5 Year Int. MSc Physics with Specialization in Theoretical Physics / Applied Materials

Curriculum and Syllabi

DEPARTMENT OF SCIENCES

AMRITA VISHWA VIDYAPEETHAM

COIMBATORE, TAMILNADU – 641112

INDIA

April 2022

CURRICULUM

Course Code	Course Title	L T P	Cr	ES	Course Code	Course Title	L T P	Cr	ES
	SEMESTER 1					**SEMESTER 2**			
22MAT106	Single variable calculus	3 1 0	4		22MAT117	Multivariable calculus	3 1 0	4	
22BIO101	Basic Principles of Biology	2 1 0	3		22BIO111	Cellular and Molecular Biology	2 1 0	3	
22PHY104	Mechanics	3 1 0	4		22PHY111	Basics of Electricity and Magnetism	3 1 0	4	
22CHY103	General Chemistry	3 1 0	4		22CHY112	Principles of Physical Chemistry	3 1 0	4	
22CSA103	Introduction to Scientific Computing Using Python	3 0 1	4		22PHY184	Physics Lab I – Mechanics, Electricity & Magnetism	0 0 2	1	
21ENG101	Communicative English	2 0 2	3		22CHY183	Chemistry Lab I	0 0 2	1	
21CUL101	Cultural Education I	2 0 0	2		21ENG111	Professional Communication	1 0 2	2	
					21CUL111	Cultural Education II	2 0 0	2	
					22AVP103	Mastery Over Mind	1 0 2	2	
	TOTAL		**24**			**TOTAL**		**23**	
	SEMESTER 3					**SEMESTER 4**			
22CHY204	Physical Organic Chemistry	3 1 0	4		22CHY215	Principles of Inorganic Chemistry	3 1 0	4	
22PHY201	Waves, Oscillations & Ray optics	3 1 0	4		22PHY211	Basics of Electronics	3 1 0	4	
22PHY202	Introduction to Mathematical Physics	3 1 0	4		21SSK211	Life Skills II	1 0 2	2	
21SSK201	Life skills I	1 0 2	2		22PHY212	Introduction to Computational physics	3 1 0	4	
21ENV200	Environmental Science and Sustainability	3 0 0	3		22PHY282	Physics Lab III – Modern Physics	0 0 2	1	
22CHY283	Chemistry Lab II	0 0 2	1		22PHY213	Basics Experimental Tech-	3 1 0	4	
22PHY281	Physics Lab II - Optics	0 0 2	1		21AVP211	Amrita Value Programme II	1 0 0	1	
22CSA281	Programming Lab I	0 0 2	1						
21AVP201	Amrita Value Programme I	1 0 0	1						
	TOTAL		**21**			**TOTAL**		**20**	
	SEMESTER 5					**SEMESTER 6**			
22PHY301	Classical Mechanics I	4 1 0	4		22PHY311	Basics of Quantum Mechanics	3 1 0	4	
22PHY302	Thermal and Statistical Mechanics	3 1 0	4		22PHY312	Mathematical Physics I	3 1 0	4	
22PHY303	Applied Electronics	3 1 0	4		22PHY313	Elements of Condensed matter physics	3 1 0	4	
22PHY304	Electricity and Magnetism in Matter	3 1 0	4			**Core Elective II**	3 0 0	3	
22PHY390	Open Elective/Live in Lab	3 0 0	3		22PHY314	Wave Optics	3 1 0	4	
22PHY381	Physics Lab IV - Electronics	0 0 3	1			Professional Elective II	3 0 0	3	
	Core Elective I		3		22PHY382	Project Based Lab (for Int. MSc students)	0 0 3	2	
	Professional elective I	3 0 0	3			**TOTAL**	**24**		
	TOTAL	**26**			22PHY399	Project (for Exit-option students)	**3**		
						TOTAL (for Exit-option students)		**139**	
	SEMESTER 7					**SEMESTER 8**			
22PHY501	Quantum Mechanics	3 1 0	4		22PHY511	Nuclear and Particle Physics	3 1 0	4	
22PHY502	Classical Mechanics II	3 1 0	4		22PHY512	Atomic and Molecular Spectroscopy	3 1 0	4	
22PHY503	Mathematical Physics II	3 1 0	4			**Core Elective IV**	3 0 0	3	
22PHY504	Electrodynamics	3 0 1	4		22PHY513	Condensed Matter Physics	31 0	4	
22PHY581	Physics Lab - VI (Project Based Lab – Common to both streams)	0 0 4	2		22PHY582/ 22PHY583	Physics Lab VII - (Project Based – Applied Materials/ Theoretical Physics)	0 0 4	2	
	Core Elective III	3 0 0	3			**Core Elective V**	3 0 0	3	
22PHY505	Statistical Mechanics	3 1 0	4		22RM500	Research Methodology	2 0 0	2	
21SSK301	Life skills III	1 0 2	2						
	TOTAL		**27**			**TOTAL**		**22**	
	SEMESTER 9					**SEMESTER 10**			
22PHY695	Project – Phase 1		10		22PHY698	Project Phase –II -Dissertation		10	
22PHY690	Viva voce (Theory)		2						
	TOTAL		**12**			**TOTAL**		**10**	
						TOTAL CREDITS		**209**	

Electives

Code	Specialization	L T P	Cr	ES
Theoretical Physics				
22PHY531	Relativistic Quantum Mechanics	3 0 0	3	
22PHY532	Advanced Particle Physics	3 0 0	3	
22PHY533	Physics of Compact Stars	3 0 0	3	
22PHY534	Theory of Nanostructures	3 0 0	3	
22PHY535	Special Theory of Relativity	3 0 0	3	
22PHY536	Introduction to Classical field theory	3 0 0	3	
22PHY537	Introduction to General Theory of Relativity	3 0 0	3	
22PHY538	Quantum Field Theory	3 0 0	3	
Applied Materials				
22PHY541	Physics of Semiconductors	3 0 0	3	
22PHY542	Physics of Nanomaterials	3 0 0	3	
22PHY543	Thin Film Technology	3 0 0	3	
22PHY544	Advanced Solar Cell Fabrication	3 0 0	3	
22PHY545	Optoelectronic Devices	3 0 0	3	
22PHY546	Electrochemical Energy Storage Systems	3 0 0	3	
22PHY547	X-Ray & Electron Diffraction Techniques	3 0 0	3	
22PHY548	Physics of Smart Materials	3 0 0	3	
22PHY549	Thermodynamics of Defects and Phase Transitions in Solid State	3 0 0	3	
22PHY550	Biomaterials	3 0 0	3	
22PHY551	Micro and Nano Magnetism Materials and its Applications	3 0 0	3	
22PHY552	Computational Materials Science	3 0 0	3	

Code	Professional Elective I & II	L T P	Cr	ES
22CSA571	Data Structures and Al-gorithms	3 0 0	3	
22CSA572	Machine Learning I	3 0 0	3	
22CSA573	Machine Learning II	3 0 0	3	
22MAT553	Probability and Statistics with R	3 0 0	3	
22MAT554	Optimization Methods	3 0 0	3	
	OPEN ELECTIVES (Physics)			
22OEL299	History and Philosophy of Science	3 0 0	3	
22OEL300	EU History of Science and Technology	3 0 0	3	

Open Electives UG				
Course Code	**Course Title**	**L – T – P**	**Cr.**	**ES**
21OEL231	A Journey towards Free India	3 0 0	3	J
21OEL232	Political Leadership	3 0 0	3	J
21OEL233	Social issues in Contemporary India	3 0 0	3	J
21OEL234	The Story of Indian Business	3 0 0	3	J
21OEL235	Industrial Psychology	3 0 0	3	J
21OEL236	Advertising	3 0 0	3	J
21OEL237	Basic Statistics	3 0 0	3	J
21OEL238	Citizen Journalism	3 0 0	3	J
21OEL239	Creative Writing for Beginners	3 0 0	3	J
21OEL240	Desktop Support and Services	3 0 0	3	J
21OEL241	Development Journalism	3 0 0	3	J
21OEL242	Digital Photography	3 0 0	3	J
21OEL243	Emotional Intelligence	3 0 0	3	J
21OEL244	Essence of Spiritual Literature	3 0 0	3	J
21OEL245	Film Theory	3 0 0	3	J
21OEL246	Fundamentals of Network Administration	3 0 0	3	J
21OEL247	Gender Studies	3 0 0	3	J
21OEL248	Glimpses of Indian Economy and Polity	3 0 0	3	J
21OEL249	Graphics and Web-designing Tools	3 0 0	3	J
21OEL250	Green Marketing	3 0 0	3	J
21OEL251	Healthcare and Technology	3 0 0	3	J
21OEL252	History of English Literature	3 0 0	3	J
21OEL253	Indian Writing in English	3 0 0	3	J
21OEL254	Industrial Relations and Labour Welfare	3 0 0	3	J
21OEL255	Introduction to Ancient Indian Yogic and Vedic Wisdom	3 0 0	3	J
21OEL256	Introduction to Computer Hardware	3 0 0	3	J
21OEL257	Introduction to Event Management	3 0 0	3	J
21OEL258	Introduction to Media	3 0 0	3	J
21OEL259	Introduction to Right to Information Act	3 0 0	3	J
21OEL260	Introduction to Translation	3 0 0	3	J
21OEL261	Linguistic Abilities	3 0 0	3	J
21OEL262	Literary Criticism and Theory	3 0 0	3	J
21OEL263	Macro Economics	3 0 0	3	J
21OEL264	Managing Failure	3 0 0	3	J
21OEL265	Media Management	3 0 0	3	J
21OEL266	Micro Economics	3 0 0	3	J
21OEL267	Micro Finance, Small Group Management and Cooperatives	3 0 0	3	J
21OEL268	Negotiation and Counselling	3 0 0	3	J
21OEL269	New Literatures	3 0 0	3	J
21OEL270	Non-Profit Organization	3 0 0	3	J
21OEL271	Personal Effectiveness	3 0 0	3	J
21OEL272	Perspectives in Astrophysics and Cosmology	3 0 0	3	J
21OEL273	Principles of Marketing	3 0 0	3	J
21OEL274	Principles of Public Relations	3 0 0	3	J
21OEL275	Science, Society and Culture	3 0 0	3	J
21OEL276	Statistical Analysis	3 0 0	3	J
21OEL277	Teamwork and Collaboration	3 0 0	3	J
21OEL278	The Message of Bhagwad Gita	3 0 0	3	J
21OEL279	Understanding Travel and Tourism	3 0 0	3	J
21OEL280	Videography	3 0 0	3	J
21OEL281	Vistas of English Literature	3 0 0	3	J
21OEL282	Web-Designing Techniques	3 0 0	3	J
21OEL283	Organic Farming	3 0 0	3	J
21OEL284	Basic Legal Awareness on Protection of Women and Rights	3 0 0	3	J
21OEL285	Ritual Performances of Kerala	3 0 0	3	J
21OEL286	Documenting Social Issues	3 0 0	3	J
21OEL287	Fabrication of Advanced Solar Cell	3 0 0	3	J
21OEL288	Basic Concepts of X-ray Diffraction	3 0 0	3	J
21OEL289	Introduction to FORTRAN and GNUPLOT	3 0 0	3	J

21OEL290	Introduction to Porous Materials	3 0 0	3	J
21OEL291	Forensic Science	3 0 0	3	J
21OEL292	Introduction to solar Physics	3 0 0	3	J
21OEL293	Recycling Recovery and Treatment Methods for Wastes	3 0 0	3	J
21OEL294	Acting and Dramatic Presentation	2 0 2	3	J
21OEL295	Computerized Accounting	2 0 2	3	J
21OEL296	Kerala Mural Art and Painting	2 0 2	3	J
21OEL297	Painting	2 0 2	3	J
21OEL298	Reporting Rural Issues	3 0 0	3	J

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22CHY103	General Chemistry	3 1 0	4	
22CSA103	Introduction to Scientific Computing Using Python	3 0 1	4	
21ENG101	Communicative English	2 0 2	3	

21CUL101	Cultural Education I	2 0 0	2	
TOTAL			**24**	

22MAT106	Single Variable Calculus	3 1 0 4

UNIT 1

Trigonometry: Expansions of sin n(θ), cos n(θ), tan n(θ) in powers of Sin θ, Cos θ, Tan θ. Expansion of Sin n(θ), Cos n(θ), Sin m(θ), Cos m(θ) in terms of Sines and Cosines of Multiplies of θ – Power series for Sin θ, Cos θ, Tan θ - Hyperbolic Functions - Inverse Hyperbolic Functions - Logarithm of complex numbers - Summation of Trigonometric Series - Gregory Series - Euler Series.

UNIT 2

Differentiation: Applications of Derivative: Mean Value theory – Concavity and Curve Sketching – Maxima and Minima.

UNIT 3

Differential Equations of First Order: Formation of Differential Equations. Solutions of Differential Equations (Variable Separable, Homogeneous Equations and Equations reducible to Homogeneous Form, Linear and Equations reducible to Linear Form, Exact Differential Equations and Equations reducible to Exact form). Differential Equations not of the first degree (solvable for ‘p’, solvable for ‘y’, solvable for ‘x’, Clairaut’s Equation). Applications.

UNIT 4

Differential Equations of Higher Order: Homogeneous Linear Differential Equations with Constant Coefficient and Euler- Cauchy Differential Equations, Basis of Solutions and Wronskian. Non-Homogeneous Equations - Method of Undetermined Coefficients and Method of Variation of Parameters.

UNIT 5

Boundary Value Problems for Second Order Equations: Green's function, Sturm Comparison Theorems and Oscillations, Eigenvalue Problems. Applications.

Recommended Reading

1. George B. Thomas, Maurice D. Weir, Joel R. Hass, ‘Calculus’, Pearson Education, 2009, 11th Ed.
2. E. Kreyszig ‘Advanced Engineering Mathematics’, John Wiley and Sons, 2002, 8th Ed.
3. P. K. Mittal ‘Mathematics for Degree students’, S. Chand & Co, 2011, New Delhi.
4. P. Kandasamy and K. Thilagavathi, “Mathematics for B.Sc.”, Branch I Vol. I, Vol. II, S. Chand & Co.

22BIO101	Basic Principles of Biology	2 1 0 3

UNIT 1: Introduction
Salient features of life, importance of biology on the frontiers of science and technology. Brief history of biology. How plants, animals and microorganisms shaped human history.

UNIT 2: **The logical structure of biology**
Concepts of complexity, emergent properties, adaptation, optimality, diversity, chance and necessity, structure function relationship, theme and variations, individual variability and plasticity. Nature of experimentation in biology and statistical inference.

UNIT 3: **Broad overview of life on earth**
Origin and progression of life on earth, evolution, concept of adaptive versus neutral evolution. Classification/taxonomy and phylogeny. Molecular relationships between life forms.

UNIT 4: **Biological information**
Nature of biological information, mechanisms of transmission of information - genetic, epigenetic, cultural and other mechanisms of inheritance. Central dogma of molecular biology.

UNIT 5: **Mechanism of perpetuation of life**
Mechanism of perpetuation of life at molecular, cellular, organismal and population levels.

Recommended Reading

1. Principles of Biology: Interactive textbook from Nature Education
2. Biology: N. Campbell and J. Reece (2005) 7th edition, Pearson, Benjamin, Cummings

22PHY104	Mechanics	3 1 0 4

Prerequisites: Higher secondary level Mathematics course

Course Objectives
This course is intended to impart students basic understanding of Newtonian mechanics involving both translational and rotational motions of bodies, vector algebra, curvilinear coordinates, concepts such as work-energy theorem, conservation of energy and momentum along with center of mass. Also basic knowledge on elastic properties of matter and fluid mechanics will be imparted to students.

Course Outcomes

At the end of the course students will be able to

CO1. Understand and analyze one, two and three dimensional translational motion problems including conservation laws.

CO2. Understand and apply Newton's laws of motion and the universal law of gravitation to solve problems.

CO3. Acquire knowledge on the concept of center of mass, collision and rotational motion.

CO4. Apply Hooke's law, determine elastic constants of solids, and apply law of buoyancy, Archimedes principle, Bernoulli's theorem to solve problems related to fluid mechanics.

CO5: Learn about different frames of reference and acquire knowledge on special theory of relativity.

Skills: Problems solving in Mechanics and Properties of Matter towards improving the analytical skills of students through assignments, quizzes, presentations and few lab experiments

CO-PO Mapping

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	
CO5	3	3	3			3	3	

UNIT 1

Learning objectives

Recognize various physical quantities such as average velocity, average acceleration, instantaneous velocity and instantaneous acceleration for the description of one, two and three-dimensional motion of an object and solve problems

Describe projectile motion of an object through appropriate equations.

One-dimensional Kinematics. Kinematics in 2D and 3 D: Projectile Motion, Circular Motion. Non-inertial frames and pseudo Forces-Rotating Coordinate Frame, Fictitious Forces, Coriolis Force, Tides, Foucault Pendulum.

UNIT 2

Learning objectives

Describe Newton's laws of motion and apply them to solve problems

Explain Work-energy theorem and conservation of energy principle.

Describe motion of an object in a uniform gravitational field

Newton's Laws of Motion - Forces, Frictional Forces-Work, Kinetic Energy, Work-Energy Theorem, Potential Energy, Conservation of Energy Newton's law of gravitation, Motion in uniform gravitational field.

UNIT 3

Learning objective

Explain the concept of center of mass for system of particles and conservation of both linear and angular momenta

Differentiate between elastic and inelastic collision and solve problems related to collision

Analyze rocket motion as an example for system of variable mass

Analyze rotational motion of bodies through rotational variables

Centre of Mass, Conservation of linear momentum, collisions, and systems with variable mass. Torque, Angular momentum, Moment of Inertia, Conservation of Angular momentum, Kinetic Energy of Rotation.

UNIT 4

Learning objectives

Explain elastic properties of matter through Hooke's law

Apply laws of Archimedes principle, Bernoulli's theorem to solve problems related to fluids in motion.

Determine surface tension of liquids after understanding the concept of surface tension and surface energy

Stress, Strain, Hooke's law Elastic properties of matter. Kinematics of moving fluids, Equation of continuity, Euler's equation, Bernoulli's theorem, Viscous fluids, Reynold's number, Surface tension, Surface energy.

UNIT 5:

Learning objectives

Understand different Frames of reference

Transformation relations

Know about length contraction and time dilation

Definition of Relativistic momentum

Special theory of Relativity-Lorentz transformations, relativistic kinematics and mass-energy equivalence.

Suggested Reading

1. David Halliday, Robert Resnick & Jearl Walker, Fundamentals of Physics, John Wiley, 9E, 2012
2. Kittel et al, Mechanics, Berkeley Physics Course Vol-1, Tata McGraw Hill, 2011
3. R.P. Feynman, R. P. Leighton and M. Sands, Feynman Lectures on Physics Vol.1, Narosa, 2003
4. Landau, Lev D., and Evgenij M. Lifshitz. Mechanics: Course of Theoretical Physics. Vol. 1. 3rd ed. Butterworth-Heinemann, 1976. ISBN: 9780750628969.
5. https://ocw.mit.edu/courses/physics/8-01sc-classical-mechanics-fall-2016/index.htm
6. Lectures by Walter Lewin on Classical Mechanics, https://www.youtube.com/watch?v=wWnfJ0-xXRE&list=PLyQSN7X0ro203puVhQsmCj9qhlFQ-As8e

Evaluation Pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO 5 to PO1 and PSO 1	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very strong affinity to PO1 and PSO 1, which is about building fundamentals in science, and create inquisitiveness and problem solving in scientific way.	3

CO1-CO5-PO2 and PSO 2	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO2 and PSO 2, which is about building analytical thinking, which is a core skill in scientific investigation.	3
CO1-CO5 – PO3	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO2 and PSO 2, which is about developing a research culture	3

22CHY103	**General Chemistry**	**3 0 1 4**

UNIT 1: Atomic structure

Bohr's model of hydrogen atom, Ritz combination principle, hydrogen spectrum, Bohr-Sommerfeld theory. Planck's quantum theory of radiation, dual character of electrons - de Broglie's equation, Heisenberg's uncertainty principle, photoelectric effect, Compton, Zeeman and Stark effects. Schrodinger wave equation, Eigen values, significance of wave function (ψ and ψ^2) and quantum numbers. Schrodinger wave equation for hydrogen and hydrogen-like systems, probability distribution of electrons around the nucleus, distribution of electrons in orbitals, shapes of atomic orbitals - s, p, d and f. Aufbau principle, Hund's rule, Pauli's exclusion principle, electronic configuration of elements.

UNIT 2: Chemical bonding

Electrovalency and ionic bond formation, ionic compounds and their properties, lattice energy. Born-Lande equation and Born-Haber cycle and their applications, solvation enthalpy and solubility of ionic compounds. Covalent bonding, formation of H_2, orbital theory of covalency. Hybridisation – VSEPR theory, sigma and pi bonds, formation of covalent compounds. Properties of covalent compounds. Molecular orbital theory – homo and hetero diatomic molecules. Polar and non-polar covalent bonds, polarization of covalent bond - polarizing power, polarisability of ions and Fajan's rule, dipole moment, percentage ionic character from dipole moment, dipole moment and structure of molecules. Co-ordinate covalent compounds and their characteristics. Metallic bond - free electron, valence bond and band theories.

UNIT 3: Acids, Bases and Non-aqueous solvents

Concepts of acids and bases - conjugate acids and bases, hard and soft acids and bases - Pearson's concept, HSAB principle and its application. Non-aqueous solvents - general characteristics of non-aqueous solvent - melting point, boiling point, latent heat of fusion and vaporization, and dielectric constant. Reactions in non-aqueous solvents like liquid ammonia, liquid SO_2 and liquid HF - complex formation, redox, precipitation and acid base type.

UNIT 4: Chemical analysis and stoichiometric calculation

Titrimetry - fundamental concepts, theory of indicators. Acid base, redox, precipitation and complexometric titrations. Problems based on stoichiometry. Gravimetry principle and calculations involving estimation of barium, calcium and nickel. Data analysis, significant figures, precision and accuracy. Types of errors, mean and standard deviation.

UNIT 5: Functional groups and Nomenclature of organic compounds

Calculation of empirical and molecular formula, determination of molecular weights – physical and chemical methods. Classification and nomenclature of organic compounds. Structure, nomenclature, isomerism in alkanes, alkenes and alkynes. General methods of preparation of alkanes, alkenes and alkynes. Introduction to functional groups.

Recommended Readings

1. Atkins, P. and Overton, T., 2010. Shriver and Atkins' inorganic chemistry. Oxford University Press, USA.
2. Catherine E. H. and Alan G. S. 2012. Inorganic Chemistry (Fourth Edition), Pearson, UK.
3. Marion Clyde Day Jr, Joel Selbin, Harry H Sisler. 2012. Theoretical Inorganic Chemistry. LLC.
4. Vogel, A. I. and Jeffery, G.H. 2009. Vogel's Quantitative Chemical Analysis, 6th Ed. Wiley.
5. Solomons, T. G. and Fryhle, C. B., 2008. Organic chemistry. John Wiley & Sons.
6. F. A. Cotton and G. Wilkinson. 1987. Advanced Inorganic Chemistry, 5th edition, John Wiley and Sons, New York.

22CSA103	**Introduction to Scientific Computing using Python**	**3 0 1 4**

Prerequisites

The students should have studied any basic computer language as a prerequisite for the course.

Course Objectives

In this course students are introduced to use Python as a tool to solve Physics problems. The emphasis is to learn using a high level programming language without actually going through the logic behind the equations that are to be coded. A minimal understanding of the basic mathematics is assumed. This develops familiarity and equips them to code a large number of physics problems and learn how to obtain results and plots using the software.

UNIT 1: Introduction to Python Programming

History of Python Programming Language, thrust areas of Python in physics, Integrated Development Environments, installation and use of python distribution: Anaconda, Spyder, Jupiter notebooks.

Fundamental programming with Python: Designing a Program, identifiers, keywords, operators, and expressions. Arithmetic, Logical and Assignment operators, Precedence, Data types: Basic data types: Strings and numbers, displaying an output, type conversion, basic string operations& methods, format specifiers.

UNIT 2: Tuples, Lists & Dictionaries

Tuples: immutable sequences, creating tuple, basic tuple operations. **Lists:** mutable sequences, basic list operations, List methods Dictionaries: basic dictionary operations, dictionary method User input variable.

UNIT 3: Control structures

Decision Structures: If, If ----else, if ….elif…..else, nested if decision flow statements.

Repetition Structures: condition controlled: while loop. Count controlled: for loop, sentinals, continue and break statements, try and except statements

UNIT 4: Functions & Files

Built in function, modules, void function, flow charting, hierarchy charts, Local variables and scope, passing an argument function, value returning functions, Random number generation

Files: introduction to file input and output

UNIT 5: Scientific computing packages

Numpy: -Array object, creating array, matrix, indexing, slicing, resizing, reshaping, arithmetic operations, functions, matrices and vector operations Matplotlib: basic plotting, Scipy: Linear algebra operations, equation solving.

Text Book

1. Mark Lutz, "Learning Python" O'Reilly Media, 2013.

Reference Books

1. Robert Johansson, "Numerical Python: Scientific Computing and Data Science Applications with Numpy, SciPy and Matplotlib" Apress, 2019.
2. Rubin H. Landu, Manuel J. Paez, and Cristian C.Bordeianu, "Computational Physics Problem solving with Python" - Third Edition, Wiley VCH, 2015.

21ENG101	**Communicative English**	**2 0 2 3**

Objectives:

To help students obtain an ability to communicate fluently in English; to enable and enhance the student's skills in reading, writing, listening and speaking; to impart an aesthetic sense and enhance creativity

UNIT I

Kinds of sentences, usage of preposition, use of adjectives, adverbs for description, Tenses, Determiners- Agreement (Subject – Verb, Pronoun- Antecedent) collocation, Phrasal Verbs, Modifiers, Linkers/ Discourse Markers, Question Tags

UNIT 2

Paragraph writing – Cohesion - Development: definition, comparison, classification, contrast, cause and effect - Essay writing: Descriptive and Narrative

UNIT 3

Letter Writing - Personal (congratulation, invitation, felicitation, gratitude, condolence etc.) Official (Principal / Head of the department/ College authorities, Bank Manager, Editors of newspapers and magazines)

UNIT 4

Reading Comprehension – Skimming and scanning- inference and deduction – Reading different kinds of material –Speaking: Narration of incidents / stories/ anecdotes- Current News Awareness

UNIT 5

Prose: John Halt's 'Three Kinds of Discipline' [Detailed]
Max Beerbohm's 'The Golden Drugget' [Detailed]
Poems: Ogden Nash- 'This is Going to Hurt Just a Little Bit' [Detailed]
Robert Kroetsch– 'I am Getting Old Now', Langston Hughes- 'I, Too' [Detailed]
Wole Soyinka- 'Telephone Conversation' [Non- Detailed]
Kamala Das- 'The Dance of the Eunuchs' [Non-Detailed]
Short Stories: Edgar Allan Poe's 'The Black Cat', Ruskin Bond's 'The Time Stops at Shamili' [Non- Detailed]

CORE READING:

1. Ruskin Bond, Time Stops at Shamli and Other Stories, Penguin Books India Pvt Ltd, 1989
2. Syamala, V. Speak English in Four Easy Steps, Improve English Foundation Trivandrum: 2006
3. Beerbohm, Max, The Prince of Minor Writers: The Selected Essays of Max Beerbohm (NYRB Classics), Phillip Lopate (Introduction, Editor), The New York Review of Book Publishers.
4. Edger Allan Poe. The Selected Works of Edger Allan Poe. A Running Press, 2014.
5. Online sources

References:

1. Ruskin Bond, Time Stops at Shamli and Other Stories, Penguin Books India Pvt Ltd, 1989
2. Martinet, Thomson, A Practical English Grammar, IV Ed. OUP, 1986.
3. Murphy, Raymond, Murphy's English Grammar, CUP, 2004
4. Online sources

21CUL101	**Cultural Education I**	**2 0 0 2**

UNIT 1

Introduction to Indian Culture - Introduction to Amma's life and Teachings – Symbols of Indian Culture.

UNIT 2

Science and Technology in Ancient India - Education in Ancient India - Goals of Life – Purusharthas - Introduction to Vedanta and Bhagavad Gita.

UNIT 3

Introduction to Yoga - Nature and Indian Culture - Values from Indian History – Life and work of Great Seers of India.

TEXTBOOKS:

1. The Glory of India (in-house publication)
2. The Mother of Sweet Bliss, (Amma's Life & Teachings)

Course Code	**Course Title**	**L T P**	**Cr**	**ES**
	SEMESTER 2			
22MAT117	Multivariable calculus	3 1 0	4	
22BIO111	Cellular and Molecular Biology	2 1 0	3	
22PHY111	Basics of Electricity and Magnetism	3 1 0	4	
22CHY112	Principles of Physical Chemistry	3 1 0	4	
22PHY184	Physics Lab I – Mechanics, Electricity & Magnetism	0 0 2	1	
22CHY183	Chemistry Lab I	0 0 2	1	
21ENG111	Professional Communication	1 0 2	2	

21CUL111	Cultural Education II	2 0 0	2	
22AVP103	Mastery Over Mind	1 0 2	2	
TOTAL			**23**	

22MAT117	Multivariable Calculus	3 1 0 4

UNIT 1

Matrices: Matrix, Algebraic operations, Transpose of a matrix, Inverse of a matrix, Properties of matrices, Kinds of matrices: Symmetric and skew symmetric matrices, Hermitian and skew Hermitian matrices, Orthogonal and unitary matrices, Determinant of a matrix, Properties of determinants.

UNIT 2

Systems of Linear Equations: Linear System of Equations, Gauss Elimination, Consistency of a linear system of equations.

UNIT 3

Eigen value problems: Eigen values, Eigen vectors, Properties of Eigen values and Eigen vectors, Cayley-Hamilton theorem, Some Applications of Eigen value Problems, Similarity of Matrices, Diagonalization of a matrix, Quadratic forms and Canonical form of a quadratic form.

UNIT 4

Vector differentiation: Limit of a vector function – continuity and derivative of vector function - Geometrical and Physical significance of vector differentiation - Partial derivative of vector function – gradient and directional derivative of scalar point functions – Equations of tangent plane and normal line to a level surface. Divergence and curl of a vector point function – solenoid and irrational functions – physical interpretation of divergence and curl of a vector point function.

UNIT 5

Integration of vector functions – Line, surface and volume integrals. Gauss - Divergence Theorem – Green's Theorem – Stoke's Theorem (Statements only). Verification of theorems and simple problems.

TEXT BOOKS

1. 'Advanced Engineering Mathematics', Erwin Kreyszig, John Wiley and Sons, 2002, 8th Edition.
2. Textbook of Matrix Algebra, Suddhendu Biswas, PHI, 2012.
3. Vector Calculus with Applications to Physics, Shaw James Byrnie - 2009
4. T. K. Manickavasakam Pillay, Vector Calculus, 2004.

22BIO111	Cellular and Molecular Biology	2 1 0 3

UNIT 1: Biomolecules

Structure, function and interrelationships between all-important biomolecules (like proteins, carbohydrates, nucleic acids and lipids) that collectively carry out the essential functions of life.

UNIT 2: Cell structure, organelles and cell division

Introduction to cell biology. Classification of living organisms. Prokaryotic cells, eukaryotic cells. Structure and function of cytoplasm, nucleus, mitochondria, ribosomes, endoplasmic reticulum, rough endoplasmic reticulum, lysosomes, the Golgi complex, peroxisomes, vacuoles. Plant cell organelles, cytoskeletal elements and architecture, cell division and cell cycle.

UNIT 3: Membrane structure and function

Membrane structure and function. Structure and composition of the cell membrane, membrane proteins, transport across the cell membrane.

UNIT 4: Molecular biology

Genes and chromosomes, chromosomal elements, DNA as genetic material. Structure of chromosome, histones and nucleosomes. DNA replication - semi-conservative replication, DNA polymerases, events at the replication form, replication of the lagging strand, telomeres, consequences of defects in telomerase. Replication of genomes - origins of replication, control of DNA replication.

UNIT 5: Molecular genetics

Gene expression - promoters, terminators. Transcriptional initiation, elongation and termination, RNA polymerases, the genetic code, codons and anticodons, the ribosome and translation. Gene mutations - missense versus nonsense mutations, insertions, deletions and frameshifts. Genetic reversion and suppression, spontaneous mutations and effects of environmental factors. Principles of genetic engineering - gene cloning and genomics. Perspectives in genetic engineering - applications, moral and ethical issues.

Recommended Readings

1. David L Nelson, and Michael M Cox et al., Lehninger principles of biochemistry W H Freeman; 7th edition, (2017).
2. Bruce Alberts et al., Essential Cell Biology; Richard Goldsby and Thomas J, & F Garland, 4th Edition, (2014).
3. Alberts, Bruce. Molecular Biology of the Cell, Garland Science; 5th edition (2008).

22PHY111	Basics of Electricity and Magnetism	3 1 0 4

Prerequisites: Nil

Course Objectives

Having successfully completed this module, the student will be able to demonstrate knowledge and understanding of: Vector algebra and vector calculus from the perspective of electrodynamics, Coulomb's law, Superposition principle, Concept of electric field, Potential formalism and its importance, working of capacitors and RC circuits, Magnetic fields and their origin, Ohm's law, Faraday's law, Lenz's law and working of LC, LR, LCR circuits.

Course Outcomes

At the end of the course students will be able to

CO1. Apply vector algebra, vector calculus and orthogonal curvilinear coordinates to solve problems

CO2. Understand electric field, electric potential concepts to solve problems in electrostatics

CO3. Acquire knowledge in magnetostatics in order to calculate magnetic field for different current distributions

CO4. Understand electrodynamics and working of LC, LR and LCR circuits

Skills: Students will be able to improve their basic understanding of electricity and magnetism subject by solving problems on various topics in electrostatics, magnetostatics and electrodynamics which are given as assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	

UNIT 1: Vector analysis

Learning Objectives

1. Apply vector algebra, vector calculus both differentiation and integration to solve problems.
2. Discuss orthogonal curvilinear co-ordinates such as spherical polar and cylindrical coordinates and their use in solving problems related to electrostatics and magnetostatics.
3. Outline the importance of Dirac-Delta function.

Review of vectors, Dot products, Cross products, and Triple products. Differential calculus: Gradient, Divergence, Curl, Second derivatives, Integral calculus: Fundamental theorem of calculus, Fundamental theorem of gradient, Fundamental theorem of divergence, Fundamental theorem of curls, Curvilinear coordinates: Spherical coordinates, Cylindrical coordinates. Dirac delta function.

UNIT 2: Electrostatics

Learning Objectives

1. Recognize electric field concept, coulomb's law and superposition principle in electrostatics.
2. Calculate electric field due to discrete and continuous charge distributions**.**
3. Apply Gauss's law to solve problems in electrostatics.

Coulomb's law. Superposition principle. Electric field – discrete and continuous distribution, Gauss's law, Applications of Gauss's law.

UNIT 3: Electric Potential

Learning Objectives

1. Explain electric potential and calculate potential for different charge distributions.
2. Apply the concept of electric potential to calculate work done in assembling point charges and continuous charge distributions.
3. Recognize the basic properties of conductors and calculate the capacitance of different capacitors.
4. Understand charging and discharging of RC circuits.

The curl of electric field, Electric potential, meaning of electric potential, Equipotential surfaces, Potential of localized charge distribution, Work and energy in electrostatics, Energy of a point charge distribution, Energy of continuous charge distribution, Conductors and Capacitors, Charging and discharging of RC Circuit.

UNIT 4: Magnetostatics

Learning Objectives

Explain the origin of magnetic field and magnetic forces.
Calculate Magnetic field due to current source employing Biot-Savart law.
Apply Ampere's law to solve problems in magnetostatics.

Magnetic fields, Magnetic forces, Currents, Biot-Savart law, Divergence and Curl of magnetic field, Ampere's law and its applications.

UNIT 4: Electrodynamics

Learning Objectives

Explain electromotive force and Faraday's laws of electromagnetic induction.
Analyze charge-discharge characteristics of simple LC, LR and LCR circuits.

Ohm's law, EMF, Motional EMF. Electromagnetic induction: Faraday's law, Lenz's law, induced electric field, Maxwell's correction to Ampere's law, Examples of LC, LR, LCR circuits.

Text Books

1. Introduction to Electrodynamics – David J. Griffiths, 4th edition, Pearson Publication, 2015.
2. David Halliday, Robert Resnick, and Jearl Walker, Fundamentals of physics, 9th Edition, John Wiley, 2012.

Reference books

1. Richard P. Feynman, Robert P. Leighton and Matthew Sands, Feynman Lectures on Physics Vol.1, 1E, Narosa Publishing House, 2008.
2. Lectures by Prof. Dipan Ghosh on "Electromagnetic Theory" - https://nptel.ac.in/courses/115/101/115101005/
3. Lectures by Prof. Walter Lewin on Electricity and Magnetism - https://www.youtube.com/watch?v=x1-SibwIPM4&list=PLyQSN7X0ro2314mKyUiOILaOC2hk6Pc3j&index=2

Evaluation Pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

CO-PO Justification

Mapping	Justification	Affinity level
CO1-CO4 to PO1 and PSO 1	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very strong affinity to PO1 and PSO 1, which is about building fundamentals in science, and create inquisitiveness and problem solving in scientific way. Hence the affinity level is maximum.	3
CO1-CO4-PO2 and PSO2	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO2 and PSO2, which is about building analytical thinking, which is a core skill in scientific investigation. Hence the affinity level is maximum.	3
CO1-CO4 – PO3	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO3, which is about undertaking complex problems and to design and develop solutions which enhance the existing scientific knowledge. Hence the affinity level is maximum.	3

22CHY112	**Principles of Physical Chemistry**	**3 1 0 4**

UNIT 1: Gaseous state

Review of empirical gas laws. Kinetic theory of gases, ideal gas equation, Maxwell distribution of energy and velocities, collision parameters. Relation between mean free path and coefficient of viscosity. van der Waals equation, other state equations, law of corresponding states, liquefaction, Andrews curves, critical parameters, methods for liquefaction. Determination of molecular mass by limiting density method, critical phenomena, critical constants and their determination.

UNIT 2: Thermodynamics – I

Thermodynamic processes - reversible and irreversible, isothermal and adiabatic processes. State and path functions. Exact and inexact differentials, concept of heat and work. First law of thermodynamics. Relation between Cp and Cv. Calculation of w, q, dE and dH for expansion of ideal and real gases under isothermal and adiabatic conditions of reversible and irreversible processes.

Thermochemistry - Enthalpy change of a reaction and different enthalpy changes - relation between enthalpy of reaction at constant volume and at constant pressure. Temperature dependence of heat of reaction - Kirchhoff's equation. Bond energy and its calculation from thermochemical data - integral and differential heats.

UNIT 3: Thermodynamics-II

Second law of thermodynamics - different statements of the law, Carnot's cycle and efficiency of heat engine, Carnot's theorem. Thermodynamic scale of temperature - concept of entropy - definition and physical significance of entropy - entropy as a function of P, V and T. Entropy changes during phase changes, entropy of mixing. Entropy criterion for spontaneous and equilibrium processes in isolated system, Gibb's free energy (G) and Helmholtz free energy (A) - variation of A and G with P, V and T – Gibb's - Helmholtz equation and its applications. Thermodynamic equation of state – Maxwell's relations.

UNIT 4: Thermodynamics – III

Third law of thermodynamics - need for third law, calculation of absolute entropy, unattainability of absolute zero, thermodynamic systems of variable composition. Fugacity functions, partial molar quantities, thermodynamics of ideal solutions, real solutions and regular solutions, dilute solutions of nonelectrolytes, Henry's law, Raoult's law, Gibbs-Duhem equations, Gibbs-Duhem-Margules equations, and activity and standard states of non-electrolytes.

UNIT 5: Chemical Kinetics

Molecularity and order of a reaction, rate law expression and rate constant. First, second, third and zero order reactions, pseudo-first order reactions (pseudo-unimolecular reactions). Complex, parallel, chain, opposing and consecutive reactions. Equilibrium and steady state approximations - mechanism of these reactions. Effect of temperature on reaction rates - Arrhenius equation and its derivation, activation energy, characteristics of activated complex. Theories of reaction rates – collision theory – derivation of rate constant of bimolecular gases reaction – failure of collision theory – Lindemann's theory of unimolecular reaction. Theory of absolute reaction rates – derivation of rate for a bimolecular reaction. Eyring equation – significance of entropy and free energy of activation.

Recommended readings

1. Atkins, P., Atkins, P.W. and de Paula, J., 2006. Atkins' physical chemistry. Oxford university press.
2. Gilbert William Castellan. 1983. Physical Chemistry, Addison Wesley; 3rd revised edition.
3. Ira Levin, 'Physical Chemistry', 6th edition, Tata Mcgraw-Hill Education, 2011.
4. Samuel Glasstone, Textbook of Physical Chemistry, Macmillan; 2nd edition.
5. Keith J Laidler, Chemical Kinetics, Pearson Publications, Third edition, 2003.
6. James E House, Principles of Chemical Kinetics, Second Edition, Academic Press, 2007.
5. Silbey, Alberty and Bawendi, Physical Chemistry, Fourth Edition, John Wiley and Sons.

22PHY184	Physics Lab I - Mechanics, Electricity & Magnetism	0 0 2 1

1. Determination of acceleration due to gravity using bar pendulum.
2. Determination of Young's Modulus of a given bar by Uniform bending method.
3. Determination of Rigidity modulus of the given wire using Torsional pendulum.
4. Determination of Coefficient of viscosity of a given liquid by Poiseulle's method.
5. Studying the liquid flow through series and parallel combinations of capillaries.
6. Melde's String-Verification of laws of vibration.

7. Studies on different exciting modes of sonometer wire.
8. Determination of spring constant of the given spring
9. Determination of velocity of sound in air using Kundt's tube apparatus.
10. Determination of surface tension of the given liquid.
11. Study of collision parameters in two dimension.
12. Studying magnetic field along the axis of the coil-verification of superposition principle of magnetic field.
13. Mapping of electric field.
14. Study of Mutual inductance
15. Deducing the magnetic properties of a sample from its Hysteresis curve on CRO

22CHY183	**Chemistry Lab I**	**0 0 2 1**

1. Conductometric estimation of weak and strong acids in a mixture
2. Determination of the rate constant of acid catalysed hydrolysis of ethyl acetate
3. Polarimetric determination of the rate of inversion of sugar
4. Spectrophotometric estimation of iron in a water sample
5. Determination of calorific value of fuels by bomb calorimetry
6. Construction of isotherms for acetic acid adsorption on activated charcoal
7. Determination of critical solution temperature for phenol water system and effect of ionic electrolytes
8. Determination of molecular weight by Rast's method-colligative properties
9. Determination of partition coefficient of iodine in CCl4-water mixture
10. Determination of molecular weight of coordination complex by partition coefficient method.
11. Determination of average molecular weight of a polymer by viscosity measurements
12. Effect of current density on the thickness of anodised aluminium films
13. pH metric estimation of strong acids

Recommended Readings

1. Das. R.C. and Behara. B., 1983. 'Experiments in Physical Chemistry', Tata McGraw-Hill.
2. Findly. A., 1972.' Practical Physical Chemistry', 9th edition, Wiley.
3. Yadav, J.B.2010. 'Advanced Practical Physical Chemistry', Krishna Prakashan Media, 29th Ed.

21ENG111	**Professional Communication**	**1 0 2 2**

Objectives:

To convey and document information in a formal environment; to acquire the skill of self-projection in professional circles; to inculcate critical and analytical thinking.

UNIT 1

Vocabulary Building: Prefixes and Suffixes; One word substitutes, Modal auxiliaries, Error Analysis: Position of Adverbs, Redundancy, misplaced modifiers, Dangling modifiers – Reported Speech

UNIT 2

Instruction, Suggestion & Recommendation - Sounds of English: Stress, Intonation - Essay writing: Analytical and Argumentative

UNIT 3

Circulars, Memos – Business Letters - e - mails

UNIT 4

Reports: Trip report, incident report, event report - Situational Dialogue - Group Discussion

UNIT 5

Listening and Reading Practice - Book Review

References

1. FelixaEskey. Tech Talk, University of Michigan. 2005.
2. Michael Swan. Practical English Usage, Oxford University Press. 2005.
3. Anderson, Paul. Technical Communication: A Reader Centered Approach, V Edition, Hercourt, 2003.
4. Raymond V. Lesikar and Marie E. Flatley. Basic Business Communication, Tata Mc Graw Hill Pub. Co. New Delhi. 2005. Tenth Edition.
5. Thampi, G. Balamohan. Meeting the World: Writings on Contemporary Issues. Pearson, 2013.
6. Lynch, Tony. Study Listening. New Delhi: CUP, 2008.
7. Kenneth, Anderson, Tony Lynch, Joan Mac Lean. Study Speaking. New Delhi: CUP, 2008.
8. Marks, Jonathan. English Pronunciation in Use. New Delhi: CUP, 2007.
9. Syamala, V. Effective English Communication For You (Functional Grammar, Oral and Written Commnication): Emerald, 2002.

21CUL111	**Cultural Education II**	**2 0 0 2**

UNIT 1

1. Relevance of Sri Rama and Sri Krishna in this Scientific Age
2. Lessons from the Epics of India
3. Ramayana & Mahabharata

UNIT 2

4. Who is a Wise Man?
5. A Ruler’s Dharma
6. The Story of King Shibi

UNIT 3

7. Introduction to the Bhagavad Gita

8. Bhagavad Gita – Action without Desire

UNIT 4
9. Role and Position of Women in India
10. The Awakening of Universal Motherhood

UNIT 5
11. Patanjali's Astanga - Yoga System for Personality Refinement
12. Examples of Heroism and Patriotism in Modern India

TEXT BOOKS
Common Resource Material II (in-house publication)
Sanatana Dharma - The Eternal Truth (A compilation of Amma's teachings on Indian Culture)

22AVP103	Mastery over Mind	1 0 2 2

1. Course Overview
Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organise university-wide programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of our efforts for sustainable stress reduction -gives an introduction to immediate and long-term benefits and equips every attendee to manage stressful emotions and anxiety facilitating inner peace and harmony. With a meditation technique offered by Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi (Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will enhance the understanding of experiential learning based on university's mission: "Education for Life along with Education for Living", and is aimed to allow learners to realize and rediscover the infinite potential of one's true Being and the fulfilment of life's goals.

2. Course Syllabus

UNIT 1 (4 hours)
Causes of Stress: The problem of not being relaxed. Need for meditation -basics of stress management at home and workplace. Traditions and Culture. Principles of meditation– promote a sense of control and autonomy in the Universal Human Value System. Different stages of Meditation. Various Meditation Models. Various practices of Meditation techniques in different schools of philosophy and Indian Knowledge System.

UNIT 2 (4 hours)
Improving work and study performance. Meditation in daily life. Cultivating compassion and good mental health with an attitude of openness and acceptance. Research and Science of Meditation: Significance of practising meditation and perspectives from diverse fields like science, medicine, technology. Philosophy, culture, arts, management, sports, economics, healthcare, environment etc. The role of meditation for stress and anxiety reduction in one's life with insights based on recent cutting-edge technology. The effect of practicing meditation for the wholesome wellbeing of an individual.

UNIT 3 (4 hours)

Communications: principles of conscious communication. Relationships and empathy: meditative approach in managing and maintaining better relationships in life during the interactions in the world, role of MAOM in developing compassion, empathy and responsibility, instilling interest, and orientation to humanitarian projects as a key to harness intelligence and compassion in youth. Methodologies to evaluate effective awareness and relaxation gained from meditation. Evaluating the global transformation through meditation by instilling human values which leads to service learning and compassion driven research.

TEXT BOOKS:

1. Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019
2. Swami Amritaswarupananda Puri," The Color of Rainbow "published by MAM, Amritapuri.

REFERENCES:

1. Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019
2. R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986
3. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019
4. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018
5. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.
6. Mata Amritanandamayi Devi "Compassion: The only way to Peace: Paris Speech", MA Center, April 2016.
7. Mata Amritanandamayi Devi "Understanding and collaboration between Religions", MA Center, April 2016.
8. Mata Amritanandamayi Devi "Awakening of Universal Motherhood: Geneva Speech" M A center, April 2016.

Course Code	Course Title	L T P	Cr	ES
SEMESTER 3				
22CHY204	Physical Organic Chemistry	3 1 0	4	
22PHY201	Waves, Oscillations & Ray optics	3 1 0	4	
22PHY202	Introduction to Mathematical Physics	3 1 0	4	
21SSK201	Life skills I	1 0 2	2	
21ENV200	Environmental Science and Sustainability	3 0 0	3	
22CHY283	Chemistry Lab II	0 0 2	1	
22PHY281	Physics Lab II - Optics	0 0 2	1	

22CSA281	Programming Lab I	0 0 2	1	
21AVP201	Amrita Value Programme I	1 0 0	1	
TOTAL			**21**	

22CHY204	**Physical Organic Chemistry**	**3 1 0 4**

Prerequisite: None, but this course is a prerequisite for Principles of Organic Chemistry, Organic Synthesis I and II.

UNIT 1: Basic concepts

Acids and Bases – Acidity - pKa, basicity. Factors influencing acidity and basicity, HSAB principle. Electron displacement effects – resonance, inductive, electromeric, mesomeric and hyper conjugative effects. Reactive intermediates - generation, structure and reactivity reactions and rearrangement involving of carbocations, non-classical carbocations, carbanions, carbon radicals, radical ions, carbenes, nitrenes, isonitrenes, arynes and Bunte salt.

UNIT 2: Aromaticity

Criteria for aromaticity – energy, structural and electronic criteria for aromaticity – relationship among them. Aromatic, antiaromatic and homoaromatic compounds. Aromaticity in annulenes, polycyclic compounds, charged rings - aromatic cations and anions, fused rings. Heteroaromatic systems.

UNIT 3: Strain and Stability

Thermochemistry of stable molecules - thermochemistry of reactive intermediates. Relationships between structure and energetics. Electronic effects, highly-strained molecules, long bonds, small rings, large rotation barrier and molecular mechanics.

UNIT 4: Energy Surfaces and Kinetic Analyses

Reaction coordinate diagram, activated complex, transition state theory, Arrhenius rate law. Boltzmann distributions, activation parameters, Hammond postulate, Curtin-Hammett principle, microscopic reversibility. Kinetic vs. thermodynamic control, kinetic experiments. Baldwin rules. Kinetic analysis of simple and complex mechanisms, steady state and saturation kinetics, methods to follow kinetics, calculating rate constants, Marcus theory and multiple reaction coordinates.

UNIT 5: Linear free energy relationship

Isotope effects, substituent effects, linear free energy relationship (LFER), Hammet plots, steric and polar effects – Taft parameters. Solvent effects-Grunwald-Weinstein plots, Schleyer adaptation, acid base effects and conditions to create LFER.

Recommended Reading

1. Modern Physical Organic Chemistry: E. Anslyn and D.A. Dougherty (2006) 1st edition, University Science Books.
2. Organic Chemistry: J. Clayden, N. Greeves, S. Warren and P. Wothers (2012) 2nd edition, Oxford University Press.
3. Advanced Organic Chemistry: Part A: Structure and Mechanism: R.J. Sundberg and F.A. Carey (2007) 5th edition, Kluwer/Plenum Press.
4. Physical Organic Chemistry: N. Isaacs (1995) 2nd edition, Addison-Wesley-Longman.
5. March's Advanced Organic Chemistry: M. Smith and J. March, 6th edition, Wiley-Interscience.

22PHY201	**Waves, Oscillations and Ray optics**	**3 1 0 4**

Prerequisites: Higher secondary level Mathematics, Optics and Electricity and Magnetism

Course Objective: This course is framed to provide in depth knowledge of waves, oscillations, ray optics and their applications in physical world.

Course Outcomes

At the end of the course students will be able to

CO 1: Understand the phenomenon of free oscillations in one and two degrees of freedom and their applications

CO 2: Understand and analyze the modes of vibrations in continuous and non-continuous systems and their applications

CO 3: Understand and analyze phenomenon of forced, damped driven and harmonic oscillations.

CO 4: Apply Fourier techniques to analyze the characteristic of group velocity, pulse and travelling waves.

CO 5: Understand the phenomenon of ray optics and its usage in optical components.

Skills: Problems solving in oscillations, waves and ray optics towards improving the analytical skills of students.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	
CO5	3	3	3			3	3	

UNIT 1

Learning objectives

Review of free oscillations of 1D harmonic oscillator. The physical aspects of inertia and return force, physical meaning of ω^2 are emphasized. Free oscillations of two coupled oscillators is considered and concept of normal mode is introduced.

Free oscillations of simple systems: Free oscillations of systems with one degree of freedom, linearity and superposition principle, free oscillations of systems with two degree of freedom, Beats

UNIT 2

Learning objectives

The number of degrees of freedom is increased from two to very large number and find transverse modes, standing waves of a continuous string. The concept of dispersion relation is introduced. The Fourier analysis of periodic functions is introduced using the modes of string.

Free oscillations of systems with many degrees of freedom: Transverse mode of continuous string, General mode of continuous string and Fourier analysis. Modes of non-continuous system with N degrees of freedom.

UNIT 3

Learning objectives

Forced oscillations in closed and open systems where resonances and travelling waves respectively can be found will be studied. Transient behavior of 1D damped oscillator will be reviewed.

Forced oscillations: Damped driven one dimensional Harmonic oscillator, Resonance in a system with two degrees of freedom, filters, forced oscillations of closed systems with many degrees of freedom.

Travelling wave: Harmonic travelling waves in one dimension and phase velocities.

UNIT 4

Learning objectives

Superpositions involving different frequencies to form pulses and wave packets will be discussed. The concepts of Fourier analysis will be extended to non-periodic functions.

Modulation, Pulse and wave packets: Group velocity, Pulse, Fourier analysis of pulses, Fourier analysis of travelling wave packets.

UNIT 5

Learning objectives

To understand behavior of light rays travelling in free space and incident on reflective surfaces and refractive index discontinuities. To trace rays through optical systems involving such features. To understand the concept of ABCD matrices. To understand Fermat’s principle, and its application for laws of reflection and refraction.

Geometrical optics: Fermat's principle - Laws of reflection and refraction. Images formed by plane mirror, spherical mirror, spherical refracting surfaces, thin lens, system of thin lens, Lens aberrations, matrix methods in optics, determining Cardinal points, optical instruments.

Text books:

1. Frank S. Crawford, Jr., Waves, Berkeley Physics Course, Vol. 3, McGraw-Hill Book Company.
2. Hecht, Eugene, Optics, 2nd Ed, Addison Wesley, 1987.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	

*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO 5 to PO1 and PSO 1	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very strong affinity to PO1 and PSO 1, which is about building fundamentals in science, and create inquisitiveness and problem solving in scientific way.	3
CO1-CO5-PO2 and PSO 2	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO2 and PSO 2, which is about building analytical thinking, which is a core skill in scientific investigation.	3
CO1-CO5 – PO3	This course is a fundamental course with objective of building strong core fundamentals; hence, all the course outcomes have very high affinity to PO2 and PSO 2, which is about developing a research culture	3

22PHY202	Introduction to Mathematical Physics	3 1 0 4

Course Objectives:

The objective of this course is to introduce the student to the two important transforms – the Fourier and Laplace transforms. Properties of the transforms, series, complex forms are introduced. The uses of these transforms in the solution of partial differential equations are also taught to the students. This course is intended to lay a mathematical foundation to other theoretical courses such as quantum mechanics and act as a primer to a student who opts to take up a higher course in physics.

Pre-requisites:

Since this is an undergraduate level course, the student is expected to be familiar with basic differential and integral calculus only.

UNIT 1: Fourier analysis:

Periodic Functions, Trigonometric Series, Fourier Series, Functions of any Period p = 2L, Even and Odd Functions, Half Range Expansions (theorem statement only), Complex Fourier Series, Applications of Parseval's Identity.

UNIT 2:

Fourier Integrals, Sine and Cosine Integrals, Fourier Transforms - Sine and Cosine Transforms, Properties, Convolution Theorem, diffraction theory- Fourier method.

UNIT 3: Laplace Transforms:

Laplace Transforms, Inverse Transforms, Properties, Transforms of Derivatives and Integrals, Second Shifting Theorem, Unit Step Function and Dirac-Delta Function,

UNIT 4:
Differentiation and Integration of Transforms, Convolution, Initial and Final Value Theorems, Periodic Functions, Solving Linear Ordinary Differential Equations with Constant Coefficients, System of Differential Equations and Integral Equations.

UNIT 1: Partial Differential Equations:
Basic Concepts, Modelling; Vibrating String, Wave Equation, Separation of Variables, Use of Fourier Series, D'Alembert's Solution of the Wave Equation, Heat Equation; Solution by Fourier Series.

Text Books:

1. E Kreyszig, Advanced Engineering Mathematics, 10^{th} Ed., John Wiley and Sons, 2015.
2. P. P. G. Dyke,An Introduction to Laplace Transforms and Fourier series, 2^{nd} Ed.,Springer, 2014.
3. Larry C. Andrews and Bhimson, K. Shivamoggi, The Integral Transforms for Engineers,Prentice Hall India Learning Private Limited, 2003.

21SSK201	**Life skills I**	**1 0 2 2**

Soft skills and its importance: Pleasure and pains of transition from an academic environment to work-environment. Need for change. Fears, stress and competition in the professional world. Importance of positive attitude, self-motivation and continuous knowledge upgradation.

Self Confidence: Characteristics of the person perceived, characteristics of the situation, Characteristics of the Perceiver. Attitude, Values, Motivation, Emotion Management, steps to like yourself, Positive Mental Attitude, Assertiveness.

Presentations: Preparations, Outlining, Hints for efficient practice, Last minute tasks, means of effective presentation, language, Gestures, Posture, Facial expressions, Professional attire.

Vocabulary building: A brief introduction into the methods and practices of learning vocabulary. Learning how to face questions on antonyms, synonyms, spelling error, analogy etc. Faulty comparison, wrong form of words and confused words like understanding the nuances of spelling changes and wrong use of words.

Listening Skills: The importance of listening in communication and how to listen actively.
Prepositions and Articles: A experiential method of learning the uses of articles and prepositions in sentences is provided.

Problem solving: Number System; LCM &HCF; Divisibility Test; Surds and Indices; Logarithms; Ratio, Proportions and Variations; Partnership; Time speed and distance; work time problems;
Data Interpretation: Numerical Data Tables; Line Graphs; Bar Charts and Pie charts; Caselet Forms; Mix Diagrams; Geometrical Diagrams and other forms of Data Representation.

Logical Reasoning: Family Tree; Linear Arrangements; Circular and Complex Arrangement; Conditionalities and Grouping; Sequencing and Scheduling; Selections; Networks; Codes; Cubes; Venn Diagram in Logical Reasoning.

TEXT BOOKS:

1. A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.
2. Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.
3. Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa& Co.
4. The Hard Truth about Soft Skills, by Amazone Publication.

REFERENCES:

1. Quantitative Aptitude, by R S Aggarwal, S Chand Publ.
2. Verbal and Non-verbal Reasoning, R S Aggarwal, S Chand Publ.
3. Data Interpretation, R S Aggarwal, S Chand Publ.
4. Nova GRE, KAPAL GRE, Barrons GRE books;
5. Quantitative Aptitude, The Institute of Chartered Accountants of India.
6. More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.
7. The BBC and British Council online resources
8. Owl Purdue University online teaching resources
9. www.thegrammarbook.com online teaching resources
10. www.englishpage.com online teaching resources and other useful websites.

21ENV200	Environmental Science and Sustainability	3 0 0 3

UNIT 1

State of Environment and Unsustainability, need for Sustainable Development, Traditional conservation systems in India, People in Environment, Need for an attitudinal change and ethics, Need for Environmental Education, Overview of International Treaties and Conventions, Overview of Legal and Regulatory Frameworks.

Environment: Abiotic and biotic factors, Segments of the Environment, Biogeochemical Cycles, Ecosystems (associations, community adaptations, ecological succession, Food webs, Food chain, ecological pyramids), Types of Ecosystems – Terrestrial ecosystems, Ecosystem Services, Economic value of ecosystem services, Threats to ecosystems and conservation strategies.

Biodiversity: Species, Genetic & Ecosystem Diversity, Origin of life and significance of biodiversity, Value of Biodiversity, Biodiversity at Global, National and Local Levels, India as a Mega-Diversity Nation (Hotspots) & Protected Area Network, Community Biodiversity Registers. Threats to Biodiversity, Red Data book, Rare, Endangered and Endemic Species of India. Conservation of Biodiversity. People’s action.

Impacts, causes, effects, control measures, international, legal and regulatory frameworks of: Climate Change, Ozone depletion, Air pollution, Water pollution, Noise pollution, Soil/ land degradation/ pollution

UNIT 2

Linear vs. cyclical resource management systems, need for systems thinking and design of cyclical systems, circular economy, industrial ecology, green technology. Specifically apply these concepts to: Water Resources, Energy Resources, Food Resources, Land & Forests, Waste management. Discuss the interrelation of environmental issues with social issues such as: Population, Illiteracy, Poverty, Gender equality, Class discrimination, Social impacts of development on the poor and tribal communities, Conservation movements: people’s movements and activism, Indigenous knowledge systems and traditions of conservation.

UNIT 3

Common goods and public goods, natural capital/ tragedy of commons, Cost benefit analysis of development projects, Environment Impact Assessment (EIA), Environment Management Plan (EMP), Green business, Eco-labelling, Problems and solutions with case studies.

Global and national state of housing and shelter, Urbanization, Effects of unplanned development case studies, Impacts of the building and road construction industry on the environment, Eco-homes/ Green buildings, Sustainable communities, Sustainable Cities.

Ethical issues related to resource consumption, Intergenerational ethics, Need for investigation and resolution of the root cause of unsustainability, Traditional value systems of India, Significance of holistic value-based education for true sustainability.

TEXTBOOKS/ REFERENCES:

1. R. Rajagopalan, Environmental Studies: From Crisis to Cure. Oxford University Press, 2011, 358 pages. ISBN: 9780198072089.
2. Daniel D. Chiras, Environmental Science. Jones & Bartlett Publishers, 01-Feb-2012, 669 pages. ISBN: 9781449645311.
3. Andy Jones, Michel Pimbert and Janice Jiggins, 2011. Virtuous Circles: Values, Systems, Sustainability. IIED and IUCN CEESP, London. URL:http://pubs.iied.org/pdfs/G03177.pdf
4. Annenberg Learner, The Habitable Planet, Annenberg Foundation 2015. URL: http://www.learner.org/courses/envsci/unit/pdfs/textbook.pdf.

22CHY283	Chemistry Lab II	0 0 2 1

Part A

1. Estimation of equivalent weight of an acid
2. Estimation of glucose
3. Estimation of phenol and aniline
4. Estimation of acetone
5. Estimation of acid value of an oil
6. Estimation of iodine value and sap value of an oil
7. Estimation of Nitrogen – Kjeldahl method
8. Estimation of formaldehyde
9. Estimation of ester

Part B

1. Estimation of sodium hydroxide and sodium carbonate in a mixture by double indicator method.
2. Estimation of calcium permanganometry
3. Estimation of Ferrous iron permanganometry
4. Estimation of ferrous iron using external and internal indicators.
5. Estimation of ferric iron using external and internal indicators.
6. Estimation of copper sulphate by iodometry titration
7. Estimation of iron in the given sample of haematite
8. Gravimetric estimation of barium as barium sulphate.
9. Gravimetric estimation of sulphate as barium sulphate.
10. Gravimetric estimation of copper as copper (I) thiocyanate.
11. Gravimetric estimation of nickel as nickel dimethyglyoximate.

Recommended Readings

1. Mann F. G., and Saunders, B. C.2009. 'Practical Organic Chemistry' 4th edition, Pearson Education.
2. Ahluwalia V. K. and Dhingra. S. 2000. 'Comprehensive Practical Organic Chemistry' Universities Press.
3. Furnis, B. S., Hannaford, A. J., Smith P. W. G. and Tatchell, T. R.1989. 'Vogel's Textbook of Practical Organic Chemistry', ELBS/Longman.
4. Vogel, A. I. 1985. 'A Textbook of Qualitative Analyses', 4th edition, Longmans publications.
5. Pass G., Sutcliffe, H. 1974. 'Practical Inorganic Chemistry', 2nd edition, Chapman & Hill,
6. Parshall, G. W. 1974. 'Inorganic Synthesis', Vol. 15, Tata McGraw-Hill Education.

22PHY281	Physics Lab II - Optics	0 0 2 1

Course Objectives

The course objective is to familiarize the students with traditional optical experiments as well as the modern optical instruments and methods. To impart the knowledge on calibrating the optical measuring equipment and identify sources of error and uncertainty in practical work. To develop the presentation skills of the students in demonstrating experimental results in the form of a scientific report, both written and oral.

Course Outcomes

Upon completion of this course, students will be able to

CO1. Understand the physical principles underlying geometrical optics, assembling the optical systems and determination of refractive index of different media
CO2. Perform the formulations and analysis of the interference and diffractions patterns
CO3. Acquire knowledge on analysing the polarizations and the fiber optic transmissions

Skills: Students will develop experimental, analysing and presentation skills by performing various optics experiments

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3				3	3	
CO2	3	3				3	3	
CO3	3	3				3	3	

Experiments

1. Determination of focal length of combination of lenses and nodal distance using nodal slide assembly. [CO1]
2. Studying the resolving power of a telescope. [CO1]
3. Studying the dispersive power of prism. [CO1]
4. Newton's ring experiment. [CO2]
5. Studying the Interference fringes in Wedge shaped films. [CO2]
6. Determination of wavelength of spectral lines using diffraction grating. [CO2]
7. Verification of Law of Malus - Polarization. [CO3]
8. Determination of refractive index of the liquids using Snell's law. [CO1]

9. Diffraction at single, double, and multiple slits using laser - studying the intensity distribution. [CO2]
10. Diffraction at circular aperture using laser and estimation of size of particles. [CO2]
11. Determination of numerical aperture of optical fiber and losses of light in fiber due to Bending and beam profile analysis of Laser. [CO3]
13. Constructing Michelson interferometer and use it to determine the wavelength of laser and refractive index of given glass plate. [CO2]

Evaluation Pattern

Assessment	**Internal**	**External**
Continuous Laboratory Assessment	80	
End Semester		20

Justification for CO-PO Mapping

Mapping	**Justification**	**Affinity level**
CO1-PO1	CO1 is related to understand the physical principles of geometric optics. Since PO1 is related inculcate strong science (physics) fundamentals, CO1 has been mapped with PO1 with maximum affinity of 3.	3
CO1-PO2	In CO1, students gain the analysing skills of the various geometric optics experiments and hence the affinity level is given maximum for CO1 when mapped with PO2.	3
CO1-PSO1	Students develops analysing skills on problems related to the experimental geometric optics which matches well with PSO1 and so it is mapped with maximum affinity	3
CO1-PSO2	By performing experiments students enhance the confidence of handling different optical instruments and it is needed to improve their research skills. The mapping of CO1-PSO2 is given a maximum level affinity.	3
CO2-PO1	In CO2, students improve their understanding on the physics of interference and diffractions. So, CO2 is given maximum affinity of 3 when mapped with PO1.	3
CO2-PO2	Students develop their analytical thinking by performing various diffraction and interference experiments. The mapping of CO2 with PO2 is assigned maximum affinity.	3
CO2-PSO1	In CO2, students learn in finding the solutions to fundamental interference and diffraction patterns such as intensity distributions and thus it is mapped with high affinity to PSO1.	3
CO2-PSO2	As students develop their experimental and analytical skills such as plotting the intensity distributions, particle/ aperture size determination etc. (CO2) . Hence, a high affinity level of 3 is given in the mapping of CO2-PSO2.	3
CO3-PO1	In CO3, students enhance their understanding about polarization phenomena and so it is given a maximum affinity with PO1.	3

CO3-PO2	In CO3, Students develop analytical skills with respect to polarization and fiber optic transmissions. So, the CO2- PO2 mapping is given an affinity level of 3.	3
CO3- PSO1	In CO3, students examine the polarization, attenuation losses in fiber, numerical aperture determination etc.. and so the mapping of CO3 with PSO1 is given a high affinity level	3
CO3- PSO2	Students increase their experimental skills such as assembling the polaroids, examining the polarization, coupling the optical fiber with laser, profiling the transmitted beam etc. The mapping with PSO2 is given a minimum affinity.	3

22CSA281	**Programming Lab I**	**0 0 2 1**

Syllabus:

1. 2D and 3D plotting of functions (Scilab, Python)
2. Curve fitting
3. Least square fit Goodness of fit& standard constant
4. Solution of Linear system of equations: Gauss elimination
5. Solution of Linear system of equations: Gauss Seidal method
6. Solution of ODE First Order Differential equation:
7. Solution of ODE second order Differential equation

List of Experiments

1. Ohms law to calculate R,
2. Hooke’s law to calculate spring constant
3. Solution of mesh equations of electric circuits
4. Solution of coupled spring mass systems
5. Radioactive decay
6. Current in RC, LC circuits with DC source
7. Newtons law of cooling
8. Classical equations of motion
9. Current in RC, LC circuits with DC source
10. Newtons law of cooling
11. Classical equations of motion
12. Harmonic oscillator •
13. Damped Harmonic oscillator- Overdamped- Critical damped
14. Forced Harmonic oscillator

Text Books:

1. A Survey of Computational Physics- Introductory Computational Science" Rubin H. Landau, Manuel José Páez, Cristian C. Bordeianu, 2008, Princeton university press.
2. Introduction to Numerical programming: Steven A. Gottlieb and Rubin H. Landau, CRC Press.

21AVP201	Amrita Values Programme I	1 0 0 1

Message from Amma's Life for the Modern World

Amma's messages can be put to action in our life through pragmatism and attuning of our thought process in a positive and creative manner. Every single word Amma speaks and the guidance received in on matters which we consider as trivial are rich in content and touches the very inner being of our personality. Life gets enriched by Amma's guidance and She teaches us the art of exemplary life skills where we become witness to all the happenings around us still keeping the balance of the mind.

Lessons from the Ramayana

Introduction to Ramayana, the first Epic in the world – Influence of Ramayana on Indian values and culture – Storyline of Ramayana – Study of leading characters in Ramayana – Influence of Ramayana outside India – Relevance of Ramayana for modern times.

Lessons from the Mahabharata

Introduction to Mahabharata, the largest Epic in the world – Influence of Mahabharata on Indian values and culture – Storyline of Mahabharata – Study of leading characters in Mahabharata – Kurukshetra War and its significance - Relevance of Mahabharata for modern times.

Lessons from the Upanishads

Introduction to the Upanishads: Sruti versus Smrti - Overview of the four Vedas and the ten Principal Upanishads - The central problems of the Upanishads – The Upanishads and Indian Culture – Relevance of Upanishads for modern times – A few Upanishad Personalities: Nachiketas, SatyakamaJabala, Aruni, Shvetaketu.

Message of the Bhagavad Gita

Introduction to Bhagavad Gita – Brief storyline of Mahabharata - Context of Kurukshetra War – The anguish of Arjuna – Counsel by Sri. Krishna – Key teachings of the Bhagavad Gita – Karma Yoga, Jnana Yoga and Bhakti Yoga - Theory of Karma and Reincarnation – Concept of Dharma – Concept of Avatar - Relevance of Mahabharata for modern times.

Life and Message of Swami Vivekananda

Brief Sketch of Swami Vivekananda's Life – Meeting with Guru – Disciplining of Narendra - Travel across India - Inspiring Life incidents – Address at the Parliament of Religions – Travel in United States and Europe – Return and reception India – Message from Swamiji's life.

Life and Teachings of Spiritual Masters India

Sri Rama, Sri Krishna, Sri Buddha, Adi Shankaracharya, Sri Ramakrishna Paramahamsa, Swami Vivekananda, Sri Ramana Maharshi, Mata Amritanandamayi Devi.

Insights into Indian Arts and Literature

The aim of this course is to present the rich literature and culture of Ancient India and help students appreciate their deep influence on Indian Life - Vedic culture, primary source of Indian Culture – Brief introduction and appreciation of a few of the art forms of India - Arts, Music, Dance, Theatre.

Yoga and Meditation

The objective of the course is to provide practical training in YOGA ASANAS with a sound theoretical base and theory classes on selected verses of Patanjali's Yoga Sutra and Ashtanga Yoga. The coverage also includes the effect of yoga on integrated personality development.

Kerala Mural Art and Painting

Mural painting is an offshoot of the devotional tradition of Kerala. A mural is any piece of artwork painted or applied directly on a wall, ceiling or other large permanent surface. In the contemporary scenario Mural painting is not restricted to the permanent structures and are being done even on canvas. Kerala mural paintings are the frescos depicting mythology and legends, which are drawn on the walls of temples and churches in South India, principally in Kerala. Ancient temples, churches and places in Kerala, South India, display an abounding tradition of mural paintings mostly dating back between the 9th to 12th centuries when this form of art enjoyed Royal patronage. Learning Mural painting through the theory and practice workshop is the objective of this course.

Course on Organic Farming and Sustainability

Organic farming is emerging as an important segment of human sustainability and healthy life. Haritamritam' is an attempt to empower the youth with basic skills in tradition of organic farming and to revive the culture of growing vegetables that one consumes, without using chemicals and pesticides. Growth of Agriculture through such positive initiatives will go a long way in nation development. In Amma's words "it is a big step in restoring the lost harmony of nature".

Benefits of Indian Medicinal Systems

Indian medicinal systems are one of the most ancient in the world. Even today society continues to derive enormous benefits from the wealth of knowledge in Ayurveda of which is recognised as a viable and sustainable medicinal tradition. This course will expose students to the fundamental principles and philosophy of Ayurveda and other Indian medicinal traditions.

Traditional Fine Arts of India

India is home to one of the most diverse Art forms world over. The underlying philosophy of Indian life is 'Únity in Diversity" and it has led to the most diverse expressions of culture in India. Most art forms of India are an expression of devotion by the devotee towards the Lord and its influence in Indian life is very pervasive. This course will introduce students to the deeper philosophical basis of Indian Art forms and attempt to provide a practical demonstration of the continuing relevance of the Art.

Science of Worship in India

Indian mode of worship is unique among the world civilisations. Nowhere in the world has the philosophical idea of reverence and worshipfulness for everything in this universe found universal acceptance as it in India. Indian religious life even today is a practical demonstration of the potential for realisation of this profound truth. To see the all-pervading consciousness in everything, including animate and inanimate, and constituting society to realise this truth can be seen as the epitome of civilizational excellence. This course will discuss the principles and rationale behind different modes of worship prevalent in India.

Temple Mural Arts in Kerala

The traditional percussion ensembles in the Temples of Kerala have enthralled millions over the years. The splendor of our temples makes art enthusiast spellbound, warmth and grandeur of color combination sumptuousness of the outline, crowding of space by divine or heroic figures often with in vigorous movement are the characteristics of murals.

The mural painting specially area visual counterpart of myth, legend, gods, dirties, and demons of the theatrical world, Identical myths are popular the birth of Rama, the story of Bhīma and Hanuman, Shiva, as Kirata, and the Jealousy of Uma and ganga the mural painting in Kerala appear to be closely related to, and influenced by this theatrical activity the art historians on temple planes, wood carving and painting the architectural plane of the Kerala temples are built largely on the pan-Indians almost universal model of the Vasthupurusha.

Organic Farming in Practice

Organic agriculture is the application of a set of cultural, biological, and mechanical practices that support the cycling of farm resources, promote ecological balance, and conserve biodiversity. These include maintaining and enhancing soil and water quality; conserving wetlands, woodlands, and wildlife; and avoiding use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering. This factsheet provides an overview of some common farming practices that ensure organic integrity and operation sustainability.

Ayurveda for Lifestyle Modification:

Ayurveda aims to integrate and balance the body, mind, and spirit which will ultimately leads to human happiness and health. Ayurveda offers methods for finding out early stages of diseases that are still undetectable by modern medical investigation. Ayurveda understands that health is a reflection of when a person is living in harmony with nature and disease arises when a person is out of harmony with the cycles of nature. All things in the universe (both living and nonliving) are joined together in Ayurveda. This leaflet endow with some practical knowledge to rediscover our pre- industrial herbal heritage.

Life Style and Therapy using Yoga

Yoga therapy is the adaptation of yogic principles, methods, and techniques to specific human ailments. In its ideal application, Yoga therapy is preventive in nature, as is Yoga itself, but it is also restorative in many instances, palliative in others, and curative in many others. The therapeutic effect comes to force when we practice daily and the body starts removing toxins and the rest is done by nature.

Course Code	Course Title	L T P	Cr	ES
SEMESTER 4				
22CHY215	Principles of Inorganic Chemistry	3 1 0	4	
22PHY211	Basics of Electronics	3 1 0	4	
21SSK211	Life Skills II	1 0 2	2	
22PHY212	Introduction to Computational physics	3 1 0	4	
22PHY282	Physics Lab III – Modern Physics	0 0 2	1	
22PHY213	Basics Experimental Techniques	3 1 0	4	
21AVP211	Amrita Value Programme II	1 0 0	1	
TOTAL			20	

22CHY215	Principles of Inorganic Chemistry	3 1 0 4

UNIT 1: Periodic properties and s-Block elements

Long form of periodic table and classification of elements based on electronic configuration. periodicity in properties – atomic, ionic, covalent radii – ionization potential – electron affinity – electro negativity – effective nuclear charge – Slater's rule and their trends in periodic table. **s-Block elements:** General characteristics – atomic and ionic radii – ionization energies – electropositive character – reducing properties – hydration of ions – flame coloration – lattice energies – diagonal relationship - chemical properties – Ellingham diagram - extraction of alkali and alkaline earth metals – uses of alkali and alkaline earth metals – complexes of alkali and alkaline earth metals – compounds of alkali and alkaline earth metals and their applications.

UNIT 2: p block elements

General characteristics – metallic and non-metallic character — extraction of p-block elements – Lewis acids – back bonding – boron compounds. Catenation – structure of graphite – intercalation compounds – carbides – silica, silicates, glass manufacturing – zeolites. Allotropy in P and S. compounds of N and P - hydrazine – hydrazoic acid – hydroxyl amine – phosphazines. anomalous behavior of second raw elements, structure - of ozone. Hydrides, halides, oxides, oxoacids, persulfuric acids, nitrides of group VI and VII elements. Inter halogen compounds and their structure. Isolation of noble gases – preparation, properties, structure and uses of noble gas compounds

UNIT 3: d block elements

Transition metals: General characteristics – metallic character – oxidation states – size – density – melting and boiling points – ionization energy – color – magnetic properties – reducing properties – catalytic properties – Non-stoichiometric compounds – complex formation – alloy formation – difference between first row and other two rows of d block elements and compounds- extractive metallurgy – Ellingham diagram – Compounds of transition metals (other than coordination compounds).

UNIT 4: f block elements

Position in the Periodic Table - General characteristics of lanthanides and actinides - Lanthanide contraction and its consequences. Isolation of Lanthanides from Monazite - Ion exchange resin method. Actinides - occurrence and preparation, comparison with lanthanides. Chemistry of Thorium and Uranium - Important compounds - preparation, properties and uses.

UNIT 5: Nuclear Chemistry

Nuclear structure, mass and charge, mass defect, binding energy, stability rules, magic numbers, nuclear quantum numbers, nuclear parity. Models of nucleus, shell model, liquid drop model, semi empirical mass equation, equations of radioactive decay and growth, half-life, average life - determination of half-lives, types of nuclear reactions. Radiation chemistry - Radiochemical methods - measurement of radioactivity, measurement of radiations – gas detector, scintillation counter, semiconductor detectors. Applications of nuclear and radiation chemistry, isotope dilution analysis - activation analysis, radiometric titrations, radiation dosimetry, hydrated electron. Effective utilisation of nuclear energy – nuclear reactors.

Recommended Readings

1. Shriver and Atkins' Inorganic Chemistry (Fifth Edition), P.W. Atkins, T.L. Overton, J.P. Rourke, M.T. Weller, and F.A. Armstrong, Oxford University Press (2010)
2. Inorganic Chemistry (Fourth Edition), Catherine E. Housecroft and Alan G. Sharpe, Pearson, 2012
3. Lee J. D., ‘Concise Inorganic Chemistry’, Black Well Science, UK. 2006
4. Concepts and Models of Inorganic Chemistry: B. Douglous, D. Rsd McDaniel and J. Alexander (2006) 3 edition (student edition), Wiley-India
5. H J Arnikar, Essentials of Nuclear Chemistry, 4th revised edition, New Age International (P) Limited publishers, 2015
6. Source book on atomic energy, Glaston
7. J.E. Huheey, R.A. Keiter, R.L. Keiter, ‘Inorganic Chemistry-Principles of Structure and Reactivity’, 4th Edn., Prentice Hall, 1997.
8. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann, ‘Advanced Inorganic Chemistry’, 6th edition, John Wiley, 1999.

22PHY211	**Basics of Electronics**	**3 1 0 4**

Course objectives:

Objective of the course: Making the students to understand, analyse and construct various DC circuits for multiple applications.

UNIT 1

Introduction: Circuit Theory: Nodal and Mesh analysis current and Voltage sources, Thevenin’s theorem, Norton’s Theorem, Open and closed circuit.

Semiconductors: Intrinsic& Extrinsic semiconductors, Doping in a semiconductor, PN Junction, Diode: forward and reverse biasing and energy bands.

UNIT 2

Diodes and Transistors: Diode characteristics, Ideal diode, rectifiers and filters, Clippers and clampers, Zener diode; Line and load regulation, Optoelectronic devices: LED, Photodiode, Schottky diode,

Transistor: Bipolar Junction Transistor, Transistor biasing, Load line analysis, Operating points, Transistor amplifier: current and voltage amplifiers.

UNIT 3

JFET: Construction, biasing and applications in switches, variable resistance and choppers
MOSFET: Characteristics and operation of D- MOSFET & E- MOSFET, Digital switching using MOSFET, CMOS Applications -Thyristors: Four-layer diode, Silicon controlled rectifier,

UNIT 4

Integrated Circuits: Differential amplifier, Operational Amplifier, Characteristics of ideal op-amp, negative feedback, filters, nonlinear opamp circuits: Integrators, Differentiator

UNIT 5

Digital Logic: Digital logic circuits CMOS and Bipolar (TTL), Combinational logic, sequential logic, Combinational logic, Sequential logic circuits: Counters & Flip Flops

Textbooks

1. Fundamental of Electrics circuits: C. K. Alexander and M. N. O. Sadiku, Third edition, Tata McGraw Hill.
2. The Art of Electronics: P. Horwitz and W. Hill (1989) 2nd edition,Cambridge University Press.
3. Electronic Devices and Circuits: Robert L. Boylestad& Louis Nashelsky.
4. Digital Principles and Their Applications: Donal P. Leach, Albert PaulMalvino and Gautam Saha (2006) Tata McGraw Hill.
5. Electronic Principles: A. Malvino and D. Bates (2006) 7th edition, Mc-Graw-Hill.

21SSK211	LIFE SKILLS II	1 0 2 2

Professional Grooming and Practices: Basics of Corporate culture, Key pillars of Business Etiquette. Basics of Etiquette: Etiquette – Socially acceptable ways of behaviour, Personal hygiene, Professional attire, Cultural Adaptability. Introductions and Greetings: Rules of the handshake, Earning respect, Business manners. Telephone Etiquette: activities during the conversation, Conclude the call, to take a message. Body Language: Components, Undesirable body language, Desirable body language. Adapting to Corporate life: Dealing with people.

Group Discussions: Advantages of Group Discussions, Structured GD – Roles, Negative roles to be avoided, Personality traits to do well in a GD, Initiation techniques, how to perform in a group discussion, Summarization techniques.

Listening Comprehension advanced: Exercise on improving listening skills, Grammar basics: Topics like clauses, punctuation, capitalization, number agreement, pronouns, tenses etc.

Reading Comprehension advanced: A course on how to approach middle level reading comprehension passages.
Problem solving – Money Related problems; Mixtures; Symbol Based problems; Clocks and Calendars; Simple, Linear, Quadratic and Polynomial Equations; Special Equations; Inequalities; Functions and Graphs; Sequence and Series; Set Theory; Permutations and Combinations; Probability; Statistics.
Data Sufficiency: Concepts and Problem Solving.

Non-Verbal Reasoning and Simple Engineering Aptitude: Mirror Image; Water Image; Paper Folding; Paper Cutting; Grouping Of Figures; Figure Formation and Analysis; Completion of Incomplete Pattern; Figure Matrix; Miscellaneous.
Special Aptitude: Cloth, Leather, 2D and 3D Objects, Coin, Match Sticks, Stubs, Chalk, Chess Board, Land and geodesic problems etc., Related Problems

TEXT BOOKS:

1. A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.
2. Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.
3. Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa& Co.
4. The Hard Truth about Soft Skills, by Amazone Publication.

REFERENCES:

1. Quantitative Aptitude, by R S Aggarwal, S Chand Publ.
2. Verbal and Non-verbal Reasoning, R S Aggarwal, S Chand Publ.
3. Quantitative Aptitude by Abjith Guha, Tata McGraw hill Publ.
4. More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.
5. The BBC and British Council online resources
6. Owl Purdue University online teaching resources
7. www.thegrammarbook.com online teaching resources
8. www.englishpage.com online teaching resources and other useful websites.

22PHY212	**Introduction to Computational Physics**	**3 1 0 4**

UNIT 1

Modelling, Computers and Error Analysis: Mathematical Modelling, Programming and Software, Approximations and Round off errors, Truncation errors and the Taylor series.

UNIT 2

Algebraic Equations and Curve Fitting: Bracketing Methods, Open Methods, Roots of Polynomials, Gauss Elimination, LU Decomposition and Matrix Inversion, Special Matrices and Gauss-Seidel, Least-Squares Regression, Interpolation, Fourier Approximations

UNIT 3

Numerical Integration and Differentiation: The Trapezoidal Rule, Simpson's Rules, Open Integration Formulas, Multiple Integrals, Gauss Quadrature, Improper Integrals, Richardson Extrapolation, Derivatives of Unequally Spaced Data, Derivatives and Integrals for Data with Errors, Partial Derivatives

UNIT 4

Ordinary Differential Equations: Euler's Method, Runge-Kutta Methods, System of Equations, Stiffness, Multistep Methods, General Methods for Boundary-Value Problem, Eigenvalue Problems

UNIT 5

Partial Differential Equations: The Laplace Equation, Solution Technique, Boundary Conditions, The Control Volume Approach, The Heat Conduction Equation, Explicit Methods, Parabolic Equations in Two Spatial Dimensions

Text Book

1. Steven Chapra, Raymond Canale, Numerical Methods for Engineers, 7th Ed., McGraw-Hill Higher Education, 2015.

Reference Book

1. V. Rajaraman, Computer Oriented Numerical Methods, PHI LEARNING PVT LTD, 2016.

22PHY213	**Basic Experimental Techniques**	**3 1 0 4**

Course Objectives: The objective of the course is to introduce the student to the concept of errors and propagation of errors; Plot linear data and do regression analysis including goodness of fits. It is also aimed at introducing the student to electronic noise and pressure and temperature measurements.

Course Outcomes

At the end of the course students will be able to:

CO1: Calculate errors in measurements

CO2: Understand error propagation

CO3 Plot a scatter graph, preferably of simple linear systems and fit a linear line and calculate the errors in the constants; Estimate the goodness of fits

CO4: Understand basic electronics instrumentation- pick out signal from noise, description of noise, optimizing and signal averaging

CO5: Understand pressure and temperature measurements, vacuum science and techniques

Skills: Problem solving skills in calculating errors and error propagation. Also, introductory-level analytical skills in statistical reasoning.

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	2						1	
CO2	2	2						
CO3	2	3	2					
CO4								
CO5	2							

UNIT 1: ERROR ANALYSIS

Learning Objectives

Calculate statistical errors in a given set of data

Understand the concept of errors from the view point of probability and statistics through the introduction of random variables

Understand the difference between total error and statistical errors

Evaluate statistical parameters of a set of data such as mean, variance etc.

Understand how error propagates from one variable to another.

Introductory probability – Random experiment, discrete random variable, continuous random variable, probability distributions, Definition of mean, median, mode, standard deviation and standard error.
Definition of Errors: Random error and systematic error, Uncertainties, precision and accuracy, reporting errors (error bars). Error Propagation.

UNIT 2: DATA ANALYSIS

Learning Objectives

Fit a straight line to a set of data (x,y) points

Know how to calculate the slope and intercepts in the fitted line and also to calculate the errors in them

Understand the concepts of regression and correlation

Evaluate goodness of the fitted line using statistical means

Curve fitting, Linear regression analysis, goodness of fits (χ^2 test), correlation analysis (R^2) – with relevance to simple physics experiments.

UNIT 3: EXTRACTION OF SIGNAL FROM NOISE

Learning Objectives

Understand the types of electronic noise and distinguish their characteristics

Understand how to calculate the signal to noise ratio and their units

Signal to noise ratio, Types of noise, Hardware and software methods for noise reduction

UNIT 4: VACUUM PHYSICS

Learning Objectives

Understand the concept of pressure and its microscopic origins

Explain the different ranges of pressure

Know how to create vacuum using different pumps and their principles of operation

Definition of pressure - Kinetic theory of gases, average velocity, mean free path, impingement rate, creation of vacuum using different pumps.

UNIT 5: MEASUREMENT OF TEMPERATURE AND PRESSURE

Learning Objectives

Understand different types of pressure gauges and their operating principles

Explain the microscopic origins of temperature and temperature scales

Understand the principle and operation of thermocouples for temperature measurement

Measurement of Vacuum- Gauges – All direct and indirect gauges, Thermometry: Scales of temperature, Temperature measurement, liquid, gas, vapour pressure, platinum resistance, Thermoelectric & radiation thermometer. Construction and calibration; Low temperature measurement creation of low temperature.

Text Books:

1. Foundations of Experimental Physics, Shailaja Mahamuni, Deepti Sidhaye and Sulabha Kulkarni, CRC Press (2021).

Other Useful Text Books (Unit-wise):

For Error analysis (Units I and II):

1. "Data Reduction and Error Analysis for the physical sciences" by Bevington and Robinson.
2. "An introduction to error analysis: The study of uncertainties in physical measurements" by John. R Taylor.

For Unit III:

1. Chapter 8 of "The Art of Electronics" by Paul Horowitz and Winfield Hill.

For Unit IV and V:

1. "Materials Science of Thin Films" by Milton Ohring.

Reference books:

1. Any introductory book on probability and statistics
2. "Building scientific instruments", John H Moore.

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	**Justification**	**Affinity level**
CO1-PO1	CO1 is about calculating errors in measurement while PO1 is knowledge in basic sciences fundamentals. The mathematical knowledge in the CO1 will help understand the dispersion in acquired data, which is also related to the knowledge in basic sciences. Hence affinity level is not 3, but 2.	2
CO1-PSO2	CO1 is about calculating errors in measurement while PSO2 is about using analytical skills. The skills acquired in calculating errors will help in improving analytical reasoning and observation. Since CO1 is generic (not particular to any model system), it is mapped at level 1.	1
CO2-PO1	CO2 is an extension of CO1 in that it permits calculating propagation of errors. This involves mathematical fundamentals. Hence mapped at level 2.	2

CO2-PO2	CO2 is related to calculating propagation of errors, while PO2 is related to analytical and critical thinking. They are mapped at affinity level 2.	2
CO3-PO1	CO3 is about presenting data and making inferences. This is based on science and math fundamentals. Hence mapped at level 2.	2
CO3-PO2	CO3 involves presentation of data to identify trends and patterns. It is strongly connected to analytical and critical thinking and hence mapped at level 3.	3
CO3-PO3	CO3 is useful to establish relations between different parameters. It helps break down a complex problem into smaller units and determine connections between them. Hence PO3 is mapped to CO3 at level 2.	2
CO5-PO1	CO5 is related to understanding the concepts of pressure and temperature. Hence related to PO1 (fundamental science) with affinity level 3.	3

21AVP211	**Amrita Values Programme II**	**1 0 0 1**

Insights into Indian Classical Music

The course introduces the students into the various terminologies used in Indian musicology and their explanations, like Nadam, Sruti, Svaram – svara nomenclature, Stayi, Graha, Nyasa, Amsa, Thala,- Saptatalas and their angas, Shadangas, Vadi, Samavadi, Anuvadi. The course takes the students through Carnatic as well as Hindustani classical styles.

Insights into Traditional Indian Painting

The course introduces traditional Indian paintings in the light of ancient Indian wisdom in the fields of aesthetics, the Shadanga (Sixs limbs of Indian paintings) and the contextual stories from ancient texts from where the paintings originated. The course introduces the painting styles such as Madhubani, Kerala Mural, Pahari, Cheriyal, Rajput, Tanjore etc.

Insights into Indian Classical Dance

The course takes the students through the ancient Indian text on aesthetics the Natyasastra and its commentary the AbhinavaBharati. The course introduces various styles of Indian classical dance such as Bharatanatyan, Mohiniyatton, Kuchipudi, Odissy, Katak etc. The course takes the students through both contextual theory as well as practice time.

Indian Martial Arts and Self Defense

The course introduces the students to the ancient Indian system of self-defense and the combat through various martial art forms and focuses more on traditional Kerala's traditional KalariPayattu. The course introduces the various exercise technique to make the body supple and flexible before going into the steps and techniques of the martial art. The advanced level of this course introduces the technique of weaponry.

Social Awareness Campaign

The course introduces the students into the concept of public social awareness and how to transmit the messages of social awareness through various media, both traditional and modern. The course goes through the theoretical aspects of campaign planning and execution.

Temple Mural Arts in Kerala

The traditional percussion ensembles in the Temples of Kerala have enthralled millions over the years. The splendor of our temples makes art enthusiast spellbound, warmth and grandeur of color combination sumptuousness of the outline, crowding of space by divine or heroic figures often with in vigorous movement are the characteristics of murals.

The mural painting specially area visual counterpart of myth, legend, gods, dirties, and demons of the theatrical world, Identical myths are popular the birth of Rama, the story of Bhīma and Hanuman, Shiva, as Kirata, and the Jealousy of Uma and ganga the mural painting in Kerala appear to be closely related to, and influenced by this theatrical activity the art historians on temple planes, wood carving and painting the architectural plane of the Kerala temples are built largely on the pan-Indians almost universal model of the vasthupurusha.

Organic Farming in Practice

Organic agriculture is the application of a set of cultural, biological, and mechanical practices that support the cycling of farm resources, promote ecological balance, and conserve biodiversity. These include maintaining and enhancing soil and water quality; conserving wetlands, woodlands, and wildlife; and avoiding use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering. This factsheet provides an overview of some common farming practices that ensure organic integrity and operation sustainability.

Ayurveda for Lifestyle Modification:

Ayurveda aims to integrate and balance the body, mind, and spirit which will ultimately leads to human happiness and health. Ayurveda offers methods for finding out early stages of diseases that are still undetectable by modern medical investigation. Ayurveda understands that health is a reflection of when a person is living in harmony with nature and disease arises when a person is out of harmony with the cycles of nature. All things in the universe (both living and non-living) are joined together in Ayurveda. This leaflet endow with some practical knowledge to rediscover our pre- industrial herbal heritage.

Life Style and Therapy using Yoga

Yoga therapy is the adaptation of yogic principles, methods, and techniques to specific human ailments. In its ideal application, Yoga therapy is preventive in nature, as is Yoga itself, but it is also restorative in many instances, palliative in others, and curative in many others. The therapeutic effect comes to force when we practice daily and the body starts removing toxins and the rest is done by nature.

22PHY282	**Physics Lab III - Modern Physics**	**0 0 2 1**

1. Study of black body spectra

2. Determination of Planck’s constant and De Broglie wavelength of Electrons using photo electric experiments.

3. Determination of Rydberg’s constant from hydrogen spectrum

4. Determination of charge to mass ratio of electron – Thomson’s method

5. Verification of Bohr’s theory - Franck – Hertz Experiment.

6. Determination of charge of electron by Millikan’s oil drop method.

7. Electron Spin Resonance- Determination of ‘g’ factor of an electron

8. Determination of Ferro magnetic Curie temperature of a given sample

9. Studying the Energy gap of semiconductors

Course Code	Course Title	L T P	Cr	ES
	SEMESTER 5			
22PHY301	Classical Mechanics I	4 1 0	4	
22PHY302	Thermal and statistical Mechanics	3 1 0	4	
22PHY303	Applied electronics	3 1 0	4	
22PHY304	Electricity and Magnetism in Matter	3 1 0	4	
22PHY390	Open Elective/Live in Lab	3 0 0	3	
22PHY381	Physics Lab IV - Electronics	0 0 3	1	
	Core Elective I		3	
	Professional elective - I	3 0 0	3	
	TOTAL		**26**	

22PHY301	CLASSICAL MECHANICS I	4 1 0 4

Prerequisites: Mechanics, Mathematics 1

Course Objectives

This is the second course in mechanics and is intended to impart students basic understanding of other techniques used beyond Newtonian mechanics. Central forces, its applications in Kepler’s laws, Scattering will be discussed. An introduction to Rotational dynamics also will be covered.

Course Outcomes

At the end of the course, students will be able to

CO1: Introduction of Phase Space- Phase portrait and sketching the phase portraits of various potentials and its interpretation including applications.

CO2: Understand the concept of constraint, principle of least action and formulation of Lagrange’s method and apply Lagrange’s equation for simple dynamical systems.

CO3: Understand Central force and its application in Kepler's problem and scattering problems. Use the Centre of mass and laboratory frames of references in solving problems.
CO 4: Understand the basics of rotating frames of references and Euler angles and Euler's equations.
CO5: Apply Hamilton's equations in solving dynamical problems.

Skill: Analytical skill to formulate dynamical problem and solve using Lagrangian Formalism.

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1		3	3			3	3	
CO2		3	3			3	3	
CO3		3	3			3	3	
CO4		3	3			3	3	
CO5		3	3			3	3	

UNIT 1

Learning Objectives

Understand the concept of phase space and its importance in Lagragian and Hamiltonian mechanics
Learn how to draw the phase portraits for different potentials and use it.
Applications of phase portrait in understanding the dynamics of physical systems.

Review of basic principles, Conservative systems, Conservation of linear momentum, Phase space-phase portrait - Dynamical Systems - Phase space dynamics - stability analysis.

UNIT 2

Learning Objectives

Introduction of concepts of constraints, degrees of freedom
Limitations of Newtonian mechanics and the concept of generalized co-ordinate
Principal of virtual work, De- Alembert's principle and Principle of Leas action
Lagrange's Equation and its simple applications.

Lagrangian and Hamiltonian Mechanics with Constraints-Euler-Lagrange Equations, D'Alembert and Hamilton principles, Conservation Laws, holonomic and nonholonomic constraints – Generalized co-ordinates - Calculus of Variation, Principle of least action - The Lagrangian, Lagrange's Equations, Degrees of Freedom, Generalized momentum & Hamilton's Equations.

UNIT 3

Learning objectives

Introduction to central forces
Bound states and scattering states
Concept of Lab frame and centre of Mass frame

Central forces - Kepler's laws - bound state and scattering states. Determining the Motion using Energy Integral- Laboratory frame and centre of mass frame- Scattering.

UNIT 4

Learning objectives

Concept of Rigid body
Introduce moment of Inertia tensor

Study rigid body rotation using Euler’s equation
Analysis of Symmetric top

Rotational Dynamics of Rigid Bodies: Conservation of Angular momentum, Moment of Inertia, Rotational Kinetic Energy, Euler Angles, Inertia Tensor, The Euler Equations-Analysis of a symmetric Top-Gyroscopes.

UNIT 5

Learning objectives

Hamiltonian using Legendre transformation
Derivation of Hamilton’s equations
Apply Hamiltonian formulation to solve dynamical problems

Hamiltonian: Hamilton’s equations using Legendre Transformation- Cyclic co-ordinates- Application of Hamilton’s formalism in solving dynamical Problems.

Suggested Readings

1. Herbert Goldstein, John Safko Charles P. Poole, Classical Mechanics, Pearson, 3rd Ed, 2011.
2. Landau, Lev D., and Evgenij M. Lifshitz. Mechanics: Course of Theoretical Physics. Vol. 1. Butterworth-Heinemann; 3rd Ed, 1982. ISBN 978-0750628969.
3. John Taylor, Classical Mechanics, University Science Books, 1st Ed, 2004.
4. S. T. Thomton and J B Marion, Classical Dynamics of Particles and Systems, Brooks Cole, 1st Ed, 2009.
5. Walter Greiner, Classical Mechanics: Point Particles and Relativity, Springer Verlag, 1st Ed, 2004.

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	**Justification**	**Affinity level**
CO1-CO 5 to PO2 and PSO 1	This is course with objective of building basic analytical skills to formulate problems and solve using techniques developed. There for it has highest affinity towards PO2 and PSO 1	3
CO1-CO5-PO3 and PSO 2	This course develops problem solving skills and form a core course in Physics which will help student to formulate research problems – hence has strong affinity towards PO3 and PSO 2	3

22PHY302	Thermal and statistical Mechanics	3 1 0 4

UNIT 1

Preliminaries: The concept of heat, temperature and equilibrium and the Zeroth Law; Extensive and intensive variables; Equation of state, First law of thermodynamics: Methods of work transfer, free expansion, work as a path function, heat: Specific heat capacity and latent heat First law of thermodynamics: Internal energy and work, Heat and Enthalpy, Path function and state function, Corollaries of First law of thermodynamics:

UNIT 2

Work and Heat: Heat Capacity: equation of state; Work done in various Processes. Einstein's and Debye theory of Specific heat capacity, Heat transfer mechanisms: -Conduction, Convection, and Radiation. Methods of thermal conduction, Kirchhoff's laws, Pressure of radiation, Stefan Boltzmann law. Wien's law, Rayleigh jeans law, Planck's law (qualitative analysis).

UNIT 3

Second law of thermodynamics: Kelvin Planck Statements, Clausius statement of second law, Heat Engines-Carnot cycle (Heat and Refrigeration) Carnot's Theorem, Equivalence of Kelvin-Planck and Clausius statement, Clausius Theorem, Entropy: - entropy in reversible and irreversible process, Clausius inequality, TS diagram, Principle of increase of entropy

UNIT4

Statistical Mechanics Preliminaries: The meaning of probability- definitions of sample space, events etc., types of random variables and probability mass and distribution functions; Functions of one and two random variables; Joint probabilities; Moments of a distribution; Correlation. Permutations and Combinations (with application to simple random walks on square grids)., statistical definition of temperature, Ensembles: canonical ensemble from Boltzmann distribution, statistical basis of entropy, entropy and probability, Equipartition Theorem.

UNIT 5

Thermodynamical Potentials: Maxwell's Thermodynamical relations, Applications: Specific heat equation, Joule Thomson cooling, Temperature inversion, Clausius Clapeyron equation. Themodynamic Potentials; Relation with Thermodynamic variables, Tds equation, Heat capacity equations, Free energies and Thermodynamic Equilibrium, Equilibrium between phases, One component system- Phase transitions; First and second order, Multi component system-Gibb's Phase Rule.

Text Books

1. M. W. Zemansky and R. H. Dittman Amit K. Chattopadhyay, Heat and Thermodynamics, 8th Ed, Tata McGraw- Hill, 2011.
2. David Halliday, Robert Resnick, and Jearl Walker, Fundamentals of Physics, 10th Ed, John Wiley, 2012.

References

1. Walter Greiner, Ludwig Neisse, Horst Stocker, Thermodynamics and statistical mechanics, 1st Ed, Springer, 1995, 3rd reprint 2001.
2. Sears. F. W and Salinger. G. L, Thermodynamics Kinetic Theory and Statistical Thermodynamics, 3rd Ed, Addison Wesley, 1998
3. Hugh. D. Young and Freedman, Sears& Zemansky's University Physics, 13th Ed, Pearson, 2013.

4. Richard P. Feynman, Robert. P. Leighton and Matthew Sands, Feynman Lectures on Physics, Vol.1, 1E, Narosa, 2008
5. P. K. Nag, Basic & Applied Thermodynamics, 2nd edition McGraw Hill Education; 2017.

22PHY303	Applied Electronics	3 1 0 4

Prerequisite: Basic of Electronics
Objective of the course: Making the students to understand, analyse and construct Analog and digital circuits for various applications.

UNIT 1
Inductors & Capacitors: Series and Parallel Capacitors, Series and Parallel Inductors, Integrator, Differentiator.
First-Order Circuits: Source-free *RL, RC Circuit*, Step Response of an *RC and RL Circuits*, First-order Op Amp Circuits.

UNIT 2
Second order circuits: Source-Free Series *RLC and* Parallel *RLC* Circuit, Step Response of Series *RLC and* Parallel *RLC* Circuits. Second-Order Circuits, Second-Order Op Amp Circuits.
Sinusoids and Phasors: Phasors, Phasor Relationships for Circuit elements, Impedance and Admittance Frequency response: Series and parallel Resonance, passive low pass, high pass, band pass and band stop filters, Active first order low pass, high pass, Band pass and band rejection filters.

UNIT 3
Analog to digital conversion, digital to Analog conversion, microcontrollers, ardunio and raspberry pi based programmable circuits.

UNIT 4
Clocks and Timing Circuits: 555 Timer: monostable, Bistable and Astable multivibrators, and function generators. BJT and FET amplifier circuits, audio and high frequency amplifier circuits, Oscillators modulators and demodulators.
Optoelectronic Devices: photo diodes, light emitting diodes, solar cells response characteristics

UNIT 5
Data-Processing Circuits: Multiplexers, Demultiplexer, Decoder, Encoder, Programmable Array Logic and applications.

Text books
1. C. K. Alexander and M. N. O. Sadiku, Fundamental of Electrics circuits, 5th Ed, McGraw Hill Education, 2013.
2. P. Horwitz and W. Hill, The Art of Electronics, 3rd Ed, Cambridge University Press, 2015.
3. Robert L. Boylestad & Louis Nashelsky, Electronic Devices and Circuits, 11th Ed, Pearson Education India, 2015.
4. Donal P. Leach, Albert Paul Malvino and Gautam Saha, Digital Principles and their Applications, 8th Ed, McGraw Hill Education, 2015.

References
1. B.G. Streetman & S.K. Banerjee, Solid State Electronic Devices, 6th edition, Pearson, 2005.

22PHY304	Electricity and Magnetism in Matter	3 1 0 4

Prerequisites: Basics of Electricity and Magnetism

Course Objectives

Having successfully completed this module, the student will be able to demonstrate knowledge and understanding of: Electric Potential, Boundary conditions, Maxwell's equations, various techniques of solving Laplace's equation, Electric field and Magnetic fields in matter.

Course Outcomes

After completion this course students will be able to

CO1: Understand the concept of electric potential, Laplace's equations and uniqueness theorems
CO2: Apply special techniques to calculate electric potential
CO3: Acquire knowledge related to bound charges and hence calculate electric field of polarized objects
CO4: Understand magnetic vector potential, magnetic field in matter and different types of magnetic materials

Skills: Through assignments and quizzes, the problem solving capability of students related to electrodynamics is enhanced.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	

UNIT 1: Review of Electrostatics

Learning Objectives

Recognize the concept of electric potential and solve associated problems.
Understand boundary value problems, Laplace's equations in 1D, 2D and 3D along with uniqueness theorems.

Electric Potential, boundary conditions, Poisson's and Laplace's equations, La-place equation in one, two and three dimensions, Boundary conditions and Uniqueness theorem, Conductors and second Uniqueness theorem.

UNIT 2: Techniques of solving Laplace equation, Numerical methods:

Learning Objectives

Apply various techniques to solve Laplace's equations.
Understand the idea behind multipole expansion.

Finite difference method, Relaxation method and other methods of finding the potentials: Method of images, Separation of variables, Spherical co-ordinates, Multipole expansion, Electric field of a dipole.

UNIT 3: Electric field in matter:

Learning Objectives

Understand Polarization, Bound charges and their physical interpretation.
Apply the idea of bound charges to calculate field of a polarized object.
Understand linear dielectrics.

Induced dipoles, Polarization, Field of polarized Object, bound charges, Physical interpretation of bound charges, Field inside a dielectric, Electric displacement, Linear dielectrics, Boundary value problem with linear dielectrics, Energy in dielectric systems, Force on dielectrics.

UNIT 4

Learning Objectives

Recognize Maxwell's equations for magnetostatics and the origin of magnetic vector potential.
Understand multipole expansion of magnetic vector potential.

Maxwell's equations for Magnetostatics, Magnetic Vector potential, Aharanov-Bohm effect, Magnetostatic Boundary Conditions, Multipole expansion of magnetic vector potential.

UNIT 5: Magnetic field in matter:

Learning Objectives

Understand Magnetization, bound currents and their physical interpretation.
Calculate magnetic field due to a magnetized object.
Explain the different types of magnetism.

Diamagnets, Paramagnets, Ferromagnets. Torques and Forces on Magnetic di-poles, Effect of magnetic field on atomic Orbits, Magnetization, Bound currents, Physical interpretation of bound currents, Magnetic field inside matter, Ampere's law in magnetized materials, Magnetostatic Bounda-ry Conditions, Linear and Non-linear media: Magnetic susceptibility and permeability. Ferromagnetism

Text Books

1. David J. Griffiths, Introduction to Electrodynamics, 4th Ed., Pearson Publication, 2015.

Reference Books

1. Richard P. Feynman, Robert P. Leighton and Matthew Sands, Feynman Lectures on Physics Vol.1, 1E, Narosa Publishing House, 2008.
2. J.D. Jackson, Classical Electrodynamics, 3rd Ed., Wiley, 2007.
3. David Halliday, Robert Resnick, and Jearl Walker, Fundamentals of physics, 10thEdition, John Wiley, 2017.
4. Lectures by Prof. Dipan Ghosh on "Electromagnetic Theory" https://nptel.ac.in/courses/115/101/115101005/

Evaluation Pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	

*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

CO-PO Justification

Mapping	Justification	Affinity level
CO1-CO4 to PO1 and PSO 1	All the four course outcomes have strong affinity to PO1 as PO1 deals with inculcating strong fundamentals in Physics and Mathematics. Also all the COs will develop inquisitiveness to solve problems scientifically in students, the affinity level of them with PSO1 is the maximum.	3
CO1-CO4-PO2 and PSO 2	All the four course outcomes have strong affinity to PO2 as PO2 deals with enhancing analytical skill and critical thinking in students to find solution to scientific problems. Also all the COs will develop analytical skills in students so that they will be equipped to take up research related problems, the affinity level of them with PSO2 is the maximum.	3
CO1-CO4 – PO3	All the four course outcomes have strong affinity to PO3 as PO3 deals preparing students to undertake complex problems and to design and develop solutions which enhance the existing scientific knowledge.	3

22PHY381	Physics Lab IV - Electronics	0 0 3 1

1. Diode rectifier –full wave bridge rectifier

2. Diode Characteristics: Si, Ge, Zener diodes and voltage regulation using Zener diode (Line and load regulation).

3. Construction of Dual supply with 12 V - IC regulator

4. Design and performance study of Op-Amp based active filters (Low pass, high pass, band pass, band rejection) and frequency response amplifiers

5. Basic Opp –amp circuits- Inverting and non-inverting amplifier, Summing and difference amplifier

6. Multivibrators: Astable, Monostable and Bistable- Using 555 -Timers

7. Combination of gate universal- NAND and NOR as universal building blocks and verification of De Morgan’s theorem

8. Flip flops: D, RS, JK and Master slave

9. Half adder, Full adder and Subtractor

10. Counters and Registers- 4 bits.

11. Encoders and Decoders 4 bits

12. Response and characteristic of RC, LC and RLC and resonance circuits

Course Code	**Course Title**	**L T P**	**Cr**	**ES**
	SEMESTER 6			
22PHY311	Basics of Quantum Mechanics	3 1 0	4	
22PHY312	Basics of Mathematical Physics	3 1 0	4	
22PHY313	Elements of Condensed matter physics	3 1 0	4	
	Core Elective II	3 0 0	3	
22PHY314	Wave Optics	3 1 0	4	
	Professional Elective – II	3 0 0	3	
22PHY382	Project Based Lab (for regular students)	0 0 3	2	
	TOTAL	**24**		
22PHY399	Project (for Exit-option students)	**3**		
TOTAL (for Exit-option students)			**141**	

22PHY311	Basics of Quantum Mechanics	3 1 0 4

Prerequisites: Knowledge of basic and advanced mathematical physics.

Course Objectives

The course emphasizes the students to familiarize the mathematical background (Hilbert space) required to understand the basic and applied quantum mechanics, postulates, standard one dimensional problems and quantum theory of angular momentum.

Course Outcomes

After completion this course student able to

CO1. Understand and familiarize the mathematical framework (Hilbert space) required for the basic and applied quantum mechanics.

CO2. Understand the basic postulate and apply them to solve standard one dimensional problems in quantum mechanics.

CO3. Understand and learn the basic properties of harmonic oscillator.

CO4. Learn the basic concepts of quantum theory of angular momentum and apply them realistic physical problems.

CO5. Understand the concepts of addition of quantum angular momentum, standard coupling schemes and apply them in solving standard physics problems.

Skills: Basic tools (Hilbert space) required for Quantum Mechanics, Standard Coupling schemes of angular momenta used for advanced topics like nuclear physics, spectroscopy, condensed matter, quantum computation etc.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3			3	3		
CO2	3	3	3			3	3		
CO3	3	3	3			3	3		
CO4	3	3	3			3	3		
CO5	3	3	3			3	3		

UNIT 1

Learning Objectives

Learn the basic methods of linear vector spaces.
Apply those methods to solve eigenvalue problem of quantum mechanics.
Understand function of operators and the generalization to infinite dimensions.

Introduction to Quantum mechanics: Wave function, expectation values, Schrodinger equation for free particles, Bound state problems.
Linear Vector Spaces: Basics, Inner Product Spaces, Dual spaces and the Dirac Notation, Subspaces, Linear Operators, Matrix elements of linear operators, Active and Passive transformations, The Eigenvalue problem, Functions of Operators and related concepts, Generalization to infinite dimensions

UNIT 2: The Postulates of Quantum Mechanics and One-Dimensional Problems

Learning Objectives

Learn and understand the postulates of quantum mechanics.
Learn and understand the symmetries and conservation laws.
Understand and solve one dimensional problems.

The Postulates, Basic postulates of quantum mechanics, Observables and operators, Measurements in quantum mechanics, Time evolution of the system's state, Symmetries and conservation laws. Connecting quantum mechanics and classical mechanics.
Properties of One-Dimensional Motion: Bound, Unbound and Mixed States, Symmetric potentials and parity, free particle, Potential step, Potential barrier and Well, Infinite square well potential, Finite square well potential.

UNIT 3: The Harmonic Oscillator

Learning Objectives

- Learn and understand the ideas and concepts of harmonic oscillator.
- Learn and understand the matrix representation of various operators.
- Apply quantum mechanical methods to find the expectation values of various operators and general expression for uncertainty relations.

Review of the Classical Oscillator, Quantization of the Oscillator (Coordinate Basis), The Oscillator in the Energy Basis, Passage from the Energy Basis to the position Basis. Matrix Representation of Various Operators, Expectation Values of Various Operators. General expression for uncertainty relations.

UNIT 4: Angular Momentum

Learning Objectives

- Understand the basic ideas and concepts of angular momentum.
- Understand the quantum mechanical methods related to the angular momentum.
- Apply quantum mechanical methods for the quantitative calculations related to angular momentum.

Introduction, Orbital Angular Momentum, General Formalism, Matrix Representation, Geometrical Representation, Spin Angular Momentum, Experimental Evidence, theory of Spin, Spin 1/2 and Pauli Matrices. Eigen functions of orbital angular momentum: The Eigen value Problem of L2 and Lz, Properties of the Spherical Harmonics.

UNIT 5: Rotations and Addition of Angular Momenta

Learning Objectives

- Learn the basic ideas and concepts of rotation in quantum mechanics.
- Learn theanalytical methods for the addition of more than two angular momenta.
- Understand the addition of more than two angular momenta and able to findrotation matrices for coupling two angular momenta, scalar, vector, and tensor operators.

Rotations in Quantum Mechanics: Infinitesimal and Finite Rotations, Properties of the Rotation Operator, Euler Rotations, Rotation Matrices.
Addition of Angular Momenta: Addition of two Angular Momenta: General formalism, Calculation of the Clebsch–Gordan Coefficients, Addition of more than two angular momenta, Coupling of Orbital and Spin Angular Momenta, Rotation matrices for coupling two angular momenta, Scalar, Vector, and Tensor Operators.

Text Books:

1. N Zettili, Quantum Mechanics Concepts and Applications, John Wiley & Sons, 2nd Ed, 2009.
2. J J Sakurai, Modern Quantum Mechanics, Pearson, 2nd Ed, 2016.

Reference Books:

1. S Gasiorowicsz, Quantum Physics, Wiley India, 3rd Ed, 2003.
3. L I Schiff, Quantum Mechanics, McGraw Hill Education; 4th edition (1 July 2017).
4. David Griffiths, Introduction to Quantum Mechanics, Pearson India (LPE), 2E, 2013.
4. R Shankar, Principles of Quantum Mechanics, Pearson India (LPE), 2nd Ed, 2005.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-PO5 to PO1 & POS1	This course imparts fundamental knowledge to students and become a foundation for applied courses. Since the contents given in all five units forms a foundation to all other courses, all COs in this course exhibits strong affinity with PO1 and PSO1.	3
CO1-PO5 to PO2 & POS2	Since all COs are strongly related to fundamental concepts, this course would equip the students in analytical and critical thinking to analyze and find solutions to any scientific problems, Thus, the entire COs are strongly related to PO2 and PSO2 and will have maximum affinity level.	3
CO1-PO5 to PO3	Since Quantum mechanics is a powerful tool in microscopic scale, any new problems arises in microscopic regime needs quantum tool to solve them. In essence this course impart underlying scientific knowledge to solve complex problems and to design and develop solutions which enhance the existing scientific knowledge. Thus, PO3 has strong affinity with all COs	3

22PHY312	Mathematical Physics I	3 1 0 4

Course Objectives: The purpose of the course is to introduce students to the methods of mathematical physics and to develop required mathematical skills to solve advanced problems in theoretical physics.

Course Outcomes

After completing the course, the student should be able to:

CO 1. Understand mathematical methods used in various advanced physics courses and apply the techniques in solving problems involved

CO 2. Understand the theory of vector calculus in orthogonal and general curvilinear coordinates and apply it to solve physically relevant problems

CO 3. Perform basic operations with tensors in algebra and calculus; formulate and express physical laws in terms of tensors, and simplify it by the use of coordinate transforms

CO4. Understand the properties of Dirac delta function, various special functions, Fourier series and integral transforms and application of the same in solving integrals and differential equations

Skills:
Problem solving skills using various mathematical methods. Mathematical outlook to physical problems.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PSO 01	PSO 02	PSO 03
CO1	3	3				3	3	
CO2	3	3				3	3	
CO3	3	3				3	3	
CO4	3	3				3	3	

UNIT 1: VECTOR CALCULUS

Learning Objectives

1. A deeper understanding of concept of vectors and its theorems in calculus and Cartesian tensors and its application in physically relevant systems.
2. Application of Cartesian tensors in problems involving vector algebra and calculus.

Coordinate transformations, Definition of vectors, Index notation, Cartesian Tensors, Kronecker delta, Levi-Civita tensor and its application in Vector algebra and calculus. The vector differential operators, Integrals of vectors, Integral forms of gradient, divergence and curl, Line, surface and volume integrals – Stoke’s, Gauss’s and Green’s theorem.

UNIT 2: CURVILINEAR COORDINATES:

Learning Objectives

1. Good understanding of the properties of general curvilinear coordinates and vector calculus operators in them
2. Describing a system using suitable coordinates and solving the relevant problem

Cartesian, spherical and cylindrical coordinates. General curvilinear coordinates, Coordinate curves, Scale factors, Unit vectors in curvilinear systems, Arc length, area elements, volume elements. Gradient, divergence, curl and Laplacian. Special orthogonal coordinate systems: Parabolic and cylindrical coordinates, Paraboloidal coordinates, Elliptic cylindrical coordinates and applications.

UNIT 3: TENSOR ANALYSIS

Learning Objectives

1. Familiarity with the concept and principles of tensor algebra and calculus
2. Application of tensor calculus in studying physical systems

Definition and basic properties of tensors. Covariant, contravariant and mixed tensors. The summation convention, Fundamental operations with tensors. The line element and metric tensor. Tensor algebra, Christoffel symbols and their transformation laws, Covariant differentiation. Tensor form of gradient, divergence and curl. Geodesic equation, Curvature tensors.

UNIT 4: DIRAC DELTA & GENERALISED FUNCTIONS, FOURIER SERIES & INTEGRAL TRANSFORMS

Learning Objectives

Study of generalised function- Dirac delta and its various properties and solving physically relevant problems modelled with Dirac delta function in different dimensions and coordinates

Study and application of Fourier Series and integral transforms

Introduction to Generalised functions, delta sequences. One dimensional Dirac delta function, properties and representations, higher dimensional Dirac delta function. Dirac Delta function in curvilinear coordinates. Heaviside unit step function. Applications and properties of Fourier series and its Complex form, Fourier representation of Dirac Delta. Integral transforms and properties, Parseval's theorem, Convolution theorem, applications. Green's function

UNIT 5: SPECIAL FUNCTIONS

Learning Objectives

1. Familiarity with various special functions and its properties
2. Application of special functions in solving integrals and as solutions of relevant differential equations describing systems with various symmetries.

Gamma, Beta and Error functions – definitions, properties and applications. Orthogonal functions, Bessel's equation, General solution for non-integer ν; general solution for integer ν; Bessel function of first kind and second, properties of Bessel functions, Integral representations. Recurrence Relation, Orthogonality, Rodrigues Formula. Modified Bessel functions, Henkel functions. Equations transformed into Bessel's equation. Other special functions: Legendre, Hermite, Laugerre functions- Recurrence relations and generating functions-. Applications.

Text Books:

1. Riley K F, Hobson M P, Bence S J, Mathematical Methods for Physics and Engineering, CUP, 3rd Ed, 2010
2. Arfken & Weber, Mathematical Methods for Physicists, Elsevier Indian Reprint, 7th Ed., 2012.

Reference Books:

1. M Boas, Mathematical Methods in Physical Sciences, Wiley Indian Reprint 3rd Ed, 2006.
2. Mathews J and Walker R L, Mathematical Methods of Physics, Pearson India, 2nd Ed, 2004.
3. C. W. Wong, Introduction to Mathematical Physics: Methods & Concepts, Oxford, 2013

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

CO-PO Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understanding and applying various mathematical techniques and applying them to solve physical problems. This improves student's knowledge in Mathematics and Physical sciences as any physical situation can be described as a mathematical problem, and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and analytical skills and CO1 is related to understanding and applying various mathematical techniques to study physical systems, to assist it; hence the affinity level is maximum ie, 3.	3
CO2-PO1	CO2 is related to study and application of vector calculus in rectilinear and general curvilinear coordinate systems and hence the affinity level 3.	3
CO2-PO2	CO2 deals with many analytical techniques of vector calculus and it enhances students analysis and analytic skills, so the affinity 3.	3
CO3-PO1	CO3, related with tensor calculus and coordinate transformations, enables students to understand mathematical formulation of physical laws and hence CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to understanding and applications of tensor calculus to physical problems, resulting in enhancement of students analysis and analytic skills; hence the affinity 3.	3
CO4-PO1	CO4 introduces many special functions, integral transforms, series expansion of functions etc, which are very essential to understand any physical system and thus CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 involves application of many special functions, integral transforms, series expansion of functions etc to solve physically relevant problems with many technical innovations and thus CO4 has maximum affinity of 3 with PO1.	3
CO1-PSO1	PSO1 is related to the proficiency in mathematical physics and other theoretical physics topics; which is the aim of this course, as shown by CO1 and hence the affinity is maximum (3).	3
CO1-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3
CO2-PSO1	CO2 enhances knowledge of vector calculus and curvilinear coordinates and it has application in other theoretical courses; hence maximum affinity is seen with PSO1	3
CO2-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	
CO3-PSO1	CO3 aims at making student comfortable with tensor calculus, which is essential in understanding advanced physics courses; hence maximum affinity is seen with PSO1	3
CO3-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	
CO4-PSO1	CO4 deals with study of special functions, generalised functions, integral transforms etc and its application to physically relevant systems that one encounters in theoretical physics. Hence there is a maximum affinity with PSO1	3

CO4-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3

22PHY313	Elements of Condensed Matter Physics	3 1 0 4

Prerequisites: Basic knowledge of calculus, classical mechanics, electricity and magnetism, statistical mechanics and quantum mechanics.

Course Objectives

- To develop a clear perception of the crystal classes and symmetries and to understand the relationship between the real and reciprocal space
- To create the knowledge on the concepts of X-ray diffractions and diffraction patterns in solids
- To study the basics of the optical and acoustic phonons in crystals
- To give clear understanding on the basic concepts of energy bands in solids
- To learn the different polarization mechanisms in dielectrics

Course Outcomes

Upon completion of the course, students will be able to

CO1. Classify the crystal system based on symmetry and explain the nature of imperfections in the solids

CO2. Explain the diffraction conditions in crystals and compute the conditions for allowed and forbidden reflections in crystals

CO3. Understand the concept of phonons in mono and diatomic lattice and explain phonon's heat capacity of solids

CO4: Familiar with the free-electron theory of metals, Fermi surfaces and basic concepts of the band theory of solids

CO5. Acquire knowledge on different types of polarization in dielectrics and describe the ferroelectricity and piezoelectricity in solids.

Skills: Problem solving skills as well as computational skills of the students in analyzing the properties of solid-state materials will be improved through assignments, quizzes, and presentations.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	2			3	2	
CO2	3	3	2	1		3	3	
CO3	3	3	2			3	1	
CO4	3	3	2			3	2	
CO5	3	3	2			3	2	

UNIT 1

Learning Objectives:

In the unit-1, students will learn to

1. Relate the crystal structure to symmetry and explain the crystallographic planes & directions of different crystal systems

2. Explain the nature of defects in the crystals
3. Discuss the solid solutions and the binary phase diagrams

Crystal Structure: Periodic array of atoms, fundamental types of lattices**,** index system for crystal planes. Crystal structure data. Crystal symmetry - point and space groups. Quasi crystals. Non-ideal Crystal Structures.

Crystal Defects: Lattice Vaccancies, Frenkel and Schottky defects, Colour centers, Dislocations: Slip and plastic deformation, Shear strength of single crystals, Edge dislocationn, Screw dislocation, Stress field around an edge dislocation, Surface defects.

Alloys: Substitutional solid solutions, Hume - Rothery rules, binary phase diagrams, lever rule.

UNIT 2:

Learning Objectives:

In the unit-2, students will learn the

1. Correspondence between real and reciprocal space
2. Diffracting planes and determination of diffraction intensity, structure of different crystalline materials
3. Different Experimental techniques used in X-ray diffractions

Diffraction of waves and reciprocal lattice: Diffraction of waves by crystals, Reciprocal lattice and Brillouin zone, Laue Condition, Bragg’s law, scattered wave amplitude, Friedel's law, Anomalous scattering, Atomic and geometric structure factors, systematic absences, Fourier analysis of basis, Ewald construction, Experimental methods.

UNIT 3:

Learning Objectives:

In the unit-3, students will learn

1. The concept of phonons and how the dispersion relationship appears for different lattices.
2. Phonon contribution to the solid’s specific heat capacity

Lattice Vibrations and Thermal Properties: Vibrations of crystals with monatomic basis-two atoms per primitive basis. Quantization of Elastic Waves, phonon momentum, inelastic scattering by phonons. Phonon heat capacity: Einstein and Debye models of phonon specific heat, anharmonic crystal interactions, Thermal Conductivity.

UNIT 4:

In the unit-3, students will learn

1. The Fermi Dirac distribution and Free electron gas in three dimensions
2. Electrical and Thermal conductivity of metals, Temperature dependent resistivity
3. The elementary band theory of solids and Fermi surfaces

Free Electron Fermi Gas: Energy levels in one dimension, effect of temperature on Fermi-Dirac distribution, free electron gas in three dimensions. Heat capacity of electron gas. Electrical conductivity and Ohm's law, motion in magnetic fields, thermal conductivity of metals. Temperature dependent conductivity in metals-Matthiessen’s rule, Nordheim rule.

Energy Bands: Bloch Functions, Kronig-Penney model. Methods of Calculation of Energy bands: Nearly free electron model, Reduced zone-periodic zone schemes, Tight Binding method.

Fermi Surfaces: Construction of Fermi surfaces, electron orbits, hole orbits, and open orbits. Experimental methods in Fermi surface studies**.**

Unit 5

In the unit-5, students will learn

1. The different types of polarizations
2. Dielectric constant and polarizability
3. Ferroelectric Crystals, Phase Transitions and Piezoelectricity

Dielectrics: Maxwell's equations, Macroscopic electric field, Depolarization field, Local electric field at an atom, Lorentz field, Dielectric constant and polarizability- Clausius-Mossotti relation, Electronic polarizability, classical theory of Electronic polarizability, Ferroelectric crystals, Displacive Transitions - Landau Theory of Phase Transitions anti-ferroelectricity and piezoelectricity.

Text Book:

Charles Kittel, Introduction to Solid State Physics, Eighth Edition, Wiley, 2016.

Reference Books:

1. Wahab M A., Solid State Physics, Narosa Publishing House Pvt. Ltd. - New Delhi, 2015.
2. Ali Omar, Elementary Solid State Physics, Pearson India; Revised edition, 2007.
3. M Vijaya, Rangarajan G, Materials Science, McGraw Hill Education, 2004.
4. Azaroff Leonid V., Introduction to Solids, McGraw-Hill Education, 2017.
5. S. O. Kasap, Principles of Electronic Materials and Devices Fourth Edition, McGraw-Hill Education, 2021.

Evaluation Pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to acquiring thorough knowledge on the Bravais lattices, symmetry, and defects in crystals. CO1improves the fundamentals of crystal physics in students. Since PO1 is related inculcate strong science (physics) fundamentals, CO1 has been mapped with PO1 with maximum affinity of 3.	3
CO1-PO2	PO2 is about developing the analytical skills and critical thinking among students. In CO1 the fundamental crystallographic problems and problems related to defects will be solved. Hence the affinity level is given maximum for CO1 when mapped with PO2.	3

CO1-PO3	Understanding the mentioned concepts of CO1 will primarily intend to solve crystallographic planes, symmetry determination and phases in alloys. PO3 is to expose students to solve complex problems which enhance the existing scientific knowledge. Since complex problems is not dealt in CO1, the affinity with PO3 is given as medium level	2
CO1-PSO1	PSO1 is related to develop curiosity and inquisitiveness among students to look at fundamental problems. As CO1 matches highly with PSO1 it is given maximum affinity level	3
CO1-PSO2	PSO2 is to impart analytical and experimental skills so that students are equipped to take up independent research. In CO1, the analysis of crystallographic directions, planes of solids, defects and phase formation in alloys are covered which partly provide the platform for analytical skills to do independent research among students, hence it is mapped with medium level affinity	2
CO2-PO1	CO2 improves the fundamental physics of diffractions. Since PO1 is related to the knowledge in fundamental sciences, CO2 is given maximum affinity of 3 when mapped with PO1.	3
CO2-PO2	Problems corresponds related to structure factors, reciprocal lattice etc. (CO2) will be solved by students which improves the analytical skills and critical thinking as mentioned in PO2. So, the CO2- PO2 mapping is given an affinity level of 3.	3
CO2-PO3	In CO2, students will primarily solve problems related to structural identification from the x-ray diffractions in solids with high symmetry. PO3 is to expose students to solve complex problems which enhance the existing scientific knowledge. Since, complex structural solving (with low symmetry structures) is not dealt in CO2, the affinity with PO3 is given as medium level	2
CO2-PO4	Students get exposed to basic analysis XRD patterns of specific solid samples, since only basic research parameters in diffractions are gained it is given a minimum affinity	1
CO2-PSO1	In CO2, as the learners will develop curiosity in solving the diffraction patterns of solids which highly matches with the described PSO1, it is mapped with a maximum affinity level of 3	3
CO2-PSO2	As students develop the analytical skills of determining the crystal structure in solids which equips them to do independent research. Hence, a high affinity level of 3 is given in the mapping of CO2-PSO2.	3
CO3-PO1	CO3 develops knowledge of phonon dispersion in lattice and thermal conductivity of solids. Since PO1 is related to acquiring strong knowledge in basic science, CO2 is given maximum affinity of 3 when mapped with PO1.	3
CO3-PO2	In CO3, Students develop analytical skills of finding solutions to the problems corresponds to the specific heat of different materials. PO2 is related to developing the analytical skills involving fundamentals of basic sciences. So, the CO2- PO2 mapping is given an affinity level of 3.	3

CO3-PO3	Learners' gain knowledge of determining the phonon modes and their dispersion in solids (CO3), which will develop them to undertake and solve problems in spectroscopic analysis and hence the mapping of CO3 is given a medium affinity of 2 with PO3.	2
CO3- PSO1	In CO3, students develop interest of determining specific heat capacity of solids and so the mapping of CO3 with PSO1 is given a high affinity level	3
CO3- PSO2	In CO3, students develop basic knowledge of phonon dispersion in solids which is the fundamental of Raman spectroscopy. It will lay the platform for them to take up independent research analysis in spectroscopy. The mapping with PSO2 is given a minimum affinity as CO3 covers the fundamentals alone.	1
CO4-PO1	Students learn the fundamentals of electrical conductivity in CO4 which highly matches with PO1. The mapping of CO4-PO1 is given a maximum affinity level	3
CO4-PO2	Students develop problem solving skills related to constructing Fermi surfaces, electrical conductivity in metals etc. Hence, the mapping of CO4 with PO2 is given a maximum affinity of 3.	3
CO4-PO3	In CO4, learners develop fundamental understanding of energy levels in bandstructure and finding solutions to the Fermi surface of metals which maps with PO3 with medium affinity level.	2
CO4-PSO1	In CO4, Students gain problem solving curiosity with respect to the Fermi surfaces, electrical conductivity in metals etc. Hence, the mapping of CO4 with PSO1 is given a maximum affinity of 3.	3
CO4-PSO2	Gaining knowledge of the formation of energy bands, Fermi surfaces and electrical conductivity gives students fundamental platform to understand materials research. The affinity with PSO2 is given a medium level.	2
CO5-PO1	In CO5, students get benefited the learning of dielectrics, ferroelectrics and piezoelectrics which matches well with PO1 and hence it is assigned maximum affinity.	3
CO5-PO2	Students develop analytical thinking and problem solving with respect to polarizations in solids, phase transitions etc. (CO5) and so it is given maximum affinity with PO2.	3
CO5-PO3	In CO5, learners gain the fundamentals of different dielectric constants which prepares them to analysis the complex problems in dielectric measurements of various materials and thus it is mapped with PO3 with a medium affinity level.	2
CO5-PSO1	In CO5, students enrich their scientific knowledge on how the different polarizations happens in solids and so it is assigned a maximum affinity with PSO1.	3
CO5-PSO2	In CO5, students develop the analysis of different dielectric constants which prepares them to do research experiments of impedance spectroscopy, hence it may be mapped with PSO2 with a medium affinity	2

22PHY314	Wave Optics	3 1 0 4

Pre-requisites: Waves and oscillations, Basics theories of interference diffraction, polarization and Fourier transform

Course Objective: The course is framed to provide in depth knowledge in wave optics and its application in various fields.

Course Outcomes

CO 1. Understand the phenomenon of interference and diffraction light wave in various optical components.

CO 2. Analyze the consequence of diffraction by Fourier techniques and applying them in realistic problems

CO 3. Understand the phenomenon of polarization of light wave and analyze them by Jone's calculus.

CO 4. Understand the generation mechanism of laser beam, its characteristic and its application

CO 5. Understand the light guiding mechanism in optical fiber, its characteristic and its day to day application

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	
CO5	3	3	3			3	3	

UNIT 1: Interference and diffraction

Learning Objectives

Learn and understand the basic concepts of interference and diffraction.

Diffraction – single, double and multiple slits, circular aperture, Resolution of imaging system, Diffraction grating, re-solving power of grating, Michelson's Interferometer, Fabry-perot interferometer, Bragg's Law.

UNIT 2: Diffraction theory

Learning Objectives

Learn the method of analyzing the phenomenon of diffraction using Fourier theory.

Fourier method: Fresnel Diffraction Integral, Uniform Amplitude and Phase Distribution, Fraunhofer approximation, Fraunhofer Diffraction by a Long Narrow Slit, Fraunhofer Diffraction by a Rectangular Aperture, Fraunhofer Diffraction by a Circular Aperture, Array of Identical Apertures, Spatial Frequency Filtering.

UNIT 3: Polarization and Double Refraction

Learning Objectives

Understand and analyze the phenomenon of polarization and their sates.

The Phenomenon of Double Refraction, linear, circular, and elliptic polarization, Quarter Wave Plates and Half Wave Plates, Optical Activity, Jone's Calculus, Faraday Rotation, Theory of Optical Activity.

UNIT 4: Laser

Learning Objectives

Understand the fundamental aspects of laser, its parameters and laser generation.

Fundamentals, Stimulated emission, Einstein's coefficients, Absorption and Emission Cross Sections, Light Amplification, Line Broadening Mechanisms, Laser Rate Equations: Two-Level System, Three-Level System, Four-Level System, Variation of Laser Power around Threshold, Optimum Output Coupling.

Properties of Lasers: Laser Beam Characteristics, Coherence Properties of Laser Light, Temporal Coher-ence, Spatial Coherence. Laser Systems: Ruby Lasers, Neodymium-Based Lasers, Nd: YAG Laser, He–Ne Laser, Argon Ion Laser, CO2 Laser, Dye Lasers. Laser Diodes. Optical resonators. Holography: fundamentals, construction and reconstruction of hologram

UNIT 5: Optical fibres and wave guides

Learning Objectives

Understand the fundamental aspects of guiding mechanism of optical wave in fiber medium.

Optical fibre, Critical angle of propagation, Mode of Propagation, Ac-ceptance angle, Fractional refractive index change, Numerical aperture, Propagation of light in dielectric medium. Basic Waveguide Theory and Concept of Modes: TE Modes of a Symmetric Step Index Planar Waveguide, Physical Understanding of Modes, TM Modes of a Symmetric Step Index Planar Waveguide, TE Modes of a Parabolic Index Planar Waveguide. Single-Mode Fibres: Basic Equations, Guided Modes of a Step Index Fibre, Pulse Dispersion in Single-Mode Fibres, Dispersion Compensating Fibres. Basics of optical fibre communication system

Text books:

1. Francis A. Jenkins, Harvey E.White, Fundamentals of Optics, 4th Ed, McGraw Hill Education; 2017.
2. K. Thyagarajan and A.K. Ghatak, Lasers Fundamentals and applications, 2nd Ed, Springer, 2012.
3. A.K. Ghatak, Introduction to Modern optics, McGraw-Hill (13 December 2016).
4. Introduction to Fourier Optics, J. W. Goodman, McGraw-Hill. Third Edition, 2004.
5. Hecht, Eugene, Optics, 5th Ed, Pearson, 2016.

References:

https://nptel.ac.in/courses/115/102/115102124/

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-PO5 to PO1 & POS1	This course imparts fundamental optical knowledge to students and become a foundation for all applied courses. Since the contents given in all five units forms a foundation to wave optics and its applications, all COs in this course exhibits strong affinity with PO1 and PSO1.	3
CO1-PO5 to PO2 & POS2	Since all COs are strongly related to fundamental concepts, this course would equip the students in analytical and critical thinking to analyze and find solutions to any scientific problems, Thus, the entire COs are strongly related to PO2 and PSO2 and will have maximum affinity level.	3
CO1-PO5 to PO3	Since waves optics is a powerful tool which can be plugged into many applied courses and most of the problems in applied regime may be addressed by the tools of waves and signals, this course imparts underlying scientific knowledge to solve complex problems and to design and develop solutions which enhance the existing scientific knowledge. Thus, PO3 has strong affinity with all COs	3

Course Code	Course Title	L T P	Cr	ES
	SEMESTER 7			
22PHY501	Quantum mechanics	3 1 0	4	
22PHY502	Classical Mechanics II	3 1 0	4	
22PHY503	Mathematical Physics II	3 1 0	4	
22PHY504	Electrodynamics	3 0 1	4	
22PHY581	Physics Lab - VI (Project Based Lab – Common to both streams)	0 0 4	2	
	Core Elective - III	3 0 0	3	
22PHY505	Statistical Mechanics	3 1 0	4	
	TOTAL		**TOTAL**	**25**

22PHY501	Quantum Mechanics	3 1 0 4

Pre-requites

Knowledge of mathematical physics and basic quantum mechanics.

Course Objectives

The course emphases the students to familiarize the application of quantum mechanics to single, many body problems, approximation methods and scattering theory. Students also learn the basic concepts of relativistic quantum mechanics.

Course Outcomes: After completion this course student able to

CO1. Understand different aspects of the 3 dimensional Schrödinger equation and solve problems related to 3D Cartesian and spherical polar coordinates.

CO2. Learn and apply the main approximation methods for stationary states.

CO3. Learn the basic ideas and methods of time-dependent perturbation theory.

CO4. Learn and apply the scattering theory and solve problems related to scattering.

CO5. Understand and learn the concepts and methods related to relativistic quantum wave equations.

Skills: Analytical skills are developed by solving problems related to advanced topics in quantum mechanics through assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3				3	3	
CO2	3	3				3	3	
CO3	3	3				3	3	
CO4	3	3				3	3	
CO5	3	3				3	3	

UNIT 1: Three Dimensional Problems

Learning Objectives

Learn the basic methods of quantum mechanics to solve 3D potentials.
Understand the difference between various 3D potentials.
Analyze the effect of magnetic field on central potentials.

The Free Particle, The Box Potential, The Harmonic Oscillator, Central Potential, The Spherical Square Well Potential, The Isotropic Harmonic Oscillator, The Hydrogen Atom, Effect of Magnetic Fields on Central Potentials.

UNIT 2: Approximation Methods

Learning Objectives

Understand the basic concepts of perturbation theory and approximation methods.

Learn analytical methods to solve problems of hydrogen atom like fine structure and anomalous Zeeman effect.

Apply mathematical methods for the quantitative calculations related tunnelling through a potential barrier.

Nondegenerate Perturbation Theory, Degenerate Perturbation Theory, Fine Structure and the Anomalous Zeeman Effect, The Variational Method, The Wentzel–Kramers–Brillouin (WKB) Method, Bound States for Potential Wells with No Rigid Walls, Bound States for Potential Wells with One Rigid Walls, Bound States for Potential Wells with Two Rigid Walls, Tunnelling through a Potential Barrier.

UNIT 3: Time Dependent Perturbation Theory

Learning Objectives

Learn and understand the basic concepts and methods of time dependent perturbation theory.

Understand the basic features of the Schrödinger picture, the Heisenberg picture and the interaction picture.

Apply quantum mechanical methods to find the transition probability for a harmonic perturbation.

The Schrödinger Picture, The Heisenberg Picture, The Interaction Picture, Transition Probability, Transition Probability for a Constant Perturbation, Transition Probability for a Harmonic Perturbation, Adiabatic Approximation, Sudden Approximation.

UNIT 4: Scattering Theory

Learning Objectives

Understand the basic ideas and concepts of scattering theory.

Understand the quantum mechanical methods related to the scattering theory.

Apply quantum mechanical methods for the quantitative calculations related to scattering.

General formalism, Connecting the Angles in the Lab and CM frames, Connecting the Lab and CM Cross Sections, Scattering Amplitude and Differential Cross Section, Scattering Amplitude, The First Born Approximation, Validity of the First Born Approximation, Partial Wave Analysis for Elastic Scattering, Partial Wave Analysis for Inelastic Scattering.

UNIT 5: Relativistic Wave Equations

Learning Objectives

Learn the basic ideas and concepts of relativistic quantum mechanics.

Understand the basic features of relativistic wave equations.

Understand the free motion of a Dirac particle and single particle interpretation of plane (Free) Dirac wave.

The Klein-Gordon Equation, Free Spin Zero Particles, Interaction of Spin Zero Particles with Electromagnetic Field, The Dirac Equation, Free motion of a Dirac Particle, Single Particle interpretation of Plane (Free) Dirac Wave.

Text Books:

1. N Zettili, Quantum Mechanics Concepts and Applications, John Wiley & Sons, 2nd Edition, 2009.
2. JJ Sakurai, Modern Quantum Mechanics, Cambridge University Press; 3rd Edition, 2020.

3. W Greiner, Relativistic Quantum Mechanics, Springer, 3rd Edition, 2000.

Reference Books:

1. F Schwabl, Quantum Mechanics, Springer, 4th Edition, 2007.
2. L I Schiff, Quantum Mechanics, McGraw Hill Education; 4th edition, 2017.
3. David Griffiths, Darrell F. Schroeter, Introduction to Quantum Mechanics, Cambridge University Press India Pvt Ltd, 3rd Edition, 2019.

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignment, Projects, and Reports.

Justification for CO-PO mapping

Mapping	**Justification**	**Affinity level**
CO1-PO1	CO1 is related to understand different aspects of the 3 dimensional Schr¨odinger equation. This improves student's knowledge in quantum mechanics and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and CO1 is also related to solve problems related to 3D Cartesian and spherical polar coordinates. Hence the affinity level between CO1 and PO2 is mentioned as 3.	3
CO2-PO1	CO2 is related to learning the main approximation methods for stationary states in quantum mechanics. Hence the affinity level is 3.	3
CO2-PO2	As CO2 is related to apply main approximation methods to stationary states. Since PO2 is related to developing analytical skills, the affinity level between them is 3.	3
CO3-PO1	Since PO1 is related to acquiring knowledge in quantum mechanics, CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to the applications of time dependent perturbation theory. As problems will be solved employing these methods and the analytical skills of students will be improved. Since PO2 is related to improving analytical skills, CO3 has maximum affinity to PO2 and hence given an affinity level of 3.	3
CO4-PO1	CO4 is related to learning scattering theory for quantum mechanical problems. As PO1 is related to improving knowledge of physics fundamentals, CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 is for solving problems related to scattering. Since PO2 is related to the development of analytical skills of students and maximum affinity level of 3 is given for CO4-PO2 mapping.	3

CO5-PO1	CO5 is related to understanding of basic concepts of relativistic quantum mechanics. Since PO1 is related to improving student's knowledge in quantum mechanics, maximum affinity level of 3 is given for CO5-PO1 mapping.	3
CO5-PO2	CO5 improves the analytical skills of students. As PO2 is related to improving analytical skills, CO5 has maximum affinity with PO5 and hence given an affinity level of 3.	3
CO1-PSO1	PSO1 is related to demonstration of proficiency in quantum mechanics which essential to understand the three dimensional Schr¨odinger equation. Hence the affinity level is 3.	3
CO1-PSO2	CO1 deals with knowledge and tools of quantum mechanics to solve 3D problems. Hence CO1 completely map with PSO2 and an affinity level of 3 is assigned.	3
CO2-PSO1	CO2 is related to understanding of the main approximation methods for stationary states which map completely with PSO1. So the affinity level is 3.	3
CO2-PSO2	Since PSO2 is related to improving knowledge in quantum mechanics. Hence the affinity level between CO2 and PSO2 is 3 instead of 2 or 1.	3
CO3-PSO1	Since CO3 is related to application of time dependent perturbation theory which require basic understanding of quantum mechanics, CO3-PSO1 mapping has the affinity level 3.	3
CO3-PSO2	The affinity level between CO3 and PSO2 is 3 since CO3 deals with applications of time dependent perturbation theory to solve problems which eventually improves not only analytical skills of students but also their knowledge in quantum mechanics.	3
CO4-PSO1	CO4 is related to learning and applying scattering theory to quantum mechanical problems. Hence CO4-PSO1 mapping has the affinity level 3.	3
CO4-PSO2	The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to scattering.	3
CO5-PSO1	CO5 is related to relativistic quantum mechanics and hence CO5-PSO1 mapping has the affinity 3. PSO1 is related to demonstrating proficiency in mathematics and mathematical concepts to understand quantum mechanics.	3
CO5-PSO2	The affinity level between CO5 and PSO2 is 3 since CO5 deals with understanding and application relativistic quantum mechanics.	3

22PHY502	Classical Mechanics II	3 1 0 4

Pre-requisites: - Mechanics, Classical Mechanics 1, Mathematics 1&2

Course Objectives: To study, understand and apply principles of Hamiltonian dynamics to solve dynamical systems

Course outcomes

CO1: Study canonical transformations and apply it to mechanical problems
CO2: Study the properties of Poisson's bracket and apply it to dynamical problems
CO3: Apply Hamilton Jacobi theory for Harmonic oscillator and Kepler problem

CO4: Apply small oscillation theory developed in getting the frequencies of different of modes of oscillations in a coupled system

CO5: Introduction to Chaos and Nonlinear dynamics

Skill: Analytical skill to formulate dynamical problem and solve using Lagrangian Formalism.

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1		3	3			3	3	
CO2		3	3			3	3	
CO3		3	3			3	3	
CO4		3	3			3	3	
CO5		3	3			3	3	

UNIT 1

Learning objectives

Understand the motivation for transformation

Study the technique of canonical transformation

To write down generating function for a given canonical transformation

Canonical Transformations: Equations of Canonical transformation, Examples-Simple Harmonic Oscillator, Liouville's Theorem. Volume preservation in phase Space, Generating function, Conditions for canonical transformation and problem.

UNIT 2

Learning objectives

Definition and properties of Poisson brackets

Application of Poisson bracklets

Poisson Brackets: Definition, Identities, Poisson theorem, Jacobi-Poisson theorem, Jacobi identity, invariance of PB under canonical transformation- Angular momentum Poisson bracket- Symmetry, invariance and Noether's theorem.

UNIT 3

Learning objectives

Hamilton- Jacobi Equation –its formation

Application of HJ equation

Action- Angle Variable

Hamilton- Jacobi Theorem: Hamilton- Jacobi Equation for Hamilton's principal function, Hamilton- Jacobi Equation for Hamilton's Characteristic Function, Harmonic oscillator problem, Action –angle variable in Systems of one variable, Kepler Problem in Action-angle variable.

UNIT 4

Learning objectives

Theory of small oscillations- Eigen value problems

Apply the theory to various applications

Small oscillations: Formal theory of small oscillations as Eigen value problems, applications to diatomic and triatomic molecules, modes of vibrations.

UNIT 5

Learning objectives

Introduction to Chaos

Elements of Non-linear dynamics- simple examples

Introduction to Chaos and Nonlinear Dynamics: Fixed points, Bifurcation, and Limit cycles, Lorenz Equations, The Logistic Map, Fractals and Strange Attractors.

Text Books:

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, Pearson Education, 3rd Edition, 2011.
2. Landau and Lifshitz, Mechanics, Butterworth-Heinemann, 3rd Edition, 1982.
3. S.T. Thornton and J.B. Marion, Classical Dynamics of Particles and Systems, Cengage, 5th edition, 2012.
4. Walter Greiner, Classical Mechanics: Systems of Particle and Hamiltonian Dynamics, Springer,2nd Edition, 2009
5. Lecture Series on Classical Physics by Prof. V. Balakrishnan - https://www.youtube.com/watch?v=Q6Gw08pwhws&list=PL5E4E56893588CBA8
6. Steven H Strogatz, Non Linear Dynamics and Chaos, Perseus Books Publishing, 1994.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO 5 to PO2 and PSO 1	This is course with objective of building basic analytical skills to formulate problems and solve using techniques developed. There for it has highest affinity towards PO2 and PSO 1	3
CO1-CO5-PO3 and PSO 2	This course develops problem solving skills and form a core course in Physics which will help student to formulate research problems – hence has strong affinity towards PO3 and PSO 2	3

22PHY503	Mathematical Physics II	3 1 0 4

Course Objectives: The purpose of the course is to introduce students to the methods of mathematical physics and to develop required mathematical skills to solve advanced problems in theoretical physics.

Course Outcomes

After completing the course, the student should be able to

CO1. Understand mathematical methods used in various advanced physics courses and apply the techniques in solving problems involved

CO2. Understand the theory of complex functions, with conditions, theorems related to Complex differentiation and Integration and apply them in solving various types of real and complex integrals

CO3. Analyse and solve second order ordinary differential equations using Series solution method etc.

CO4. Sturm-Liouville Problem and Green's functions and its usage in Physics, solutions of differential equations in rectilinear and curved coordinates with special importance to PDEs of physically relevant systems; introduction to group theory.

Skills

Problem solving skills using various mathematical methods. Mathematical outlook to physical problems.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PSO 01	PSO 02	PSO 03
CO1	3	3				3	3	
CO2	3	3				3	3	
CO3	3	3				3	3	
CO4	3	3				3	3	

UNIT 1: Complex Variables I

Learning Objectives

Analysis of functions in complex plane

Complex numbers, Roots, Functions of a complex variable, Differentiation of a complex function, Cauchy-Riemann conditions, Analytic functions, Harmonic functions, Special Analytical functions, Multivalued functions and branch cuts, Singularities, and zeros of complex functions

UNIT 2: Complex Variables - II

Learning Objectives

Theorems on Complex Integration, Taylor and Laurant Series, Residue Theorem

Evaluation of complex and real integrals using Cauchy‘s theorem and Residue theorem.

Complex integrals, Contour integrals, Darboux inequality, Cauchy's theorem, Cauchy's integral formula, Derivatives of analytic functions, Taylor and Laurent series, Uniqueness and Convergence. Poles, Residues at Poles, Residue Theorem, Evaluation of integrals using the Residue Theorem, Jordan's lemma, Application of Residue Theorem. Applications of Complex variables.

UNIT 3: Ordinary Differential Equations (ODE) - Series Solution

Learning Objectives

Study of second order ordinary differential equations with special emphasis to Series solution method

Basics of series and first order ODE, Second-order linear ordinary differential equations, Ordinary and singular points, Series solution: Frobenius Method, second solution, the Wronskian method, the derivative method, series form of the second solution, Polynomial solution, Solutions of Legendre, Bessel equations etc. and properties.

UNIT 4: Partial differential equations

Learning Objectives

Study of partial differential equations in rectilinear and curved coordinates with special importance to PDEs of physically relevant systems.

Familiarity with Orthogonal functions and Sturm-Lioville theory

Partial differential equations (PDEs) in Physics: Laplace, Poisson, Helmholtz equations, treatment in curvilinear coordinates. Other PDEs of Mathematical Physics: diffusion and wave equations, Separation of variables and other methods, Applications.

UNIT 5: Sturm-Liouville theory

Learning Objectives

Study of Sturn-Lioville problem and its use in theoretical physics, Green‘s function techniques and familiarity with basics of group theory.

Sturm-Liouville Problem and its usage in Physics, Problems with Cylindrical symmetry: Bessel functions, Problems with Spherical Symmetry- Spherical Harmonics, Classical Orthogonal Polynomials.
Introduction to Green's function: Introduction to Green's function, Properties, Green's function in one-dimension, Application in differential equations, Eigen function expansion.
Elements of Group theory: Definition, Cyclic groups, group multiplication table, Isomorphic group, Representation, Special groups: SU(2), O(3).

Text Books:

1. K.F. Riley, M.P. Hobson, S.J. Bence, Mathematical Methods for Physics and Engineering, Cambridge University Press, 3rd Edition, 2018.
2. G. Arfken, H. Weber and F.E. Harris, Mathematical Methods for Physicists, Elsevier Indian Reprint, 7th Edition, 2012.

Reference Books:

1. M.L.Boas, Mathematical Methods in Physical Sciences, Wiley, 3rd Edition, 2006.
2. J. Mathews and R.L. Walker, Mathematical Methods of Physics, Pearson India, 2nd Edition, 2004.
3. C. W. Wong, Introduction to Mathematical Physics: Methods & Concepts, Oxford, 2nd Edition, 2013.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	

*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understanding and applying various mathematical techniques and applying them to solve physical problems. This improves student's knowledge in Mathematics and Physical sciences as any physical situation can be described as a mathematical problem, and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and analytical skills and CO1 is related to understanding and applying various mathematical techniques to study physical systems, to assist it; hence the affinity level is maximum ie, 3.	3
CO2-PO1	CO2 is related to study and application of complex analysis and hence the affinity level 3.	3
CO2-PO2	CO2 deals with many analytical techniques of complex analysis and it enhances students analysis and analytic skills, so the affinity 3.	3
CO3-PO1	CO3, related with solutions of second order differential equations using series solution method with application to physically relevant systems and hence CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to solving and applications of second order differential equations, resulting in enhancement of students analysis and analytic skills; hence the affinity 3.	3
CO4-PO1	CO4 introduces many advanced topics of mathematical physics, which are very essential to understand any physical system and thus CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 involves application of many advanced mathematical methods to solve physically relevant problems and thus CO4 has maximum affinity of 3 with PO2.	3
CO1-PSO1	PSO1 is related to the proficiency in mathematical physics and other theoretical physics topics; which is the aim of this course, as shown by CO1 and hence the affinity is maximum (3).	3
CO1-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3
CO2-PSO1	CO2 enhances knowledge of vast field of complex analysis and it has arious application in other theoretical courses; hence maximum affinity is seen with PSO1	3
CO2-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3
CO3-PSO1	CO3 is related with analysing and solving second order ordinary differential equations; which is a very essential tool solving physically relevant systems; so maximum affinity is seen with PSO1	3
CO3-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3
CO4-PSO1	CO4 covers various advanced mathematical techniques and its application to physically relevant systems that one encounters in theoretical physics. Hence there is a maximum affinity with PSO1	3

CO4-PSO2	PSO2 involves imparting analytical skills and the CO matches with maximum affinity	3

22PHY504	Electrodynamics	3 01 4

Prerequisites: Basics of Electricity and Magnetism, Electricity and Magnetism in Matter

Course Objectives: Having successfully completed this module, the student will be able to demonstrate knowledge and understanding of: Conservation laws in electrodynamics, Connection between electromagnetic phenomena and light, Wave equations for electromagnetic waves, Reflection and transmission in dielectric media, Reflection, and transmission in conducting media, Waveguides, Radiation, Power radiated by a point charge, The physical basis of radiation reaction. Special theory of relativity and its connection to electrodynamics, Applications of electrodynamics in particle accelerators.

Course Outcomes

CO1. Understand Maxwell's equations and different conservation laws used in electrodynamics
CO2. Describe electromagnetic waves, their propagation in different media and wave guides
CO3. Acquire knowledge on potential formulations, basic theory of radiation
CO4. Understand basic aspects of special theory of relativity, relativistic electrodynamics and applications of electrodynamics

Skills: Through assignments and quizzes, the problem solving capability of students related to electrodynamics is enhanced.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3	3			3	3	
CO2	3	3	3			3	3	
CO3	3	3	3			3	3	
CO4	3	3	3			3	3	

UNIT 1: Conservation Laws

Learning Objectives

Recognize Maxwell's equations and electrodynamic boundary conditions
Describe various conservation laws in electrodynamics

Review of Maxwell's equations, The Continuity Equation, Poynting's Theorem, Newton's Third Law in electrodynamics, Maxwell's Stress Tensor, Conservation of Momentum, Angular momentum

UNIT 2: Electromagnetic Waves and Wave Guides:

Learning Objectives

Describe electromagnetic wave propagation in free space and different media.
Discuss reflection and transmission of em wave at interfaces, energy and momentum associated with em waves.
Understand the theory of wave guides.

The wave equation, Sinusoidal waves, Boundary conditions: Reflection and Transmission, Polarization, The wave equation for *E* and *B*, Monochromatic plane waves, Energy and Momentum in Electromagnetic Waves, Propagation in linear media, Reflection and Transmission at Normal Incidence, Reflection and Transmission at Oblique Incidence. Electromagnetic Waves in Conductors, Reflection at a Conducting Surface, The frequency dependence of Permittivity, Wave Guides, The waves in a Rectangular Wave Guide, The Coaxial Transmission Line.

UNIT 3: Potentials and Fields:

Learning Objectives

Understand potential formulations and Gauge transformations.

Discuss retarded potential, Jefimenko's equation and the field of a moving point charge.

Scalar and Vector Potentials, Gauge transformations, Lorenz and Coulomb Gauge, Retarded Potentials, Jefimenko's equations, Lienard-Wiechert Potentials, The Fields of a Moving Point Charge

UNIT 4: Radiation

Learning Objectives

Understand electric dipole and magnetic dipole radiation.

Discuss power radiated by a point charge and physical basis of radiation reaction.

Definition of radiation, Electric dipole radiation, Magnetic dipole radiation, Radiation from an arbitrary source, Power radiated by a point charge, Radiation reaction, The physical basis of radiation reaction.

UNIT 5: Electrodynamics and Special Theory of Relativity

Learning Objectives

Recognize postulates of special theory of relativity, relativistic kinematics and dynamics.

Understand magnetism as a relativistic phenomenon.

Discuss applications of electrodynamics.

Einstein's postulates, Geometry of relativity, The Lorentz transformations, The Structure of space time, Proper time and proper velocity, Relativistic energy and momentum, Relativistic kinematics, Relativistic dynamics, Relativistic Electrodynamics: Magnetism as a relativistic phenomenon, How the fields transform, The field tensor, Electrodynamics in tensor notation. Relativistic potentials, Lagrangian and Hamiltonian for a relativistic charged particle in external electromagnetic fields. Applications of electrodynamics in particle accelerators.

Textbooks

1. David J Griffiths, Introduction to electrodynamics, 4th Ed, Pearson Education India Learning Pvt. Ltd., 2015.

Reference books

1. J.D. Jackson, Classical Electrodynamics, 3rd Edition, Wiley, 2007.
2. W. Greiner, Classical Electrodynamics, 1st Ed, Springer, 2006.
3. The Physics of Particle Accelerators: An Introduction - Klaus Wille, Oxford University Press, 2000.
4. Robert Resnick, Introduction to Special Relativity, John Wiley and Sons, Inc., 2013.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO4 to PO1 and PSO1	All the four course outcomes have strong affinity to PO1 as PO1 deals with inculcating strong fundamentals in Physics and Mathematics. Also all the COs will develop inquisitiveness to solve problems scientifically in students, the affinity level of them with PSO1 is the maximum.	3
CO1-CO4-PO2 and PSO2	All the four course outcomes have strong affinity to PO2 as PO2 deals with enhancing analytical skill and critical thinking in students to find solution to scientific problems. Also all the COs will develop analytical skills in students so that they will be equipped to take up research related problems, the affinity level of them with PSO2 is the maximum.	3
CO1-CO4 – PO3	All the four course outcomes have maximum affinity to PO3 as PO3 deals with preparing students to undertake complex problems and to design and develop solutions which enhance the existing scientific knowledge.	3

22PHY581	Physics Lab VI - (Project Based Lab - Common to both streams)	0 0 4 2

1. Quantification of functional groups using –FTIR
2. Construction of spectrophotometer
3. Analysis of X-Ray spectrum using public database
4. Analysis of 2D diffraction spectra of some cubic crystals- SAED-TEM data
5. UV –Visible spectrometer
    a. Band gap determination of NiO or ZnO by spray pyralysis
    b. Verification of bears Lamber's Law- Concentration dependent
    c. Dispersion analysis of nano structure
    d. Photo catalytic dye degradation
6. Impedance spectroscopy
    a. RC circuit analysis or some standard circuit analysis through impedance
    b. Analysis of effective particle size- grain boundary effect

c. Impedance measurements of ceramics to study grain and grain boundaries response to AC signal.

7. Analysis of ESR spectra of some standard samples
8. Analysis of NMR spectra of some standard samples
9. Experiment of Fabry perot interferometer
10. Experiments based on Raman spectra.

22PHY505	Statistical Mechanics	3 1 0 4

Pre-requisites: Mathematics 1 &2, Thermal and Statistical Physics

Course objective: To expose the students to Statistical mechanics- both classical and quantum and introduce various applications.

Course outcomes

CO1: Review thermodynamics with specific reference to thermodynamic potentials and co-ordinates and various relationship

CO2: Understand canonical ensemble and arrive at expression for partition function and its computation

CO3: Apply classical and quantum probability distribution functions to various systems

CO4: Understand the Phase transition phenomena and study various theory explaining phase transitions.

CO5: Introduce Non –linear equilibrium statistics

Skill: Analytical and problems solving skill to apply principles of statistical physics to various system in thermal equilibrium.

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1		3	3			3	3	
CO2		3	3			3	3	
CO3		3	3			3	3	
CO4		3	3			3	3	
CO5		3	3			3	3	

UNIT 1

Learning objective

Review of Thermodynamic potentials

Introduce various probability distribution functions and their property

Thermodynamics Review: Review of thermodynamic variables and thermodynamic potentials. Review of probability functions- random walk problem.

UNIT 2

Learning objective

Canonical ensemble and definition of inverse temperature

Introduce partition function and its computation

Canonical Ensemble: Micro canonical ensemble - phase space - trajectories and density of states - Liouville's theorem - canonical and grand canonical ensembles-partition function - calculation of statistical quantities - Energy and density fluctuations.

UNIT 3

Learning objectives

Classical and Quantum statistical distribution function

Application of MB, FE and BE distribution functions

Classical and Quantum Statistics: Maxwell- Boltzmann, Fermi Dirac and Bose Einstein statistics, properties of ideal Bose and Fermi Gases, Bose-Einstein condensation

UNIT 4

Learning Objectives

Phase diagram of single simple systems

Phase transition – Paramagnetic to ferromagnetic system

Landau theory of phase transition

Bose Einstein Condensation

Phase Transition and Critical Phenomena: Phase transitions, phase diagram for a real gas, Analogy of fluid and magnetic Systems, Cluster expansion of classical gas, Landau theory of phase transition, critical indices, scale transformation and dimensional analysis-Bose Einstein Condensation.

Unit 5:

Learning g objectives

Intro to Non-equilibrium statistics

Stochastic and Markov Process

Langevin equation

Non-equilibrium Statistical Mechanics: Introduction to non-equilibrium processes, diffusion, transport, Brownian motion, review of probability distributions, stochastic processes, Markov processes, master equation, Fokker-Planck equation, Langevin equation, normal and anomalous diffusion, Levy flights and fractional Brownian motion

Suggested Reading:

1. F Reif, Foundations of Statistical and Thermal Physics, Tata McGraw-Hill, IE, 2011.
2. Silivio R.A. Salinas, Introduction to Statistical Physics, Springer, 2010.
3. R.K. Pathria, Paul D. Beale, Statistical Mechanics, Elsevier, 3rd Edition, 2011.
4. L.D. Landau and E.M. Lifshitz, Statistical and Thermal Physics, Butterworth-Heinemann; 3rd Edition, 1996.
5. Daniel J Amit and Yosef Verbin, Statistical Physics- An Introductory course, World Scientific Co Pvt Ltd, 1999.
6. V Balakrishnan, Elements of Non- Equilibrium Statistics, ANE Books- New Delhi, 2009

Evaluation pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO 5 to PO2 and PSO 1	This is course with objective of building basic analytical skills to formulate problems and solve using techniques developed. There for it has highest affinity towards PO2 and PSO 1	3
CO1-CO5-PO3 and PSO 2	This course develops problem solving skills and form a core course in Physics which will help student to formulate research problems – hence has strong affinity towards PO3 and PSO 2	3

21SSK301	Life Skills III	1 0 2 2

Team Work: Value of Team work in organisations, Definition of a Team, Why Team, Elements of leadership, Disadvantages of a team, Stages of Team formation. Group Development Activities: Orientation, Internal Problem Solving, Growth and Productivity, Evaluation and Control. Effective Team Building: Basics of Team Building, Teamwork Parameters, Roles, Empowerment, Communication, Effective Team working, Team Effectiveness Criteria, Common characteristics of Effective Teams, Factors affecting Team Effectiveness, Personal characteristics of members, Team Structure, Team Process, Team Outcomes.

Facing an Interview: Foundation in core subject, Industry Orientation/ Knowledge about the company, Professional Personality, Communication Skills, activities before interview, upon entering interview room, during the interview and at the end. Mock interviews.

Advanced Grammar: Topics like parallel construction, dangling modifiers, active and passive voices, etc.

Syllogisms, Critical reasoning: A course on verbal reasoning. Listening Comprehension advanced: An exercise on improving listening skills.

Reading Comprehension advanced: A course on how to approach advanced level of reading, comprehension passages. Exercises on competitive exam questions.

Specific Training: Solving campus recruitment papers, National level and state level competitive examination papers; Speed mathematics; Tackling aptitude problems asked in interview; Techniques to remember (In

Mathematics). Lateral Thinking problems. Quick checking of answers techniques; Techniques on elimination of options, Estimating and predicting correct answer; Time management in aptitude tests; Test taking strategies.

TEXTBOOKS:

1. A Communicative Grammar of English: Geoffrey Leech and Jan Svartvik. Longman, London.
2. Adair J (1986) - "Effective Team Building: How to make a winning team", London, U.K: Pan Books.
3. Gulati S (2006) - "Corporate Soft Skills", New Delhi, India: Rupa& Co.
4. The Hard Truth about Soft Skills, by Amazon Publication.

REFERENCES:

1. Speed Mathematics, Secrets of Lightning Mental Calculations, by Bill Handley, Master Mind books;
2. The Trachtenberg Speed System of Basic Mathematics, Rupa& Co., Publishers;
3. Vedic Mathematics, by Jagadguru Swami Sri BharatiKrsnaTirthayi Maharaja, MotilalBanarsidass Publ.;
4. How to Ace the Brainteaser Interview, by John Kador, Mc Graw Hill Publishers.
5. Quick Arithmetics, by Ashish Agarwal, S Chand Publ.;
6. Quicker Maths, by M tyra& K Kundan, BSC Publishing Co. Pvt. Ltd., Delhi;
7. More Games Teams Play, by Leslie Bendaly, McGraw-Hill Ryerson.
8. The BBC and British Council online resources
9. Owl Purdue University online teaching resources
10. www.thegrammarbook.com online teaching resources
11. www.englishpage.com online teaching resources and other useful websites.

Course Code	Course Title	L T P	Cr	ES
SEMESTER 8				
22PHY511	Nuclear and Particle Physics	3 1 0	4	
22PHY512	Atomic and Molecular Spectroscopy	3 1 0	4	
	Core Elective IV	3 0 0	3	
22PHY513	Condensed Matter Physics	31 0	4	
22PHY582/22PHY583	Physics Lab - VII (Project Based – Applied Materials/ Theoretical Physics)	0 0 4	2	
	Core Elective V	3 0 0	3	
22RM500	Research Methodology	2 0 0	2	
TOTAL			22	

22PHY511	Nuclear and Particle Physics	3 1 0 4

Prerequisites
Knowledge of basic and advanced Quantum Mechanics.

Course Objectives
The objective of the course is to impart knowledge about basic nuclear physics properties and nuclear models for understanding of related reaction dynamics and basic concepts and fundamental principles of particle physics.

UNIT 1
Basic Concepts: History and Overview, Units and Dimensions, Nuclear Properties, Radius, Mass and Abundance of nuclides, Binding energy, Angular Momentum, Spin and Parity, Electromagnetic moments, and nuclear excited states

UNIT 2
Nuclear Structure: The Deuteron, Nucleon-Nucleon Scattering, Proton-Proton and Neutron-Neutron Interactions, Properties of Nuclear Forces, The Exchange Force Model, Nuclear Models, Liquid-Drop Model, Shell Model, Collective Model of the Nucleus

UNIT 3
Radioactive Decays: Alpha Decay, The Q-value of alpha decay, Gamow's theory of alpha decay, Beta decay, Fermi theory of beta decay, Parity violation in beta decay, Gamma Decay, Internal conversion, Nuclear Isomers

UNIT 4
Nuclear Reactions: The Optical Model, The Compound Nucleus and Direct Reactions, Resonance Reactions, Heavy-Ion Reactions, Nuclear Fission, Characteristics of Fission, Energy in Fission, Nuclear Fusion, Characteristics of Fusion, Solar Fusion.

UNIT 5
Particle Physics: Particle Interactions and Families, Symmetry and Conservation laws, Standard Model, Quark Dynamics, Grand Unified Theories.

Text Books:

1. S. Krane, Introductory Nuclear Physics, 2nd Edition, Wiley India Pvt Ltd, 2013.

Reference Books:

1. V. Devanathan, Nuclear Physics, Narosa Publishing House, 2012.
2. B. Povh, K. Rith, C. Scholz, F. Zetsche, Particles and Nuclei: An Introduction to the Physical Concepts, Springer; 6th Edition, 2008.
3. A. Das, T. Ferbel, Introduction to Nuclear and Particle Physics, World Scientific Publishing Co Pte Ltd; 2nd Edition, 2003.
4. A. Seiden, Particle Physics a comprehensive introduction, Pearson, 1st Edition, 2004.
5. W.E. Burcham and M. Jobes, Nuclear and particle Physics, Prentice Hall, 1994.

22PHY512	Atomic and Molecular Spectroscopy	3 1 0 4

UNIT 1
Atomic Physics: Dipole selection rules examples, Natural and Doppler Broadening, Spin-orbit coupling, Lamb shift and Rutherford experiment,

UNIT 2
Hyperfine structure: Hyperfine structure of lines, Normal and specific mass shifts, Anomalous Zeeman effect, Paschen-Back and Stark Effects, Quantum defect.

UNIT 3
Molecular Physics: Rotational Spectra: Transition probabilities, selection rules. Rotational spectra of diatomic molecule- rigid and non-rigid rotator models. The Franck Condon principle. Dissociation energy. A brief discussion of Intensity alternation and missing lines in rotational spectra

UNIT 4
Vibrational spectra: Vibrational spectra of a diatomic molecule - harmonic and anharmonic oscillator models. Normal modes of vibration and their distribution into symmetry species of the molecule, Overtone and Combination Bands, Vibrational Potentials, Infrared and Raman Selection rules. Vibration-Rotation Energy Levels and Spectra: Spectra of rotational vibrational levels, Rotational Raman and IR Spectra of linear molecules and Determination of their Geometry. Rotation-Vibration Band of a Diatomic Molecule and polyatomic molecules. Vibrational structure of electronic transition

UNIT 5
Resonance Spectroscopy: ESR and NMR. Lande g factor, Spliting of degenerate states. Precession and spectra, selection rules, fine structure, Resonance spectra of some organic molecules.

Reference Books:

1. B.H. Bransden and C.J. Joachain, Physics of Atoms and Molecules, Pearson 2nd edition, 2003.
2. H.E. White, Introduction to Atomic Spectra, McGraw-Hill Education, 1963.
3. H.G. Kuhn, Introduction to Atomic Spectra, Prentice Hall Press; 2nd edition, 1970.

22PHY513	Condensed Matter Physics	3 1 0 4

Pre-requisites: Basic knowledge of crystal physics, quantum mechanics and electromagnetic theory.

Course objectives:

- To learn the quantum many body systems and calculation of energy bands in solids
- To differentiate the various magnetism and the quantum theories of magnetic origin in solids
- To understand the superconducting phenomena and differentiate the Type I and Type II superconductors
- To study the electron and hole behavior, mobility, effective masses in semiconductors
- To learn the doping process, Fermi energy levels and junction formations
- To understand the optical properties of metals, semiconductors, and insulators

Course Outcomes:

On completion of the course, students will be able to:

CO1. Acquire comprehensive understanding on the basics of electronic band structure calculations

CO2. Describe various magnetic phenomena and the origin of magnetic ordering in solids

CO3. Understand the properties of superconductors and the theories of superconductivity

CO4. Explain the carrier dynamics in semiconductors and junction formations.

CO5. Describe the optical properties of different solids

Skills: Problem solving skills as well as computational skills of the students in analyzing the various properties of solid-state materials will be improved through assignments, quizzes, and presentations.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	2	3	3	1		3	2	
CO2	3	3	2	1		3	3	
CO3	3	3				3	1	
CO4	3	3	2			3	2	
CO5	3	3	2			3	2	

UNIT 1

Learning Objectives

In the unit-1, students will learn the

1. Many electron wavefunctions and exchange-correlation effects
2. Basic ideas behind the Kohn-Sham equations
3. Fundamentals of Density Functional Theory and density approximations

Electronic Structure: Electron-Electron Interactions: Born-Oppenheimer approximation Hartree-Fock approximation, exchange and correlation effects, Kohn-Sham Equations, Local Density Approximation (LDA), generalized gradient approximation (GGA). Realistic Calculations in Solids: Pseudopotentials and Orthogonalized Planes Waves (OPW), Plane wave method. Electronic Structure of selected materials - Metals, Semiconductors, Semimetals.

UNIT 2

Learning Objectives

In the unit-2, students will learn the

1. Classification of materials based on magnetic property
2. Quantum theories of magnetism
3. Local and Band contributions to ferromagnetism and Domain theory

Diamagnetism and Paramagnetism: Langevin theory of diamagnetism and paramagnetism, Quantum theory of diamagnetism of mononuclear systems, quantum theory of paramagnetism: Rare earth ions, Hund rules, crystal field splitting, paramagnetic susceptibility of conduction electrons.
Ferromagnetism and antiferromagnetism: Ferromagnetic order: Heisenberg Model - exchange, Stoner theory, Hubbard model, Kondo effect, temperature dependence of saturation magnetization, Ferrimagnetic order: Curie temperature and susceptibility of ferrimagnets, antiferromagnetic order, susceptibility below Neel temperature, ferromagnetic domains.

UNIT 3
Learning Objectives
In the unit-3, students will learn

1. Properties of Superconductors
2. Macroscopic and microscopic theories and classifications of superconductors
3. To explain the flux quantization and Josephson effects

Superconductivity: Meissner effect, Phenomenological theory: London's equations, Thermodynamics of Superconductors, Landau-Ginzburg Free Energy, Type I and Type II superconductors, Microscopic Theory of Superconductivity: BCS theory and its prediction. Experimental detection of Bandgap, flux quantization, Josephson effects, application: SQUID. High Temperature Superconductors.

UNIT 4
Learning Objectives:
In the unit-4, students will learn the

1. Classification of semiconductors, doping process
2. Transport behaviour of the carriers in semiconductors
3. Formation of P-N junctions and semiconductor low dimensional structures

Semiconductors: energy band structure, intrinsic and extrinsic semiconductors, Effective mass, carrier concentration, Hydrogenic model of impurity levels, law of mass action, Compensated doping, Degenerate Semiconductors, Fermi levels of intrinsic and extrinsic semi-conductors, Temperature dependent conductivity and mobility, Direct and indirect gap semiconductors, Hall effect, p-n junctions: theory of I–V characteristics, Ohmic contact and Schottky-barrier, Heterostructures, quantum Hall effect.

UNIT 5
Learning Objectives:
In the unit-5, students will learn the

1. Concepts of polaritons and Polarons
2. Details of Plasma frequency, plasmons and anomalous skin effect
3. Optical absorptions in semiconductors, excitons, and luminescence

Optical properties of solids: Kramers - Kronig relations; Sum rules, Dielectric function for ionic lattice, Polaritons, Polarons, Dielectric function for free electron gas; loss spectroscopy. Optical properties of metals-Plasmons, skin effect and anomalous skin effect. Free carrier absorption in semiconductor and Excitons: Interband transition - direct and indirect transition, Mott- Wannier excitons, Frenkel excitons, Luminescence.

Reference books:

1. M. Marder, Condensed Matter Physics, Wiley India, Second edition, 2010.
2. Charles Kittel, Introduction to Solid State Physics, Wiley, Eighth edition, 2016.
3. Philips Philip, Advanced Solid State Physics, Cambridge University Press; second edition, 2012.
4. Philip Hofmann, Solid State Physics - An Introduction, second edition, Wiley-VCH Verlag GmbH & Co, 2015.
5. Gerald D. Mahan, Condensed Matter in a Nutshell, Princeton University Press, 2011.
6. Leonard Sander, Advanced Condensed Matter Physics, Cambridge University Press, first edition, 2009.
7. N.W. Ashcroft and N.D. Mermin, Solid State Physics, Cengage Learning India, first edition, 2003.

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	**Justification**	**Affinity level**
CO1-PO1	Students enrich advance knowledge on the formation of band structure of solids in CO1, which may be assigned a medium affinity with PO1.	2
CO1-PO2	Learns develop the analytical skills and critical thinking of using different approaches for the electronic band structure determination of solids and hence it can be given a maximum affinity with PO2.	3
CO1-PO3	Student understands the usage of different theories and models to solve complex electronic energy levels in solids and so a maximum affinity level is mapped with PO3.	3
CO1-PO4	In CO4, students are exposed to DFT, exchange and correlation functions used in the current research computing of bandstructure calculations. It builds confidence in students to take up computational research and hence it is mapped a minimum affinity with PO4.	1
CO1-PSO1	PSO1 is related to develop curiosity and inquisitiveness among students to look at fundamental problems. As CO1 matches highly with PSO1 it is given maximum affinity level	3
CO1-PSO2	As CO1 equips the students in enhancing their analytical skills of determining the energy level of solids, it is mapped with maximum level affinity to PSO2.	2
CO2-PO1	CO2 improves the fundamental physics of magnetism. Since PO1 is related to the knowledge in fundamental sciences, CO2 is mapped with maximum affinity of 3 to PO1.	3

CO2-PO2	Problems corresponds related to various magnetic parameters (CO2) will be solved by students which improves the analytical skills and critical thinking as mentioned in PO2. So, the CO2- PO2 mapping is given an affinity level of 3.	3
CO2-PO3	In CO2, students will gain the understanding and analyzing the type of magnetism exhibited in solids, so it is mapped with a minimum affinity to PO3.	2
CO2-PO4	Students get exposed to basic analysis of hysteresis loop of different solid samples, the magnetic origin and so they will gain confidence in the basic research of magnetic materials. Hence CO2 is assigned a minimum affinity to PO4.	1
CO2-PSO1	In CO2, as the learners will develop curiosity in solving the magnetic hysteresis of solids, magnetic origin etc., which highly matches with the described PSO1 and so it is mapped with a maximum affinity level of 3	3
CO2-PSO2	As students develop the analytical skills of determining the magnetic properties in solids which equips them to do independent research. Hence, a high affinity level of 3 is given in the mapping of CO2-PSO2.	3
CO3-PO1	In CO3, students develop knowledge on the fundamentals of superconductivity. Since PO1 is related to acquiring strong knowledge in basic science, CO2 is given maximum affinity of 3 when mapped with PO1.	3
CO3-PO2	Students improve their analytical skills in finding solutions to the problems with respect to superconducting phenomena. PO2 is related to developing the analytical skills involving fundamentals of basic sciences. So, the CO2- PO2 mapping is given an affinity level of 3.	3
CO3-PSO1	In CO3, students develop interest of determining coherence length, penetration depth etc.. and so the mapping of CO3 with PSO1 is given a high affinity level	3
CO3-PSO2	In CO3, students develop basic knowledge on the working of SQUID. The mapping with PSO2 is given a minimum affinity as CO3 covers the fundamentals alone.	1
CO4-PO1	Students learn the fundamentals of Semiconductor devices in CO4 which highly matches with PO1. The mapping of CO4-PO1 is given a maximum affinity level	3
CO4-PO2	Students develop problem solving skills related to carrier mobilities, effective masses, Fermi levels etc.. Hence, the mapping of CO4 with PO2 is given a maximum affinity of 3.	3
CO4-PO3	In CO4, learners are exposed to fundamental understanding of quantum hall effect, semiconductor quantum structures which maps with PO3 with medium affinity level.	2
CO4-PSO1	In CO4, Students gain knowledge of solving problems regarding semiconductor carriers, Fermi levels, p-n junctions etc. Hence, the mapping of CO4 with PSO1 is given a maximum affinity of 3.	3
CO4-PSO2	Gaining knowledge of the formation of p-n junctions, quantum wells gives students fundamental platform to understand research in the device fabrications. The affinity with PSO2 is given a medium level.	2
CO5-PO1	In CO5, students get benefited the learning of optical properties of solids and hence it is mapped with high affinity to PO1	3

CO5-PO2	Students develop analytical thinking and problem solving with respect to absorptions and luminescence in solids (CO5) and so it is given maximum affinity with PO2.	3
CO5-PO3	In CO5, learners gain the fundamentals of excitons, plasmons, absorption coefficient which prepares them to analysis the complex problems in optical properties of various materials and thus it is mapped with PO3 with a medium affinity level.	2
CO5-PSO1	In CO5, students enrich their scientific knowledge on the optical properties of different solids and so it is assigned a maximum affinity with PSO1.	3
CO5-PSO2	In CO5, students develop the analysis of plasmons, excitons, types of transitions, defects emissions and hence it may be mapped with PSO2 with a medium affinity	2

22PHY582	Physics Lab VII - (Project Based Lab – Applied Materials stream)	0 0 4 2

Course Objective: Preparing students to handle research standard equipment and familiarise the prerequisites required for research program.

List of Project based experiments

1. Fabrication and characterization of Solar cell
2. Fabrication quantum dots and study of quantum confinement effect.
3. Fabrication and characterization of Super capacitor
4. Fabrication and characterization of semiconductor devices
5. Analysis of Luminance centers- PL study
6. Characterization of photodetector
7. Temperature dependence conductivity analysis
8. Diffusion coefficient study- Temperature dependent Impedance analysis
9. Determination of conduction mechanism of Polymers
10. Fabrication of nano materials using ball milling unit.
11. Thin film deposition by PVD technique and study of the film.

22PHY583	Physics Lab VII - (Project Based Lab – Theoretical Physics stream)	0 0 4 2

Course Objective: Preparing students to equip analytical and computational skill and expose them to familiarise certain research standard computational software. Train the students to familiarise the prerequisites required for perusing research program.

Skill learned: Analytical and computational skill for solving theoretical problems, usage of certain standard software, data reduction process, understanding research articles, Preparation of project reports, presentation skill etc.

Proposed topics for theoretical based projects.

Visualization and simulation of certain quantum phenomenon using simulation software.

Simulation and data reduction of few astronomical data, modelling of certain natural phenomenon like micro-wave background etc. using public data base, modelling of certain nuclear phenomena such decay parameter etc by analytical and computational modelling etc.

22RM500	Research Methodology	2 0 0 2

Unit 1: Ethics in Research

Ethics, moral philosophy, nature of moral judgements and reactions. Scientific conduct - ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts - falsification, fabrication and plagiarism. Redundant publications - duplicate and overlapping publications. Selective reporting and misrepresentation of data.

Unit 2: Literature Survey

Importance of literature survey, planning a literature search, identifying key concepts and key words, locating relevant literature and reliability of a source.

Unit 3: Design of Experiments and Data Analysis

Aim, objectives, expected outcome, and methodology to be adopted. Importance of reproducibility of results. Objectives and basic principles of designs of experiments. Data presentation - using graphs, in tables, schemes and figures. Software for drawing. Bibliography using Mendeley and Zotero.

Unit 4: Publication Ethics

Best practices and standards, conflicts of interest, publication misconduct, unethical behaviour and related problems. Authorship and contributorship. Identification of publication misconduct, complaints and appeals.

Unit 5: Research Communication

General aspects of scientific writing - reporting practical and project work, writing literature survey and reviews, organizing a poster display, oral presentation. Guidelines for manuscript writing - abstract, introduction, methodology, results and discussion, conclusion, acknowledgement, references and citation. Intellectual property (IP) and intellectual property rights (IPR).

Recommended Readings

1. Bird, A., 2006. Philosophy of science. Routledge.
2. MacIntyre, A., 2017. A short history of ethics: A history of moral philosophy from the Homeric age to the twentieth century. University of Notre Dame Pess.
3. Chaddah, P., 2018. Ethics in Competitive Research: Do not get scooped; do not get plagiarized.
4. Bordens, K.S. and Abbott, B.B., 2002. Research design and methods: A process approach. McGraw-Hill.
5. Kothari C.R., 2020. Research methodology methods and Techniques. New Age International Publishers.
6. Thomas, C.G., 2021. Research methodology and scientific writing. Thrissur: Springer.

Code	Core Electives	L T P	Cr	ES
Theoretical Physics				
22PHY531	Relativistic Quantum Mechanics	3 0 0	3	
22PHY532	Advanced Particle Physics	3 0 0	3	
22PHY533	Physics of Compact Stars	3 0 0	3	
22PHY534	Theory of Nanostructures	3 0 0	3	
22PHY535	Special Theory of Relativity	3 0 0	3	
22PHY536	Introduction to Classical field theory	3 0 0	3	
22PHY537	Introduction to General Theory of Relativity	3 0 0	3	
22PHY538	Quantum Field Theory	3 0 0	3	

22PHY531	Relativistic Quantum Mechanics	3 0 0 3

Prerequisites

Knowledge of basic quantum mechanics and advanced mathematical physics.

Course Objectives

The objective of the course is to learn relativistic quantum mechanics and its applications along with covariant perturbation theory.

Course Outcomes: After completion this course student able to

CO1: Learn the key ideas and concepts of classical fields.

CO2: Learn the key ideas and concepts of quantum theory of radiation.

CO3: Analyze and solve problems related to quantum theory of radiation.

CO4: Learn and solve problems for spin half particles.

CO5: Analyze and solve problems related to covariant perturbation theory.

Skills: Improvement of student's problem solving capability related to relativistic quantum mechanics through assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	3	3				3	2		
CO2	3	3				3	2		
CO3	3	3				2	3		
CO4	3	3				3	3		
CO5	3	3				3	3		

UNIT 1: Classical Fields

Learning Objectives

Understand the concept of particle and fields and their relation with discrete and mechanical systems.
Understand the classical scalar and Maxwell fields.
Learn and analyze the vector potential in quantum mechanics.

Particle and Fields, Discrete and Mechanical system, Classical scalar fields, Classical Maxwell fields, Vector potential in quantum mechanics.

UNIT 2: The Quantum Theory of Radiation

Learning Objectives

Learn about classical radiation field and quantized radiation field.
Learn the creation, annihilation and number operators.
Understand and analyze the emission and absorption of photons by atoms.

Classical radiation field, Creation, annihilation, and number operators, Quantized radiation field, Emission and absorption of photons by atoms.

UNIT 3: Applications of Quantum Theory of Radiation

Learning Objectives

Learn and understand Rayleigh scattering, Thompson scattering and Raman effect.
Understand the radiation damping, resonance fluorescence, dispersion relations and causality.
Analyze the self-energy of a bound electron and Lamb shift.

Rayleigh scattering, Thompson scattering and Raman effect, Radiation damping and resonance fluorescence, Dispersion relations and causality, The self-energy of a bound electron; Lamb shift.

UNIT 4: Relativistic Quantum Mechanics for spin 1/2 particles

Learning Objectives

Learn and understand the Dirac equation and relativistic covariance.
Understand the Dirac operators and negative energy solutions.
Analyze the quantization of Dirac field as well as weak interaction and non-conservation of parity.

Probability conservation, Dirac equation, Relativistic covariance, Bilinear covariants, Dirac operators in Heisenberg representation, Ztiterbewegung; Negative energy solutions, The hydrogen atom, Hole theory and charge conjugation, Qunatization of Dirac field, Weak interaction and non-conservation of parity.

UNIT 5: Covariant Perturbation Theory

Learning Objectives

Learn and understand the S-matrix expansion in the interaction representation.
Understand the electron propagator and Feynman's space-time approach to the electron propagator.
Learn and analyze the one-meson exchange interactions and radiative corrections.

Natural units and dimensions, S-matrix expansion in the interaction representation, First-order processes; Mott scattering and hyperon decay, Two-photon annihilation and Compton scattering; the electron propagator, Feynman's space-time approach to the electron propagator, Moller scattering and the photon propagator; one-meson exchange interactions, Mass and charge renormalization; radiative corrections.

Text Book:

1. J. J. Sakurai, Advanced Quantum Mechanics, Pearson, 1st Ed, (1994).

Reference Books:

1. W. Greiner, Relativistic Quantum Mechanics, Springer, 3rd Ed, (2000).
2. J. D. Bjorken and S. D. Drell, Relativistic Quantum Mechanics, McGraw-Hill, 1st Ed, (1964).

Evaluation pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understand the key ideas and concepts of classical fields. This improves student's knowledge in classical fields and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and CO1 is about concepts of classical fields which is important to solve the problems related to classical fields. Hence the affinity level between CO1 and PO2 is mentioned as 3.	3
CO2-PO1	CO2 is related to ideas and concepts of quantum theory of radiation. Hence the affinity level is 3.	3

CO2-PO2	As CO2 is related to concepts of quantum theory of radiation. Since PO2 is related to developing analytical skills, the affinity level between them is 3.	3
CO3-PO1	Since PO1 is related to strong fundamentals of physics and math which is essential to solve and analyze the problems related to quantum theory of radiation. Hence CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to the applications of quantum theory of radiation. As PO2 is related to improve critical thinking and analytical skills. So, CO3 has maximum affinity to PO2 and hence given an affinity level of 3.	3
CO4-PO1	CO4 is related to learn and solve problems for spin half particles. As PO1 is related to improving knowledge of physics fundamentals, CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 is for solving problems related to spin half particles. Since PO2 is related to the development of analytical skills of students and maximum affinity level of 3 is given for CO4-PO2 mapping.	3
CO5-PO1	CO5 is related to analyze and solve problems related to covariant perturbation theory. Since PO1 is related to improving student's knowledge in physics and math. Hence maximum affinity level of 3 is given for CO5-PO1 mapping.	3
CO5-PO2	CO5 improves the analytical skills of students. As PO2 is related to improving analytical skills, CO5 has maximum affinity with PO5 and hence given an affinity level of 3.	3
CO1-PSO1	PSO1 is related to fundamental problems and their solutions in scientific way and CO1 is to learn about classical fields which is very essential to solve problems in scientific way. Hence the affinity level is 3.	3
CO1-PSO2	CO1 deals with knowledge and tools of classical fields. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.	2
CO2-PSO1	CO2 is related to understanding of the quantum theory of radiation which map completely with PSO1. So the affinity level is 3.	3
CO2-PSO2	Since PSO2 is related to improve the analytical skills which maps partially with CO2. Hence the affinity level between CO2 and PSO2 is 2.	2
CO3-PSO1	Since CO3 is related to application of quantum theory of radiation which is partially mapped with PSO1. Hence the affinity level 2.	2
CO3-PSO2	The affinity level between CO3 and PSO2 is 3 since CO3 deals with applications of quantum theory of radiation to solve problems which eventually improves the analytical skills of students.	3
CO4-PSO1	CO4 is related to learn and solve problems for spin half particles. Hence CO4-PSO1 mapping has the affinity level 3.	3
CO4-PSO2	The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to spin half particles.	3
CO5-PSO1	CO5 is related to analyze and solve problems related to covariant perturbation theory and hence CO5-PSO1 mapping has the affinity 3. PSO1 is related to look fundamental problems and scientific solutions.	3
CO5-PSO2	The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to covariant perturbation theory.	3

22PHY532	Advanced Particle Physics	3 0 0 3

Prerequisites

Knowledge of basic and advanced nuclear physics.

Course Objectives

The objective of the course is to impart knowledge about advanced particle physics with special emphasis on particle dynamics, relativistic kinematics, symmetries, basics of Feynman calculus, weak interactions and electrodynamics of quarks and hadrons.

Course Outcomes: After completion this course student able to

CO1: Learn the key ideas and concepts of particle dynamics.

CO2: Learn basic features of symmetries and their application in particle physics.

CO3: Analyze and solve problems related to Feynman calculus.

CO4: Analyze and solve problems related to electrodynamics of quarks and hadrons.

CO5: Analyze and solve problems related to weak interactions.

Skills: Improvement of student's problem solving capability related to advanced particle physics through assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	3	3				3	2		
CO2	3	3				3	3		
CO3	3	3				3	3		
CO4	3	3				3	3		
CO5	3	3				3	3		

UNIT 1: Particle Dynamics and Relativistic Kinematics

Learning Objectives

Understand the four forces, decays and conservation laws.
Learn and understand the unification schemes and Lorentz transformations.
Learn and analyze the four vectors and particle collisions.

The Four Forces, Quantum Electrodynamics, Quantum Chromodynamics, Weak Interactions, Decays and Conservation Laws, Unification Schemes, Lorentz Transformations, Four-Vectors, Energy and Momentum, Collisions.

UNIT 2: Symmetries

Learning Objectives

Learn and understand the symmetries group and conservation laws.
Learn and analyze basic properties of spin half particles.
Learn and understand the time reversal and TCP theorem.

Symmetries, Groups, Conservation Laws, Spin and Orbital Angular Momentum, Addition of Angular Momenta, Spin ½, Flavor Symmetries, Parity, Charge Conjugation, CP Violation, Time Reversal and the TCP Theorem.

UNIT 3: The Feynman Calculus
Learning Objectives

Learn and understand the lifetimes and cross sections.
Learn and analyze the Feynman rules for Quantum Electrodynamics.
Learn and understand the concept of renormalization.

Lifetimes and Cross Sections, The Golden Rule, The Feynman Rules for a Toy Theory, Scattering, Higher-Order Diagrams, The Feynman Rules for Quantum Electrodynamics,
Cross Sections and Lifetimes, Renormalization.

UNIT 4: Electrodynamics of Quarks and Hadrons
Learning Objectives

Learn and understand the electron-quark interactions.
Learn and analyze the elastic and inelastic electron-proton scattering.
Understand and analyze the Parton model and Bjorken scaling.

Electron-Quark Interactions, Hadron Production in Electron-Positron Scattering, Elastic Electron-Proton Scattering, Inelastic Electron-Proton Scattering, The Parton Model and Bjorken Scaling, Quark Distribution Functions.

UNIT 5: Weak Interactions
Learning Objectives

Learn and understand the decays of leptons.
Learn and analyze the charged weak interactions of quarks.
Learn and understand the electroweak unification.

Charged Leptonic Weak Interactions, Decay of the Muon, Decay of the Neutron, Decay of the Pion, Charged Weak Interactions of Quarks, Neutral Weak Interactions, Electroweak Unification.

Text Book:

1. D. J. Griffiths, Introduction to Elementary Particles, John Wiley & Sons, Inc (1987).

Reference Books:

1. F. Halzen and A. D. Martin, Quarks and Leptons: An Introductory Course in Modem Particle Physics, John Wiley & Sons, Inc (1984).
2. B. R. Martin and G. Shaw, Particle Physics, 3Ed., John Wiley & Sons Ltd (2008).

Evaluation pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understand the key ideas and concepts of particle dynamics. This improves student's knowledge in classical fields and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and CO1 is about concepts of particle dynamics which is important to solve the problems related to particle physics. Hence the affinity level between CO1 and PO2 is mentioned as 3.	3
CO2-PO1	CO2 is related to symmetries and their application in particle physics. Hence the affinity level is 3.	3
CO2-PO2	As CO2 is related to concepts of symmetries in particle physics. Since PO2 is related to developing analytical skills, the affinity level between them is 3.	3
CO3-PO1	Since PO1 is related to strong fundamentals of physics and math which is essential to solve and analyze the problems related to Feynman calculus. Hence CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to the Feynman calulus. As PO2 is related to improve critical thinking and analytical skills. So, CO3 has maximum affinity to PO2 and hence given an affinity level of 3.	3
CO4-PO1	CO4 is related to analyze and solve problems related to electrodynamics of quarks and hadrons. As PO1 is related to improving knowledge of physics fundamentals, CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 is for solving problems related to electrodynamics of quarks and hadrons. Since PO2 is related to the development of analytical skills of students and maximum affinity level of 3 is given for CO4-PO2 mapping.	3
CO5-PO1	CO5 is related to analyze and solve problems related to weak interactions. Since PO1 is related to improving student's knowledge in physics and math. Hence maximum affinity level of 3 is given for CO5-PO1 mapping.	3
CO5-PO2	CO5 improves the analytical skills of students. As PO2 is related to improving analytical skills, CO5 has maximum affinity with PO5 and hence given an affinity level of 3.	3
CO1-PSO1	PSO1 is related to fundamental problems and their solutions in scientific way and CO1 is to learn about particle dynamics which is very essential to solve problems in scientific way. Hence the affinity level is 3.	3
CO1-PSO2	CO1 deals with knowledge and concepts of particle dynamics. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.	2

CO2-PSO1	CO2 is related to understanding of the symmetries in particle physics which map completely with PSO1. So the affinity level is 3.	3
CO2-PSO2	Since PSO2 is related to improve the analytical skills which maps completely with CO2. Hence the affinity level between CO2 and PSO2 is 3.	3
CO3-PSO1	Since CO3 is related to analyze Feynman calculus which is completely mapped with PSO1. Hence the affinity level 3.	3
CO3-PSO2	The affinity level between CO3 and PSO2 is 3 since CO3 deals with applications of Feynman calculus to solve problems which eventually improves the analytical skills of students.	3
CO4-PSO1	CO4 is related to analyze and solve problems related to electrodynamics of quarks and hadrons. Hence CO4-PSO1 mapping has the affinity level 3.	3
CO4-PSO2	The affinity level between CO4 and PSO2 is 3 since the CO4 deals with analyze and solve problems related to electrodynamics of quarks and hadrons.	3
CO5-PSO1	CO5 is related to analyze and solve problems related to weak interactions and hence CO5-PSO1 mapping has the affinity 3. PSO1 is related to look fundamental problems and scientific solutions.	3
CO5-PSO2	The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to weak interactions.	3

22PHY533	Physics of Compact Stars	3 0 0 3

Prerequisites

Knowledge of basic and advanced astrophysics.

Course Objectives

The objective of the course is to gain knowledge about low and high energy cold dense matter physics and their application to understand the formation and basic properties of compact stars.

Course Outcomes: After completion this course student able to

CO1: Learn the key ideas and concepts of cold equation of state below neutron dripline.
CO2: Analyze and solve problems related to white dwarf.
CO3: Learn the key ideas and concepts of cold equation of state above neutron dripline.
CO4: Analyze and solve problems related to neutron stars.
CO5: Analyze and solve problems related to black holes.

Skills: Improvement of student's problem solving capability related to compact stars through assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	3	3	-	-	-	3	2	-	-
CO2	3	3	-		-	3	3	-	-
CO3	3	3	-	-	-	3	2	-	-
CO4	3	3	-	-	-	3	3	-	-

CO5	3	3	-	-	-	3	3	-	-

UNIT 1: Cold Equation of State below Neutron Dripline
Learning Objectives

Learn and analyze the equation of state of a completely degenerate ideal Fermi gas.
Understand the electrostatic corrections to the equation of state.
Learn and analyze the beta-equilibrium between relativistic electrons and nuclei.

Thermodynamic Preliminaries, Kinetic Theory, Equation of State of a Completely Degenerate, Ideal Fermi Gas, Electrostatic Corrections to the Equation of State, Inverse β decay: The Ideal, Cold n-p-e Gas, Beta-Equilibrium Between Relativistic Electrons and Nuclei: The Harrison-Wheeler Equation of State.

UNIT 2: White Dwarf
Learning Objectives

Learn and understands the onset of degeneracy and polytropes.
Understand and analyze the Chandrasekhar mass limit for white dwarfs.
Understand the structure of the surface layers and white dwarf cooling.

The Onset of Degeneracy, Polytropes, The Chandrasekhar Limit, Improvements to the Chandrasekhar White Dwarf Models, Comparison with Observations: Masses and Radii, Structure of the Surface Layers, Elementary Treatment of White Dwarf Cooling, Crystallization and the Melting Temperature, Heat Capacity of a Coulomb Lattice, Refined Treatment of White Dwarf Cooling, Comparison with Observations.

UNIT 3: Cold Equation of State above Neutron Dripline
Learning Objectives

Learn and analyze the Baym-Bethe-Pethick equation of state and basic properties of nucleon-nucleon interactions.
Understand the electrostatic corrections to the equation of state.
Learn and understand the Δ resonance, pion condensation and quark matter.

The Baym-Bethe-Pethick Equation of State, The Nucleon-Nucleon Interaction, Saturation of Nuclear Forces, Dependence of the NN Potential on the Nucleon Separation, The Yukawa Potential, The Δ Resonance, Pion Condensation, Ultrahigh Densities, Quark Matter.

UNIT 4: Neutron Stars
Learning Objectives

Learn and understands the observational tools to detect neutron stars.
Understand and analyze the superfluidity in neutron stars, pulsar glitches and hadron superfluidity.
Understand the weak interaction, free neutron decay and modified URCA process.

Ideal Gas Equation of State in the Nuclear Domain, Observations of Neutron Star Masses,
The Maximum Mass, The Effects of Rotation, Observed Properties of Pulsars, The Dispersion Measure, The Magnetic Dipole Model for Pulsars, Superfluidity in Neutron Stars, Pulsar Glitches and Hadron Superfluidity, Neutrino Reactions in Neutron Stars, Weak Interaction Theory, Free Neutron Decay, The Modified URCA Rate, Other Reaction Rates.

UNIT 5: Black Holes

Learning Objectives

Learn and understands the basic properties of black holes.
Understand and analyze the Schwanschild geometry and nonsingularity of the Schwanschild radius.
Understand the Kerr black holes, area theorem and black hole evaporation.

History of the Black Hole, Schwanschild Black Holes, Test Particle Motion, Massless Particle Orbits in the Schwanschild Geometry, Nonsingularity of the Schwanschild Radius, Kerr Black Holes, The Area Theorem and Black Hole Evaporation.

TEXT BOOK:

1) Stuart L. Shapiro and Saul A. Teukolsky, Black Holes, White Dwarfs, and Neutron Stars, John Wiley & Sons, Inc (1983).

REFERENCE BOOK:

1) Norman K. Glendenning, Compact Stars, Astronomy & Astrophysics Library, 2Ed., (2000).

Evaluation pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understand the key ideas and concepts of cold equation of state below neutron dripline. This improves student's knowledge in low density neutron matter and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and CO1 is about concepts of cold equation of state below neutron dripline which is important to solve the problems related to low energy matter. Hence the affinity level between CO1 and PO2 is mentioned as 3.	3
CO2-PO1	CO2 is related to analyze and solve problems related to white dwarf. Hence the affinity level is 3.	3
CO2-PO2	As CO2 is related to solve problems related to white dwarf. Since PO2 is related to developing analytical skills, the affinity level between them is 3.	3
CO3-PO1	CO3 is related to understand the key ideas and concepts of cold equation of state above neutron dripline which improves the student' knowledge. Hence CO3 has maximum affinity 3 when mapped with PO1.	3

CO3-PO2	CO3 is related to the key ideas and concepts of cold equation of state above neutron dripline As PO2 is related to improve critical thinking and analytical skills. So, CO3 has maximum affinity to PO2 and hence given an affinity level of 3.	3
CO4-PO1	CO4 is related to analyze and solve problems of neutron stars. As PO1 is related to improving knowledge of physics fundamentals, CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 is for solving problems related to neutron stars. Since PO2 is related to the development of analytical skills of students and maximum affinity level of 3 is given for CO4-PO2 mapping.	3
CO5-PO1	CO5 is related to analyze and solve problems related to black holes. Since PO1 is related to improving student's knowledge in physics and math. Hence maximum affinity level of 3 is given for CO5-PO1 mapping.	3
CO5-PO2	CO5 improves the analytical skills of students. As PO2 is related to improving analytical skills, CO5 has maximum affinity with PO5 and hence given an affinity level of 3.	3
CO1-PSO1	PSO1 is related to fundamental problems and their solutions in scientific way and CO1 is to learn about cold equation of state below neutron dripline which is very essential to solve problems in scientific way. Hence the affinity level is 3.	3
CO1-PSO2	CO1 deals with knowledge and tools of cold equation of state below neutron dripline. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.	2
CO2-PSO1	CO2 is related to analyze and solve problems related to white dwarf which map partially with PSO1. So the affinity level is 2.	3
CO2-PSO2	Since PSO2 is related to improve the analytical skills which maps completely with CO2. Hence the affinity level between CO2 and PSO2 is 3.	3
CO3-PSO1	Since CO3 is related to the key ideas and concepts of cold equation of state above neutron dripline which is completely mapped with PSO1. Hence the affinity level 3.	3
CO3-PSO2	The affinity level between CO3 and PSO2 is 2 because CO3 deals the key ideas and concepts of cold equation of state above neutron dripline which is partially mapped with PSO2.	2
CO4-PSO1	CO4 is related to analyze and solve problems of neutron stars. Hence CO4-PSO1 mapping has the affinity level 3.	3
CO4-PSO2	The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to neutron stars.	3
CO5-PSO1	CO5 is related to analyze and solve problems related to black holes and hence CO5-PSO1 mapping has the affinity 3. PSO1 is related to look fundamental problems and scientific solutions.	3
CO5-PSO2	The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to black holes.	3

22PHY534	Theory of Nanostructures	3 0 0 3

Prerequisites
Knowledge of basic quantum mechanics.

Course Objectives
The objective of the course is to learn about nanostructures and apply quantum mechanics to understand the phenomena related to nanostructures.

Course Outcomes: After completion this course student able to

CO1: Learn the key ideas and concepts related to layered nanostructures.
CO2: Learn and apply quantum mechanics to quantized motion and quantum states.
CO3: Learn the basic features of quantum states in atoms and molecules.
CO4: Analyze and solve problems related to quantization in nanostructures.
CO5: Learn about basic features of nanostructures and their applications.

Skills: Improvement of student's problem solving capability related to nanostructure physics through assignments and quizzes.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	3	3				3	2		
CO2	3	3				3	3		
CO3	3	3				3	2		
CO4	3	3				3	3		
CO5	3	3				3	3		

UNIT 1: Layered Nanostructures
Learning Objectives

Learn about the motion of a free electron in vacuum and potential barriers.
Learn and understand the propagation of an electron above the potential well.
Learn and analyze the propagation of an electron in the region of a potential barrier.

The motion of a free electron in vacuum, an electron in a potential well with infinite barriers, an electron in a potential well with finite barriers, Propagation of an electron above the potential well, Tunneling: propagation of an electron in the region of a potential barrier.

UNIT 2: Quantized Motion and Quantum States
Learning Objectives

Learn and analyze different potential barriers and quantum harmonic oscillators.
Understand the stationary perturbation theory for non-degenerate and degenerate systems.
Analyze the non-stationary perturbation theory and quasi-classical approximation.

Rectangular Potential Well, Spherically symmetric Potential Well, Quantum Harmonic Oscillators, Stationary perturbation theory for a system with non-degenerate states, Stationary perturbation theory for a system with degenerate states, Non-stationary perturbation theory, The Quasi-Classical Approximation.

UNIT 3: Quantum States in Atoms and Molecules

Learning Objectives

Learn and understand basic features of hydrogen atom.
Learn and understand many electron systems.
Analyze the wave function of a system of identical particles.

The Hydrogen Atom, The emission spectrum of the hydrogen atom, The spin of an electron, Many-electron atoms, The wave function of a system of identical particles, The Hydrogen Molecule.

UNIT 4: Quantization in Nanostructures

Learning Objectives

Learn and analyze dimensional quantization and low dimensional structures.
Learn and understand number and densities of states for nanostructure.
Analyze a three-dimensional super lattice of quantum dots.

The number and density of quantum states, Dimensional quantization and low-dimensional structures, Quantum states of an electron in low-dimensional structures, The number of states and density of states for nanostructures, Double-quantum-dot structures, A one-dimensional super lattice of quantum dots, A three-dimensional super lattice of quantum dots.

UNIT 5: Nanostructures and their applications

Learning Objectives

Learn method of fabrication of nanostructures.
Learn and understand tools for characterization with nanoscale resolution.
Understand and analyze the basic features of nanodevices and systems.

Methods of fabrication of nanostructures, Tools for characterization with nanoscale resolution, selected examples of nanodevices and systems.

Text Book:

1. V. V. Mitin, D. I. Sementsov and N. Z. Vagidov, Quantum Mechanics for Nanostructures, Cambridge University Press (2010).

Reference Book:

1. V. V. Mintin, V. A. Kochelap, M. A. Storscio, Quantum Heterostructures: Microelectronics and Optoelectronics, Cambridge University Press (2000).

Evaluation pattern

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to concepts of layered nanostructures. This improves student's knowledge in layered nanostructures and hence the affinity level is 3.	3
CO1-PO2	Since PO2 is related to problem analysis and CO1 is about concepts of layered nanostructures which is important to solve the problems related to layered nanostructures. Hence the affinity level between CO1 and PO2 is mentioned as 3.	3
CO2-PO1	CO2 is related to application of quantum mechanics to quantized motion and quantum states. Hence the affinity level is 3.	3
CO2-PO2	As CO2 is related to quantized motion and quantum states. Since PO2 is related to developing analytical skills, the affinity level between them is 3.	3
CO3-PO1	Since PO1 is related to strong fundamentals of physics and math which is essential to solve and analyze the problems related to basic features of quantum states in atoms and molecules. Hence CO3 has maximum affinity 3 when mapped with PO1.	3
CO3-PO2	CO3 is related to the basic features of quantum states in atoms and molecules. As PO2 is related to improve critical thinking and analytical skills. So, CO3 has maximum affinity to PO2 and hence given an affinity level of 3.	3
CO4-PO1	CO4 is related to analyze and solve problems related to quantization in nanostructures. As PO1 is related to improving knowledge of physics fundamentals, CO4 has maximum affinity of 3 with PO1.	3
CO4-PO2	CO4 is for solving problems related to nanostructures. Since PO2 is related to the development of analytical skills of students and maximum affinity level of 3 is given for CO4-PO2 mapping.	3
CO5-PO1	CO5 is related to basic features of nanostructures and their applications. Since PO1 is related to improving student's knowledge in physics and math. Hence maximum affinity level of 3 is given for CO5-PO1 mapping.	3
CO5-PO2	CO5 related to basic features of nanostructures and their applications. As PO2 is related to improving experimental skills, CO5 has maximum affinity with PO5 and hence given an affinity level of 3.	3
CO1-PSO1	PSO1 is related to fundamental problems and their solutions in scientific way and CO1 is to learn about layered nanostructure which is very essential to solve problems in scientific way. Hence the affinity level is 3.	3
CO1-PSO2	CO1 deals with concepts of layered nanostructures. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.	2
CO2-PSO1	CO2 is related to application of quantum mechanics to quantized motion and quantum states which map completely with PSO1. So the affinity level is 3.	3
CO2-PSO2	Since PSO2 is related to improve the analytical skills which maps completely with CO2. Hence the affinity level between CO2 and PSO2 is 3.	3
CO3-PSO1	Since CO3 is related to basic features of quantum states in atoms and molecules. which is completely mapped with PSO1. Hence the affinity level 3.	3
CO3-PSO2	The affinity level between CO3 and PSO2 is 2 since CO3 deals with basic features of quantum states in atoms and molecules which is partially mapped.	2

CO4-PSO1	CO4 is related to learn and solve problems for nanostructures. Hence CO4-PSO1 mapping has the affinity level 3.	3
CO4-PSO2	The affinity level between CO4 and PSO2 is 3 since the CO4 deals with to solve problems related to quantization in nanostructures.	3
CO5-PSO1	CO5 is to learn about basic features of nanostructures and their applications. Hence CO5-PSO1 mapping has the affinity 3. PSO1 is related to look fundamental problems and scientific solutions.	3
CO5-PSO2	The affinity level between CO5 and PSO2 is 3 since CO5 deals basic features of nanostructures and their applications .	3

22PHY535	Special Theory of Relativity	3 0 0 3

Prerequisites: Mechanics & Electrodynamics

Course Objectives: To have a comprehensive physical idea and mathematical understanding of Special theory of Relativity and its applications in Electrodynamics, Fluid Dynamics etc using four-dimensional covariant analysis.

UNIT 1
Classical Mechanics and Relativity: Galilean Relativity, Newtonian Mechanics, Electrodynamics and Galilean Relativity, Ether, Michelson–Morley experiment, Attempts by Lorentz & Poincare.

UNIT 2
Special Theory of Relativity: Einstein's postulates, Lorentz's transformation, Length contraction, Time dilation. Relativistic Kinematics, Doppler shift, Minkowski Diagrams, Boosts and Minkowski space.

UNIT 3
Four dimensional Space-Time geometry: Space-time continuum, Lorentz transformations as coordinate transformations, tensors, contravariant and covariant objects, four vectors.
Relativistic Dynamics: Four velocity, Four momentum, Four acceleration, Relativistic Collisions, Conservation of four-momentum, Equivalence of Mass and Energy. Central force problem in relativity.

UNIT 4
Electromagnetic Theory in covariant form: Maxwell's equations in covariant form, Four dimensional vector potential, Energy-Momentum Tensor and Conservation Laws, Lagrangian formulation of Electrodynamics, Radiation.

UNIT 5
Covariant formulation Fluid Dynamics: Perfect fluids, Pressure and proper density, Energy-Momentum tensor, Relativistic Euler equations, Equation of state, Speed of sound.
The Lorenz & Poincare groups: The Lorentz and Poincare algebras and their representations.
The Principle of Equivalence and preamble to General Theory of Relativity.

Text Books:

1. N. M. J. Woodhouse, Special Theory of Relativity, Springer, 2003.

2. Steven Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Reactivity, Wiley India, 2008.

Reference Books:

1. Landau & Lifshitz, Classical Field Theory, University Science Books, 1E, 2004.
2. Ashok Das, Lectures on Electromagnetism, Hindustan Book Agency – World Scientific, 2013.
3. A. Einstein, Relativity: The Special and the General Theory.

22PHY536	Introduction to Classical Field Theory	3 0 0 3

Prerequisites: Classical Mechanics & Special Theory of Relativity

Course Objectives

The course introduces the concepts and calculations involved in classical field theory. It extensively explains the classical field theories of Electromagnetism and Gravitation

UNIT 1

Continuum Mechanics: Review of Classical Mechanics: Lagrangian and Hamiltonian formalisms, Transformation theory, Action-Angle variables, Hamilton-Jacobi equations. Lagrangian and symmetries: Energy-Momentum tensor, Noether's theorem and applications

UNIT 2

Electromagnetism as a classical field theory: Lorentz transformation, The electromagnetic field tensor, covariant charge density and current, action formalism for electrodynamics, Maxwell's equations and relativistic covariance, Lagrangian and Hamiltonian formalism, Symmetries and covariance, Gauge invariance.

UNIT 3

Classical Field Theory of Gravitation: Principle of equivalence, curvilinear coordinates, metric, connection, curvature tensor, energy-momentum tensor, Einstein field equations and its Newtonian limit.

Reference Books:

1. L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields, Pergamon Press, 4th Edition, 1980.
2. G. Giachetta, L. Mangiarotti and G. Sardanashvily, Advanced Classical Field Theory, World Scientific, 2009.
3. Florian Scheck, Classical FieldTheory, Springer, 2012.

22PHY537	Introduction to General Theory of Relativity	3 0 0 3

Prerequisites: Mathematical Physics & Special Theory of Relativity

Objectives: To have a physical idea and mathematical understanding of General theory of Relativity and its applications

UNIT 1

Tensor Calculus and Differential Geometry: Riemannian space, Curvilinear coordinates, Tensors, Affine connection, Covariant derivative, Geodesics, Riemann-Christoffel curvature tensor, Bianchi identities, Ricci Tensor, Curvature Scalar.

UNIT 2

Special Theory of Relativity and Introduction to Gravity: Minkowski spacetime, Special Theory of Relativity, Relativistic Dynamics. The principle of equivalence, Principle of General covariance, General Theory of Relativity – historical developments.

UNIT 3

Einstein Field Equations: Gravity and Geometry, Energy-momentum tensor, Curvature tensors, Bianchi identities, Einsten tensor, Field equation, Weak Gravitational Field.

UNIT 4

Schwartzchild Solution: Centrally symmetric Gravitational Field, Static spherically symmetric space-time, Schwartzchild Solutions

Black Holes: Relativistic Stellar star structure, Gravitational Collapse, Black Holes

Text Books:

1. Steven Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Wiley India, 2008.
2. Øyvind Grøn, Sigbjorn Hervik, Einstein's general theory of relativity: with modern applications in cosmology, 2002.
3. Ashok Das, Lectures on Gravitation, World Scientific, 2013.

Reference Books:

1. Landau & Lifshitz, Classical Field Theory, University Science Books, 1E, 2004.
2. C. W. Misner, K. S. Thorne and J. A. Wheeler, Gravitation, Princeton Univ Press
3. A. Einstein, Relativity: The Special and the General Theory

22PHY538	Quantum Field Theory	3 0 0 3

Course Objectives: To learn the basic concepts and techniques of quantum field theory, with applications to elementary particle physics, with special emphasis to Quantum Electrodynamics (QED).

UNIT 1

Non-relativistic quantum field theory: quantum mechanics of many particle systems; second quantisation; Schrodinger equation as a classical field equation and its quantisation; inclusion of inter-particle interactions in the first and second quantised formalism

UNIT 2

Canonical quantization of free fields: Real and complex scalar fields, Dirac field, electromagnetic field, Bi-linear covariants, Projection operators, Charge conjugation and Parity on scalar, Dirac and electromagnetic fields.

UNIT 3

Interacting fields: Interaction picture, Interacting Klein-Gordon field, Covariant perturbation theory, S-matrix and its computation from n-point Green functions, Wick's theorem, Feynman diagrams.

UNIT 4

QED: Feynman rules, Example of actual calculations: Rutherford, Bhabha, Moeller, Compton etc. Decay and scattering kinematics. Mandelstam variables and use of crossing symmetry, coupling Dirac field to electromagnetic field, Feynman rules for computing Green functions, symmetries and Ward identity.

UNIT 5

Higher order corrections: One-loop diagrams. Basic idea of regularization and renormalization, Landau pole. Degree of divergence, Calculation of self-energy of scalar in φ4 theory using cut-off or dimensional regularization, Path integrals for scalar and fermionic fields.

Gauge theories: Gauge invariance in QED, non-abelian gauge theories (classical theory, quantization), QCD (introduction), Asymptotic freedom, Spontaneous symmetry breaking, Goldstone theorem, Higgs mechnism,Yang-Mills theory.

Reference Books

1. M. E. Peskin and D. V. Schroeder, An Introduction to Quantum Field Theory, Addison-Wesley, New York, 1995.
2. Steven Weinberg, Quantum Theory of Fields, Vols. I and II, Cambridge University Press, 1996.
3. I.J.R. Aitchison and A.J.G. Hey,Gauge Theories in Particle Physics, Vol. 1: From Relativistic Quantum Mechanics to QED, 3rd Edition, Taylor & Francis
4. Lahiri and Pal, A First Book of Quantum Field Theory, Narosa, 2007
5. J.D. Bjorken and S.D. Drell, Relativistic Quantum Fields, McGraw-Hill, 1965

Course Code	Core Electives	L T P	Cr	ES
	Applied Materials			
22PHY541	Physics of Semiconductors	3 0 0	3	
22PHY542	Physics of Nanomaterials	3 0 0	3	
22PHY543	Thin Film Technology	3 0 0	3	
22PHY544	Advanced Solar Cell Fabrication	3 0 0	3	
22PHY545	Optoelectronic Devices	3 0 0	3	
22PHY546	Electrochemical Energy Storage Systems	2 0 2	3	
22PHY547	X-Ray & Electron Diffraction Techniques	3 0 0	3	
22PHY548	Physics of Smart Materials	3 0 0	3	
22PHY549	Thermodynamics of Defects and Phase Transitions in Solid State	3 0 0	3	
22PHY550	Biomaterials	3 0 0	3	
22PHY551	Micro and Nano Magnetism Materials and its Applications	3 0 0	3	
22PHY552	Computational Materials Science	3 0 0	3	

22PHY541	Physics of Semiconductors	3 0 0 3

Course Objectives: This course is intended to impart students, basic knowledge on crystallography, defects and imperfections in solids, classical and quantum free electron theories of metals along with band theory of solids, types of semiconductors and band structure. It is also aimed at improving the understanding of students related to basic theory and operations of various semiconductor devices such as p-n junction diode, BJT, MOSFET and semiconductor optoelectronic devices such as solar cells, LEDs and photodetectors.

UNIT 1: Crystal Structure of Solids
Unit cell, Bravais lattices, Crystal systems, Crystal planes and Miller indices, Symmetry elements, Defects and imperfections – Point defects, Line defects, Surface defects and Volume defects.

UNIT 2: Classical and Quantum Theories of Solids
Classical free electron theory assumptions, Drift velocity, Mobility and Conductivity, Drawbacks. Quantum free electron theory: Fermi energy, Density of States. Band theory of solids: Origin of energy bands, Effective mass, Distinction between metals, insulators and semiconductors.

UNIT 3: Carrier Transport Phenomena
Intrinsic and extrinsic semiconductors, Band structure of semiconductors, Carrier concentration in intrinsic and extrinsic semiconductors, Electrical conductivity and Conduction mechanism in semiconductors, Fermi level in intrinsic and extrinsic semiconductors and its dependence on temperature and carrier concentration, Carrier generation - Recombination, Mobility, Drift and diffusion current, Hall effect.

UNIT 4: Theory of p-n junction Diode and Transistors
p-n junction under thermal equilibrium, Forward bias, Reverse bias, Carrier density, Current, Electric field, Barrier potential, V-I characteristics, Junction capacitance and voltage breakdown. Bipolar junction transistor: p-n-p and n-p-n transistors: principle and modes of operation, current relations, V-I characteristics. Fundamentals of MOSFET, JFET, and Heterojunctions – quantum wells.

UNIT 5: Optical Devices
Optical absorption in a semiconductor, electron-hole generation, Solar cells: p-n junction, conversion efficiency, Heterojunction solar cells, Photo detectors: Photo conductors, Photodiode, p-i-n diode, Light emitting diode (LED): Generation of light, Internal and external quantum efficiency, **Modern Semiconducting Devices:** CCD-Introduction to nano devices, Fundamentals of tunneling devices, Design considerations, physics of tunneling devices.

TEXTBOOKS:

1. C. Kittel, “Introduction to Solid State Physics”, Wiley, Eighth Edition, 2012.
2. D.A. Neamen, “Semiconductor Physics and Devices”, TMH, Fourth Edition, 2021.

REFERENCES:

1. S.M. Sze, “Physics of Semiconductor Devices”, Wiley, Third Edition. 2015.
2. P. Bhattacharya, “Semiconductor Optoelectronic Devices”, Prentice Hall, 1996.
3. M.K. Achuthan, K.N. Bhat, “Fundamentals of Semiconductor Devices”, TMH, 2007.
4. J. Allison, “Electronic Engineering Materials and Devices”, TMH, 1990.

22PHY542	Physics of Nanomaterials	3 0 0 3

Prerequisites: Solid State Physics

Course Objectives: To make the students to understand about physics of nanostructured materials, synthesis of nanomaterials, structure-property correlation in nanomaterials, application of nanomaterials in diversified fields along with device fabrication using various nanostructures.

UNIT 1: Basics of Nanomaterials

Introduction to nanomaterials, Comparison of bulk and nanomaterials: Change in band gap, Novel properties of nanomaterial. Classification of nanostructured materials, Synthesis of nanomaterials: Classification and fabrication methods - Top down and bottom-up methods.

UNIT 2: **Concept of Quantum Confinement and Phonon Confinement**

Basic concepts - Excitons, Effective mass, Free electron theory and its features, Band structure of solids. Bulk to nano transition - Density of states, Quantum confinement effect - weak and strong confinement regime. Electron confinement in infinitely deep square well, Confinement in two and three dimension. Blue shift of band gap, Effective mass approximation. Vibrational properties of Solids - Phonon Confinement effect and presence of surface modes.

UNIT 3: Tools for Characterization

Structural: X-ray Diffraction, **Surface Analysis**: Transmission Electron Microscope, Scanning Tunneling Microscope, Atomic Force Microscope, **Optical studies**: UV - Visible absorption, Photoluminescence, Raman spectroscopy.

UNIT 4: **Nanostructured Materials**

Carbon nanotubes: Structure, electrical, vibration and mechanical properties, Applications of carbon nanotubes - Field emission and shielding, Computers, Fuel cells, Chemical sensors, Catalysis, Mechanical reinforcement. Quantum dots and Magnetic nanomaterials – Applications.

UNIT 5: **Nanoelectronics and Nanodevices**

Impact of nanotechnology on conventional electronics, Nanoelectromechanical systems (NEMSs): Fabrication (Lithography) and applications, Nanodevices: Resonant tunneling diode, Quantum cascade lasers, Single electron transistors: Operating principles and applications.

TEXT BOOKS:

1. Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, “Nanoscale Science and Technology”, John Wiley and Sons Ltd., 2004.
2. W.R. Fahrner (Ed.), Nanotechnology and Nanoelectronics, Springer, 2006.

REFERENCE BOOKS:

1. Charles P. Poole, Jr. Frank J. Owens, “Introduction to nanotechnology”, First Edition, Wiley-Interscience, 2003.
2. T. Pradeep, “Nano: The essentials: Understanding nanoscience and nanotechnology”, First Edition, McGraw Hill Education, 2017.

22PHY543	Thin Film Technology	3 0 0 3

Prerequisite: Solid State Physics

Course Objectives: To make the students to understand about the difference between bulk and thin film, the optical, electrical, dielectric and magnetic properties of thin film, the theories explaining the formation of thin film and the fabrication and advantages of thin film devices.

Course Outcomes

At the end of the course students will be able to

CO1. To understand the principle, differences and similarities, advantages, and disadvantages of different thin film deposition Techniques.

CO2. To understand and evaluate and use models for understanding nucleation and growth of thin films.

CO3. To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications.

CO4. To improve problems solving skills related to evaluation of different properties of thin films.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	PSO4
CO1	1	2						2	
CO2	1	2						2	
CO3	1	2	2	2				2	
CO4	1	2	2	2				2	

UNIT 1: Preparation Methods

Learning Objectives

Understand about the various physical and chemical deposition metods

Physical methods: Thermal evaporation, Cathodic sputtering, Molecular beam epitaxy and Laser ablation methods.

Chemical methods: Electrolytic deposition, Chemical vapor deposition.

UNIT 2: **Thickness Measurement and Characterization**

Learning Objectives

Understand the principle in measuring the thickness of thin films and to find a suitable method for measuring the thickness of thin films.

Understand and analyze the characteristics of thin films using different instrumentation technique.

Electrical, Mechanical, Optical, Microbalance, Quartz crystal methods.

Analytical techniques of characterization: X-ray diffraction, Electron microscopy, High and low energy electron diffraction, Auger emission spectroscopy.

UNIT 3: **Growth and Structure of Films**

Learning Objectives

Able to understand the nucleation theories leading to the growth.
Able to understand different types of growth mechanisms in the growth of thin films
Understand, analyze and treating the Structural defects in thin films.

General Features, Nucleation theories, Effect of electron bombardment on film structure, Post-nucleation growth, Epitaxial film growth, Structural defects.

UNIT 4: Properties of Thin Films

Learning Objectives

Understanding the mechanical behavior of thin films.
Understanding and calculating the optical constants of thin films and hence draw the conclusions regarding the optical behavior of thin films.
Understanding he electrical and superconducting behavior of thin films and hence to draw a valuable conclusion regarding the properties of the material

Mechanical properties: Elastic and Plastic behavior.

Optical properties: Reflectance and transmittance spectra, Absorbing films, Optical constants of film material, Multilayer films, Anisotropic and isotropic films.

Electrical properties: Conductivity in metal, Semiconductor and Insulating films, Discontinuous films, Superconducting films.

UNIT 5: Magnetic Properties of Thin Films and Thin Film Devices

Learning Objectives

Understanding the theories of magnetism and the application of magnetic thin films in various fields.
Understanding the working principle of thin film devices and the fabrication and application of thin film devices.

Molecular field theory, Spin wave theory, Anisotropy in magnetic thin films, Domains in thin films, Applications of magnetic thin films.

Thin film devices: Fabrication and applications.

TEXT BOOKS:

1. K.L. Chopra, “Thin Film Phenomena”, First Edition, McGraw-Hill, 1969.
2. George Hass, “Physics of Thin Films”, Volumes 1, Academic Press Inc., 1963.

REFERENCE BOOKS:

1. K. L. Chopra and S. R. Das, “Thin Film Solar Cells”, Springer, 1983.
2. L. I. Maissel and Glang, “Handbook of Thin Film Technology”, McGraw Hill Higher Education, 1970.
3. J. C. Anderson, “The Use of Thin Films in Physical Investigation”, Academic Press Inc., 1966.
4. J. J. Coutts, “Active and Passive Thin Film Devices”, Academic Press Inc., 1978.
5. R.W. Berry, P.M. Hall and M.T. Harris, “Thin Film Technology”, Van Nostrand, 1968.

Evaluation Pattern

Assessment	**Internal**	**External Semester**
Periodical 1 (P1)	15	

Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understanding the principle, differences and similarities, advantages and disadvantages of different thin film deposition methods it require the basic knowledge regarding the differences between the thin and thick film and the basic knowledge regarding the deposition so it is related to PO1	1
CO1-PO2	As CO1 is related to the basic understanding regarding the differences between thick and thin film and the parameters adjusted to get a uniform thickness thin film, it requires the analyzing capacity of the students to go for a suitable method of preparation and so it is related to PO2.	2
CO2-PO1	CO2 is related to evaluation and use of models for understanding nucleation and growth of thin films it requires the basic knowledge of various nucleation theories and so it is related to PO1	1
CO2-PO2	As CO2 is the understanding and evaluation of different nucleation models for the growth of the thin films it requires the analyzing skills of the students regarding the nucleation theories and to find the radius of the nuclei and hence draw conclusions and hence it is related to PO2.	2
CO3-PO1	CO3 is related to analyzing the thin film properties for various applications the students should know the basic knowledge in selecting the suitable material with properties foe suitable applications, so it is related to PO1.	1
CO3-PO2	The application of thin films depends on the thin film properties; students should analyse the material properties for suitable applications so CO3 is related to PO2.	2
CO3-PO3	Application of thin films are based on the material properties students should know the proper selection of the material for suitable applications with appropriate consideration for the public health and safety and environmental considerations. So CO3 is related to PO3.	2
CO3-PO4	The analysis of thin film properties to apply for various applications includes the use of research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. So CO3 is related to PO4.	2
CO4-PO1	To improve problems solving skills related to evaluation of different properties of thin films it requires basic knowledge regarding the physics of thin films. So CO4 it is related PO1.	1

CO4-PO2	To improve different properties of thin films students should be able to identify and analyze the problems so that they can formulate the synthesis process. So CO4 is related to PO2.	2
CO4-PO3	To improve the knowledge in the evaluation of different properties of thin films one should be able to design solutions for complex chemical process problems and evolve procedures that meet the specified needs with appropriate consideration for the public health and safety and environmental considerations. So CO4 is related to PO3.	2
CO4-PO4	The problem-solving skills in tuning and improving the properties of thin films require the use of research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. So CO4 is related to PO4.	2
CO1-PSO3	To understand the principle, differences and similarities, advantages and disadvantages of different thin film deposition methods. After gaining the knowledge Students will acquire experimental skills which enable them to take precise measurements in labs and analyze the measurements to draw valid conclusions. In addition, students will exhibit skills in solving problems using computer programming, plotting tools, and related software. SoCO1 is related to PO3	2
CO2-PSO3	By understanding nucleation theories Students will acquire skills which enable them to analyze it to draw valid conclusions. In addition, students will exhibit skills in solving problems using computer programming, plotting tools, and related software	2
CO3-PSO3	After getting the knowledge to analyze thin film properties to apply for various applications Students will acquire experimental skills which enable them to take precise measurements and analyze the measurements to draw valid conclusions. In addition, students will exhibit skills in solving problems using computer programming, plotting tools, and related software	2
CO4-PSO3	After improving the problems solving skills in the of different properties of thin films students will acquire experimental skills in measurements and analyze the measurements to draw valid conclusions. In addition, students will exhibit skills in solving problems using computer programming, plotting tools, and related software.	2

22PHY545	Optoelectronic Devices	3 0 0 3

Pre-requisite: Basic Electrodynamics

Course Objectives:

The objective of the course is to give students an introduction to optoelectronic fundamentals and devices. This course serves as a perquisite course to prepare students to do research in the semiconductor optics and optoelectronics devices

UNIT 1: Review of Basic Concepts

Electromagnetic waves, Maxwell's and Fresnel equations, Introductory quantum mechanics, Semiconductors, Einstein relations

UNIT 2: Electron–Photon Processes

Review of Semiconductors and Energy bands, p-n junction diodes, Carrier radiative recombination and light-emitting devices, Stimulated processes, Lasing mechanism and modes, Semiconductor laser, Holography

UNIT 3: Photon–Electron Processes
p-n junction photodiode, Photodiode materials, Quantum efficiency and responsivity, p-i-n photodiode, Avalanche photodiode, Heterojunction photodiode, Phototransistors, Photoconductive detectors: Gain, Noise in photodetectors, Photo-voltaic devices.

UNIT 4: Photon-Photon Processes
Waveguides, Planar slab waveguide, Eigenvalues for the slab waveguide, Optical mode confinement, Dispersion in waveguides, Coupling of modes between waveguides, Coupling between optical sources and waveguides, Grating couplers, Coupling coefficient, Propagation optical fibers, Dispersion, Solitons in nonlinear fibers.

UNIT 5: Advanced Optoelectronics
Photonic and optoelectronic integrated circuits, Organic, Molecular and Terahertz optoelectronics, Display technology, Optoelectronic nanomaterials.

Text Books
1. S. O. Kasap. "Optoelectronics and Photonics", Pearson Prentice Hall, Second Edition, 2012.
2. Govind P. Agrawal, Niloy K. Dutta. “Semiconductor Lasers”, Second Edition, Springer-Verlag, 1993.

Reference Books
1. Mitsuo Fukuda, “Optical Semiconductor Devices”, John-Wiley and Sons, 2005.
2. Ben G. Streetman and Sanjay Kumar Banerjee, “Solid State Electronic Devices,” Seventh Edition Global Edition, Pearson, 2016.
3. Pallab Bhattacharya, “Semiconductor Optoelectronic Devices,” Second Edition, Prentice-Hall, 2017.
4. Clifford R. Pollock, “Fundamentals of Optoelectronics”, Richard d Irwin, 1995.
5. Emmanuel Rosencher, Borge Vinter, “Optoelectronics”, First Edition, Cambridge University Press, 2002.

22PHY546	Electrochemical Energy Storage Systems	3 0 0 3

UNIT 1: Basic Principles
Review of Faradays laws, thermodynamics of electrochemical cells and kinetics of electrochemical reactions. Performance evaluation of energy storage devices - cell voltage – capacity - specific and volumetric energy and power densities, Peukert curves, Ragone plot, discharge profiles. Factors affecting the performance. Design and classification of electrochemical storage devices, importance of nanotechnology. Battery components – current collector, separator, electrolyte and active materials.

UNIT 2: Primary Batteries
The chemistry, fabrication and performance aspects, packing classification and rating of the following batteries - zinc-carbon - Leclanche type, zinc alkaline - duracell, zinc/air, zinc-silver oxide batteries, lithium primary cells - liquid cathode - solid cathode and polymer electrolyte types.

UNIT 3: Secondary Batteries

Fabrication, performance characteristics, electrode and electrolyte materials of the following batteries: Lead acid and VRLA, nickel-cadmium, nickel-zinc, nickel-metal hydride batteries, silver peroxide, lithium-ion batteries, lithium polymer cells. Advanced Batteries for electric vehicles, specifications - sodium-beta and redox batteries.

UNIT 4: Reserve Batteries and Fuel Cells
Reserve batteries - water activated, electrolyte activated and thermally activated batteries - remote activation - pyrotechnic materials. Fuel Cells-Principle, chemistry and functioning - carbon, hydrogen-oxygen, proton exchange membrane (PEM), direct methanol (DMFC), molten carbonate electrolyte (MCFC) fuel cells, solid oxide fuel cells and outline of biochemical fuel cells. Fuel cell stack technology.

UNIT 5: Supercapacitors
Types - double layer, hybrid and pseudo capacitors, symmetric and asymmetric capacitors. Mechanism of energy storage, materials for supercapacitors, carbon materials-activated carbon, carbide-derived carbon, CNT, graphene, mesoporous carbon, metal oxides, metal sulphides, conducting polymers. Effect of ratio of ion and molecule sizes and pore sizes. Electrolytes- aqueous, organic and ionic liquid. Determination of capacitor performance-cyclic voltammetry, galvanostatic charge-discharge, impedance spectroscopy. Flexible and wearable supercapacitors.

Recommended Readings

1. Beard, K.W., 2019. Linden's handbook of batteries. McGraw-Hill Education.
2. Bagotsky, V.S., Skundin, A.M. and Volfkovich, Y.M., 2015. Electrochemical power sources: batteries, fuel cells, and supercapacitors. John Wiley & Sons.
3. Allen, J. and Bard, R.L., 2000. Faulkner. Electrochemical Methods: Fundamentals and Applications, John Wiley and Sons. Inc. New York.
4. Conway, B.E., 2013. Electrochemical supercapacitors: scientific fundamentals and technological applications. Springer Science & Business Media.

22PHY544	Advanced Solar Cell Fabrication	3 0 0 3

Prerequisites: Preliminary concept of semiconductor physics and light mater interaction

Course Objectives

This course is developed to educate the student on recent trends in solar cell fabrication and the device structure. So the student should learn the different techniques of solar cell fabrication from materials to devices.

Course Outcomes

At the end of the course students will be able to

CO1 Different methods of solar energy harvesting like solar thermal power and solar PV.
CO2: Working principle of solar PV, physics behind photocurrent and photovoltage generation in the solar cell.
CO3: Fabrication of different types of solar cell and methods to enhance solar cell efficiency.
CO4: Recent trends and current research focus on solar cell fabrication.
CO5: Hands-on Experience on Fabrication of solar cell, characterization of solar cell.

Skills: Fabrication of solar cell, characterization of solar cell

CO-PO Mapping

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3	3				3		
CO2	3	3				3		
CO3	3	3	3	3		3	3	3
CO4	3	3	3	3		3	3	3
CO5	3	3	3	3		3	3	3

UNIT 1

Learning objectives

Basic understanding of Si solar cell

Know about different type of solar energy harvesting

Developing knowledge on semiconductor physics for PV applications

Basic understanding of Solar PV

The Solar Resource and types of solar energy converters, Requirements of an ideal photoconverter, Principles of a solar cell design, material and design issues; Revisions of Semiconductor Physics, Physics of semiconductor Junctions; p-n junction under dark and under illumination, effect on junction characteristics, Other device structures. Photovoltaic cell and power generation, Characteristic of the Photovoltaic Cell.

UNIT 2

Learning objectives

Basic knowledge on Si sollar cell

Single crystal Si solar cell structure

Single crystal Si sollar cell Fabrication

Basic knowledge on thin film solar cell

Knowledge on CIGS solar cell

Knowledge on CdTe solar cell

Silicon Solar cell, Mono -crystalline and poly–crystalline cells, Metallurgical Grade Si, Electronic Grade Si, wafer production, Mono–crystalline Si Ingots, Poly–crystalline Si Ingots, Si–wafers, Si–sheets, Solar grade Silicon, Si usage in solar PV, Commercial Si solar cells, process flow of commercial Si cell technology, Process in solar cell technologies, Sawing and surface texturing, diffusion process, thin film layers, Metal contact..

UNIT 3

Learning objective

Explain the concept of center of mass for system of particles and conservation of both linear and angular momenta

Differentiate between elastic and inelastic collision and solve problems related to collision

Analyze rocket motion as an example for system of variable mass

Analyze rotational motion of bodies through rotational variables

Centre of Mass, Conservation of linear momentum, collisions, and systems with variable mass. Torque, Angular momentum, Moment of Inertia, Conservation of Angular momentum, Kinetic Energy of Rotation.

UNIT 4

Learning objectives

Basic Knowledge on Thin Film Solar cell

2nd generation solar cell, Thin film solar cell, Advantage of thin film, Thin film deposition techniques, Evaporation, Sputtering, LPCVD and APCVD, Plasma Enhanced, Hot Wire CVD, closed space sublimation, Ion Assisted Deposition, Substrate and Super -state configuration, Thin film module manufacturing, Thin film and Amorphous Si Solar cell, Cadmium Telluride Solar Cell, CIGS solar Cell, CZTS solar cell, New materials for thin film solar cell.
Optics in solar energy conversion: antireflection coatings, concentration of light: Light confinement, photon recycling, multiple exciton generation.

UNIT 5:
Learning objectives

Development of expertise on device fabrication

Hand on experience on solar cell fabrication, DSSC fabrication, Perovskite solar cell fabrication, Thin film solar cell fabrication.

Suggested Reading

1. Physics of Solar cells-Jenny Nelson, Imperial College Press (2006)
2. Crystalline Silicon Solar Cells, by A. Goetzberger, J. Knobloc h, and B. Voss (Wiley, 1998)
3. Third Generation Photovoltaics: Advanced Solar Energy Conversion, by M. A. Green (Springer, 2006)
4. Semiconductor Materials for Solar Photovoltaic Cells; Paranthaman, M. P. (et al.) (Eds.) (2016)

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

Mapping	Justification	Affinity level
CO1-CO 5 to PO1 and PSO 1	This course delivers the understanding of solar energy harvesting with the objective of building strong core knowledge; hence, all the course outcomes have very strong affinity to PO1 and PSO 1, which is about building fundamentals in science and creating inquitiveness problem-solving in a scientific way.	3
CO1-CO5-PO2	This course is building core fundamentals on the solar energy harvesting; hence, all the course outcomes have a very high affinity to PO2, which is about building critical thinking.	3

CO3-CO5 –PSO2	These course out comes take care to develope the knowledge of solar cell fabrication, so they are strongly bound to the development of research skills on the student and PSO2	3
CO3-CO5 – PO3 and PSO3	As these CO's are developed the the experimental skill of the student for solar cell fabrications, all the course outcomes have very high affinity to PO2 and PSO 2, which is about developing problem solving culture and translational research	3
CO3-CO5 – PO4	This course outcomes deals with the recent trends of the solar cell research and hands-on experience so the student can enhance the quality of the research, so these cos are strongly bound to the PO4.	3

22PHY547	X-Ray and Electron Diffraction Techniques	3 0 0 3

Prerequisites: The student is expected to have covered topics in basic solid-state physics and geometric ray-optics.

Course Objectives:

1. Introduce the concept of diffraction with X-rays and electrons to the students.
2. Briefly describe the use of X-rays to determine crystal structures, construct phase diagrams and analyse phase transitions and particle agglomeration in materials; a topic on refinement methods is also introduced.
3. Introduce the student to conventional transmission electron microscopy (TEM) and its utility to analyse crystal structures, analyse line and planar defects and grain boundaries in materials.
4. Qualitative treatment of phase contrast (High Resolution) TEM will be introduced to students.

Course Outcomes:

CO1: Understand fundamental concepts of X-ray diffraction

CO2: Apply diffraction techniques to study materials

CO3: Understand electron diffraction and the instrumentation of the TEM

CO4: Understand how to index 2D electron diffraction patterns.

Skills: Problem solving skills and analytical thinking skills will be enhanced. Software tools will be introduced to the student.

CO-PO Mapping

POs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PSO1**	**PSO2**	**PSO3**
CO1	3							
CO2	3	2		2				
CO3	3							
CO4	3							

UNIT 1: Properties of X-rays and Description of Crystals

Learning Objectives

Introduction to X-rays and microstructures of common solids

Production and detection of X-rays, Directions and intensities of diffracted beams, Detectors and measuring intensities of X-rays, Methods of X-ray diffraction, Penetration of X-rays, Grain size, Particle size and Crystal perfection and Orientation.

UNIT 2: X-ray Analysis

Learning Objectives

Understand the methods of using X-rays to construct phase diagrams distinguish reactions and measure compositions of alloys

Determination of phase diagrams, Order-disorder phase transitions, Chemical analysis by diffraction: Hanawalt method, Direct comparison and Internal standard methods, Chemical analysis by Fluorescence and Absorption.

UNIT 3: Precise Lattice Parameter Measurements

Learning Objectives

Learn to use curve fitting methods to measure lattice parameters precisely; Introduction to full pattern refinement methods

Rietveld refinement method, General methods of precise lattice parameter measurement: Least Squares method, Cohen's method, Calibration method, Hugo Rietveld's method of full pattern refinement, Introduction and practice of refinement using the Full Proof software (open source).

UNIT 4: Transmission Electron Microscopy

Learning Objectives

Introduction to scattering by electrons; instrumentation and imaging modes in the TEM including CBED technique

Comparison of scattering by electrons and X-rays, Elastic and inelastic electron scattering, Basic instrumentation and imaging modes in TEM, Obtaining and indexing parallel beam electron diffraction patterns, Kikuchi lines and use of Convergent Beam Electron Diffraction (CBED) techniques.

UNIT 5: Phase Contrast Imaging and HR-TEM

Learning Objectives

Learn to use the TEM to image defects (line defects and planar defects); Image formation in the HRTEM

Different contrast mechanisms in the TEM: Amplitude, Mass-thickness, Z-contrast, STEM diffraction contrast, Analysing defects: Two beam condition, Weak beam dark field imaging, Thickness and bending effects, Planar defects, Strain field imaging, High resolution TEM.

Reference Books:

1. B. D. Cullity and S. R. Stock, "Elements of X-ray Diffraction", Third Edition, Pearson Education India, 2014.
2. Vitalij K. Pecharsky, Peter Y. Zavalij, "Fundamentals of Powder Diffraction and Structural Characterization of Materials", Second Edition, Springer, Boston, MA, 2005.
3. David B. Williams and C. Barry Carter, Transmission Electron Microscopy – A Textbook for Materials Science, Second Edition, Springer, 2011.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping:

Mapping	Justification	Affinity level
CO1-PO1	CO1 is related to understanding the fundamental phenomenon of diffraction, while PO1 is related to basic sciences. Hence, they are mapped at the highest level of 3.	
CO2-PO1	CO2 is application of the diffraction method to study about the fundamental properties of materials. This is related to fundamental science and hence is mapped with level 3 with PO1.	
CO2-PO2	CO2 pertains to application of the diffraction method to study about the fundamental properties of materials. PO2 is about developing methods to formulate and analyze complex behaviour. Hence they are mapped at level 2.	
CO2-PO4	The methods studied in this course also form a primary basis of many research methods which is relevant to PO4 which suggests using research-based methods for arriving at the solution to a problem.	
CO3-PO1	CO3 refers to understanding and introduction to electron diffraction and microscopy. It is strongly correlated to fundamental sciences as mentioned in PO1. Hence it is mapped at level 3.	
CO4-PO1	CO4 refers to indexing 2D electron diffraction patterns. This is related to application of fundamental science and its relevance in the course. Hence mapped at level 3.	

22PHY549	Thermodynamics of Defects and Phase Transitions in Solid State	3 0 0 3

Prerequisites: The student is expected to have covered topics in basic solid-state physics/ crystal physics and a basic course in thermodynamics.

Course Objectives:

1. Present a general outline of solid-state phase transitions in materials starting from point defects to phase diagrams
2. Understand how to calculate free energy of a solid using various approximations and construct a simple phase diagram for a binary alloy

3. Description of diffusion and how to solve diffusion problems
4. Combining thermodynamics and kinetics to understand how microstructures develop in real materials

Course Outcomes:

CO1. Understand the concept of crystalline defects in solids and their implications in phase diagrams
CO2. Apply the notion of effective charges to write defect chemistry equations
CO3. Understand how to construct binary phase diagrams
CO4. Understand the concept of diffusion in solids and their implications in phase transitions.

Skills: The student will develop a better understanding of thermodynamics by applying it to the formation of solids. Problem solving skills and analytical thinking skills will also be enhanced.

CO-PO Mapping

POs	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
CO1	3							
CO2	3	2		2				
CO3	3							
CO4	3							

UNIT 1: Defect Chemistry

Learning Objectives

Learn different types of defects present in solids and differentiate between thermodynamically permitted defects and other types of defects and their energies and optimal concentration in a solid; Deduce the connection between defects and defect compensations.

Point and electronic defects; Kröger-Vink notation; Effective charge on a defect; Frenkel and Schottky defects; Defect formation and reaction equations; Extended defects – Line and planar defects; Population and energy of defects: Equilibrium population of vacancies, Schottky and Frenkel defects; Energy of a point defect and a line defect; Non-stoichiometric defects – the phase diagram.

UNIT 2: Thermodynamics of Solid Solutions

Learning Objectives

Review basic thermodynamic potentials and calculate them using appropriate formulas. Understand the relevant thermodynamic models and concepts necessary to understand the formation of solids.

Review of basic thermodynamic functions – heat capacities, enthalpy, entropy, chemical potential, activity and activity coefficients; Statistical definition of entropy; Thermodynamics of solutions – entropy, enthalpy and free energy of solution and mixtures; First order and second order phase transitions; Approximations to the free energy function – Ideal solution, Regular solution and Sub-lattice model; the calculation of Phase Diagrams (CALPHAD) technique using the sub-lattice model.

UNIT 3: Binary Phase Diagrams

Learning Objectives

Learn how to interpret a practical phase diagram and gleaning information from published phase diagrams.

The Gibbs phase rule; the common tangent rule; the Lever rule; understanding the binary phase diagram; Miscibility gap.

UNIT 4: Diffusion

Learning Objectives

Review solution techniques of differential equations describing diffusional phenomena using Fick's laws.

Basic review of parabolic partial differential equations (PDEs); solution by analytical and numerical methods; Fick's laws; solution of the Fick's diffusion equation; Mechanisms of diffusion; Kirkendall effect.

UNIT 5: Non-classical diffusion

Learning Objectives

Understand the limitations of the classical Fick's laws; Introduction to the two C-H and A-H equations describing non-classical diffusion and solution method(s).

Overview of the types of solid state phase transitions; Failure of the classical Fick's law; Spinodal decomposition; Cahn-Hillard (C-H) equation; Solution of the C-H equation using the semi-implicit Fourier spectral method; Using the C-H equation for understanding microstructural evolution in solids.

References

1. "Physical metallurgy principles" by Robert E Reed-Hill and Reza Abbaschian, Chapters 3-5.
2."Defects in Solids" by Richard J Tilley, Chapters 2-4.
3. "Thermodynamics of materials", by Gaskell.
4. "Thermodynamics of microstructures" by Taiji Nishizawa
5. "Statistical Thermodynamics and model calculations" by Tetsuo Mohri-Chapter 10 of "Alloy Physics".
6. "Mathematics of diffusion" by J. Crank, Oxford University Press
7. "Physical metallurgy principles" by Robert E Reed-Hill and Reza Abbaschian.

Evaluation Pattern:

Assessment	Internal	External Semester
Periodical 1 (P1)	15	
Periodical 2 (P2)	15	
*Continuous Assessment (CA)	20	
End Semester		50

Justification for CO-PO mapping:

Mapping	Justification	Affinity level

CO1-PO1	CO1 is related to a particular aspect of understanding of solids (namely, defects), while PO1 is related to basic sciences. The basic physics and thermodynamics of defect formation in solids will be discussed in this course. Hence, they are mapped at the highest level of 3.	
CO2-PO1	CO2 is application of the methods developed in this course to describe the behaviour of solids (both electrical and mechanical). This is related to fundamental science and hence is mapped with level 3 with PO1.	
CO2-PO2	CO2 pertains to application of certain methods to describe the complicated behaviour of solids. PO2 is about developing methods to formulate and analyze complex behaviour. Hence they are mapped at level 2.	
CO2-PO4	The methods studied in this course also form a primary basis of many research methods which is relevant to PO4 which suggests using research-based methods for arriving at the solution to a problem.	
CO3-PO1	CO3 refers to a basic application of fundamental thermodynamics to construct phase diagrams. It is strongly correlated to fundamental sciences as mentioned in PO1. Hence it is mapped at level 3.	
CO4-PO1	CO4 also refers to the basic concept of diffusional movement in solids. This is related to basic kinetic processes in solids that is correlated with fundamental science and its relevance in the course. Hence mapped at level 3.	