differentiation and how it describes the real systems	*U*	1
2	Solve problem using Matrix Algebra and formulate new methodology for formulating new physical systems	*An*	1,2
3	Can solve problems in Quantum Mechanics	*C*	2
4	Analyse the problems and classify the functions and formulate new solution and explore it for understanding complex systems of design new systems	*C*	2
5	Can develop analytical skill and confidence for approaching higher level scientific problems	*C*	2, 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT :

Content	**CO**	**Hours**
Unit I- Vector Analysis Basics of Vector Algebra and its physical concepts, Gradient, Divergence and Curl, vector integration, Gauss's theorem, Green's theorem and Stokes theorem, Potential theory, Gauss's Law and Poisson's Equation, Dirac Delta function and its properties, Orthogonal curvilinear coordinates Gradient, Divergence, Curl and Laplacian. Evaluation of line, surface and volume integrals	**1,3,4,5**	**18**
Unit II- Linear Vector Space and Matrix Algebra Matrix algebra, Matrix multiplication, Transportation and Hermitian conjugate, Trace and determinants, Inverse of matrix, orthogonal and	**1-5**	**18**

unitary matrices, Linear vector spaces, Metric space, Schmidt orthogonalisation, Linear operators, dual space, ket and bra notation, Hilbert space, Function spaces, Basis, Orthogonal expansion of separable Hilbert spaces, Bessel’s inequality, Parseval’s formula		
Unit III- Complex Analysis Functions of a complex variable, The derivative and Cauchy Riemann conditions, Line integrals of complex functions, Cauchy’s integral theorem, Cauchy’s integral formula, Taylor’s series, Laurent’s series, Residues, Cauchy’s residue theorem – Singular points of an analytic function the point at infinity, Evaluation of residues, Evaluation of definite integrals by contour integration, Method of steepest descent (Stirling’s formula)	**1,3,4,5**	**18**
Unit IV- Special Functions Gamma and Beta functions and its properties, Frobenius method Bessel, Legendre differential Equation, Hermit equations, Recurrence relations, Generating functions, Rodrigues formulae for the Bessel, Legendre and Hermits functions, Linear differential operators, adjoint operators, Green’s identity, Eigen values and Eigen functions, Sturm-Liouville operators	**1,3,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Mathematical Methods for Physicists, George B. Arfken \& Hans J. Weber Academic Press, Elsevier, 2005
2. Introduction to Mathematical Physics, Charlie Harper, PHI Learning Private Limited, New Delhi, 2012.
3. Applied Mathematics for Engineers and Physicists, Louis A. Pipes \& Lawrence R. Harvill, McGraw Hill international Book edition, 1981

SUGGESTED READINGS

1. Theory and problems of vector analysis – M Spiegel, Schaum's outline series, McGraw Hill

2. Introduction to Mathematical Physics – Charlie Harper, Prentice Hall

3. Applied Mathematics for Engineers and Physicists – Pipes and Harvill

4. http://nptel.ac.in/courses/111105035/# Mathematics through ICT

(Students may experiment with) Geo-bra Wolfram Alpha

Course Name	**Classical Mechanics**					
Type of Course	Core					
Course Code	PHM21C03					
Course Summary & Justification	The course is designed to introduce students to Classical Mechanics. This course deals with the fundamental understanding of Classical mechanics developed by Newton, Lagrangian, Hamilton and others. The study of classical mechanics gives the students an opportunity of basic understanding of vast field of physics through various mathematical techniques.					
Semester	1					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic understanding of Mechanics with mathematical knowledge including vectors and calculus (Undergraduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Students will understand the disciple-specific knowledge in classical mechanics. Basic understanding of Mechanics with mathematical knowledge including vectors and calculus	U	1,7
2	Analyse various problems associated with mechanics and interpret the result with real time observations. Relate symmetries to conservation laws in physical systems, and apply these concepts to practical situations	A	1,2,7
3	Students will know the concepts of classical mechanics and demonstrate a proficiency in the fundamental concepts in this area of science. Suggest solutions of unsolved problems using various concepts and mathematical tools.	An	1,2,5,7
4	Explain the Lagrangian and Hamiltonian formulations and demonstrate its effectiveness in solving variety of problems. Describe the physical principle behind the derivation of Lagrange and Hamilton's equations, and the advantages of these formulations.	E	1,2,7
5	Explain the motion of rigid bodies and basic understanding of fluid dynamics.	U	1,2,7

6	Use of perturbation theory for the application of complex chaotic dynamical systems.	U	1,2,7
7	They will use critical thinking skills using their knowledge to formulate and solve quantitative problems in applied physics	S	1,7
8	Employ conceptual understanding to make predictions, and then approach the problem mathematically and understand the important connections between theory and experiment. Develop concepts and mathematical rigor in order to enhance understanding.	E	1,2,3,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit 1-Lagrangian and Hamiltonian formulation A review of Newtonian Mechanics of a particle and system of particles. Conservation laws, Lagrangian formalism, constraints and their classifications, Generalized co-ordinate. Principle of virtual work, D'Alembert's principle, Lagrange's equations and its applications, Velocity Dependent potential, Dissipative force, Generalized Momentum, cyclic co-ordinates, Conservation laws and symmetry properties, Homogeneity of space and time, Variational Principle, Hamilton's principle, Lagrange's equation from Hamilton's principle, The Principle of least action.	**1,2,3, 4,7**	**18**
Unit II- Hamiltonian mechanics and Hamilton-Jacobi theory Hamiltonian formalism, Hamiltonian of a system, Hamilton's equations of motion, Integrals associated with cyclic co-ordinate, Canonical transformations, Poisson Brackets and their properties, equations of motion, Hamilton-Jacobi Theory, Hamilton's Characteristic function, Harmonic Oscillator problem in Hamilton's-Jacobi method, Action Angle variable, Harmonic Oscillator and Kepler Problem in Action-angle variable.	**1,3,4, 7,8**	**18**
Unit III- Motion of rigid bodies and Fluid Mechanics Kinematics of rigid body motion, Infinitesimal rotations, Coriolis force, rigid body equation of motion, Central force motion, Scattering & centre of mass, Theory of small oscillations, normal modes of the system, Fluid Mechanics-equation of state and equation of continuity, Bernoulli's theorem-interpretation of Lagrangian formalism of continuous system, Sound vibration in gases.	**1,3,5, 7**	**18**
Unit IV- Perturbation Theory and Chaotic Dynamical Systems Classical Perturbation theory, Time dependent perturbation- Simple pendulum with finite amplitude, Kepler problem, Chaotic Dynamical system-conservative system- integrable systems, KAM theorem (qualitative Idea),Nonlinear perturbation, Hamiltonian-chaos, Dissipative systems-continuous systems, Duffing oscillator- discrete systems, Logistic maps-fixed points- limit cycle, Period doubling- - chaotic Attractors- Lyapunov exponent, Fractals and their dimension- Koch curve.	**1,3,4, 6,7,8**	**18**

Teachnical and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, E-learning, interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Internal Test – One MCQ based and on extended answer type 3. Book review – every student to review reference books. 4. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar **Semester End examination**

REFERENCES

Text Books

1. Classical Mechanics -H. Goldstein
2. Classical Mechanics -N. C Rana & P. S. Joag
3. Classical Mechanics - G. Aruldhas
4. Chaotic Dynamics -G.L. Baker & J.P. Gollub
5. Mechanics - Landau - Lifshitz

Suggested Reading

1. Classical Mechanics -R. Douglas Gregory
2. Deterministic Chaos -N .Kumar, University Press
3. Classical mechanics -Takwala and Puranik
4. Classical Mechanics -P. V. Panat
5. Classical Mechanics -J. C. Upadhyaya
6. Analytical Dynamics -E. T. Whittaker

Course Name	**Classical Electrodynamics**					
Type of Course	Core					
Course Code	PHM21C04					
Course Summary & Justification	Classical Electrodynamics course extends the fundamental understanding of static electric and magnetic fields and associated potential to time-varying fields. This master level course offers the familiarization of the concept of propagation of electromagnetic radiation and wave guiding, dynamics of charged particles under electromagnetic fields and its extension to relativistic conditions, which could be applied to physical situations. Electromagnetic fields and dynamics is an integral part of Physics to understand the phenomena associated with charged bodies in motion and varying electric and magnetic fields based on Maxwell's equations.					
Semester	1					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Graduate level Mathematics (Calculus, Vectors)					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Use calculus and vector in Physical situations containing charges	*U*	1,2
2	Analyse the electromagnetic field due to time varying charge and current distribution using Maxwell's equations	*An*	1,2
3	Explain charged particle dynamics and radiation from localized time varying electromagnetic sources.	*S*	2,3
4	Explain the nature of electromagnetic wave and its propagation through different media and interfaces.	*C*	2,6
5	Use the theorems and laws to predict the electric filed around various surfaces containing charges and its extension to quantum electrodynamics.	*A*	1,5,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
UNIT I :Electrostatics & Magnetostatics Gauss's law and its applications, Poisson and Laplace equations, the electrostatics potential, electrostatic field due to point charges and continuous charge distribution, Electric field energy, Boundary value problems and their solutions, Multipole expansion, Biot-Savart law, Ampere's theorem, Magnetics field of a steady current, the divergence and curl of **B**, Applications of Ampere's law, the vector and scalar potentials.	**1,2,5**	**18**
UNIT II :Time varying fields Electromagnetic induction and Faraday's law, Maxwell's displacement current, Maxwell's equations in free space and linear isotropic media, boundary conditions on the fields at interfaces, time dependent scalar and vector potentials, Gauge invariance, Coulomb and Lorentz Gauge, magnetic field energy, conservation laws, continuity equation, Poynting's theorem, Maxwell's stress tensor and conservation of momentum.	**1,2,3,5**	**18**
UNIT III :Electromagnetic radiation & Guided waves Electromagnetic waves in free space, Dielectrics and conductors, reflection and refraction at interfaces, Polarization, Fresnel's law, interference, coherence and diffraction, waveguides and transmission lines, Transmission line equations and wave characteristics, skin effect, Modes in rectangular wave guide, Retarded potentials, The Lienard- Wiechert potentials, radiation from moving point charges and oscillating electric and magnetic dipoles, dispersion relations in plasma.	**1,3,4,5**	**20**
UNIT IV :Relativistic Electrodynamics Lorentz transformation equations, Lorentz invariance of Maxwell's equations, Transformations of electromagnetic fields under Lorentz transformation, electrodynamics in tensor notation, potential formulation of relativistic electrodynamics, Four potential of a field, Dynamics of charged particles in static and uniform electromagnetic fields.	**1,2,3,5**	**16**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Teaching, Seminar, Group Assignments, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Introduction to Electrodynamics, D J Griffiths, Prentice Hall India.
2. The classical theory of fields, L D Landau and E M Lifshitz, Pergamon Press.
3. Electrodynamics and radiative systems, E. C. Jordan and K. G. Balmain Prentice Hall India.

SUGGESTED READINGS

4. Introduction to Relativity, R. Resnik, Wiley India.
5. Classical Electromagnetic Radiation, J. B. Marion
6. Electrodynamics of continuous media L. D. Landau and E. M. Lifshitz, Pergamon Press.
7. Classical electrodynamics, J. D. Jackson, Wiley India.
8. Introduction to Modern Optics, G. R. Fowles, Dover Publications.

Course Name	**Quantum Mechanics - I**
Type of Course	Core
Course Code	**PHM21C06**
Course Summary &Justification	This course is aimed at teaching the student some of the mathematical machinery used in performing quantum mechanical calculations and the setting up and solving of some basic problems from a variety of situations. The case of the free particle, bound particle, particle under a time independent perturbation and tunnelling of a particle through a potential barrier are considered. In addition, how angular momentum is envisioned in quantum mechanics is set out as a fourth unit. The teaching is to be aimed at bringing out the link between the physical system and the mathematical machinery that is used to analyse the system. A few online courses/sites that would supplement the curriculum as well as enhance the ability of the student to navigate on-line and pick up useful information are also included to enhance and enrich the learning experience. This course is intended to be followed by the course 'Quantum Mechanics - II', the two together giving the students a comprehensive introduction to the basics and methods of Quantum Mechanics with respect to single particle systems (bound and unbound, non-relativistic and relativistic), many particle systems and an introduction to quantum field theory. The various units of the syllabus take the student through – (A) the basic mathematical set up (B) various representations and stationary states of some systems (C) approximation methods for more complicated potentials and (D) angular momentum.
Semester	2

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
72	Authentic learning Collaborative learning Direct Instruction	72	18		15	105
Pre-requisite	Good understanding of BSc level quantum mechanics					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understanding and navigating the mathematical setup of the quantum prescription for physical systems	R, U, An, E	1, 3, 7
2	Understanding the mathematical setups for tracking the time evolution of a physical system	R, U, Ap	1, 2, 6, 7
3	Solving for the stationary states of some standard three-dimensional systems	R, U, A, S	3, 7
4	Understanding and applying perturbation methods to systems with Hamiltonians that are not exactly solvable	R, U, A, E, S	1, 2, 7
5	Developing of approximation methods for quasi-classical systems and application of these	U, E, C, S	1, 2, 7
6	Developing and generalizing operators for angular momentum	U, C, An, S	1, 2, 3, 7
7	Developing the mathematical setup for combining angular momenta	U, An, C, Ap	1, 2, 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	**CO**	**Hours**
Unit I – Postulates of Quantum Mechanics Linear vector space and Hilbert space, Dirac Bracket notation, Operators - Commutator algebra, Generalized Heisenberg uncertainty relations, Eigen values and eigen functions of an operator, Representation in discrete bases, change of bases and Unitary Transformations, Representation in continuous bases, Connecting Position and Momentum bases, Matrix and Wave Mechanics, Postulates of quantum mechanics- principle of superposition, State of a system, Observables and Operators, Measurements in Quantum Mechanics, Poisson brackets and commutators, Ehrenfest's theorems.	**1,2,3, 4**	**18**
Unit II – Representations and stationary states Schrodinger, Heisenberg and Interaction representations, Time dependent Schrodinger equation and continuity equation, Time independent Schrodinger equation – 1 D Harmonic Oscillator – eigen values and eigen states, Creation and annihilation operators, 3D problems in spherical coordinates, Free particle in spherical coordinates, spherically symmetric potentials, Particle in a three-dimensional box, Three-dimensional isotropic harmonic oscillator, Hydrogen atom- energy eigen values and eigen functions.	**1,2,5**	**18**
Unit III – Approximation methods Time independent perturbation theory (degenerate and nondegenerate cases) - wave function and correction to energy to second order, Anharmonic oscillator, Degenerate case: secular equation- corrections to eigen values and eigen functions in the first approximations for a doubly degenerate level, First order Stark and Zeeman effect in hydrogen, WKB approximation (Quasi classical case), Boundary conditions in quasi classical case- Connection formulae, Quasi classical motion in a centrally symmetric field - Quantization condition, Penetration through a potential barrier.	**1,2,4,**	**18**
Unit IV – Angular momentum Rotations in Classical and Quantum Mechanics - operators for infinitesimal and finite rotations, Commutation relations of angular momentum operator - Generalised angular momentum operators, Eigen values and eigen functions of the angular momentum operator - spherical harmonics, Matrix representation – Pauli spin matrices, Addition of angular momenta - Clebsch – Gordon coefficients for $j_1 = ½, j_2 = ½$.	**1,2,3, 6,7**	**18**

REFERENCES

Text books

1. Quantum Mechanics – Concepts and Applications - Zettili
2. Quantum Mechanics - Greiner
3. Quantum Mechanics - Landau &Lifshitz
4. Quantum Mechanics - G Aruldas
5. Quantum Mechanics - Merzbacher
6. Quantum Mechanics - V K Thankappan

Online resources
YouTube: Lectures by Prof V Balakrishnan
Keyword Quantum Mechanics at
https://ocw.mit.edu
https://www.ias.ac.in/search/index/reso

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction: Brain storming lecture, Explicit Teaching, E-learning, Interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student / Group representative, Flipped classroom
Assessment Types	**Mode of Assessment** • Continuous Internal Assessment (CIA) • Internal Test – One MCQ based and an extended answer type • Book review – every student to review a chapter from Merzbacher's textbook on Quantum Mechanics and submit a report • Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar • Semester end examination

Course Name	**Mathematical Physics II**					
Type of Course	Core					
Course Code	PHM21C07					
Course Summary & Justification	The course comprises the theory and techniques fundamental problems in Nature From business transactions to basic execution program of computer, Mathematics become an inevitable part of life. This is an advanced Course on Mathematics which specifically for the need of understanding the complex scientific problems in physics.					
Semester	2					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about integration, differentiation					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Students can understand the nature of problems and its periodicity. They would develop a skill to use the transform method for solving research problems	*U*	1
2	Students understands the concept of space and its role over the Astrodynamics	*An*	1,2
3	Develop a skill to formulate groups and to find the missing elements in the advanced level problems in particle physics and solid state physics	*C*	2
4	Students understand to classify the differential equation and solve it with different approach and hence develop an analytical skill to formulate and find new methods to adapt.	*C*	2
5	Can develop analytical skill and confidence for approaching higher research problems	*C*	2, 3
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT

Content	CO	Hours
UNIT I :Fourier Series, Fourier Transforms, Laplace Transforms Fourier series – Dirichlet's conditions – Fourier series of even and odd functions – complex form of Fourier series – Fourier integral and its complex form – Fourier transforms – Fourier sine and cosine transforms – Convolution theorem and Parseval's identity – Laplace transform of elementary functions – Inverse Laplace transforms – methods of finding inverse Laplace transforms – Heaviside expansion formula – solutions of simple differential equations	**1,2,3,5**	**18**

UNIT II Differential Geometry, Elements of Probability Theory (18 hrs) Definition of tensors – metric tensor – covariant, contravariant and mixed tensors – differentiable manifolds and tensors – parallel transport – equation of geodesics –Christoffel symbols and curvature – Riemann curvature tensor – Ricci tensor and Ricci scalar. Elementary probability theory – random variables – Binomial, Poisson and Normal distributions – Central Limit Theorem	**1,2,3,5**	**18**
UNIT III Group Theory Definition of groups - examples – matrix groups – transformation groups – cosets – conjugacy classes – Lagrange's theorem – invariant subgroups – factor groups – homomorphism – homomorphism theorem – isomorphism – direct product of groups – representation of groups – matrix, faithful, unitary, reducible and irreducible representations – Schur's lemma – orthogonality theorem – Lie groups and Lie algebras – definition of Lie group – representation of SU(2) SO(3)	**1,3,5**	**20**
UNIT IV Green's Functions Definition and physical significance of Green's functions – translational invariance – eigen function expansion of Green's function – Green's functions for ordinary differential operators – first order linear differential operators and second order linear differential operators (eg forced harmonic oscillator) – Green's functions for partial differential operators – Laplace equation – solution of boundary value problems using Green's functions	**1-5**	**16**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Mathematical Methods for Physicists, George B. Arfken \& Hans J. Weber Academic Press, Elsevier, 2005
2. Introduction to Mathematical Physics, Charlie Harper, PHI Learning Private Limited, New Delhi, 2012.
3. Applied Mathematics for Engineers and Physicists , Louis A. Pipes \& Lawrence R. Harvill , McGraw Hill international Book edition, 1981

SUGGESTED READINGS

1. Theory and problems of vector analysis – M Spiegel, Schaum's outline series, McGraw Hill
2. Introduction to Mathematical Physics – Charlie Harper, Prentice Hall
3. Applied Mathematics for Engineers and Physicists – Pipes and Harvill
4. http://nptel.ac.in/courses/111105035/# Mathematics through ICT
(Students may experiment with) Geo gebra Wolfram Alpha

<table>
<tr><td>Course Name</td><td colspan="6">Statistical Physics</td></tr>
<tr><td>Type of Course</td><td colspan="6">Core</td></tr>
<tr><td>Course Code</td><td colspan="6">PHM21C08</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">Statistical Physics deals principally with equilibrium systems whose particles are either independent or effectively independent. It also treats equilibrium systems whose particles are strongly interacting as well as nonequilibrium systems. Statistical physics gives a rational understanding of Thermodynamics in terms of microscopic particles and their interactions. Statistical physics allows not only the calculation of the temperature dependence of thermodynamics quantities, such as the specific heats of solids for instance, but also of transport properties, the conduction of heat and electricity for example. Moreover, statistical physics in its modern form has given us a complete understanding of second-order phase transitions, and with Wilson’s Renormalization Group theory we may calculate the scaling exponents observed in experiments on phase transitions. However, the field of statistical physics is in a phase of rapid change. New ideas and concepts permit a fresh approach to old problems. With new concepts we look for features ignored in previous experiments and find exciting results.

Statistical physics, in fact, provides an intellectual framework and a systematic approach to the study of real-world systems with complicated interactions and feedback mechanisms. It is expected that the new concepts in statistical physics will eventually have a significant impact not only on other sciences, but also on the public sector to an extent that we may speak of as a paradigm shift.</td></tr>
<tr><td>Semester</td><td colspan="6">2</td></tr>
<tr><td>Total Student LearningTime (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
<tr><td></td><td>Authentic learning
Collaborative learning
Independent learning</td><td>72</td><td>18</td><td></td><td>15</td><td>105</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Basic Quantum Mechanics, Thermodynamics and Basic Mathematical Physics</td></tr>
</table>

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Conceptual ideas of ensemble formalism, particularly partition function and it's relation to thermodynamics properties	*U, C*	1,2
2	Different ensembles with examples	*An*	1,2
3	Thermodynamics of systems through ensemble formalism	*U, C*	1,2,3
4	Basics of probability theory and correlation to a statistical system	*U, C*	1,2,3
5	Concepts of phase transitions and theory	*U, C*	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
UNIT I Thermodynamics and Statistical theory Laws of thermodynamics and their consequences. Thermodynamic potentials and Maxwell's relations. Chemical potential. Phase equilibrium. The macroscopic and microscopic states – Contact between statistics and thermodynamics – The classical ideal gas – Entropy of mixing and the Gibb's paradox – Phase space of a classical system – Liouville's theorem and its consequences – The micro canonical ensemble – Quantum states and phase space – The equipartition theorem - The Virial theorem	**1,2**	**18**
UNIT II The Canonical and Grand Canonical Ensembles Equilibrium between a system and heat reservoir – a system in the canonical ensemble – Thermodynamical relations in a canonical ensemble – the classical systems – Energy fluctuations in the canonical ensemble: correspondence with micro canonical ensemble – Equilibrium between a system and a particle energy reservoir – A system in the grand canonical ensemble – Physical significance of statistical quantities – Density and energy fluctuations in the grand canonical ensemble: Correspondence with other ensembles	**1,3**	**18**
UNIT III Quantum Statistics Quantum mechanical basis – Statistical distribution – An ideal gas in quantum mechanical micro canonical ensemble and other quantum mechanical ensembles – Detailed balance – Partition functions and other thermodynamic quantities of mono-atomic and diatomic molecules. Thermodynamic behavior of a Bose gas – Thermodynamics of Black body radiation – The Planck distribution law – Bose Einstein condensation – Thermodynamic behavior of an ideal Fermi gas – Pauli paramagnetism – Electron gas in metals and thermionic emission	**1,2,3**	**18**

UNIT IV Theory of Phase Transitions and Fluctuations Problem of condensation – Theory of Yang and Lee – Bragg – Williams approximation– comparison with experiment near transition temperature - Ising model and it's solution for a linear chain – Equivalence of the Ising model to other models – Lattice gas and binary alloy – Brownian motion – Langevin equation – Random walk problem – Diffusion equation–-Introduction to non-equilibrium processes - Boltzmann transport equation.	**1,2,4,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual students
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Surprise Tests Seminar Presentations Assignments End Semester Examination

REFERENCES

1. Statistical Mechanics - R K Pathria
2. Statistical Mechanics - K Huang
3. Statistical Mechanics-Donal A McQuarrie
4. Introductory Statistical Mechanics –Roger Bowley
5. Statistical Mechanics – Donald A. Mc Quarrie
6. Statistical Mechanics and Properties of Matter – E S R Gopal
7. Fundamentals of Statistical and Thermal Physics-FederickReif

SUGGESTED READING

1. Classical Mechanics-Herbert Goldstein,
2. Higher Algebra-Hall and Knight,
3. The Feynman Lectures on Physics-Richard Feynman, Robert Leighton, Matthew Sands

Course Name	**Solid State Physics**					
Type of Course	Core					
Course Code	PHM21C09					
Course Summary & Justification	This course gives an introduction to solid state physics, and will enable the student to employ classical and quantum mechanical approaches to analyse physical properties of solids. The first part of the course is on "crystal lattice" focussing on crystal structure, lattice defects, lattice vibrations and lattice specific heat. This follows classical and quantum mechanical formulations of free electron theory and band theory of solids. The last two units are devoted to study the magnetic, dielectric and superconducting properties of solids. The course explains the concepts that are used to describe the structure and physical properties of crystalline substances. Solid State Physics forms the theoretical basis of Materials Science, hence by studying Solid State Physics students will understand how the macroscopic properties of materials result from their microscopic, atomic scale properties.					
Semester	2					
Total Student LearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about atoms, molecules and properties of matter					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basics of crystal structures	*U*	1
2	Formulate the theory of lattice vibrations (phonons) and use that to determine thermal properties of solids	*An*	1,2
3	Understand the concepts of free electron theory and band theory of solids.	*U*	1
4	Evaluate the electrical and magnetic parameters of the solid	*E*	2
5	Think how to alter the properties of solids to make them suitable for particular applications	*C*	2,3
6	Apply the knowledge obtained to make a judicious choice of a solid in terms of its desired property	*C*	2,3
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Content	CO	Hours
Unit I : Crystal Lattice (18 hours) Crystal structure: Unit cell, Bravais lattices, Miller indices, Reciprocal lattice, Bragg's law. Lattice defects: Point defects, Schottky and Frenkel defects – Equilibrium concentration of defects, Color centres. Line defects – Edge and screw dislocations, Dislocation energy, Plane defects. Lattice vibrations: Vibrations in one dimensional monatomic and diatomic lattices, Quantization of lattice vibrations, Phonon momentum. Inelastic scattering by phonons. Lattice heat capacity: Classical theory of specific heat, Einstein model, Debye model, Anharmonic crystal interactions.	**1,2,5,6**	**18**
Unit II : Free electron theory and Band theory (18 hours) Free electron theory: Drude-Lorentz classical theory, Free electron gas in one and three dimensions, Quantum state and degeneracy, Density of states, Fermi-Dirac distribution and effect of temperature, Electronic specific heat, Electrical conductivity and ohm's law. Hall effect. Band theory of metals: Energy bands, Bloch theorem, Kroning-Penny model, Brillouin zones, Number of states in the band, Effective mass. Band theory of semiconductors: Carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors, Electrical conductivity of semiconductors, Hall effect in semiconductors.	**3,5,6**	**18**
Unit III : Magnetic properties (18 hours) Diamagnetism and paramagnetism: Langevin's theory of diamagnetism and paramagnetism, Quantum theory of paramagnetism, Comparison with theory and experiment - Rare earth group and iron group ions, Paramagnetic susceptibility of conduction electrons. Ferromagnetism: Weiss molecular field theory, Heisenberg's exchange interaction, Ferromagnetic domains, Bloch wall, Spin waves, Dispersion relation for spin waves, Magnons, Magnon specific heat. Antiferromagnetism and ferrimagnetism. Two sub-lattice model of Anti ferromagnetism, Neel's model of ferrimagnetism.	**4,5,6**	**18**
Unit IV : Dielectrics and Superconductivity (18 hours) Dielectric properties: Polarization, Dielectric constant, Local electric field, Dielectric polarizability, Clausius-Mossoti Relation, Types of polarizability, Frequency dependence of polarizability. Ferroelectricity: Ferroelectric crystals and their properties, Classification of ferroelectric materials, Dipole theory of ferroelectricity. Superconductivity: Meissner effect, Type I and Type II superconductors, Thermodynamics of super conducting transition, London equation, Basic ideas of BCS theory – Flux quantization – Josephson effects (AC & DC) - High Tc superconductors.	**4,5,6**	**18**

References

1. Introduction to Solid State Physics – C Kittel
2. Solid State Physics – A J Dekker
3. Solid State Physics: Structure and Properties of Materials - M A Wahab

Suggested Readings

1. Elementary Solid State Physics – M Ali Omar
2. Principles of Solid State Physics – R A Levy
3. Solid State Physics – N W Ashcroft and N D Mermin

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

Course Name	**Quantum Mechanics II**					
Type of Course	Core					
Course Code	PHM21C11					
Course Summary & Justification	The course covers advanced topics in quantum mechanics that find application in almost all other branches of modern physics. It includes the application of quantum mechanics to scattering experiments, which help probing the nature of fundamental interactions between microparticles at the subatomic level. It also extends the student's knowledge in single particle quantum systems to many particle systems consisting of bosons and fermions. The mathematical skills of the student are enhanced by way of solving the Schrodinger equation for physical systems that experience time-dependent potentials. The application of the theory of relativity to quantum mechanics is covered and the new insights provided by the theory are discussed. An introductory review of quantum field theory helps to realise how theoretical physics explains several properties of fundamental particles, which are the building blocks of the physical world.					
Semester	3					
Total Student LearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic understanding of the fundamental postulates of quantum mechanics and workingknowledge in its general formalism, including that of representations, stationary states, approximation methods and angular momentum theory.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	The student should be able to remember both the definitions of basic measurable quantities in scattering experiments and how these quantities are predicted with the help of quantum theory. Various techniques of time-dependent perturbation theory are to be memorised. The quantum nature of many particle systems consisting of identical particles, the statistics obeyed by them, the relativistic formulation of quantum theory, and introductory quantum field theory are also studied and remembered.	R	1
2	The first Unit of the course will help the student to understand under what conditions the Born approximation and the partial wave approach are useful in scattering experiments. The Unit on identical particles will help to understand the origin of Bose-Einstein and Fermi-Dirac statistics obeyed by fundamental particles. The relativistic formulation of quantum mechanics explains particle-antiparticle pair production and annihilation and the origin of intrinsic spin of electrons. The student will find Quantum field theory helpful in understanding several properties of fundamental particles of nature.	U	1
3	The student becomes capable of applying the quantum scattering theory in probing the nature of interaction potentials between target and incident particles. They will also be able to apply time-dependent perturbation theory to obtain transition rates, when atomic electrons interact with radiation.	A	1,2
4	The analysis of wavefunctions of a system of particles leads to the understanding of the statistics obeyed by them. Similarly, analysing the solutions of relativistic	An	1,2

	wave equations and the quantisation of the resulting fields help to obtain deep insights into the properties of fundamental particles.		
5	The relative merits of Born approximation and partial wave analysis, while applying them to concrete problems, are subject to evaluation. Similarly, the advantage of time-dependent perturbation theory in evaluating transition probabilities for electrons in atoms are studied.	E	1,2
6	Various kinds of many particle wave functions, for distinguishable and indistinguishable particles, are created by the students. Their creative ability to solve the fundamental problem of solving the Schrodinger equation is extended to time-dependent problems also.	C	1,2
7	Skills are developed for solving the Schrodinger equation of many particle systems. Skills for making approximations in the quantum theoretical evaluation of scattering amplitudes and transition probabilities are also imparted.	S	1,2
8	The course is expected to arouse the interest of the student in understanding the properties of fundamental particles, the quantum behavior of systems of identical particles, the new insights obtained by applying relativity to quantum mechanics and by quantizing the resulting relativistic fields. The Units on Scattering theory and Approximation methods is to help the students in appreciating the role of experiments in physics. In general, they will appreciate the satisfactory explanation of several properties of subatomic and fundamental particles that make up the microworld.	I, Ap	1,2
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	**CO**	**Hours**
UNIT I Scattering Theory Scattering Cross Sections; Laboratory and CM reference frames – connecting angles and cross-sections; Scattering amplitude of spin-less particles; Scattering Amplitude and Differential cross section - Total scattering cross section; Born Approximation – First Born Approximation – Validity of Born Approximation; Scattering by Coulomb potential; Partial wave analysis for elastic and inelastic scattering; Optical theorem; Scattering by a square well potential.	**1,2,3**	**18**

UNIT II Identical Particles The Indistinguishability Principle; Symmetry of wave functions; Spin and Statistics; The Pauli's Exclusion principle; Scattering of identical particles; Spin function for many electron systems; Slater determinants; Sate vector space for a system of Identical particles – Creation and Annihilation Operators – Fermions and Bosons	**2,4,6,8**	**18**
UNIT III **IIIa. Approximation Methods** Variational method. Time Dependent Perturbation theory - Transition probabilities for constant and harmonic perturbations; Adiabatic and Sudden approximations – Interaction of atoms with radiation – Classical treatment of the incident radiation; Transition rates for Absorption and Emission of radiation – Transition rates within the dipole approximation – Spontaneous emission. **IIIb. Relativistic Quantum Mechanics** Klein-Gordon equation; Difficulties with the Klein-Gordon equation; First order wave equations Dirac equation – Free Dirac Particle ; Equation of continuity - Non-relativistic limit of Dirac equation; Spin and orbital angular momentum of the electron from Dirac equation – Hole theory	**1,5,8**	**20**
UNIT IV Quantum Field Theory Lagrangian Field theory – Classical field equations - Hamiltonian formulation; Quantization of the field – Bosons and Fermions – Relativistic fields – Quantization of the Klein – Gordon , Dirac and electromagnetic fields - Gupta-Bleular formalism.	**7,8**	**16**

Teachical and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Internal Test – One MCQ based and on extended answer type 3. Book review – every students to review reference books. 4. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar **Semester End examination**

REFERENCES &SUGGESTED READINGS

Quantum mechanics - Cohen-Tannoudji C., Diu B., Laloe F.

Quantum Mechanics - Concepts and Applications N Zettilli

Modern Quantum Mechanics – Sakurai, J.J.

Advanced Quantum Mechanics – Sakurai J.J.

Quantum Mechanics. V K Thankappan

Quantum Mechanics 2 ndEdn E Merzbacher

Quantum Field Theory, L.Ryder

Quantum Field Theory, C.Itzykson and J.Zuber

Course Name	**Computational Methods in Physics**					
Type of Course	Core					
Course Code	PHM21C12					
Course Summary & Justification	Computational method is an easy and faster tool to analyze applied/specific mathematical problems in science and engineering, which are difficult to solve with ordinary analytical methods. This core course – computational methods in Physics, is formulated to provide fundamental knowledge about various numerical methods necessary to solve mathematical problems relevant to physics. The course will also provide ample experience for the solution of theoretical and computation-oriented problems. Polynomial interpolation methods for the estimation of function values at intermediate points for data sets with both equal and unequal intervals comprise unit 1, along with commonly used curve fitting methods. Unit II is devoted to numerical differentiation and integration. Different methods for the solution of algebraic and transcendental equations are the part of unit III. Solution of ordinary differential equations by Euler's method, Runge-Kutta method, Predictor-corrector method, finite difference method etc. are the content of Unit IV. Elementary ideas of solution of partial differential equation are also included. Computational methods are a better alternative of conventional methods to solve problems involving interpolation, differentiation and integration with limited data points and solution of differential equations relevant to physical science.					
Semester	3					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Graduate level Mathematics (Algebra, Calculus)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Familiarisation with the concept of finite difference and polynomial interpolation method for the estimation of function values at intermediate data points.	*U*	1,2
2	Application of numerical methods for error analysis and curve fitting.	*An*	1,2,5,7
3	Acquainted with numerical differentiation with polynomial approximation and application of the method for specific problems.	*S*	2,3
4	Training integration using different numerical methods and numerical double integration.	*C*	2,6
5	Application of numerical methods to find solution of algebraic equations using different methods and numerical solution of system of equations.	*A*	1,5,6
6	Learning various numerical methods for the solution of ordinary differential equations and finding solutions for initial value problems and boundary value problems.	*An*	1,2,5,7
7	Familiarisation with the solution of partial differential equations using finite difference approximation.	*A*	1,2,7
8	Gain conceptual idea about various computational methods applicable in physics and expertise in solving problems with appropriate method.	*An*	1,2,5,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
UNIT I Interpolation and Curve Fitting Finite difference operators, Differences of a polynomial, Interpolation with equal intervals - Newton's interpolation formulae, Gauss's Formulae, Bessel's formula, Stirling's formula, Everett's formula, Interpolation with unequal intervals–Lagrange's interpolation formula, Newton's divided difference formula, Basic ideas of Spline interpolation, Curve fitting –method of group averages, least squares method.	**1,2,8**	**18**
UNIT II Numerical differentiation and Integration	**3,4,8**	**18**

Numerical differentiation - derivatives using difference formulae, Differentiation using Lagrange's polynomial and divided difference polynomial, Numerical integration: Newton–Cotes quadrature formula, Trapezoidal rule, Simpson's rule, Romberg's method, Gaussian quadrature method, Numerical double integration, Elementary ideas of Monte Carlo evaluation of integrals.		
UNIT III Solution of Algebraic and Transcendental Equations Solution of algebraic and transcendental equations: Bisection method, Regula-Falsi method, Iteration method, Newton-Raphson method, Secant method, Convergence of solutions, Solution of system of linear equations : Method of determinants, Matrix inversion method, Gauss elimination method, Gauss – Jordan method, LU factorization, Jacobi method, Gauss-Seidel method.	**5,8**	**18**
UNIT IV Solution of Differential Equations Solution of ordinary differential equations: Initial value problems, Taylor's series method, Picard's method, Euler's method, Modified Euler's method, Runge Kutta method, Predictor- corrector methods - Milne's method, Adam - Bashforth's method, Boundary value problems – Finite difference method, Elementary ideas of solution of partial differential equations, Solution of Laplace equation using Finite difference approximation.	**6,7,8**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Teaching, Seminar, Group Assignments, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

Course Name	**Lasers and Spectroscopy**
Type of Course	Core
Course Code	PHM21C13
Course Summary & Justification	**Course Objectives** The topics, Lasers and spectroscopy have played an integral role in developing quantum mechanics leading to identify the constituents of matter. The main objective of this course is to understand the origin of the quantum nature of atomic and molecular energy levels. More over this course explores the interaction of Matter with EM radiation leading its application in molecular structure determination. This course also aims to give the basics of lasing action and a detailed working principle of different laser systems.

	The topics dealing in this course have numerous applications in industry, material science, medicine, telecommunications and defence.					
Semester	3					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about concept of atoms, molecules, energy levels, electron distribution, quantum mechanics.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Capable of writing rate equations of three-level and four-level laser systems, describe the working principle of specific laser systems and their applications. (Module 1)	***U***	1
2	Knowledge of the electronic energy states in atoms in terms of quantum numbers, origin of spectra and the consequence of spin-orbit coupling, effect of magnetic and electric fields, and the interpretation of term symbols. (Module 2)	***An***	1,2
3	Explain the transitions between rotational, vibrational and electronic states of molecules, spectra of molecules and their use in molecular structure determination (Module 3)	***C***	2
4	Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR) (Module 4)	***C***	2
5	Develop skills to characterise and identify the structure of molecules.	***C***	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I: Atomic Spectroscopy Quantum numbers and spectroscopic terms, Spin orbit interaction- Lande g factor ,Equivalent and non-equivalent electrons, Zeemen effect and Paschen Back effect, LS and JJ coupling schemes, Hund's rule, Examples of LS and JJ coupling, Lande-intervel rule, Stark effect- hyperfine structure.	**1,2,5**	**15**

Unit II- Microwave, IR and Raman spectroscopy Different types of molecules, Rotational spectra of diatomic molecules, Intensity of spectral lines, Isotopic substitution, non-rigid rotator, Diatomic molecules as harmonic and anharmonic oscillators, diatomic vibrating rotator, Spectrum of CO and CO_2 molecules, Rotational Raman spectra, vibrational Raman spectra, Mutual exclusion principle, structure determination from Raman and IR spectroscopy, Elementary ideas of Nonlinear Raman effect.	**1,3,5**	**20**
Unit III Electronic and Spin Resonance Spectroscopy Electronic spectra of diatomic molecules, Intensity of spectral lines, Frank-Condon principle dissociation energy, Rotational fine structure of electronic vibrational transitions- Fortrat diagram, pre-dissociation, NMR–Bloch equations, relaxation processes, chemical shift, ESR-hyperfine structure, Mossbauer effect- hyperfine interaction- chemical isomer shift.	**1,4,5**	**20**
Unit IV-Laser spectroscopy Spontaneous and stimulated emission; Einstein A and B coefficients, The laser idea – amplification of light – threshold condition, Coherence time, coherence length, three- and four-level rate equation analysis- laser systems, solid-state lasers-Ruby laser and Nd-YAG laser, Gas lasers-He-Ne and CO_2 laser, Dye lasers, Semiconductor lasers, Modes of resonators, Applications.	**1,2,5**	**17**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Class quiz Assignments End Semester Examination

REFERENCES

1. Introduction to atomic spectra- HE White, McGraw hill.
2. Molecular structure & Spectroscopy G Aruldhas, Prentice Hall of India.
3. Fundamentals of molecular spectroscopy C BanwellMcGraw Hill Education
4. Optical Electronics-A. Ghatak& K Thyagarajan, Cambridge University Press.
5. Lasers theory and applications - Ghatak&Thyagarajan Springer

SUGGESTED READINGS

1. Spectroscopy volume I and II-Stroaughan and valker, John wiley.
2. Principles of lasers –O Svelto, Springer
3. Quantum Electronics-A Yariv, John Wiley
4. Laser Fundamentals-W T Silfvast, Cambridge Univ press

Course Name	**Nuclear and Particle Physics**					
Type of Course	Core					
Course Code	PHM21C15					
Course Summary & Justification	The forces that bind nuclei together, nuclear structures and dynamics, as well as nuclear reactions and their probabilities are studied in detail in this course. This is important to learn various nuclear reactions and associated energy release. The ideas on nuclear fusion and fission processes are explained and will be useful to conduct research on joint nuclear fusion programmes. Also, the smallest building blocks of the universe such as quarks will be discussed in detail here.					
Semester	4					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	70	18	0	17	105
Pre-requisite	Graduate level Mathematics (Calculus, Vectors), Quantum Mechanics, Classical Mechanics, Electrodynamics					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Use the knowledge of atomic physics and extend it to perceive the basic properties of the nucleus	***R, U***	1,2
2	Modelling a physical system from first principles of physics and compare it with the experimental outcome.	***An***	1,2
3	Explain nuclear interactions based on scattering processes	***S***	1,2
4	Express different radioactive decays and hence calculate the half-times using various theories.	***A***	2,6
5	Explain about the smallest building blocks of the universe and how modern science define it.	***E***	1,5,6
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

Content	CO	Hours
Unit I- Nuclear Structure and Models Basic properties of nucleus-Nuclear radius, Distribution of nuclear charge, Skin thickness, Isotope shift, Nuclear matter distribution, Nuclear binding energy, Magnetic dipole moment -quadrupole moment, Liquid drop model - Semi-empirical mass formula of Weizsacker Nuclear stability, Mass parabolas, Bohr-Wheeler theory of fission, Shell model - Spin-orbit coupling, Magic numbers, Elementary ideas of collective model.	**1,2,5**	**16**
Unit II- Nuclear Interactions Nuclear forces-Two body problem, Meson theory of nuclear forces - Yukawa potential, Nucleon-nucleon scattering, Effective range theory, Spin dependence, Charge independence and charge symmetry of nuclear forces, Isospin formalism.	**1,3,5**	**16**
Unit III-Nuclear reactions Radioactivity, Types of reactions and conservation laws - Reaction dynamics-Q-value equation, Basics of alpha decay and Gamow's theory of Alpha decay, Beta decay and energetic of beta decay, Fermi's theory of Beta decay, Kurie plots, Mass of the neutrino, lifetime, Allowed and Forbidden transitions, selection rules and parity violation in beta decay, Neutrino physics, non-conservation of parity, Gamma decay - Internal conversion, Multipole moments, lifetimes, Energetics of fission process, controlled fission reactions, Fusion process and solar fusion, Nuclear radiation detectors.	**1,3,5**	**18**
Unit IV-Particle Physics Elementary particles, Types of interactions between - Hadrons and Leptons, Symmetry and conservation laws, Elementary ideas of CP and CPT invariance, Classification of Hadrons -SU (2) - SU (3) multiplets, Quark model, Gell-Mann-Okubo mass formula for octet and decuplet Hadrons, Quantum chromodynamics (QCD), Elementary ideas of standard model of weak interaction and QCD.	**1,4,5**	**22**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Teaching, Seminar, Group Assignments, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. K.S. Krane, 1987, Introductory Nuclear Physics, Wiley, New York.
2. D. C. Thayal, Nuclear Physics, Himalaya Pub. House 1997
3. H.A. Enge, 1975, Introduction to Nuclear Physics, Addison Wesley, London.
4. I. Kaplan, 1989, Nuclear Physics, 2nd Edition, Narosa, New Delhi.
5. R.R. Roy and B.P. Nigam, 1983, Nuclear Physics, New Age International, New Delhi.
6. D. Griffiths, 1987, Introduction to Elementary Particle Physics, Wiley-VCH ,2008

SUGGESTED READINGS

1. Y.R. Waghmare, 1981, Introductory Nuclear Physics, Oxford-IBH, New Delhi.
2. Ghoshal, Atomic and Nuclear Physics, Volume 2.
3. J.M. Longo, 1971, Elementary Particles, McGraw-Hill, New York.
4. R.D. Evans, 1955, Atomic Nucleus, McGraw-Hill, New York.
5. B.L. Cohen, 1971, Concepts of Nuclear Physics, TMH, New Delhi.
6. M.K. Pal, 1982, Theory of Nuclear Structure, Affl. East-West, Chennai.
7. W.E. Burcham and M. Jobes, 1995, Nuclear and Particle Physics, Addison-Wesley, Tokyo.

<table>
<tr><td>Course Name</td><td colspan="6">Basic Astronomy</td></tr>
<tr><td>Type of Course</td><td colspan="6">Elective</td></tr>
<tr><td>Course Code</td><td colspan="6">PHM21E01</td></tr>
<tr><td>Course Summary &Justification</td><td colspan="6">This course is aimed at teaching the student the basics of astronomy in addition to introducing the Sun, the nearest star, as an astronomical object. The teaching is to be aimed at bringing out the link between the physics / mathematics / statistics that has been / is being taught and the use it has been put to / found in the astronomical topics included in this course. A few online courses / sites that would supplement the curriculum as well as enhance the ability of the student to navigate on-line and pick up necessary information are also included to enhance and enrich the learning experience. This course is intended to be followed by the course 'Stars Galaxies &Cosmology', the two together giving the students a comprehensive introduction to the basics and methods of Astronomy &Astrophysics. The various units of the syllabus take the student through – (A) Measurements in astronomy and the units used (B) The Sun as a star (C) The basics of various types of telescopes and(D) Generation and Transmission of Radiation</td></tr>
<tr><td>Semester</td><td colspan="6"></td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

		Lecture	Tutorial	Practical	Others	Total Learning Hours
72	Authentic learning Collaborative learning Direct Instruction	72	18		15	105
Pre-requisite	Good understanding of basic physics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand basic direct measurements in astronomy	R, U An, E	1, 2, 7
2	Exploring and understanding the closest star	R, U, An, Ap	1, 2, 3,7
3	Understanding observing instruments and the process of data acquisition	R, U, A, C, S	1, 3, 5
4	Understanding the imprint of physical conditions in the gneration and transmission of radiation / particles / gravitational waves	R, U, A, E, Ap	1, 2, 5, 7
5	Getting skilled in making inferences from observations through application of physical laws and modeling	U, E, C, S	1, 4, 6
6	Develop analytical abilities wrt the observational processes involved in astronomical data acquisition and their interpretation	U, C, I, Ap	1, 3, 5, 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I – Basic Units and Measurements Coordinate systems, Sidereal, solar, universal, standard and ephemeris times, Parallax, precession, nutation, aberration, Proper motion - radial and transverse velocities, space velocity, Units of distance - AU, light year and parsec, Magnitude scale - magnitudes and luminosities (apparent and absolute), Color indices, surface temperature, Distance modulus – distances of stars, Radii of stars, Masses of stars.	**1,2,3,6**	**15**
Unit II – The Sun as a star Solar structure – photosphere, chromosphere and corona, Solar activities – sunspots, flares, solar oscillations and helio-seismology, CME's, The solar system – general characteristics, Origin of the solar system, Orbits of planets, satellites and comets, Exoplanets.	**1,2,3,6**	**15**
Unit III – The basics of various types of telescopes Concepts of sensitivity, resolving power and signal to noise ratio, Optical telescopes - parts, different focii and mountings, Radio telescopes - Interferometers,synthesis telescopes, VLBI, X-ray astronomy - detection and collimation, Infra-red, gammaray, neutrino and gravitational - wave detectors (basics only), CCD's as detectors.	**1,4,6**	**21**
Unit IV – Generation and Transmission of Radiation Radiation mechanisms, Lienard-Wiechert potentials and fields for a point charge (withoutdetailed derivations), Total power radiated by a point charge, Larmor formula and relativistic generalization (without detailed derivations), Black body, bremsstrahlung,cyclotron, synchrotron, curvature, plasma and inverse Compton radiation, Interstellar extinction, The 21cm line of hydrogen, Transmission through an ionized medium -Faraday rotation, Doppler, cosmological and gravitational redshifts.	**1,5,6**	**21**

REFERENCES

Text books
Astrophysics BaidyanathBasu
Astrophysics: Stars & Galaxies K. D. Abhyankar

Astronomy & Astrophysics through ICT – (Students may experiment with)
Stellarium
SciPOP -IUCAA
https://arxiv.org/abs/1402.3674
Suggested reading
The Physical Universe F. H. Shu
http://study.com/articles/5_Sources_for_Free_Astronomy_Education_Online.html
https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction: Brain storming lecture, Explicit Teaching, E-learning, Interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student / Group representative, Flipped classroom
Assessment Types	**Mode of Assessment** •Continuous Internal Assessment (CIA) •Internal Test – One MCQ based and an extended answer type •Book review – every students to review a chapter from T Padmanabhan's textbook on Theoretical Astrophysicsand submit a report •Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar •Semester end examination

Course Name	**Stars, Galaxies and Cosmology**
Type of Course	Elective
Course Code	PHM21E02
Course Summary &Justification	This course is aimed at teaching the student the basics of astrophysics. The teaching is to be aimed at bringing out the link between the physics / mathematics / statistics that has been / is being taught and the use it has been put to in understanding the physical nature of stars, our own galaxy, galaxies and the universe. A few online courses / sites that would supplement the curriculum as well as enhance the ability of the student to navigate on-line and pick up necessary information are also included to enhance and enrich the learning experience. This course is intended as a sequel to the course 'Basic Astronomy', but may be taught independently also if the student is prepared to pick up a few basic concepts in astronomy on their own. The two courses 'Basic Astronomy'and 'Stars Galaxies and Cosmology'together, is intended to give the students a comprehensive introduction to the basics and methods of Astronomy &Astrophysics. The various units of the syllabus take the student through – (A) Stellar structure – a star as a ball of gas (B) Stellar evolution – end stages (C) Our Galaxy -its structure, components, properties and general inferences – Galaxies -their morphologhy and classification – onto hierarchical structure in the Universe (D) Brief introduction to the General Theory of Relativity and Cosmology

Semester						
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
72	Authentic learning Collaborative learning Direct Instruction	72	18	15		105
Pre-requisite	Good understanding of basic physics at Masters level and basic astronomy					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding the steps in the setting up of a physical model of a star	A, An, C	1, 7
2	Understanding the formation, evolution and end stages of stars of various masses	An, I, Ap	1, 3, 6
3	Understanding the structure, contents and formation scenario of the Milky Way galaxy, star formation theory, dark matter and, classification and hierarchical clustering of galaxies	U, A, Ap	2, 3, 4, 6
4	Understanding the current observational status wrt our knowledge of the universe and setting up a model for the physical universe	U, An, C, Ap	1, 2, 3,4, 7
5	Getting skilled in developing physical models, comparing with observations and drawing inferences about astronomical systems and the whole universe	R, U, An, S	1, 2, 6
6	Develop analytical abilities wrt astrophysical modeling and the use of models in making inferences about the physical conditions in astronomical sources	An, I, Ap	3, 5, 6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I – Stellar structure Correlations between stellar properties - M-L relation, HR diagram, Physical state of the stellar interior, Hydrostatic equilibrium, distribution of mass, estimation of central temperature and pressure, Energy generation equations, Energy transport by radiation and convection, Equations of stellar structure, Equation of state for stellar interiors - perfect gas - degenerate gas, Sources of opacity.	**1,6**	**18**
Unit II – Stellar evolution – its end stages Nuclear reactions, H burning, CNO cycle, Helium burning, Neutrinos, solar neutrino experiments, Structure of main sequence stars, Qualitative account of pre-main sequence evolution, Early post main sequence evolution, Turn off and the ages of stellar clusters, Advanced evolutionary stages, degenerate stars.	**2,6**	**18**
Unit III– Our Galaxy, galaxies, hierarchical structure in the Universe The Galaxy, structure of the Galaxy, Stellar populations and the formation of the Galaxy, The ISM – its components, Giant Molecular Clouds and star formation, Determination of the rotation curve of the Galaxy - its implications regarding dark matter, Classification of galaxies, Hierarchy of structures (groups, clusters, super-clusters), Active Galactic Nucleii and quasars.	**3,6**	**18**
Unit IV – General Theory of Relativity and Cosmology The equivalence principle, Action for the gravitational field, Einstein's equation (without derivation), Olber's paradox, Hubble's law, Fundamental assumptions -homogeneity and isotropy, the FRW metric, Contents of the Universe - dust and radiation, density evolution, critical density, Cosmological constant, the uniformity of the CMB, the origin of the anisotropies in the CMB, Conditions in the early universe, big bang nucleo-synthesis, accelerated expansion, dark energy.	**4,5,6**	**18**

REFERENCES

Text books

Astrophysics BaidyanathBasu

Astrophysics: Stars & Galaxies K. D. Abhyankar

General references

The Physical Universe F. H. Shu

Introduction to Cosmology – J V Narlikar

Theoretical Astrophysics, T. Padmanabhan

https://www.springboard.com/blog/astronomy-for-beginners-free-online-courses/

https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/

Astronomy & Astrophysics through ICT – (Students may experiment with)

VO India

NED – NASA Extragalactic Database

https://www.galaxyzoo.org/

https://einsteinathome.org/

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction: Brain storming lecture, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** •Continuous Internal Assessment (CIA) •Internal Test – One MCQ based and an extended answer type •Book review – every students to review a chapter from T Padmanabhan's textbook on Theoretical Astrophysicsand submit a report •Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar •Semester end examination

Course Name	**Applied Photonics**
Type of Course	Elective
Course Code	PHM21E03
Course Summary & Justification	The course covers the basic principles of important photonic components of Optoelectronics which find its application in visible, near-infrared, and mid-infrared wavelength ranges. Several of these devices, such as semiconductor lasers, detectors, sensing and display technologies, are the foundation for our modern information society. Also discuss the white-light LEDs and solar cells, have also drastic impact on our modern lives in terms of energy saving.Other topics covered, including photonic materials including semiconductors and photonic crystals and Nano photonics.

Specifically, the course covers the following topics

- Electronic properties of semiconductors
- Electronic properties of semiconductors
- p-n junction band diagram
- Light-emitting diodes
- Semiconductor lasers
- Optical amplifiers
- Optical detectors
- Solar cells
- Optical Modulators
- Optoelectronic integration
- Display technologies
- Photonic crystals
- Photonics in lighting
- Infrared sources
- Nanophotonics
- Quantum confined structure

Intended leaning outcomes

After completing the course, the student should be able to

Explain the structure and working principles of basic photonic devices.

Make calculations and measurements to quantify performances of various photonic devices.

Design appropriate photonic devices for achieving certain system requirements, including the aspects of energy consumption and sustainable development.

The technological limits of various photonic devices and describe potential solutions to those problems.

We describe the content of the course on photonics sometimes referred as optoelectronics. The main goal of the course is to equip students with sound theoretical and practical knowledge for photonic related research and also for industry. The content of the course are constantly updated to keep the latest technological development in the field of optoelectronics, owing to the dynamic nature of photonic research and application. This paper presents various aspects related to this course such as its acting role in the program curriculum system, teaching methods and assessment

Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Good understanding of BSc level Spectroscopy, Mathematics and Advanced learning in Quantum Mechanics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Knowledge of optoelectronic development and understanding information on various photonic devices, optoelectronic information system and the corresponding functional components. Knowledge of major photonic materials and its applications of optoelectronic technology	U	1,7
2	Mastering fundamental theories, basic knowledge and professional skills in the fields of optoelectronic information and electronic information.	A	1,2,7
3	Students will know the concepts of optoelectronics and demonstrate a proficiency in the fundamental concepts in this area of science.	Ap	1,2,5,7
4	Develop device-level knowledge & concept, such as light sources, optical modulators, optical waveguides, optical detectors, and optical displays etc.	E	1,2,7
5	Explain the basic concept of semiconductors and detectors.	U	1,2,7
6	Advance knowledge in photonic crystals and optical communications.	U	1,2,7
7	They will use critical thinking skills using their knowledge for applied photonics	S	1,7
8	Employ conceptual understanding to make predictions, and understand the important concepts in optoelectronics and Nano photonics.	E	1,2,3,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
UNIT I - Basics of optoelectronics Electronic properties of semiconductors, Energy level and density of carriers in intrinsic and extrinsic semiconductors, consequence of heavy doping, Direct and indirect band gap semiconductors, Electron and hole pair formation and recombination, recombination life time, p-n junction band diagram, Conduction process in semiconductors, open circuit- forward and reverse bias, Light emitting diodes-principles, device structures, LED materials, Heterojunction high intensity LEDs, Double heterostructure, LED characteristics and LEDs for optical communications, Surface and edge emitting LEDs.	**1,2,7,8**	**18**
UNIT II - Optoelectronic devices and detectors Principle of p-n junction photodiode, Absorption coefficient and photodiode materials, Quantum efficiency and responsivity, PIN photodiode, Avalanche photodiode, Phototransistors, photoconductive detectors and photoconductive gain, Noise in avalanche photodiode, Solar energy spectrum, photovoltaic device principle, I-V characteristics, temperature effects, Solar cell materials, device and efficiencies.	**1,3,7,8**	**18**
UNIT III - Photonic crystals Basic concept of photonic crystals, Theoretical modelling of photonic crystals, One dimensional photonicmaterials, Bloch modes- dispersion relation, Photonic band gap- methods of fabrication, Photonic crystal optical circuitary, Non-linear photonic crystals and optical communications, Photonic crystal sensors.	**1,4,7,8**	**18**
UNIT IV- Nano Photonics Photons and electron similarities and differences, Confinement of photons and electrons, Propagation through classically forbidden zone- tunnelling, Nano scale optical interactions, Quantum confinement effect, Nano crystals and quantum confined materials, Quantum confined structures and lasing media, Supper lattice- Optical properties, Metallic nano particle and nanorods, Applications of metallic nano structures.	**1,5,7,8**	**18**

REFERENCES &SUGGESTED READINGS

Text Books

1. Laser fundamentals :- T. Silfast, CUP 2nd Edition
2. Optoelectronics and Photonics- Principle and Practice:-S O Kasap, Pearson 2009
3. Nano Photonics:- P N Prasad, Wiley Interscience 2003
4. Semiconductor Optoelectronic devices:- Pallab Bhattacharya, Pearson 2008
5. Optoelectronic: An introduction to material and devices:-Jasprit Singh, Mc Graw Hills International Edn 1996
6. Fundamentals of Photonics:- Teich and Saleich

Suggested Reading

1. Handbook of Nonlinear Optics:- R L Sutherland, Marcel Dekker Inc, NY
2. Non linear optics:- Y R Shen, John Wiley
3. Principles of Lasers:- O Scelto, Plenum Press
4. Laser Spectroscopy:- W Demtroder, Springer Verlag

Teachnical and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, E-learning, interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student.
Assessment Types	**Mode of Assessment** 5. Continuous Internal Assessment (CIA) 6. Internal Test – One MCQ based and on extended answer type 7. Book review – every student to review reference books. 8. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar **Semester End examination**

Course Name	**Nanophotonics**
Type of Course	Elective
Course Code	PHM21E04
Course Summary & Justification	Nanophotonics investigates the behaviour of light on nanometer scale as well as the interactions of nanometer-sized objects with light. The field is considered as a branch of nanotechnology, photonics, electrical engineering, optics and optical engineering. Nanophotonics is a very active field of research. The understanding of fundamental phenomena and the progress in technologies have already been made possible numerous applications but a large number of new applications will certainly come in the near future. The 21st century will be the century of nanophotonics. A significant multidisciplinary challenge lies ahead for the broader nanophotonics visions to become reality. These challenges require a significant increase in the number of knowledgeable researchers and trained personnel in this field. This need can be met by providing training for the future generation of researchers at graduate level.
Semester	

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about Electromagnetic waves, Ray and Wave Optics, Photonics and Nanotechnology.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Make a better understanding of the basics of electrodynamics and photonics	*U*	1
2	Distinguish/analyse the types of nanomaterials	*An*	1,2
3	Understand light – matter interaction at nanoscale	*U*	1, 2
4	Understand the working of optoelectronic devices	*U*	1, 2
5	Develop, at least conceptually, a new Nanophotonic device	*C*	2,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	**CO**	**Hours**
Unit I Fundamentals of photonics and photonic devices, Lasers, LEDs, Optical Modulators, Optical fibers and fiber optic components, Frequency conversion, Introduction to nanophotonics, Propagation and confinement of photons and electrons, Tunneling, Electronic energy transfer and emission.	**1,2,5**	**18**
Unit II Near field optics and near field scanning optical microscopy, Fundamentals of near field microscopy, Aperture and apertureless technique, Near-field Probes, Single Molecule Spectroscopy, Time resolved studies.	**1,3,5**	**18**
Unit III Introduction to plasmonics, Metallic nanoparticles and nanorods, Metallic nano shells, Local field enhancement, Sub wavelength aperture plasmonics, Plasmonic waveguiding, Radiative decay engineering.	**1,4,5**	**18**
Unit IV	**1,4,5**	**18**

Content for Classroom Transaction (Sub-units) Introduction to photonic crystals, Modelling of photonic crystals, Photonic crystal optical circuitry, Non-linear photonic crystals, Photonic crystal fibers, Applications in communication and sensing.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

4. Nanophotonics, Paras N Prasad
5. Nanophotonics with surface plasmons, Vladimir m Shalaev, StoshiKawata
6. Principles of nanophotonics, MotoichiOhtsu, Kiyoshi Kobayashi, MakatoNaruse

SUGGESTED READINGS

9. Photonic devices, Jia Ming Liu
10. Integrated photonics: Fundamentals
11. Photonic crystals, Kurt Busch, Stefan lolkes

Course Name	**X-ray Crystallography**
Type of Course	Elective
Course Code	PHM21E05
Course Summary & Justification	**Course Objectives** Invention of X-ray and the development of crystallography have opened up various disciplines in science including solid state physics. Crystallography is an unambiguous technique for the structure determination of molecules and identifying intermolecular interactions.

	The main objective of this course is to understand the basic concepts of x-ray diffraction from matter and its applications in molecular structure determination and identification of molecular assemblies. The properties of molecules are closely related to their structure. Topics dealing in this course have numerous applications in industry, material science, molecular biology and medicine.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about concept of atoms, molecules, energy levels, electron distribution, quantum mechanics.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Knowledge of crystal growth of various types of molecules. (Module 1)	***U***	1
2	Basic theory of diffraction from crystals, powder and glassy materials (Module 2)	***An***	1,2
3	Explain the data collection strategies, data analysis and structure determination (Module 3)	***C***	2
4	Accuracy of structure determination and calculation of molecular geometry and intermolecular interactions. (Module 4)	***C***	2
5	Develop skills for the structural characterisation and molecular assembly in crystals, powder and amorphous samples.	***C***	2,3
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT

Content	CO	Hours
Unit I- Crystallization methods and processes Crystal nucleation and growth, Types of crystallization: Slow Cooling from solution and the melt, Slow Evaporation, Vapour diffusion methods, Liquid-liquid diffusion, Gel growth method, Macromolecular crystallization methods, Factors affecting crystal nucleation and growth, Solvents used in crystallization and its solubility factors.		**18**
Unit II-X-ray Diffraction theory Concept of lattice and reciprocal lattice, Bragg's law in reciprocal space,Point groups and space groups, Diffraction of X-rays from an electron, an atom, 1D lattice and a crystal, Atomic scattering factor and structure factor, Intensity of scattering from an hkl plane and various factors affecting the intensity, Elementary ideas about neutron and electron diffraction.		**18**
Unit III -Structure Determination methods X-ray data collection strategies,Determination of symmetry and space group from diffraction data, Fourier transform and calculation of electron density, Phase Problem in crystallography, Structure determination from X-ray data: Direct method, Intrinsic phasing method,Heavy atom method,Molecular replacement methods,anomalous scattering and absolute structure determination.		**18**
Unit IV-Accuracy and structure refinement The determination of unit cell parameters,Structure refinement strategies, Least-squares refinement based on F and F2, isotropic and anisotropic refinement strategies, Disorder: substitutional and positional disorder, refinement of disorder, Twinning: merohedral, pseudo- merohedral and nonmerohedral twinning, twin law and component identification and refinements, Calculation of geometrical parameters and estimated standard deviation, Error estimation in the data and the final structure validation.		**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Class quiz Assignments End Semester Examination

REFERENCES

7. An introduction to X-ray crystallography, M. M. Woolfson. Cambridge Univ. press
8. Elements of X-ray crystallography, L. A. Azaroff. McGraw Hill
9. X-ray Structure Determination, Stout & Jensen. Wiley
10. Protein Crystallography, Blundel& Johnson. Academic Press
11. Crystal Structure Refinement A Crystallographer's guide to SHELXL, P. Muller, R. Herbst-Irmer, A. L Spek, T. R. Schneider, M. R. Sawaya. 6. SHELX Manual, G. M. Sheldrick.

SUGGESTED READINGS

1. X-ray crystallography G. S. Girolami University Science Books
2. X-ray Crystallography William Clegg Oxford University Press
3. Introduction to Crystallography Dover publications Inc.

Course Name	Physics of Nanomaterials
Type of Course	Elective
Course Code	PHM21E06
Course Summary & Justification	The emerging fields of nanoscale science, engineering and technology are fundamentally based on the ability to develop new materials at the atomic and molecular level and to employ them to achieve novel properties for next generation devices and systems. ***On December 29th 1959, the famous Nobel Laureate Richard P Feynman said in his famous speech "There is plenty of room at the bottom":"In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this (nanometer) direction"***. In the years after people did want to move in this direction but not much progress was made until 1980's when the Scanning Tunneling Microscope (STM) was invented because there were not many analytical tools were developed (and still being developed), which enable the characterization and manipulation of small objects down to few nanometer bringing human being's view into real atomic world. The word '*nano*' has attracted enormous attention, interest and investigation in recent years. What it presents in terms of Science & technology, which are also called Nanoscience & Nanotechnology, is much, much more than just a word describing a specific length scale. Nanometer is a special point in overall length scale because nanometer scale is the junction where the smallest manufacturable objects 'meet' the largest molecules in nature. At this size scale, everything, regardless

	of what it is, has new exotic properties and these make "**Nano**" so fascinating! The breadth and vastness of the exploding field of nanotechnology makes it essential to limit the content covered in a one semester course offering. The course on "**PHYSICS OF NANOMATERIALS**" is designed to introduce students to the fundamental changes in various physical properties which occur when particle sizes approach atomic and molecular dimensions. A major goal is to provide students with a design tool based on nanotechnology that will allow them to engineer next generation materials and devices and appreciate the different properties offered by nanostructured materials. This course focuses on **Nanomaterials synthesis, characterization and various applications.** The basic physics and fundamental mechanisms responsible for nanoscale-induced changes in properties will be stressed. Representative advances in each of the targeted topical areas will be discussed and examined to provide students with some insight with regard to the potential future impact of nanotechnology on materials science and engineering.
Semester	

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Solid Sate Physics, Basic Quantum Mechanics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understanding the concepts of Nanoscience and Nanotechnology	***U, C***	1,2
2	Different approaches of nanomaterials syntheses such as chemical, physical, engineering, biological and hybrid methods	***An***	1,2
3	Quantum concepts of nanomaterials and envisaged applications	***U, C***	1,2,3

4	Detailed understanding of different characterization methods	***U, C***	1,2,3
5	Potential applications of nanomaterials in diversified fields	***U, C***	2,3
6	Social, ethical, legal and environmental (SELE) issues of Nanoscience and nanotechnology	***U, A, An, Ap***	4,5,6,7
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT

Content	CO	Hours
Unit I Introduction Overview: When does size matter? Trend of miniaturization and Moore's law, Scales of various systems, Characterization methods-Direct and Indirect methods.	**1**	**10**
Unit II Synthesis, preparation and fabrication Preparation of Nanomaterials: Bottom-up approach, Top-down approach. Chemical approaches: Self assembly, Sol-gel synthesis. Physical approaches: Molecular beam epitaxy, Atomic layer deposition, Laser Plasma Ablation. Engineering approaches: Lithography-Photolithography, Electron beam lithography, X-ray lithography, Focused ion beam (FIB) lithography, Soft lithography-Micro contact printing, Molding, Nanoimprint, Dip-pen nanolithography. Biological approaches.	**2**	**15**
Unit III Properties and characterization of nanomaterials Physical properties of nanomaterials: Melting points and lattice constants, Mechanical properties, Optical properties-Surface Plasmon Resonance, Quantum size effects. Electrical conductivity-Surface scattering, Charge of electronic structure, Quantum transport, Effect of microstructure, Structural characterizations: X-ray diffraction, Scanning Electron Microscopy, Transmission Electron Microscopy, Scanning Probe Microscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy, Chemical characterizations: FTIR Spectroscopy, Electron Spectroscopy, Ionic Spectroscopy, Functional characterization:-Optical properties, Magnetic properties, Electrical properties.	**3,4**	**20**
Unit IV Applications of nanomaterials Molecular Electronics and Nanoelectronics, Biological applications of nanomaterials, Band gap engineered quantum devices, Nanomechanics, Photonic crystals and Plasmon waveguides, Carbon nanostructures-Carbon nanotubes-Graphene.	**5**	**15**
Unit V Social and ethical issues of nanoscience and nanotechnology and research article presentation	**6**	**12**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual students
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES & SUGGESTED READING

The course lectures will be mostly based on research articles and information available from various web sites related to Nanoscience & Nanotechnology. However, the following books might be useful for the preparation the course.

1. ***Nanoparticle Technology Handbook-Edited by Masuo Hosokawa et al, Elsevier Publications***
2. ***Nano: The Essentials by T. Pradeep, Tata MacGraw-Hill Publishing Company Limited***
3. ***Nanophotonics by Paras N Prasad, Wiley Interscience***
4. ***Nanostructures & Nanomaterials-Synthesis, Properties and Applications-Guozhong Cao, Imperial college Press***
5. ***Characterization of Nanophase Materials- Zong Lin Wang, Wiley VCH***
6. ***Hand Book of Nanotechnology- Bhushan, Springer (Electronic Copy available)***
7. ***Introduction to Solid State Physics- Charles Kittel, Wiley 7th Edition***
8. ***Solid State Physics by Gerald Burns, Academic Press Inc.***

Course Name	NANOSCIENCE AND NANOSTRUCTURED MATERIALS
Type of Course	Elective
Course Code	PHM21E07
Course Summary & Justification	The course designed to introduce students to NANOSCIENCE AND NANOSTRUCTURED MATERIALS, which include the understanding Nanoscience and nano structured materials and its novel properties application in the modern technological world. This course deals with the fundamental understanding of Nano structured materials,

	and its various methods of synthesis, characterisation and properties. The study of Nano Materials gives the students an opportunity of better understanding of vast field of nanoscience and nano materials based technologies.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic understanding of Quantum Mechanics, Solid state Physics and Spectroscopy with fair mathematical knowledge (Graduate level)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Students will understand the disciple-specific knowledge in Material sciences especially nanomaterials. Basic understanding of Quantum Mechanics, Solid state physics and spectroscopy	U	1,7
2	Analyse various novel properties of materials in the nano regime. Students will understand the basic skill to be achieved for making the nano structured materials and its importance in the fabrication of sophisticated devices for technological applications	A	1,2,7
3	Students will know the concepts of various synthesis methods, chemical and physical methods. Also able to understand technology needed materials and their synthesis	Ap	1,2,5,7
4	The theoretical understanding of various sophisticated characterisation techniques and their use in designing material based devices.	E	1,2,7
5	Explain the use of nano devices for various societal needs	U	1,2,7
6	Application in various field of activity in science engineering and agriculture etc.	U	1,2,7
7	They will use critical thinking skills using their knowledge to design new devices	S	1,7

8	Employ conceptual understanding to make new materials of technological importance, and then approach different methods and understand the important skills needed for this synthesis and characterization.	E	1,2,3,6,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit 1- Introduction to Materials in the Nanoscale Materials in the Nanoscale, Size effect of nano system, Dependence of properties on size, Moore's law, Scale of various systems, Quantum structure: 2D(Quantum well), 1D(quantum wire), 0D(Quantum dot), Quantum behavior of nanomaterials, Molecular physics :Molecular bond, covalent bond, Molecular Spectra:- Rotational, Vibrational, & Electronic, Raman spectra.	**1**	**18**
Unit II- Synthesis, Preparation,& Fabrication of Nanomaterials Top down and Bottom up approach of synthesis with examples, Chemical approaches: Self Assembly, Sol-Gel method ,Hydrothermal method, Chemical reduction, electro and electroless deposition, Chemical bath deposition, Examples, Physical Approaches: Molecular beam epitaxy, Pulse laser deposition, Engineering Approaches and other methods, Lithography, photolithography, Electron beam lithography, X-ray lithography, Ball milling, sputtering , examples.	**2,3**	**20**
Unit III- Properties and characterization of Nanomaterials. Mechanical Properties: Theoretical aspects, strength of nanomaterials and measurements, Optical properties:-Refractive index and dispersion, Non linear refractive index, Absorption coefficient and other special optical properties, Surface plasmon resonance, Magnetic properties, Magnetic anisotropy, Spin glass, Spintronics, Electrical properties, Characterization of nanomaterials: X-ray diffraction, Scanning electron microscopy, Transmission electron microscopy, Scanning tunnelling microscopy, Atomic forced microscopy, FTIR spectroscopy.	**4,6**	**18**
Unit IV-Nano structured materials and applications Carbon Nanotubes, Semiconductor quantum dots, Core-shell nanoparticles, Nanoshells, Nano ceramics, Nano polymers, Photonic crystals, Nano electronics, Nano medicines, Nano sensors, Molecular Nanomachines, Biological applications.	**5,7,8**	**16**

Teachical and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, E-learning, interactive section, Instruction:, Active co-operative learning, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student.
Assessment Types	**Mode of Assessment** 9. Continuous Internal Assessment (CIA) 10. Internal Test – One MCQ based and on extended answer type 11. Book review – every students to review reference books. 12. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar **Semester End examination**

REFERENCES &SUGGESTED READINGS

Text Books

1. Nano: The Essentials- Understanding Nano Science and Nanotechnology:-
(McGraw-Hill Education) :- T. Pradeep
2. Nano Materials: (New Age):- :- A K Bandhopadhyaya
3. Introductory Nanoscience: (Garland Science Publication) :- Masaru Kuno
4. Introduction to Nanoscience and Nanotechnology: (PHI Learning Pvt. Ltd) :-
:- K K Chattopadhyay and A N Banerjee
5. Encyclopaedia of Nanoscience and Nanotechnology :- Nalwa H S 2004

Reference books and Suggested Reading

1. Nanostructure & Nanomaterials, synthesis, properties and application:-
(Imperial College Press 2004) :-Guozhong Cao
2. Nanoscale materials :- Liz Marzen and Kamat
3. Carbon Nanotubes:Properties and Applications:- Michael J O Coneell
4. Principle of Lithography :- Harry J. Levinso
5. Nanotubes and Nanowires :- CNR Rao and A Govindraj
6. Nanomaterials, nanotechnilogies and design : M F Ashby

Course Name	**Physics of semiconductor materials**
Type of Course	Elective
Course Code	PHM21E08
Course Summary & Justification	The course mainly comprises the physics behind the behaviour/properties of semiconductor materials under equilibrium and nonequilibrium conditions. Methods for growing semiconductor crystals have also been discussed. Semiconductors have the unique ability to act either as insulators or as conductors, at different ambiences. This unique feature makes semiconductors pivotal in modern industries / technologies. Without semiconductors, transistors, integrated circuits,

	solar cells, and many other electronic/optoelectronic devices would not have existed. Semiconducting materials range in availability and price from abundant silicon to expensive rare earth elements. Silicon is the most widely used semiconductor material till date. New materials are being invented and the future of semiconductor industry looks bright. To understand the changing nature of semiconductor materials and industry and to manufacture them for various applications, it's necessary to understand the physics of existing semiconductor materials. This course of 'Physics of semiconductor materials' equips students with the necessary knowledge of semiconductors and help them to design and develop new materials and then devices.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about energy bands in crystals, types of solids, concept of electrons, holes and photons.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Make a better understanding of the basics of semiconductor materials	U	1
2	Analyse the different carrier transport mechanisms and effects in semiconductors	An	1,2
3	Analyse the behaviour of semiconductor materials in equilibrium and nonequilibrium conditions	An	1,2
4	Understand the various methods of semiconductor material growth	U	1
5	Develop, at least conceptually, new semiconductor materials with various electrical and optical properties	C	2,3,4,6,7
**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*			

COURSE CONTENT

Content	CO	Hours
Unit I- Semiconductors in equilibrium Energy bands, Charge carriers in semiconductors, Direct and indirect semiconductors, Effective mass of charge carriers, Intrinsic and extrinsic semiconductors, energy bands of n-type and p-type semiconductors, Elemental and compound semiconductors, Amphoteric dopants, Variation of energy bands with alloy composition, Carrier concentration at thermal equilibrium, Density of states, Fermi level Effective density of states, n0p0 equations, Temperature dependence of carrier concentration, Compensation and space charge neutrality.	**1,5**	**18**
Unit II- Carrier transport phenomena Drift of carriers in electric and magnetic fields, Carrier mobility, Mean free time of carriers, Current density, Conductivity and Resistivity of semiconductors, Conductivity effective mass, Ohmic contacts, Effects of temperature and doping on mobility of charge carriers - lattice scattering and impurity scattering, High field effects - hot carrier effect, scattering limited velocity, Hall effect, Heterogeneous systems, Invariance of Fermi level in a heterogeneous system at equilibrium.	**2,5**	**18**
Unit III-Nonequilibrium excess carriers in semiconductors Excess carrier generation via optical absorption, Absorption coefficient, Excess carrier recombination via luminescence, Photoluminescence – fluorescence and phosphorescence, Electroluminescence, and indirect recombination, Recombination lifetime, Minority carrier lifetime, Trapping centers, Photoconductivity, Photoconductive decay, Steady state carrier generation, Quasi Fermi levels, Photoconductive devices, Diffusion of carriers, Diffusion coefficients, Diffusion, and Drift of carriers, Built-in-fields, Energy band diagram of a semiconductor in an electric field, Einstein relation, Diffusion and recombination, Continuity equation, Diffusion equation, Steady state carrier injection, Diffusion length, Gradients in the Quasi Fermi levels, Modified Ohm's law.	**3,5**	**20**
Unit IV- Semiconductor crystal growth methods Bulk growth of device grade semiconductor crystals, Metallurgical grade silicon, Semiconductor grade silicon, Growth of single crystal ingots, Czochralski method, Liquid encapsulated Czochralski method, Wafer manufacturing, Distribution coefficient in doping, Epitaxial growth, Lattice matching in epitaxial growth, Vapor phase epitaxy, Molecular beam epitaxy.	**4,5**	**16**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student

Assessment Types	Mode of Assessment
	Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Solid state electronic devices by Ben G. Streetman & Sanjay Banerjee
2. Physics of semiconductor devices by S.M.Sze& Kwok K.Ng
3. Semiconductor Physics and devices by Donald A Neamen&Dhrubes Biswas
4. Semiconductor materials & devices by D.N. Bose
5. Optoelectronics: An introduction to materials and devices by Jasprit Singh
6. Introduction to solid state physics by Charles Kittel
7. Solid state physics: Structure and properties of materials by M. A. Wahab
8. Solid state physics by S.O. Pillai
9. Optoelectronics and Photonics: Principles and practices by S.O Kasap
10. Semiconductor optoelectronic devices by Pallab Bhattacharya

Course Name	Physics and applications of semiconductor devices
Type of Course	**Elective**
Course Code	PHM21E09
Course Summary & Justification	Modern world quite literally owes its existence to semiconductors. We never use semiconductors as such in our daily lives; then how semiconductors are so important? The fact is that most of the facilities/ appliances we use in this modern era are semiconductor based. Throughout the years scientists have made great strides in progressing semiconductor innovations. They accomplish great achievements by experimenting variations in semiconductor materials and device structures. The process of semiconductor device manufacturing consists of a large number of precise and expert steps. Semiconductor industry is world's largest industry and experts predict that the industry will continue to achieve the highest revenue in future too. A lot many career opportunities exist in this field. This course of 'Physics and applications of semiconductor devices' starts with the theory of p-n junction which forms the fundamental unit of any semiconductor device. Working of p-n junctions under steady and transient conditions are explained. A unit is dedicated to explain the fabrication techniques of p-n junctions. Finally, the students get introduced to optoelectronic applications of

	semiconductors. On completing this course students will acquire the knowledge and skills to design, develop and operate different kinds of semiconductor-based electronics systems.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about solids, semiconductors, charge carriers, electrons, holes and photons.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Make a better understanding of the basics of p-n junctions	U	1
2	Analyse the behaviour of p-n junctions under steady state and transient conditions	An	1,2
3	Understand the various fabrication techniques of p-n junctions	U	1
4	Understand the working of semiconductor based optoelectronic devices	U	1
5	Design and develop any electronic or optoelectronic device based on p-n junctions	A, C, S	2,3,4,6,7
**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*			

COURSE CONTENT

Content	CO	Hours
Unit I- Steady state p-n junctions Step and graded p-n junctions, Contact potential, Diffusion and drift, Properties of an equilibrium p-n junction, Equilibrium Fermi levels, Depletion approximation, Space charge and electric field distribution within the transition region, Doping concentration and width of deletion region, P-N junction under forward bias, Effects of bias on transition region width, electric field, electrostatic potential, energy band diagram, particle flow and current directions, ideal diode approximation, Diode equation, Charge control approximation, P-N junction under reverse bias, Reverse bias breakdown.	**1,5**	**18**

Unit II- p -n junction under transient conditions and heterojunctions Switching of a p-n junction diode from forward state to reverse state, Time variation of stored charge, Quasi steady state approximation ,Narrow base diode, Reverse recovery transient, Storage delay , Effects of storage delay time on switching signal, Improving the diode switching time, Capacitance of p-n junctions, Junction capacitance, Charge storage capacitance, Voltage variable capacitance, Varactor, AC conductance, Heterojunctions, Band diagram of heterojunctions.	**2,5**	**18**
Unit III- Fabrication of p-n junctions Growth of single crystal substrates and epitaxial layers, Thermal oxidation, Dry and wet oxidation processes, Oxide thickness as a function of time and temperature, Diffusion, Thermal budget, Impurity concentration profile, Complementary error function, Rapid thermal processing, Time-temperature profile, Ion implantation, Projected range, Distributions of implanted impurities, Annealing, Chemical vapor deposition, Photolithography, Reticle, Mask, Photoresist, Positive and negative resists, Stepper, Diffraction limited minimum geometry, Depth-of focus, Chemical mechanical polishing, Electron projection lithography, Etching, Wet etching, Dry and plasma-based etching, Reactive ion etching, Metallization.	**3,5**	**18**
Unit IV- Optoelectronic device applications P-N junction photodiodes, Optical generation of carriers in a p-n junction, Current and voltage in an illuminated junction, Photovoltaic effect, I-V characteristics, Solar cells, Short circuit current, Open circuit voltage, Fill factor, Photodetectors, Depletion layer photodiode, p-i-n photodetector, Avalanche photodiodes, Intrinsic and extrinsic detectors, Gain, bandwidth and signal to noise ratio of photodetectors, Light emitting diodes, Injection electroluminescence, Internal radiative efficiency, Extraction efficiency, External quantum efficiency, Fiber optic communication, Step Index and Graded Index Fibers, Single mode and multimode fibers, Losses in fibers, Semiconductor Lasers, Population inversion at a junction, Emission spectra for p-n junction lasers, Homojunction and heterojunction lasers, Semiconductor materials used for optoelectronic device fabrication.	**4,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Solid state electronic devices by Ben G. Streetman & Sanjay Banerjee
2. Physics of semiconductor devices by S.M.Sze& Kwok K.Ng
3. Semiconductor Physics and devices by Donald A Neamen&Dhrubes Biswas
4. Semiconductor materials & devices by D.N. Bose
5. Optoelectronics: An introduction to materials and devices by Jasprit Singh
6. Introduction to solid state physics by Charles Kittel
7. Solid state physics: Structure and properties of materials by M. A. Wahab
8. Solid state physics by S.O. Pillai
9. Optoelectronics and Photonics: Principles and practices by S.O Kasap
10. Semiconductor optoelectronic devices by Pallab Bhattacharya

Course Name	X-ray Characterization Methods					
Type of Course	Elective					
Course Code	PHM21E10					
Course Summary & Justification	**Course Objectives** Invention of X-ray and the development of theoretical and experimental methods over a period of more than a century have opened up various characterization methods which nowadays are extensively used for characterization of materials in science and technology. The main objective of this course is to understand the basic concepts of x-ray diffraction from matter and its applications in characterization of crystalline, powder and amorphous materials. Topics dealing in this course have numerous applications in industry, material science, molecular biology and medicine.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about concept of atoms, molecules, solids energy levels,basic mathematics, quantum mechanics.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Knowledge of crystal structure, symmetry and arrangement of molecules in crystals. (Module 1)	***U***	1
2	Basic theory of x-ray diffraction from crystals, powder and glassy materials (Module 2)	***An***	1,4
3	Explain the data collection strategies, data analysis, structure determination and validation (Module 3)	***C***	2
4	Structural studies on powder, amorphous and glassy materials (Module 4)	***An***	2
5	Develop skills for the structural characterisation and molecular assembly in crystals, powder and amorphous samples.	***C***	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I: Structure and Symmetry in Solids Introduction to bonding in solids, Basic ideas about crystalline and amorphous materials, crystal packing: HCP and CCP, Interstitial sites, coordination number and Packing fraction, NaCl, CsCl, ZnS, Fluorite, Wurtzite structure, Diamond structure, Cristobalite, Perovskite structure, Corundum Structure, Rutile structure, Spinel Structure, Graphite, Silicate structures, Fullerenes, symmetry in crystals, super symmetry and super lattices.	**1,5**	**18**
Unit II-Diffraction theory Real lattice and the concept of reciprocal lattice and Bragg's law, Point groups and space groups, Geometry of diffraction, diffraction of X-rays from an electron, an atom, 1D lattice and a crystal, Atomic scattering factor and structure factor, Intensity of scattering from an hkl plane and various factors affecting the intensity, Elementary ideas about neutron and electron diffraction.	**2,5**	**18**
Unit III Structure Determination methods	**3,5**	**18**

Determination of symmetry and space group from diffraction data, Fourier transform and calculation of electron density, Phase Problem in crystallography, Elementary ideas about Structure determination from X-ray data, Heavy atom method, Equal atom method and Molecular replacement methods of structure solution, Extraction of molecular geometry and intermolecular interactions.		
Unit IV-Powder and Amorphous Materials Powder diffraction, Data collection strategies, Rietveld refinement, Direct methods in powder diffraction, Ceramics and Glasses, Structural studies of glasses: RDF analysis, EXAFS analysis , Small angle scattering, wide angle scattering.	**4,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Class quiz Assignments End Semester Examination

REFERENCES

1. An introduction to X-ray crystallography, M. M. Woolfson, Cambridge Univ. Press
2. Elements of X-ray crystallography, L. A. Azaroff. McGraw Hill
3. X-ray Structure Determination, Stout & Jensen. Wiley
4. Crystal Structure Refinement A Crystallographer’s guide to SHELXL, P. Muller, R. Herbst- Irmer, A. L Spek, T. R. Schneider, M. R. Sawaya. 6. SHELX Manual, G. M. Sheldrick.
5. Structure Determination from Powder Diffraction Data Ed By W.I.F. David ,K.Shankland, L.B. McCusker and Ch. Baerlocher
6. Science of Engineering materials, Srivastava and Srinivasan
7. The Science and Engineering of materials, Askeland.
8. Characterization of Nano-phase materials edited by Zhong Lin Wang
9. Basic Solid State Chemistry, A.R. West

SUGGESTED READINGS

1. X-ray crystallography G. S. Girolami University Science Books
2. Protein Crystallography, Blundel& Johnson. Academic Press
3. Science of Engineering Materials, Srivasthava and Srinivasan
4. X-ray Crystallography William Clegg Oxford University Press

Course Name	Fundamentals of Plasma Physics					
Course Code	PHM21E11					
Course Summary & Justification	Plasmas are so much a part of our daily lives. The field of Plasma physics is very diverse with lot many applications and a lot many career opportunities. This course of 'Plasma Physics' equips students with the necessary knowledge understand various processes in nature and design the fusion-based devices. The course comprises the theory and applications of plasma physics. Students are introduced to the systems of plasma and understand the natural and laboratory plasma and its application to both the Astrophysical and industrial devices.					
Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge in electrodynamics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Make a better understanding of the basics of plasma physics	U	2
2	Understanding plasma as describing as Fluid will enhance the knowledge of fluid systems both in the Astrophysical and Laboratory plasmas	An	3
3	Studying the plasma with Kinetic theory would enhance the theoretical aspects of particle dynamics and its effects on various systems	C	3
4	Understanding various types waves in nature and the energy transfer mechanism in the various plasmas	C	6
5	The subject's completion would enhance the analytical power of the students to understand plasma systems and give the ability to formulate and solve the problems in both Astrophysical and Laboratory plasmas	C	4
**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*			

COURSE CONTENT

Content	CO	Hours
Unit I-Basics of plasma Occurrence of plasma in nature, Concept of Plasma State: Ionized gas, Saha's ionization equation; Collective degrees of freedom, Definition of Plasma, Concept of Plasma temperature, Debye shielding, Quasi-neutrality, Plasma parameters, Validity of Plasma approximation, Single Particle Motions: Motion of charged particles in uniform E and B fields, non-uniform B field, non-uniform E field, time-varying E field, time varying B field, curvature drifts, adiabatic invariants	**1,5**	**18**
Unit II-Plasma as Fluids Derivation of Fluid Equations, Magneto-Hydrodynamic (MHD) Equations, Hydromagnetic Equilibria, Magnetic Pressure, Magnetic Field Convection and Diffusion, Magnetic Reconnection, MHD Shocks and Discontinuities, Two Fluid Equations, fluid drifts perpendicular to B, fluid drift parallel to B, DC conductivity, AC conductivity, RF conductivity	**2,5**	**18**
Unit III-Kinetic theory of Plasma The Distribution Function,Differential Flux, Velocity Distribution Functions, Vlasov Equation, Fokker-Planck Equation, Plasma Transport, Landau Damping, Collisions, Basic Binary Collisions, Long-Range Character of Collisions, Friction, Energy Scattering, Pitch-Angle scattering	**3,5**	**18**
Unit IV-Wave Particle Interaction Introduction to waves, Plasma oscillations, electron plasma waves, Alfven Waves, Ion Acoustic Waves, Lower and Upper hybrid hybrid frequency, Resonances, Magneto-hydromagnetic waves, Magneto sonic waves, Concept of instability, Basic Mathematical techniques for studying instability, Fundamental instabilities: Two-stream instability, Gravitational instability, Ballooning, Instability, Kelvin- Kelmhotz instability, Landau Damping and Cyclotron Resonance, Synchrotron emission and Cerenkov radiation	**4,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Chen, F. F., Introduction to Plasma Physics and Controlled Fusion, 2nd ed. (Plenum, New York, 1984).

2. Bittencourt, J. A., Fundamentals of Plasma Physics, 3rd ed. (Springer, New York, 2004).

3. Bellan, P. M., Fundamentals of Plasma Physics (Cambridge, UK, 2006).

4. Pecseli, H. L., Waves and Oscillations in Plasmas (CRC Press, New York, 2013).

5. Swanson, D. G., Plasma Waves (IoP, Bristol, 2003).

6. Kono, M. and Skoric, M. M., Nonlinear Physics of Plasmas (Springer, Berlin, 2010).

7. Hasegawa, A., Plasma Instabilities and Nonlinear Effects (Springer, Berlin, 1975).

8. Davidson, R. C., Methods in Nonlinear Plasma Theory (Academic Press, New York, 1972).

9. Spitzer, L., Physics of Fully Ionized Gases (John Wiley & Sons, New York)

10. Nicholson, D.R., Introduction to Plasma Theory (Wiley, USA, 1983).

12. Shukla, P. K. and Mamun, A. A., Introduction to Dusty Plasma Physics (IoP, Philadelphia, 2001)

13. Vinod, K., Astrophysical Plasmas and Fluids (Springer, New Delhi, 199

Course Name	**Advanced Solid State Physics**					
Type of Course	Elective					
Course Code	PHM21E12					
Course Summary & Justification	*This course is an extension of the topics included in the basic course on solid state physics. The first part of the course is on band theory of solids followed by detailed aspects of semiconductor physics. The remaining parts of the course focus on low dimensional quantum structures and quasi particles in condensed state.* The purpose of this course is to provide a framework for post-graduate students to understand some of the important aspects of the physics of condensed matter at an advanced level employing *quantum mechanical approaches.*					
Semester						
Total Student LearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105

Pre-requisite	Basic knowledge on solid state physics

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Familiarize with the description of energy bands in solids through various approaches	***U***	1
2	Formulate the theory of band structure	***An***	1,2
3	Analyze the transport characteristics of semiconductor materials	***U***	1
4	Understand the quantum mechanical considerations of nanostructures	***E***	2
5	Familiarize the origin of quasi particles as excitations in interacting systems	***C***	2,3
6	Altering the properties of solids to make them suitable for particular applications	***C***	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I- Band Structure of Solids Bloch function, Kronig-Penney model for an electron in a periodic potential,E-k relationship in various representations, Energy band calculations, Nearly free electron approximation, Tight binding approximation,Wigner-Seitz cellular method, Augmented plane wave method,Orthogonalized plane wave method, Pseudopotential method.	**1,2,6**	**18**
Unit II-Semiconductor Physics Density of states, Effective density of states, mass action law, Doping: intrinsic vs. extrinsic semiconductors, Charge neutrality,Fermi energy as a function of temperature, Carrier concentration in semiconductor, Electrical conductivity, Hall effect, Charge carrier diffusion- Diffusion currents, Einstein Relations, Diffusion lengths, Quasi-Fermi energy, Carrier generation and recombination mechanism- direct band to band recombination.	**1,3,6**	**18**
Unit III-Low Dimensional Quantum Structures Two-dimensional Quantum structures, Quantum Wells- Energy spectrum, density of states, Influence of effective mass, One- dimensional structures- Quantum wires, density of states, Infinitelydeep rectangular wire, Zero dimensional structures-	**4,6**	**18**

quantum dotes, density of states, Infinite spherical quantum dot,Optical properties of two dimensional and three dimensional structures, Examples of low dimensional structures.		
Unit IV-Quasi Particles in Materials Science Phonons, Oscillations within a one-dimensional diatomic chain of atoms, Vibrations of a three-dimensional crystal, Polarons- dielectric polarons, Molecular polarons, Holstein's model,Bipolarons, Excitons, Wannier and charge transfer excitons, Frenkel excitons, Plasmons, Dielectric response of an electronic gas, Spin waves, Magnons.	**5,6**	**18**

References

1. Introduction to Solid State Theory- Otfried Madelung
2. Quantum Theory Of Solids- Eoin O'Reilly
3. Solid State Physics- James D Patterson and Bernard C Bailey
4. Fundamentals of Solid State Engineering - ManijehRazeghi
5. Solid State Physics for Electronics - André Moliton

Course Name	**Applied Optics**					
Type of Course	Elective					
Course Code	PHM21E13					
Course Summary & Justification	Applied optics course syllabus is constructed to orient the interested students towards a career in experimental optics and associated technologies for the next generation systems based on the modern optical tools available today. The syllabus covers basic review of optics, important optical systems, charged particle optics, materials, sources and modern laser systems available currently along with their applications. Further, applied optics covers the framework of the advanced optical systems and their importance for the implementation of new-generation table-top optical setups.					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	10	8	15	105
Pre-requisite	Graduate level Mathematics (Calculus, Vectors) and Optics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Use calculus and vectors in Physical situations where electromagnetic fields are involved	***U***	1,2
2	Manipulation of properties of light upon its propagation via reflection and/or transmission.	***An***	1,2
3	Miniature optical assembly for various applications	***S***	2,3
4	Explain the nature of electromagnetic wave and its propagation through different media and interfaces for simulating different optical detectors and assemblies	***C***	2,6
5	Evaluate the problems/challenges associated with the implementation and commissioning of optical systems	***E, A***	1,5,6
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT

Content	CO	Hours
Unit I-Review of optics Review on ray optics, Wave optics, Interference, Diffraction, Wave vector optics, Ray propagation, Ray transfer matrix, Linear/angular magnification, The ABCD matrix, Fresnel and Fraunhofer propagation, Point spread function, Ray tracing and aberrations, Modular transfer function, Impedance in optics, Jones vectors and matrices, Partial polarization, Stokes parameters.	**1,5**	**16**
Unit II- Optical Systems and charged particle optics Gaussian beams, Focusing a laser beam with a thin lens, Fourier optics, Optical components, Flat mirrors, spherical mirrors, Paraboloidal and ellipsoidal mirrors, Dielectric coatings,Beam splitters, pellicles, windows, Lens and lens systems, Camera lens L, Laser beam expanders Spatial filters, Lens aberrations and corrections, Fresnel lens, Prisms, Diffraction gratings, Polarizers, retardation plates, Optical isolators, Optical filters.	**2,5**	**18**

Unit III-Optical Materials and sources Optical materials, Optical sources, Radiometry, Photometry, Spectrometers, Calibration of spectrometer and spectrographs, Fabry-Perot interferometers, Fabry-Perot etalons, Michelson interferometer, Fourier transform spectroscopy, Mach-Zehnder interferometer, Charged particle optics, Electrostatic lens,SIMION simulation examples Dielectrics and conductors.	**3,4,5**	**20**
Unit IV-Lasers Lasers, Continuous and pulsed lasers, Spatial and temporal coherence, Intensity and phase, Instantaneous frequency and group delay, Second order nonlinear processes, Third order nonlinear processes, Multi-order nonlinear processes, Chirped pulse amplification, Self-phase modulation, Pulse characterization techniques, SHG intensity autocorrelation, Single-shot autocorrelation, Interferometric autocorrelation.	**3,4,5**	**16**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Teaching, Seminar, Group Assignments, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

1. Introduction to modern optics, Grant R Fowles, Dover Publications Inc. NewYork.
2. Introduction to Optics, Frank L. Pedrotti, Leno M. Pedrotti, and Leno S Pedrotti, Cambridge University Press.
3. Building Scientific Apparatus, John H. Moore F Christopher C. Davis F Michael A. Coplan, Sandra C. Greer, Cambridge University Press
4. Laser Fundamentals, William T. Silfvast, Cambridge University Press.

SUGGESTED READINGS

1. Ultrafast Optics, Andrew M Weiner, John Wiley and son’s publication.
2. Nonlinear Optics, Second Edition, Robert W Boyd, Academic Press, Elsevier.
3. Light—Matter Interaction: Fundamentals and Applications, John Weiner, P.T. Ho, John Wiley & Sons, Inc.

Course Name	**Nonlinear optics and advanced laser systems**					
Type of Course	Elective					
Course Code	PHM21E14					
Course Summary & Justification	Nonlinear optics and advanced laser systems is one of the specialized electives that the School of Pure and Applied physics offers to students looking forward to build their career in the field involving intense light matter interaction, such as Laser Wake field acceleration, coherent x-ray science and technologies, ultrafast and attosecond sciences etc. The course covers broad range of topics such that the students get benefitted to a career either in the ultrashort laser/optics industry or academia,focussing on research towards developing novel techniques and next-generation light sources.					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	10	8	15	105
Pre-requisite	Applied Optics (Elective course)					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Use nonlinear optics to replicate various phenomena using calculus and employ coding to visualize them.	***U***	1,2,5
2	Manipulation of properties of light upon its propagation thorough nonlinear optical instruments.	***An***	1,2
3	Predict the nature of the pulse by simulation upon its propagation through different dispersive optical components	***S***	2,3
4	Apply mathematical transforms, i.e. Fourier Transform for evaluating transform limited pulses	***C***	2,6
5	Evaluate the problems/challenges associated with the implementation and commissioning of attosecond pulse generation or any other experiments with the similar level of complexity.	***E, A***	1,5,6
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Content	CO	Hours
Unit I-Nonlinear optics Maxwell's equations and polarization, Nonlinear Polarization, Sum and difference frequency generation, Optical rectification, Parametric amplification and oscillation, The Pockels effect, Pockels cells, The Faraday effect, Faraday isolator, Acousto-optic modulator, Dazzler, Kerr effect, Self-phase modulation and Cross-phase modulation, Self-focusing, Super-continuum generation, Four-wave mixing, Raman conversion.	**1,5**	**14**
Unit II- Ultrashort laser pulses Description of pulses, Intensity and phase, Fourier transform, Instantaneous frequency and group delay, Carrier-envelope phase, First-, second-, and higher-order phase, The linearly chirped Gaussian pulse, Pulse propagation in linear medium, Time-Bandwidth product, Generation of ultrashort pulses, Q-switching, Mode-locking, Femtosecond oscillator, Amplification of ultrashort laser pulses, Intensity and average power, Gain saturation: Frantz-Nodvick equation, Multi-pass and regenerative amplifiers, Chirped pulse amplification (CPA), Temporal stretching and compression, Gain narrowing and thermal effects, Carrier Envelope Phase (CEP) stabilized lasers, Hollow-core fiber (HCF) based pulse compressors, Temporal intensity contrast, Contrast, pointing and beam profiling of ultrashort pulses, OPCPA basics.	**2,5**	**20**
Unit III-Ultrashort pulses- Characterization Characterization of ultrashort pulses - General characterization of ultrashort pulses, (Czerny-Turner imaging) spectrometer, Temporal characterization: The dilemma, Intensity and phase, Time domain detector, Michelson interferometer, SHG Intensity autocorrelation, Pulse and autocorrelation, Single-shot autocorrelation, Interferometric autocorrelation, Other autocorrelation techniques (THG, cross correlator, two photon processes), Complete temporal characterization, Spectrogram, Frequency-Resolved Optical Gating (FROG), Spectral interferometry (principle, evaluation, SPIDER), Spatio-temporal distortions, Carrier envelope phase (CEP).	**2,3,5**	**20**
Unit IV-Attosecond Science Intense light-matter interaction, Multiphoton ionization, Tunneling ionization, Over the barrier ionization, Extreme nonlinear optics, High Harmonic Generation (HHG), HHG spectroscopy, Attosecond pulse generation, Attosecond Pulse characterization,RABITT, Isolated attosecond pulse generation, Attosecond spectroscopy.	**3,4,5**	**14**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Teaching, Seminar, Group Assignments, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

REFERENCES

4. Nonlinear Optics, Second Edition, Robert W Boyd, Academic Press, Elsevier.
5. Ultrafast Optics, Andrew M Weiner, John Wiley and son's publication.
6. Fundamentals of attosecond optics, Zenghu Chang @ CRC Press
7. Ultrafast lasers, A comprehensive Introduction to Fundamental Principles with practical applications U. Keller, Springer

SUGGESTED READINGS

8. Attosecond and XUV Physics: Ultrafast Dynamics and Spectroscopy, Dr. Thomas Schultz, Dr. Marc Vrakking © 2014 Wiley-VCH Verlag GmbH & Co. KGaA.
9. Attosecond and Strong-Field Physics- Principles and Applications,C. D. Lin, Anh-Thu Le, Cheng Jin and Hui Wei, Cambridge University Press

Course Name	**Advanced characterization techniques**
Type of Course	Elective
Course Code	PHM21E15
Course Summary & Justification	**Course Objectives** Characterisation techniques are inevitable for materials and technology development. Main objective of this course is to introduce various essential characterisation techniques commonly used for characterization of materials in science, technology and medicine. Topics dealing in this course have numerous applications in industry, material science, molecular biology and medicine.

Semester						
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about solid state physics, mathematics and quantum mechanics.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Knowledge and experience of basic structural characterisation techniques. (Module 1)	***U***	1
2	Knowledge and experience of basic spectroscopic and biophysical characterisation techniques (Module 2)	***An***	1,4
3	Knowledge and experience of basic elemental characterisation techniques (Module 3)	***C***	2
4	Knowledge and experience of basic thermal and magnetic characterisation techniques (Module 4)	***An***	2
5	Knowledge and experience of basic characterisation techniques essential for material scientists.	***C***	2,3
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Content	**CO**	**Hours**
Unit I: Structural characterization: X-ray diffractometry, Powder diffraction method, GI XRD, Optical microscopy, Auger electron Spectroscopy (AES), SEM, TEM, AFM, FESEM-basic principle, instrumentation and analysis.	**1,5**	**18**
Unit II- Spectroscopic and Biophysical characterization: UV-Vis-NIR Spectrometry, FTIR Spectroscopy, fluorescent Spectroscopy, Basic principle and Applications, X-ray Absorption Spectroscopy (XAS)-EXAFS, EXANES, Raman Spectroscopy. Mass spectroscopy, Circular Dichroism Spectroscopy (CD), Melting temperature Analysis, Isothermal Titration Calorimetry (ITC).	**2,5**	**20**

Unit III Elemental characterization Energy Dispersive X-Ray Analysis (EDAX), X-ray Photoelectron spectroscopy (XPS), Electron probe microanalysis (EPMA), Atomic Absorption Spectroscopy (AAS), X-ray fluorescence (XRF), Secondary ion mass Spectroscopy.	**3,5**	**18**
Unit IV- Thermal and magnetic characterization: Differential scanning calorimetry (DSC), Thermo-gravimetric analysis (TGA), Differential Thermal Analysis (DTA), Vibration Sample Magnetometer, Thermal conductivity measurements, Electrical conductivity measurements.	**4,5**	**16**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Class quiz Assignments End Semester Examination

REFERENCES

1. Introduction to nanoscience and Nanotechnology – K. K Chattopadhyaya and A.N.Banerjee
2. Elements of X ray diffraction (second edition)- B.D.Cullity
3. Powder Methods in X-ray Crystallography Hardcover –by Leonid V. Azaroff M.L. and Buerger.
4. Characterization techniques for nanomaterials
   PS Kumar, KG Pavithra, M Naushad - Nanomaterials for solar cell …, 2019 – Elsevier
5. Biophysical characterization of proteins in developing biopharmaceuticals.
   DJ Houde, SA Berkowitz - 2019 - books.google.com
6. Sam Zhang, Lin Li and Ashok Kumar, Materials Characterization Techniques, CRC Press, (2008)
7. Elton N. Kaufmann, Characterization of Materials, Vol.1, Wiley & Sons (2003) 18
8. Characterization of nano-phase materials ed. by Zhong Lin Wang.

SUGGESTED READINGS

9. An introduction to X-ray crystallography, M. M. Woolfson, Cambridge Univ. Press
10. Structure Determination from Powder Diffraction Data Ed By W.I.F. David , K.Shankland, L.B. McCusker and Ch. Baerlocher

Course Name	**Materials Science**					
Type of Course	Elective					
Course Code	PHM21E16					
Course Summary & Justification	*The course serves as a foundation for understanding different categories of materials such as crystalline, thin films, nanomaterials, ceramics and glasses and their synthesize methods. This will provide the students the basic knowledge of materials science, so that they would be able to understand and distinguish between variety of materials based on their structure and properties.* The content of this course is distributed over four units. It equips them with all the basics required for a deeper understanding of the physical properties of materials, which will be dealt separately in the other courses. On completion of this course students will be well versed with the different classes of materials used in engineering applications and would be able to choose the right materials for specific applications.					
Total Student LearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge of Solid State Physics and Quantum Mechanics					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	The student should be familiar with the crystal growth techniques with the necessary nucleation-growth theory. Good foundation on these topics would be helpful during their career in research or industry.	*A*	7
2	The student will be well versed with the fundamentals of thin films, deposition parameters affecting the structure thereby properties	*E*	2
3	The student acquires information about the physics behind nanomaterials and their synthesis for specific applications.	*An*	1
4	Provide a platform for the students to acquire the science of ceramic and glassy materials. Also, students get aware of the related environmental issues.	*A*	7
5	Develop the competence to apply concepts of physics for the structural modifications to make them suitable for particular applications	*C*	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I : Crystalline materials (18 hours) Classification of materials – Crystalline and amorphous materials, Importance of single crystals, Concepts of Crystal Growth: Saturation and Super saturation-Nucleation - Classical Theory of Nucleation- homogeneous and heterogeneous nucleation, Crystal Growth Theories: KSV theory, BCF theory. Methods of Crystal Growth: Solution Growth Technique- Gel Growth Method- Melt growth – Bridgman – Czochkralski, float zone and zone melting techniques. Vapour Growth Methods: Physical Vapour Deposition- Chemical Vapour Deposition.	**1,2,3,4**	**18**
Unit II : Thinfilms (18 hours) Mechanism of thin film formation: Condensation and nucleation, Theories of nucleation-Capillarity theory, effect of deposition parameters. atomistic theory and rate equation approach of nucleation. Influence of various factors on the structure of thin films, Preparation of Thin films: Evaporation – thermal, e-beam, Sputter Deposition - DC, RF, Microwave, pulsed laser, Ion-Beam, Arc Deposition – Cathodic, Anodic, Molecular Beam Epitaxy, Chemical methods of Film deposition: Chemical Vapor Deposition -Electrolysis, Spray pyrolysis, polymerization.	**1,3,5**	**18**
Unit III : Nanomaterials (18 hours) Nanostructured materials: Characteristics and properties – Nanocrystals, One Dimensional, Two Dimensional and Three Dimensional nanostructured materials-Nanocomposites-Top down and bottom up approaches for the synthesis of nanomaterials: Ball Milling- Solid State Reaction-Microwave method-Coprecipitation Method-Sol-gel method- Electrospinning -Hydrothermal Method - Solution Combustion Method - Microemulsion Method – Thermolysis – Electrodeposition -Ultrasonic precipitation method. Important nanomaterials and applications	**1,2,5**	**18**
Unit IV : Ceramic and Glassy materials (18 hours) Ceramics and their structure- silicate structure - polymorphism and allotropy: Processing - Recrystallization and grain growth, sintering, hot pressing, fire shrinkage. Basic refractory materials. Glasses: Preparation and structure - Types of glasses - borate glasses, silicate glasses, oxide glasses, metallic and semiconducting glasses. Applications - photo sensitive, photochromic glasses, optical fiber- principle of fiber communication. Economic, Environmental, and Societal Issues in Materials Science and Engineering.	**1,4,5**	**18**

References

1) Crystal Growth, J C Brice
2) Thin Film Technology and Applications – K L Chopra and L K Malhothra
3) Nano: The essentials – T Pradeep
4) Ceramic and Glass Materials : Structure, Properties and Processing, James F. Shackelford
5) Fundamentals of Materials Science and Engineering, William D. Callister and David G.

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

Course Name	**Materials Physics**					
Type of Course	Elective					
Course Code	PHM21E17					
Course Summary & Justification	*This course is envisaged to enable the students to employ the concepts of solid state physics learned by them to practical applications. This course is intended provide basic concepts and theory about the physical properties of materials and to equip them for a research career.* The content of this course is distributed over four units dealing the electrical, dielectric, magnetic and optical properties of material. The syllabus is planned in such a way that students will acquire both theoretical concepts and idea about experimental methods in the above mentioned characteristics of materials.					
Semester						
Total Student LearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	72	18		15	105
Pre-requisite	Basic knowledge of Solid State Physics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Apply the concepts of free electron theory and band theory of solids.	*A*	7
2	Evaluate the electrical and magnetic parameters of the solid	*E*	2
3	Capable of analyzing the electric properties on the basis of electronic band structure, charge carrier statistics	*An*	1
4	Develop the competence to apply physics for the description of electric, magnetic and optical properties.	*A*	7
5	Think how to alter the properties of solids to make them suitable for particular applications	*C*	2,3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Content	CO	Hours
Unit I : Electrical properties (18 hours) Electrical conduction - Drude, Sommerfeld and quantum theories of electric conduction in metals, Maitthiessen rule of electrical conductivity, Energy bands in solids - Conduction in terms of band and atomic bonding models - Electrical resistivity of metals - Factors affecting electrical resistivity - Two probe and four probe techniques. Ionic conduction – review of defect equilibrium and diffusion mechanisms; Theory of ionic conduction, conduction in glasses; Effect of stoichiometric and extrinsic defects on conduction.	**1,2,3,4**	**18**
Unit II : Dielectric properties(18 hours) Dielectrics- Electronic, ionic, and orientational polarization - Static dielectric constant of gases and solids - Complex dielectric constant and dielectric losses - Relaxation time - Debye equations - Cases of distribution of relaxation time, Cole - Cole distribution parameter – Normal and anomalous dispersion – classical theory of electronic polarization -Cauchy's relation and Sellmeyer's dispersion formula – Ionic polarization and LST relation. Dielectric Characterization- Impedance measurements, Complex impedance spectroscopy.	**1,3,5**	**18**
Unit III : Magnetic properties (18 hours) Orbital and spin magnetic moment of atoms, Ordered magnetism - Ferro, anti-ferro and ferri magnetism, Exchange interaction, Magnetic domains, Hysteresis, Single domain magnets, superparamagnetism, easy and hard axis surface magnetism, Spintronics, Basic mechanism of spin polarization and application of Spintronics devices. Memory devices, Superconductors, Multiferroic materials, Soft Magnetic Materials - Hard Magnetic Materials -	**1,2,5**	**18**

Conventional and High Energy Hard Magnetic Materials. Vibrating sample magnetometer.		
Unit IV : Optical Properties (18 hours) Light-matter interaction- reflection, absorption, transmission, secondary-scattering, refraction, diffraction; refractive index- definition and dependencies; dispersion. Luminescence – types of luminescence, photoluminescence study- fluorescence, phosphorescence - absorption, excitation, emission, up-conversion, down-conversion; energy transfer mechanism, Optical Analysis – UV-Vis-NIR absorption spectroscopy, diffuse reflectance spectroscopy and optical bandgap determination, photoluminescence spectroscopy, luminescence quenching and decay analysis, internal and external quantum efficiency, CIE chromaticity coordinates.	**1,4,5**	**18**

References

1. Introduction to Magnetism and Magnetic Materials - D. Jiles
2. Physical Properties of Materials – Mervyn Lovell, Alan Avery, Michael Verno
3. Optoelectronics an Introduction: J Wilson, J.F.B Hawkes
4. Introduction to electronic properties of materials – David Jiles

Suggested Readings

4. Elementary Solid State Physics – M Ali Omar
5. Principles of Solid State Physics – R A Levy
6. Solid State Physics – N W Ashcroft and N D Mermin

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

Course Name	**Quantum Field Theory**					
Type of Course	Elective					
Course Code	PHM21E18					
Course Summary & Justification	This course is designed to introduce students to theoretical high energy physics. The course covers topics such as free-field quantization, perturbative field theory and computing scattering cross-sections. It gives the students an opportunity to get a flavour of research in particle physics.					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Collaborative learning Independent learning	72	18		15	105
Pre-requisites	Classical Mechanics, Quantum Mechanics I, Quantum Mechanics II, Electromagnetic Theory					

Course Outcomes (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1.	Students will be able to apply the variational principle to obtain the Euler-Lagrange equation of motion for a given Lagrangian.	A	**1,6**
2.	Apply Noether's theorem to get the conserved charge.	A, U, Ap	**1,6**
3.	Understand particles as excitations of fields.	U, Ap	**6**
4.	Compute Fock-state representation of observables like Hamiltonian.	An, E	**6**
5.	Apply Wick's theorem.	A	**2,6**
6.	Write down scattering amplitudes for different processes using Feynman rules.	R, A, E	**2,6**
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Course Content

Content	CO	Hours
Unit-1: Classical field theory Variational principle for fields, Euler-Lagrange field equation of motion, Hamiltonian formulation, Noether's theorem - spacetime symmetries and internal symmetries, Symmetry transformation of fields.	**1,2**	**16**
Unit-2: Quantisation of free scalar field Plane wave expansion of real scalar field. Canonical quantisation. Field as a system of oscillators: Fock state representation of Hamiltonian, momentum. Plane wave expansion of complex scalar fields. Charge operator. Particles as excitations of field, Feynman-propagator for real and complex fields. Particle and anti-particle concept.	**3,4**	**16**
Unit-3: Quantisation of Dirac and Maxwell field Dirac field Lagrangian-Plane wave expansion- need for anticommutators, Hamitonian, Charge In Fock space; Feynman propagator. Covariant quantisation of Maxwell. Lorentz condition. Gupta-Bleuer method. Feynman propagator.	**3,4**	**20**
Unit-4: S-matrix expansion to Feynman diagram and QED Dyson perturbation, S-matrix, Wick's theorem, Example of interacting scalar field theory. Sample calculation of matrix element- Feynman rules, Cross section formula Lagrangian for QED; gauge invariance; Feynman rules- Feynman amplitude for tree level process. Cross-section formula- cross section for Compton scattering.	**5,6**	**20**

Technical and Learning Approach	**Classroom Procedure** Lectures, Tutorials, Interactive Instruction, Seminars, Individual Assignments, Presentations by students.
Assessment Types	**Modes of Assessment** 1. Continuous Internal Assessment (CIA) 2. Internal Examinations: two subjective tests 3. Seminar Presentations: students pick a topic from a given list of topics to present before the rest of the class. 4. Assignments 5. End Semester Examination

References:

1. An Introduction to Quantum Field Theory: M. Peskin and D. Schroeder

2. Quantum Field Theory: L. H. Ryder

Course Name	**Introduction to Mathematical Science**
Type of Course	Open Course
Course Code	PHM21O01
Course Summary & Justification	The course comprises the basic ideas of mathematics and formulate techniques of attempting higher level problems
Semester	3

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning, Collaborative learning, Independent learning	72	18		15	105
Pre-requisite	Basic knowledge about numbers, addition & division, subtraction & multiplication					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understands the concepts of mathematical concepts	*U*	1
2	Solve problem using Matrix Algebra	*An*	1,2
3	Can solve problems in trigonometry	*C*	2
4	Analyse the problems using differentiation and integration.	*C*	2
5	Can develop analytical skill and confidence for approaching higher level scientific problems	*C*	2, 3
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT :

Content	CO	Hours
UNIT 1 Relations and functions: Introduction, Types of Relations, types of Functions, composition of Functions and Invertible Function, Binary Operations. Trigonometric and inverse trigonometric Functions: Introduction Basic trigonometric functions and its relations, Concepts Properties of Inverse Trigonometric Functions and Applications.	**1,5**	**18**
UNIT 2 Matrices: Introduction, Matrix, types of Matrices, Operational on Matrices, transpose of a Matrix, symmetric and Skew symmetric Matrices, elementary Operation (Transformation) of a Matrix, Invertible Matrices, Determinant, properties of Determinants, Minors and Cofactors, Adjoint and Inverse of a Matrix, Applications of Determinants and Matrices.	**1,2,5**	**18**
UNIT 3 Continuity and Differentiability: Introduction to Continuity, Differentiation, Differentiability, Exponential and Logarithmic Functions, Logarithmic Derivatives of Functions in Parametric Forma, second Order Derivative Mean value Theorem, Applications of Derivatives. Integrals: Introduction, Integration as an Inverse Process of Differentiation, Methods of Integration, Integrals of some particular Functions, Integration by Partial Fractions, Integration by Parts, Definite Integral, Fundamental Theorem of Calculus, Evaluation of Definite integrals by substitution, some properties of Definite integrals, Applications.	**1,4,5**	**18**
UNIT 4 Vector Algebra : Introduction, Some basic Concepts, Types of Vectors, Addition of Vectors, Multiplication of a Vector by a Scalar, |Product of two vectors. Three Dimensional Geometry : Introduction, Direction Cosines and Direction ratio of a Line, equation of a Line in space, Angle between Two Lines, shortest Distance between Two Lines, Planes, Coplanarity of Two Lines, angle between Two Planes, Distance of a Point from a Plane, Angle between a Line and a plane.	**1,5**	**18**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture, Explicit Teaching, Seminar, Group Assignments Authentic learning, Library work and Group discussion, Presentation by individual student
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Internal Test Seminar Presentation Assignments End Semester Examination

References:

1. Mathematical Physics. Edn4. B.D. Gupta, Vikas Publications.
2. Foundations of Mathematical Physical Sciences. Riley Hobson, Cambridge University Press.
3. Advanced Engineering Mathematics, Erwin Kreyszig, Wiley

School of Pure and Applied Physics

Pattern of question paper for End Semester Examination

Maximum marks -60 Time – 3 hours

<table>
<tr><td colspan="3">SECTION A
Short answer type questions
(Answer any Five questions. Each question carries Two marks)</td></tr>
<tr><td>1)</td><td rowspan="2">Unit I</td><td rowspan="8">2 x 5 = 10 marks</td></tr>
<tr><td>2)</td></tr>
<tr><td>3)</td><td rowspan="2">Unit II</td></tr>
<tr><td>4)</td></tr>
<tr><td>5)</td><td rowspan="2">Unit III</td></tr>
<tr><td>6)</td></tr>
<tr><td>7)</td><td rowspan="2">Unit IV</td></tr>
<tr><td>8)</td></tr>
<tr><td colspan="3">SECTION B
Short derivation/problem type questions
(Answer any Three questions. Each question carries Four marks)</td></tr>
<tr><td>9)</td><td>Unit I</td><td rowspan="4">5 x 2 = 10 marks</td></tr>
<tr><td>10)</td><td>Unit II</td></tr>
<tr><td>11)</td><td>Unit III</td></tr>
<tr><td>12)</td><td>Unit IV</td></tr>
<tr><td colspan="3">SECTION C
Essay type questions
(Answer All questions. Each question carries Ten marks)</td></tr>
<tr><td>13)
OR
14)</td><td>Unit I</td><td rowspan="4">10 x 4 = 40 marks</td></tr>
<tr><td>15)
OR
16)</td><td>Unit II</td></tr>
<tr><td>17)
OR
18)</td><td>Unit III</td></tr>
<tr><td>19)
OR
20)</td><td>Unit IV</td></tr>
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The questions should be in tune with the CO’s of the course.

MODEL QUESTION PAPER

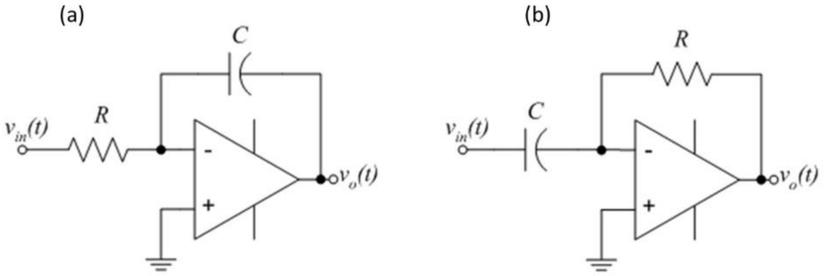
BASIC ELECTRONICS

Time: 3 Hrs
Max. Marks: 60

Part A

Answer **any FIVE** questions; each question carries **TWO marks** (5 x 2 = 10)

1. Mention any four assumptions that we make for considering an op-amp as an ideal one **(CO1, U)**
2. Why open-loop op-amp configuration is not used in linear applications? **(CO1, CO2, U)**
3. Identify the following circuits **(CO1, CO2, An)**



4. How a second order filter differs from a first order filter? **(CO1, CO2, An)**
5. Is a parallel counter advantageous over a ripple counter? Justify your answer. **(CO1, CO2, An, E)**
6. Calculate the number of flip flops required to construct a mod 64 counter **(CO1, CO2, A)**
7. Define modulation index. Explain its significance **(CO1, R, U)**
8. What are the different types of errors in communication systems? **(CO1, R)**

Part B

Answer **any TWO** questions; each question carries **FIVE marks** (2 x 5 = 10)

9. Analyze and compare closed-loop differential amplifiers constructed using one and two op-amps respectively **(CO1, CO2, U, A)**
10. Discuss the principle of Schmitt trigger **(CO1, R, U)**
11. Calculate the number of memory chips needed to design 8K-byte memory if the memory chip size is 1024x1. Also find the number of address lines required for a memory chip with 256 registers. **(CO1, A)**
12. Calculate the rejection ratio at 1000 kHz for a broadcast superheterodyne receiver having no RF amplifier. The loaded Q of the antenna coupling circuit is 100 and the intermediate frequency is 455 kHz. **(CO1, CO2, A)**

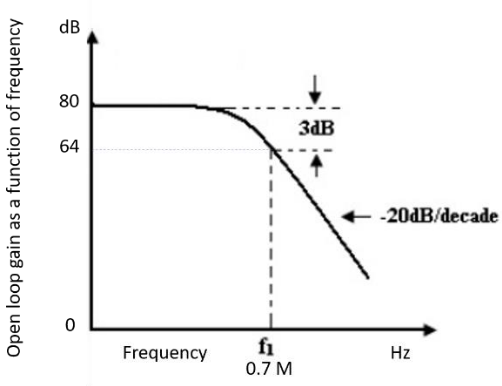
Part C

Answer **any FOUR** questions; each question carries **TEN marks** (4 x 10 = 40)

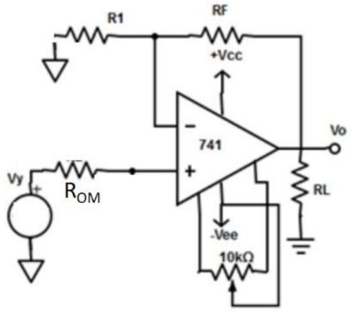
13. **(i)** Differentiate between SSI, MSI, LSI and VLSI ICs. **(CO1, CO2, An)** (5)
(ii) Consider 741C configured as a noninverting negative feedback amplifier. Compute closed loop gain, input and output resistances, bandwidth and total output offset voltage. Given, A = 400,000, R_1 = 470 Ω , R_i = 33 MΩ, R_F = 4.7 kΩ , R_o = 60 Ω , Supply voltages = ±15V, Maximum output voltage swing = ±13V, Unity gain bandwidth = 0.6 M Hz. **(CO1, CO2, A)** (5)

OR

14. **(i)** How does the high-frequency model of an op-amp differ from the general equivalent circuit of op-amps? How does this model account for the observed frequency response of op-amps? **(CO1, CO2, An, E)** (5)
(ii) Frequency response of a certain op-amp is shown below. Write the open-loop gain equation for the op-amp as a function of break frequencies and dc gain A. **(CO1, CO2, U, An)** (5)



15. **(i)** With the help of circuit diagram explain how op-amps are used as inverting DC amplifier **(CO1, CO2, U, An)** (5)
(ii) For the circuit shown below R_F = 4.7 kΩ , R_1 = 100 Ω , R_L = 10 KΩ , R_{OM} = 100 Ω . Determine the output voltage if V_y = 100 mV. Assume that the op-amp is initially nulled and the supply voltages = ±15V. **(CO1, CO2, A)** (5)



OR

16. **(i)** Design a low-pass filter at a cut-off frequency of 1kHz with a passband gain of 2. Let C = 0.01 μF. How will you convert this cut-off frequency to 1.6 kHz? **(CO1, CO2, CO3, C)** (5)

(ii) Plot the frequency response of this low-pass filter. **(CO1, U, A)** (5)

17. Explain the working of **(CO1, CO2, U, An)**

(i) Parity generators (5)

(ii) Parity checkers (5)

OR

18. How the following flipflops work and what is their dominant advantage? **(CO1, CO2, U, An, E)**

(i) Edge triggered JK flipflops (5)

(ii) JK master-slave flipflops (5)

19. **(i)** What are radio receivers? Explain with an example. **(CO1, U)** (3)

(ii) What are the advantages of a receiver having RF amplifier. **(CO1, U)** (2)

(iii) Define image frequency and rejection ratio of a superheterodyne receiver and explain its importance. **(CO1, R, U)** (5)

OR

20. **(i)** Discuss the advantages of single-side band (SSB) modulation **(CO1, U)** (4)

(ii) Explain in detail any two methods of SSB generation. **(CO1, U)** (6)