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

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### Theoretical Physics

- Relativistic Quantum Mechanics
- Advanced Particle Physics
- Physics of Compact Stars
- Theory of Nanostructures
- Special Theory of Relativity
- Introduction to Classical field theory
- Introduction to General Theory of Relativity
- Quantum Field Theory

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### OPEN ELECTIVES (Physics)

- History and Philosophy of Science
- EU History of Science and Technology
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UNIT 1

**Trigonometry:** Expansions of \( \sin n(\theta) \), \( \cos n(\theta) \), \( \tan n(\theta) \) in powers of \( \sin \theta \), \( \cos \theta \), \( \tan \theta \). Expansion of \( \sin n(\theta) \), \( \cos n(\theta) \), \( \sin m(\theta) \), \( \cos m(\theta) \) in terms of Sines and Cosines of Multiplies of \( \theta \) – Power series for \( \sin \theta \), \( \cos \theta \), \( \tan \theta \) - 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


UNIT 4


UNIT 5


**Recommended Reading**

UNIT 1: Introduction

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

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 con-
servation 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 prin-
ciple, 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

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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 Pen-
dulum.

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, Poten-
tial 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 an-
gular 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, An-
gular 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, Reynolds 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
6. Lectures by Walter Lewin on Classical Mechanics, https://www.youtube.com/watch?v=wWnfJ0-xXRE&list=PLyQSN7X0ro203puVhQsmCj9qhIFQ-As8e

Evaluation Pattern

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

Justification for CO-PO Mapping

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<td>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.</td>
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</table>
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 ($\psi$ and $\psi^2$) 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

UNIT 3: Acids, Bases and Non-aqueous solvents

UNIT 4: Chemical analysis and stoichiometric calculation

UNIT 5: Functional groups and Nomenclature of organic compounds

Recommended Readings

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

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

Reference Books

21ENG101 Communicative English 2023

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]
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
5. Online sources

References:
1. Ruskin Bond, Time Stops at Shamli and Other Stories, Penguin Books India Pvt Ltd, 1989
3. Murphy, Raymond, Murphy’s English Grammar, CUP, 2004
4. Online sources

21CUL101 Cultural Education I 2002

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)

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UNIT 1

UNIT 2
Systems of Linear Equations: Linear System of Equations, Gauss Elimination, Consistency of a linear system of equations.

UNIT 3

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.
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

Recommended Readings
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

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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.


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.

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

Reference books
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

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CO-PO Justification

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<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1-CO4 to PO1 and PSO 1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO4-PO2 and PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO4 – PO3</td>
<td>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.</td>
<td>3</td>
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</tbody>
</table>

22CHY112 Principles of Physical Chemistry 3 1 0 4

UNIT 1: Gaseous state

UNIT 2: Thermodynamics – I
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

UNIT 5: Chemical Kinetics

Recommended readings

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. Meldé’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
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

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

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. 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)

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.

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

REFERENCES:
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

<table>
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<tr>
<th>Course Code</th>
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**Prerequisite:** None, but this course is a prerequisite for Principles of Organic Chemistry, Organic Synthesis I and II.

**UNIT 1: Basic concepts**

**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**
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-Weinsteın plots, Schleyer adaptation, acid base effects and conditions to create LFER.

Recommended Reading

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

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
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</table>

UNIT 1
Learning objectives
Review of free oscillations of 1D harmonic oscillator. The physical aspects of inertia and return force, physical meaning of $\omega^2$ 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.


Text books:

Evaluation Pattern:

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Internal</th>
<th>External Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodical 1 (P1)</td>
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<tr>
<td>Periodical 2 (P2)</td>
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</table>
Justification for CO-PO Mapping

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<tr>
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<tr>
<td>CO1-CO 5 to PO1 and PSO 1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO5-PO2 and PSO 2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO5 – PO3</td>
<td>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.</td>
<td>3</td>
</tr>
</tbody>
</table>

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:

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:

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:

REFERENCES:
1. Quantitative Aptitude, by 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.
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.

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
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:

22CHY283 Chemistry Lab II

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
10. Gravimetric estimation of copper as copper (I) thiocyanate.

Recommended Readings
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

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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

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Justification for CO-PO Mapping

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<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO1-PO2</td>
<td>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.</td>
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<tr>
<td>CO1-PSO1</td>
<td>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</td>
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<tr>
<td>CO1-PSO2</td>
<td>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.</td>
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<tr>
<td>CO2-PO1</td>
<td>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.</td>
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<tr>
<td>CO2-PO2</td>
<td>Students develop their analytical thinking by performing various diffraction and interference experiments. The mapping of CO2 with PO2 is assigned maximum affinity.</td>
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<tr>
<td>CO2-PSO1</td>
<td>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.</td>
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<tr>
<td>CO2-PSO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO3-PO1</td>
<td>In CO3, students enhance their understanding about polarization phenomena and so it is given a maximum affinity with PO1.</td>
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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.

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.

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.

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**22CSA281  Programming Lab I**

**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:

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

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 ‘Unity 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 Bhima 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.
UNIT 1: Periodic properties and s-Block elements

UNIT 2: p block elements

UNIT 3: d block elements

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

Recommended Readings
2. Inorganic Chemistry (Fourth Edition), Catherine E. Housecroft and Alan G. Sharpe, Pearson, 2012
6. Source book on atomic energy, Glaston

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 op 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

21SSK211   LIFE SKILLS II    1 0 2 2


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:

REFERENCES:
1. Quantitative Aptitude, by R S Aggarwal, S Chand Publ.
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

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

UNIT 5
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.

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<thead>
<tr>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
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</table>

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 ($\chi^2$ 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:


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.

For Unit III:
1. Chapter 8 of “The Art of Electronics” by Paul Horowitz and Winfield Hill.

For Unit IV and V:

Reference books:
1. Any introductory book on probability and statistics

Evaluation Pattern

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<th>Internal</th>
<th>External Semester</th>
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<td>Periodical 2 (P2)</td>
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<td>End Semester</td>
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*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

<table>
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<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>2</td>
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<tr>
<td>CO1-PSO2</td>
<td>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.</td>
<td>1</td>
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<tr>
<td>CO2-PO1</td>
<td>CO2 is an extension of CO1 in that it permits calculating propagation of errors. This involves mathematical fundamentals. Hence mapped at level 2.</td>
<td>2</td>
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<tr>
<td>CO2-PO2</td>
<td>CO2 is related to calculating propagation of errors, while PO2 is related to analytical and critical thinking. They are mapped at affinity level 2.</td>
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</tr>
<tr>
<td>CO3-PO1</td>
<td>CO3 is about presenting data and making inferences. This is based on science and math fundamentals. Hence mapped at level 2.</td>
<td>2</td>
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<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO3-PO3</td>
<td>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.</td>
<td>2</td>
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<tr>
<td>CO5-PO1</td>
<td>CO5 is related to understanding the concepts of pressure and temperature. Hence related to PO1 (fundamental science) with affinity level 3.</td>
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</table>

**21AVP211 Amrita Values Programme II**

**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 (Six 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 Natyasasatra and its commentary the AbhinavaBharati. The course introduces various styles of Indian classical dance such as Bharatanatyam, 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.
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<table>
<thead>
<tr>
<th>22PHY282</th>
<th>Physics Lab III - Modern Physics</th>
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</thead>
</table>

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

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**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.

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<th>POs</th>
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**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- Alember’s principle and Principle of Leas action
- Lagrange’s Equation and its simple applications.


**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**

**Evaluation Pattern**

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

**Justification for CO-PO Mapping**

<table>
<thead>
<tr>
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<th>Justification</th>
<th>Affinity level</th>
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<tbody>
<tr>
<td>CO1-CO 5 to PO2 and PSO 1</td>
<td>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</td>
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<tr>
<td>CO1-CO5-PO3 and PSO 2</td>
<td>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</td>
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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

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

UNIT 4
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

References
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.

UNIT 2
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, arduino 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

References
**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**

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**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 Boundary Conditions, Linear and Non-linear media: Magnetic susceptibility and permeability. Ferromagnetism

Text Books

Reference Books
4. Lectures by Prof. Dipan Ghosh on “Electromagnetic Theory” https://nptel.ac.in/courses/115/101/115101005/

Evaluation Pattern

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CO-PO Justification

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<tr>
<td>CO1-CO4 to PO1 and PSO 1</td>
<td>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.</td>
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<td>CO1-CO4-PO2 and PSO 2</td>
<td>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.</td>
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<tr>
<td>CO1-CO4 – PO3</td>
<td>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.</td>
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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

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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

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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.

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.


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.


UNIT 5: Rotations and Addition of Angular Momenta
Learning Objectives
Learn the basic ideas and concepts of rotation in quantum mechanics.
Learn the analytical methods for the addition of more than two angular momenta.
Understand the addition of more than two angular momenta and able to find rotation matrices for coupling two angular momenta, scalar, vector, and tensor operators.

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:

Reference Books:

Evaluation Pattern:
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**Justification for CO-PO Mapping**

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<tr>
<td>CO1-PO5 to PO1 &amp; PSO1</td>
<td>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.</td>
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<tr>
<td>CO1-PO5 to PO2 &amp; PSO2</td>
<td>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.</td>
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<tr>
<td>CO1-PO5 to PO3</td>
<td>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</td>
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**22PHY312 Mathematical Physics I**

**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

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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

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 \( \nu \); general solution for integer \( \nu \); 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, Laguerre functions- Recurrence relations and generating functions-. Applications.

Text Books:

Reference Books:

Evaluation Pattern:

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<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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 i.e., 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to study and application of vector calculus in rectilinear and general curvilinear coordinate systems and hence the affinity level 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>CO2 deals with many analytical techniques of vector calculus and it enhances students analysis and analytic skills, so the affinity 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO1-PSO1</td>
<td>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).</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO1</td>
<td>CO2 enhances knowledge of vector calculus and curvilinear coordinates and it has application in other theoretical courses; hence maximum affinity is seen with PSO1</td>
<td>3</td>
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<tr>
<td>CO2-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO1</td>
<td>CO3 aims at making student comfortable with tensor calculus, which is essential in understanding advanced physics courses; hence maximum affinity is seen with PSO1</td>
<td>3</td>
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<tr>
<td>CO3-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
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</tr>
<tr>
<td>CO4-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
<th>PSO1</th>
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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 Vacancies, 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.


**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:

Reference Books:

Evaluation Pattern

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<tr>
<th>Assessment</th>
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*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

<table>
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<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
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<tbody>
<tr>
<td>CO1-PO1</td>
<td>CO1 is related to acquiring thorough knowledge on the Bravais lattices, symmetry, and defects in crystals. CO1 improves 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.</td>
<td>3</td>
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<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO1-PO3</td>
<td>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</td>
<td>2</td>
</tr>
<tr>
<td>CO1-PSO1</td>
<td>PO1 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</td>
<td>3</td>
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<tr>
<td>CO1-PSO2</td>
<td>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</td>
<td>2</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO3</td>
<td>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</td>
<td>2</td>
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<tr>
<td>CO2-PO4</td>
<td>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</td>
<td>1</td>
</tr>
<tr>
<td>CO2-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO3</td>
<td>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.</td>
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<tr>
<td>CO3-PSO1</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>CO3-PSO2</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO4-PO3</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO4-PSO1</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO4-PSO2</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO5-PO1</td>
<td>In CO5, students get benefited the learning of dielectrics, ferroelectrics and piezoelectrics which matches well with PO1 and hence it is assigned maximum affinity.</td>
<td></td>
</tr>
<tr>
<td>CO5-PO2</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO5-PO3</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO5-PSO1</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO5-PSO2</td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
**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:**

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
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<th>PO4</th>
<th>PO5</th>
<th>PSO1</th>
<th>PSO2</th>
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</table>

**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.


**UNIT 3: Polarization and Double Refraction**
**Learning Objectives**

Understand and analyze the phenomenon of polarization and their states.
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.


UNIT 5: Optical fibres and wave guides
Learning Objectives
Understand the fundamental aspects of guiding mechanism of optical wave in fiber medium.


Text books:

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

Evaluation Pattern

<table>
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<tr>
<th>Assessment</th>
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<th>External Semester</th>
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Justification for CO-PO Mapping

<table>
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<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
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<tbody>
<tr>
<td>CO1-PO5 to PO1 &amp; POS1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO5 to PO2 &amp; POS2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO5 to PO3</td>
<td>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</td>
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Course Title

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

<table>
<thead>
<tr>
<th>CO1</th>
<th>PO1</th>
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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.


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.


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.


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.


Text Books:

Reference Books:

Evaluation Pattern

<table>
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<th>Assessment</th>
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<td>*Continuous Assessment (CA)</td>
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<tr>
<td>End Semester</td>
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</table>

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

Justification for CO-PO mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1-PO1</td>
<td>CO1 is related to understand different aspects of the 3 dimensional Schrödinger equation. This improves student’s knowledge in quantum mechanics and hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to learning the main approximation methods for stationary states in quantum mechanics. Hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>Since PO1 is related to acquiring knowledge in quantum mechanics, CO3 has maximum affinity 3 when mapped with PO1.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO5-PO1</td>
<td>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.</td>
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<tr>
<td>CO5-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO1</td>
<td>PSO1 is related to demonstration of proficiency in quantum mechanics which essential to understand the three dimensional Schrödinger equation. Hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO1</td>
<td>CO2 is related to understanding of the main approximation methods for stationary states which map completely with PSO1. So the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PSO1</td>
<td>CO4 is related to learning and applying scattering theory to quantum mechanical problems. Hence CO4-PSO1 mapping has the affinity level 3.</td>
<td>3</td>
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<tr>
<td>CO4-PSO2</td>
<td>The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to scattering.</td>
<td>3</td>
</tr>
<tr>
<td>CO5-PSO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO5-PSO2</td>
<td>The affinity level between CO5 and PSO2 is 3 since CO5 deals with understanding and application relativistic quantum mechanics.</td>
<td>3</td>
</tr>
</tbody>
</table>

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 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.

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<tr>
<th>POs</th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
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**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 brackets

**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


Text Books:
5. Lecture Series on Classical Physics by Prof. V. Balakrishnan - https://www.youtube.com/watch?v=Q6Gw08pwhws&list=PL5E4E56893588CBA8

Evaluation Pattern:

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Justification for CO-PO Mapping

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<tbody>
<tr>
<td>CO1-CO 5 to PO2 and PSO 1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO5-PO3 and PSO 2</td>
<td>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</td>
<td>3</td>
</tr>
</tbody>
</table>
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

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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.


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-Liouville 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 Sturm-Liouville problem and its use in theoretical physics, Green’s function techniques and familiarity with basics of group theory.


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:

Reference Books:

Evaluation Pattern:

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</tr>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to study and application of complex analysis and hence the affinity level 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>CO2 deals with many analytical techniques of complex analysis and it enhances students analysis and analytic skills, so the affinity 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>CO4 involves application of many advanced mathematical methods to solve physically relevant problems and thus CO4 has maximum affinity of 3 with PO2.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO1</td>
<td>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).</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO2</td>
<td>PSO2 involves imparting analytical skills and the CO matches with maximum affinity</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
</tbody>
</table>
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

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</table>

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.

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

Reference books
Evaluation Pattern:

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Justification for CO-PO Mapping

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<tbody>
<tr>
<td>CO1-CO4 to PO1 and PSO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO4-PO2 and PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO4 – PO3</td>
<td>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.</td>
<td>3</td>
</tr>
</tbody>
</table>

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.

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.

<table>
<thead>
<tr>
<th>POs</th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
<th>PSO1</th>
<th>PSO2</th>
<th>PSO3</th>
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</table>

UNIT 1
Learning objective
   Review of Thermodynamic potentials
   Introduce various probability distribution functions and their property


UNIT 2
Learning objective
   Canonical ensemble and definition of inverse temperature
   Introduce partition function and its computation

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


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:
### Evaluation pattern

<table>
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<tr>
<th>Assessment</th>
<th>Internal</th>
<th>External</th>
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<tr>
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### Justification for CO-PO Mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
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<tbody>
<tr>
<td>CO1-CO 5 to PO2 and PSO 1</td>
<td>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</td>
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<tr>
<td>CO1-CO5-PO3 and PSO 2</td>
<td>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</td>
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</table>

| 21SSK301                         | Life Skills III                                                                                                                                         | 1 0 2 2        |

### Team Work:

### 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:**
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;
5. Quick Arithmetics, by Ashish Agarwal, S Chand Publ.;
8. The BBC and British Council online resources
9. Owl Purdue University online teaching resources
10. www.grammarbook.com online teaching resources
11. www.englishpage.com online teaching resources and other useful websites.

<table>
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<tr>
<th>Course Code</th>
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<td>Physics Lab - VII (Project Based – Applied Materials/Theoretical Physics)</td>
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<td>Research Methodology</td>
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</table>

**TOTAL** | 22 |
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

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

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

Text Books:

Reference Books:
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

UNIT 4

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:
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

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
<th>PSO1</th>
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</tbody>
</table>

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


UNIT 2
Learning Objectives
In the un-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


**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:

Evaluation Pattern

<table>
<thead>
<tr>
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<tbody>
<tr>
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<tr>
<td>*Continuous Assessment (CA)</td>
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<tr>
<td>End Semester</td>
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<td>50</td>
</tr>
</tbody>
</table>

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

Justification for CO-PO Mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1-PO1</td>
<td>Students enrich advance knowledge on the formation of band structure of solids in CO1, which may be assigned a medium affinity with PO1.</td>
<td>2</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO3</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO4</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>CO1-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO3</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO2-PO4</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>CO2-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PSO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PSO2</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO4-PO3</td>
<td>In CO4, learners are exposed to fundamental understanding of quantum hall effect, semiconductor quantum structures which maps with PO3 with medium affinity level.</td>
<td>2</td>
</tr>
<tr>
<td>CO4-PSO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PSO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO5-PO1</td>
<td>In CO5, students get benefited the learning of optical properties of solids and hence it is mapped with high affinity to PO1</td>
<td>3</td>
</tr>
</tbody>
</table>
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.

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.

In CO5, students enrich their scientific knowledge on the optical properties of different solids and so it is assigned a maximum affinity with PSO1.

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.

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.

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 microwave background etc. using public data base, modelling of certain nuclear phenomena such decay parameter etc by analytical and computational modelling etc.

| 22RM500 | Research Methodology | 2002 |

Unit 1: Ethics in Research

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
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<th>Code</th>
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**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

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<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
<th>PSO1</th>
<th>PSO2</th>
<th>PSO3</th>
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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, Zitterbewegung; Negative energy solutions, The hydrogen atom, Hole theory and charge conjugation, Quantization 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, Møller scattering and the photon propagator; one-meson exchange interactions, Mass and charge renormalization; radiative corrections.

**Text Book:**


**Reference Books:**


**Evaluation pattern**

<table>
<thead>
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**Justification for CO-PO mapping**

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to ideas and concepts of quantum theory of radiation. Hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO2-PO2</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO3-PO1</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO3-PO2</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO4-PO1</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO4-PO2</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO5-PO1</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO5-PO2</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO1-PSO1</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO1-PSO2</strong></td>
<td>CO1 deals with knowledge and tools of classical fields. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.</td>
<td></td>
</tr>
<tr>
<td><strong>CO2-PSO1</strong></td>
<td>CO2 is related to understanding of the quantum theory of radiation which map completely with PSO1. So the affinity level is 3.</td>
<td></td>
</tr>
<tr>
<td><strong>CO2-PSO2</strong></td>
<td>Since PSO2 is related to improve the analytical skills which maps partially with CO2. Hence the affinity level between CO2 and PSO2 is 2.</td>
<td></td>
</tr>
<tr>
<td><strong>CO3-PSO1</strong></td>
<td>Since CO3 is related to application of quantum theory of radiation which is partially mapped with PSO1. Hence the affinity level 2.</td>
<td></td>
</tr>
<tr>
<td><strong>CO3-PSO2</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO4-PSO1</strong></td>
<td>CO4 is related to learn and solve problems for spin half particles. Hence CO4-PSO1 mapping has the affinity level 3.</td>
<td></td>
</tr>
<tr>
<td><strong>CO4-PSO2</strong></td>
<td>The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to spin half particles.</td>
<td></td>
</tr>
<tr>
<td><strong>CO5-PSO1</strong></td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td><strong>CO5-PSO2</strong></td>
<td>The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to covariant perturbation theory.</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>CO1</th>
<th>PO1</th>
<th>PO2</th>
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</table>

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 $\frac{1}{2}$, 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.


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.


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:

Reference Books:
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### Justification for CO-PO mapping

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<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to symmetries and their application in particle physics. Hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>CO3 is related to the Feynman calculus. 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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO5-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO5-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PSO2</td>
<td>CO1 deals with knowledge and concepts of particle dynamics. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.</td>
<td>2</td>
</tr>
</tbody>
</table>
CO2-PSO1: CO2 is related to understanding of the symmetries in particle physics which map completely with PSO1. So the affinity level is 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.

CO3-PSO1: Since CO3 is related to analyze Feynman calculus which is completely mapped with PSO1. Hence the affinity level 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.

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.

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.

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.

CO5-PSO2: The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to weak interactions.

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

<table>
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<tr>
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</table>
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.


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.


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 $\Delta$ resonance, pion condensation and 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.

UNIT 5: Black Holes

Learning Objectives

Learn and understand 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.


TEXT BOOK:

REFERENCE BOOK:

Evaluation pattern

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Justification for CO-PO mapping

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<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to analyze and solve problems related to white dwarf. Hence the affinity level is 3.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO3-PO2</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO4-PO1</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO4-PO2</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO5-PO1</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO5-PO2</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO1-PSO1</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO1-PSO2</strong></td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td><strong>CO2-PSO1</strong></td>
<td>CO2 is related to analyze and solve problems related to white dwarf which map partially with PSO1. So the affinity level is 2.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO2-PSO2</strong></td>
<td>Since PSO2 is related to improve the analytical skills which maps completely with CO2. Hence the affinity level between CO2 and PSO2 is 3.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO3-PSO1</strong></td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO3-PSO2</strong></td>
<td>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.</td>
<td>2</td>
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<tr>
<td><strong>CO4-PSO1</strong></td>
<td>CO4 is related to analyze and solve problems of neutron stars. Hence CO4-PSO1 mapping has the affinity level 3.</td>
<td>3</td>
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<tr>
<td><strong>CO4-PSO2</strong></td>
<td>The affinity level between CO4 and PSO2 is 3 since the CO4 deals with understanding and solving problems related to neutron stars.</td>
<td>3</td>
</tr>
<tr>
<td><strong>CO5-PSO1</strong></td>
<td>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.</td>
<td>3</td>
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<tr>
<td><strong>CO5-PSO2</strong></td>
<td>The affinity level between CO5 and PSO2 is 3 since CO5 deals with analyzing and solve problems related to black holes.</td>
<td>3</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
<th>PO5</th>
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</table>

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.


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:

Reference Book:

Evaluation pattern

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Internal</th>
<th>External Semester</th>
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<td>End Semester</td>
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### Justification for CO-PO mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
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<tbody>
<tr>
<td>CO1-PO1</td>
<td>CO1 is related to concepts of layered nanostructures. This improves student’s knowledge in layered nanostructures and hence the affinity level is 3.</td>
<td>3</td>
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<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>CO2 is related to application of quantum mechanics to quantized motion and quantum states. Hence the affinity level is 3.</td>
<td>3</td>
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<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>3</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
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<tr>
<td>CO5-PO1</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO5-PO2</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO1-PSO1</td>
<td>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.</td>
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<tr>
<td>CO1-PSO2</td>
<td>CO1 deals with concepts of layered nanostructures. Hence CO1 partially map with PSO2 and an affinity level of 2 is assigned.</td>
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<tr>
<td>CO2-PSO1</td>
<td>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.</td>
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<tr>
<td>CO2-PSO2</td>
<td>Since PSO2 is related to improve the analytical skills which maps completely with CO2. Hence the affinity level between CO2 and PSO2 is 3.</td>
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<tr>
<td>CO3-PSO1</td>
<td>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.</td>
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<tr>
<td>CO3-PSO2</td>
<td>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.</td>
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<tr>
<td>CO4-PSO1</td>
<td>CO4 is related to learn and solve problems for nanostructures. Hence CO4-PSO1 mapping has the affinity level 3.</td>
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<tr>
<td>CO4-PSO2</td>
<td>The affinity level between CO4 and PSO2 is 3 since the CO4 deals with to solve problems related to quantization in nanostructures.</td>
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<tr>
<td>CO5-PSO1</td>
<td>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.</td>
<td>3</td>
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<tr>
<td>CO5-PSO2</td>
<td>The affinity level between CO5 and PSO2 is 3 since CO5 deals basic features of nanostructures and their applications.</td>
<td>3</td>
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</table>

**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**


**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:**

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

Reference Books:

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, Trans-
formation 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 t-
transformation, The electromagnetic field tensor, covariant charge density and current, action formalism for electrodynamics, Maxwell’s equations and relativ-
istic covariance, Lagrangian and Hamiltonian formalism, Symmetries and covariance, Gauge invariance.

UNIT 3
Classical Field Theory of Gravitation: Principle of equivalence, curvilinear coordinates, metric, connec-
tion, curvature tensor, energy-momentum tensor, Einstein field equations and its Newtonian limit.

Reference Books:

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


UNIT 3

Einstein Field Equations: Gravity and Geometry, Energy-momentum tensor, Curvature tensors, Bianchi identities, Einstein 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 structure, Gravitational Collapse, Black Holes

Text Books:

Reference Books:

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

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

Reference Books
5. J.D. Bjorken and S.D. Drell, Relativistic Quantum Fields, McGraw-Hill, 1965

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Core Electives</th>
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<td>22PHY549</td>
<td>Thermodynamics of Defects and Phase Transitions in Solid State</td>
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<td>22PHY551</td>
<td>Micro and Nano Magnetism Materials and its Applications</td>
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<td>22PHY552</td>
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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

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

TEXTBOOKS:
REFERENCES:

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

UNIT 3: Tools for Characterization

UNIT 4: Nanostructured Materials

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:
REFERENCE BOOKS:

<table>
<thead>
<tr>
<th>Code</th>
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<tr>
<td>22PHY543</td>
<td>Thin Film Technology</td>
<td>3 0 0 3</td>
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</table>

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

<table>
<thead>
<tr>
<th></th>
<th>PO1</th>
<th>PO2</th>
<th>PO3</th>
<th>PO4</th>
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</table>

UNIT 1: Preparation Methods
Learning Objectives
Understand about the various physical and chemical deposition methods

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.


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 the 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:

REFERENCE BOOKS:

Evaluation Pattern

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Internal</th>
<th>External</th>
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<tbody>
<tr>
<td>Periodical 1 (P1)</td>
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Page 115 of 127
### Justification for CO-PO Mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
</tr>
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<tbody>
<tr>
<td>CO1-PO1</td>
<td>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</td>
<td>1</td>
</tr>
<tr>
<td>CO1-PO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>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</td>
<td>1</td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>CO3-PO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO3-PO3</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO3-PO4</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>CO4-PO2</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO4-PO3</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO4-PO4</td>
<td>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.</td>
<td>2</td>
</tr>
<tr>
<td>CO1-PSO3</td>
<td>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. So CO1 is related to PO3.</td>
<td>2</td>
</tr>
<tr>
<td>CO2-PSO3</td>
<td>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</td>
<td>2</td>
</tr>
<tr>
<td>CO3-PSO3</td>
<td>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</td>
<td>2</td>
</tr>
<tr>
<td>CO4-PSO3</td>
<td>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.</td>
<td>2</td>
</tr>
</tbody>
</table>

**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 prerequisite 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 responsivility, 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

Reference Books

UNIT 1: Basic Principles

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

UNIT 5: Supercapacitors

Recommended Readings

22PHY544 Advanced Solar Cell Fabrication 3 0 0 3

Prerequisites: Preliminary concept of semiconductor physics and light matter 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
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

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

Evaluation Pattern:

<table>
<thead>
<tr>
<th>Assessment</th>
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<th>External Semester</th>
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*CA - Can be Quizzes, Assignments, Projects, and Reports.

Justification for CO-PO Mapping

<table>
<thead>
<tr>
<th>Mapping</th>
<th>Justification</th>
<th>Affinity level</th>
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<tbody>
<tr>
<td>CO1-CO 5 to PO1 and PSO 1</td>
<td>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 inquityness problem-solving in a scientific way.</td>
<td>3</td>
</tr>
<tr>
<td>CO1-CO5-PO2</td>
<td>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.</td>
<td>3</td>
</tr>
</tbody>
</table>
These course outcomes take care to develop the knowledge of solar cell fabrication, so they are strongly bound to the development of research skills on the student and PSO2.

As these CO's are developed the experimental skill of the student for solar cell fabrications, all the course outcomes have very high affinity to PO2 and PSO2, which is about developing problem solving culture and translational research.

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.

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

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<thead>
<tr>
<th>POs</th>
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</table>

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: Hana- walt 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


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:
Evaluation Pattern:

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<tbody>
<tr>
<td>CO1-PO1</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO2-PO1</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO2-PO2</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO2-PO4</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO3-PO1</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>CO4-PO1</td>
<td>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.</td>
<td></td>
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</tbody>
</table>

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**

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**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-Hilliard (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.
4. “Thermodynamics of microstructures” by Taiji Nishizawa
5. “Statistical Thermodynamics and model calculations” by Tetsuo Mohri-Chapter 10 of “Alloy Physics”.

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</table>

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| 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. |