Centurion
UNIVERSITY
Shaping Lives...
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M.Sc.

Applied Physics Syllabus

(Two Years Programme)

School of Applied Sciences

Centurion University of Technology & Management

2025-26

Department of Physics

M.Sc. Physics

Two Year Programme

Course Structure 2025-26

Basket I - Core Courses					
Sl. No.	**Code**	**Subject Name**	**T-P-P**	**Credits**	**Level**
SEMESTER – I					
1.	CUTM4528	Materials Synthesis and Applications	3-1-0	4	**6**
2.	CUTM 2377	Material behavior of nanostructures	3-1-0	4	**6**
3.	CUTM 1407	Emerging materials	3-0-1	4	**6**
4.	CUTM 1413	Physics of solids and semiconductors	3-1-0	4	**6**
5.	CUTM 1414	Laser technology	2-1-1	4	**6**
SEMESTER – II					
6.	CUTM 1404	Corrosion and advanced coating application	3-0-1	4	**6**
7.	CUTM 1401	Photovoltaic technology and nanocatalysis	3-1-0	4	**6**
8.	CUTM1399	Energy Storage Materials	3-1-0	4	**6**
9.	CUTM 1410	Plasma technology	3-0-1	4	**6**
10.	CUTM 1412	Advanced quantum mechanics	2-0-2	4	**6**
SEMESTER – III					
11.	CUTM 1409	Computational materials science	2-2-0	4	**6.5**
12.	CUTM4526	Instrumentation Techniques	2-2-0	4	**6.5**
SEMESTER – IV					
13.	CUTM4527	Scientific Computing using MATLAB	1-2-1	4	**6.5**
14.	CUTM4525	Quantum Computing	1-2-1	4	**6.5**
Total			**14*4=56**		
Basket II (Specialization)				**24**	
Basket III (Research Methodology and IPR)				**04**	
Skill				**04**	
Grand Total				**88**	

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM 4528	Materials Synthesis and Applications	3-1-0	Nil

Objective

- To provide students with a comprehensive understanding of the synthesis, properties, and applications of nanomaterials and composite systems.
- Students will gain practical experience in synthesizing and characterizing nanomaterials, while exploring their potential in various industrial and technological applications.

Learning outcome

COs	Course outcomes
CO1	Understand the fundamental principles, types, and properties of nanomaterials and nanocomposites.
CO2	Describe and compare various synthesis techniques for nanomaterials and composite systems.
CO3	Apply appropriate synthesis methods to prepare nanomaterials and composite materials in the laboratory.
CO4	Analyze the relationship between synthesis method and material properties.
CO5	Evaluate materials for real-world applications (electronics, catalysis, biomedical, etc.).

Course Outcome to Program Outcome Mapping:

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	-	2	3	-	-	-	-	-	-	2	3	2	2
CO2	3	3	2	3	3	-	-	-	-	-	-	2	3	3	2
CO3	2	2	1	3	3	-	-	-	-	-	-	2	3	2	1
CO4	2	3	2	3	2	-	-	-	-	-	-	3	2	3	2
CO5	2	3	3	2	2	2	2	-	-	1	1	3	2	3	1

***High-3, Medium-2, Low-1**

Course content

Module-I:

Introduction to Nanomaterials and Composite Systems

Introduction to nanomaterials, Properties of materials and nanomaterials, role of size in Nanomaterial, Types of nanomaterials (0D, 1D, 2D, 3D) based on morphology and quantum confinement effect, Overview of composite materials (matrix and reinforcement), Definition of nanocomposite, Properties of composite and nanocomposite.Types of nanocomposite (i.e. metal oxide, ceramic,polymer and carbon based); Core-Shell structured nanocomposites

Module-II:

Synthesis Approaches of Nanomaterials

Bottom-up approach and Top-down approach, Importance of synthesis methods in tailoring nanomaterials properties, Thermodynamics and kinetics in nanoparticle formation, Factors affecting synthesis: temperature, pH, concentration, surfactants, stabilizing agents.

Module -III:

Physical Methods of Synthesis

Mechanical milling (ball milling, high-energy attrition), Physical vapor deposition (PVD), sputtering, Laser ablation, thermal evaporation, Arc discharge and electron beam evaporation,Advantages and limitations of physical techniques

Practice-1: Preparation of metal nano powder using Ball milling method.

Module - IV:

Chemical Methods of Synthesis

Sol-gel method, Co-precipitation, microemulsion, Hydrothermal and solvothermal techniques, Chemical vapor deposition (CVD) and atomic layer deposition (ALD), Synthesis of carbon based nanomaterials: Graphene, Graphene oxide and Carbon nanotubes (CNTs), Synthesis of quantum dots (QDs)

Practice-2: Sol-Gel Synthesis of ZnO Nanomaterial

Practice-3: Co-Precipitation Synthesis of Fe_3O_4 Magnetic Nanomaterials

Practice-4: Synthesis of graphene oxide using modified Hummer's method.

Module-V:

Fabrication of composite and nanocomposites

Synthesis of composite: Filament Winding, Injection and compression molding, Pultrusion Process, Synthesis of nanocomposite: In-situ and ex-situ synthesis techniques, Polymer, metal, and ceramic matrix nanocomposites.Processing methods: melt mixing, solution casting, electrospinning

Practice-5: Fabrication of Polymer Nanocomposites

Practice-6: Preparation of natural fibers reinforced composite materials

Module VI:

Propertiesof Composites

Geometrical aspects: volume and weight fraction, Unidirectional continuous fiber, Determination of stiffness and strengths of unidirectional composites, tension, compression, flexure and shear.

Module VII:

Applications of Nanomaterials and Composites

Aerospace and automotive components, Electronics and sensors, Biomedical applications (drug delivery, tissue engineering), Energy storage and conversion (batteries, fuel cells, supercapacitors), Environmental remediation (water purification, air filters)

Practice-7: Electrical Conductivity Test of Carbon-based Nanocomposites

Practice-8: Water purification test of synthesized nanomaterials

Text Books:

1. Inorganic Materials Synthesis and Fabrication by J.N. Lalena, D.A. Cleary, E.E. Carpenter, N.F. Dean, John Wiley & Sons Inc.
2. Introduction to Nanoscience and Nanotechnology" – K.K. Chattopadhyay & A.N. Banerjee.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham.
4. Polymer Nanocomposites: Processing, Characterization, and Applications" – Joseph H. Koo.
5. Introduction to Nanocomposite Materials: Synthesis, Properties and Applications" – Thomas E. Twardowski

Reference Books:

1. Encyclopedia of Nanotechnology by M.BalakrishnaRao and K.Krishna Reddy, Vol I to X,
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill
4. Handbook of chemical Vapor deposition (cvd), Principles, technology, and applications, By Hugh o. Pierson, Second edition, Noyes publications, William Andrew Publishing, LLC.
5. Mohr - SPIE Handbook of Technology and Engineering of Reinforced Plastics/Composites – (Van Nostrand, 1998

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM2377	Material Behavior of Nanostructures.	3-1-0	Nil

Course Objective:

To understand the influence of dimensionality of the object at nanoscale on their properties;

- To study size and shape controlled synthesis of nanomaterials and their future applications in industry.
- To bring out the distinct properties like mechanical, magnetic, thermal, electronic, optical, and photonic properties of of nanostructures.

Course Outcomes:

COs	Course outcomes
CO1	A deep understanding of material behavior at the nanoscale
CO2	Analyze the mechanical behavior of nanostructures, including their strength, deformation mechanisms, and the role of defects and dislocations in nanomaterials
CO3	Investigate the thermal and electrical properties of nanostructures, including thermal conductivity, electron transport, and thermoelectric effects
CO4	Explore magnetic properties of nanostructures, including magnetic ordering, and their significance
CO5	Apply the knowledge of material behavior to practical applications

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4													3	2	3
CO5													3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module-I(3 Hours Theory)

Introduction: Peculiarities of nanostructured materials: Introduction, Extended internal surface, Increasing of surface energy and tension, Grain boundaries, Instability of three dimensional nanostructured materials due to grain growth, Size effects in nanostructured materials.

Module -II (5 Hours Theory+ 2 Hours Practice)

Mechanical Properties:Mechanical properties of nanocrystalline metals and alloys, Inverse Hall Petch effect, Strain-rate sensitivity, Ceramics and composites. Types of indentation: Oliver &Pharr, Vickers indentation process, Nano Indentation by Atomic Force Microscope , Young's modulus, Contact angle.

Practice-1 : Strength vs ductility of steel bar

Module -III (5 Hours Theory+2 Hours Practice)

Thermal Properties of Nanostructures:Thermo electric materials (TEM): Concept of phonon, Thermal conductivity, Specific heat, Exothermic & endothermic processes. Bulk TEM properties, Different types of TEM; One dimensional TEM; Composite TEM; Applications.

Practice-2: Thermal conductivity measurement

Module–IV(4 Hours Theory+4 Hours Practice).

Magnetic Properties: Introduction of magnetic materials, basics of ferromagnetism – ferro magnetic resonance and relaxation, Magnetic properties of bulk nanostructures, Magnetic clusters, Dynamics of nanomagnets, Nanopore containment of magnetic particles, Nano carbon ferromagnets, Ferrofluids.

Practice-3: Exploring magnetic nanoparticles with Diana Borca

Practice -4: B -H curve of ferromagnetic material

Module–V(5 Hours Theory+ 2 Hours Practice)

Electronic Properties : Energy bands and gaps in semiconductors, Fermi surfaces , Localized particle, Donors, Acceptors, Deep traps, Excitons, Mobility, Size dependent effects, Conduction electrons and dimensionality Fermi gas and density of states, Semiconducting nano particles , Direct and reciprocal lattices of the fcc structure.

Practice-5: Determination of band gap energy of semiconductor.

Module–VI(4 Hours Theory+ 2 Hours Practice)

Optical Properties: Optical properties , Photonic crystals, Defects in photonic crystals , Optical properties of semiconductors, Band edge energy, Band gap, Dependence on nanocrystallins size, Quantum dots, Optical transitions, Absorptions, Interband transitions.

Practice- 6: Explanation of surface plasmon resonance.

Module -VII (4 Hours Theory).

Luminescence Properties: Fluorescence/luminescence, Photoluminescence / fluorescence, Optically excited emission Electroluminescence, Laser emission of quantum dot, Photo fragmentation and columbic explosion, Phonons in nanostructures, Luminescent quantum dots for biological labeling.

Total theory 30 hours and total practice 12 hours.

Text books:

1. Introduction to Nano Technology by Charles. P. Poole Jr& Frank J. Owens. Wiley India Ltd.
2. Solid State physics by Pillai, Wiley Eastern Ltd.

Reference Books:

1. Processing & properties of structural naonmaterials -Leon L. Shaw (editor)
2. Nanoscale materials -Liz Marzan and Kamat

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1407	Emerging Materials	3-0-1	Nil

Course Objective

- Efficient to understand materials and materials properties
- Develop their confidence on self driven experimental materials research
- Able to work in research and industrial set up on material research
- Understanding of materials behavior, or conceived, designed, and realized useful products and technology

Course outcome

COs	Course outcomes
CO1	understand and appreciate the concept of emerging materials at the microscopic and macroscopic scales
CO3	Understand the manufacturing processes and recent technological developments
CO4	Acquire knowledge of the advanced synthesis and fabrication techniques used to create emerging materials
CO5	Evaluate the environmental, Sustainability and ethical aspects of emerging materials

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2								3	2	3
CO2	3	3	3	2	2								3	2	3
CO3	3	3	3	2	2								3	2	3
CO4	-	3	2	2	2								3	2	3

CO5	-	3	2	2	2								3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module I (4 Hours Theory)

Classification of Materials: Classification of materials: Conductor, Semiconductor, Insulator, Superconductor, Ceramics

Module II (4 Hours Theory+ 2 Hours Assignment)

Carbon Nano science : Carbon allotropes(Basic), new carbon structures, Carbon Nanotube (CNT), Single Wall Carbon Nanotubes (SWCNT), Multi Wall Carbon Nanotubes (MWCNT), Carbon fiber

Assignment-1

Advanced Carbon Materials and Technology

Module III (5 Hours Theory+ 2 Hours Assignment)

Graphene Science: Introduction of Graphene, Graphene Reinforced Metal (aluminum) composites, From a Graphene Sheet to a Nanotube -Archiral and Chiral Nanotubes, Graphene Reinforced Non-Metal (aluminum oxide) composites

Assignment-3

Graphene for industrial applications

Module IV (5 Hours Theory+ 2 Hours Assignment)

Synthesis Techniques: CNT: Arc discharge, Laser ablation, Chemical vapour deposition; Graphene: Mechanical exfoliation, Hummers' method, Chemical vapour deposition

Assignment-3

Method of preparation of Graphene

Module V (4 Hours Theory+ 2 Hours Assignment)

Properties of Carbon Nanotubes and Graphene: Mechanical, Electronic, and Optical properties of Carbon Nanotubes and Graphene; Raman spectroscopy of carbon nanotubes, Absorption spectroscopyof carbon nanotubes and Transmission Electron Microscopic (TEM) of carbon nanotubes.

Assignment-4

Study of the XRD of CNT through experimental/MS Studio

Module VI (4 Hours Theory+ 2 Hours Assignment)

Application of nanostructure graphene: carbon material for energy storage, hydrogen storage in carbon nanotubes, Role of carbon nano-tubes in Li ion battery (electrodes), Supercapacitor

Assignment-5

Application of CNT and Graphene in developing advanced electrodes used in Li ion battery

Module VII (4 Hours Theory+2 Hours Assignment)

Other Advanced Materials: High-temperature material, Bulletproof, material Amorphous Materials, Nano Quasicrystals

Assignment-6

Material for high temperature and bulletproof applications

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1413	Physics of solid state and semiconductors	3-1-0	Nil

Course Objective

- To learn about crystal structure, electronic and dielectric properties of solids.
- To learn about basic properties of metals, insulators and semiconductors.
- To learn about semiconductor physics and discus working & applications of basic devices.

Course outcome

COs	Course outcomes
CO1	Understand crystal structures in terms of the crystal lattice and the basis of constituent atoms
CO2	Understand the origin of energy bands in solids
CO3	Understand the electronic structure and optical and transport properties
CO4	Develop research skills to explore and analyze in solid-state physics, including quantum dots, superconductivity, and low-dimensional systems
CO5	Explore Environment and Sustainability of solid-state physics

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2			2			2	2	3	2	3
CO2	3	3	3	2	2			2			2	2	3	2	3
CO3	3	3	3	2	2			2			2	2	3	2	3
CO4	-	3	2	2	2			2			2	2	3	2	3
CO5	-	3	2	2	2			2			2	2	3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module I **(5 Hours Theory+ 2 Hours practice)**

Structure of Solids

Bravais lattice, primitive unit cell, Wigner-Seitz cell, classification of 2- and 3-dimensional Bravais lattices, miller indices, Braggs law of X-ray difrcation Atomic and geometric structure factors,Reciprocal lattice and Brillouin zone

Practice-1
V Lab: To study various crystals structures

Module II **(4 Hours Theory+ 2 Hours practice)**

Introduction to Free electron theory ,Bloch equation, Nearly free electron model. Kronig-Penny model, effective mass

Practice-2
Determination of band gap of semiconductor by Four probe method

Module III **(4 Hours Theory+ 2 Hours practice)**

Classical theory of lattice vibration under harmonic approximation, Dispersion relations of one dimension lattices, Mono atomic and diatomic cases, Characteristics of different modes, Long wavelength limit

Practice-3
Determination of thermal and electrical conductivity of metals (copper and silver)

Module IV **(4 Hours Theory+ 2 Hours practice)**
Specific Heat
Lattice heat capacity, Debye and Einstein models-comparison with electronic heat capacity, Drude model of electrical and thermal conductivity

Practice-4
Determination of specific heat of solids (copper, glass and lead)
Module V **(5 Hours Theory+ 2 Hours practice)**
Dielectric Properties of Solids

Dielectric constant and polarizability (ionic, electronic and dipolar), local field, ClaussiusMossotti relation, Complex dielectric constant and dielectric losses

Practice-5
Determination of dielectric constant of air, glass and polystyrenes
Module VI **(4 Hours Theory)**
Magnetism and superconudticity
Magnetic properties of solids; quantum theories of dia, para and ferromagnatism, superconductivity: Type-I and Type II superconductors, Meissner effect, London equation, BCS Theory

Module VII **(4 Hours Theory+2 Hours practice)**
Semiconductors and defects
semiconductor and theirs types (P and N type) and insulator, Conductivity of semiconductor, Mobility, Direct and indirect band gap semiconductors, Defects and their classification, Frenkel and Schottky defects,

Practice-6
Study of Hall Effect (Determination of nature of charge carriers in a semiconductor)

Total theory 30 hours and total practice 12 hours

Textbook:

1. .Introduction to Solid State Physics, C. Kittel, Wiley
2. Principles of Semiconductor devices, Bart Van Zeghbroeck.

Reference Books:

1. Solid State Physics, by N. W. Ashcroft and N. D. Mermin (Cornell University)
2. Introduction to Solid State Physics,S. O. Pillai, New Age International-

Code	Subject Name	Type of course	T-P-P	Prerequisite
CUTM1414	Lasers Technology	• Theory, Practice &Assignment	2-1-1	Nil

Course Objective
The aim of this course is

- To acquire a thorough understanding of the theory of modern Laser Physics
- understand different types of modern lasers and their applications
- computationally verify material properties for Laser production.

Course outcome

COs	Course outcomes
CO1	Describe and explain fundamental concepts in laser physics
CO2	Compare the function and properties of a number of common lasers
CO3	Verify properties of materials used for laser production
CO4	Understand laser safety protocols and practices to ensure safe and efficient laser operation.
CO5	Explore advanced topics in laser technology and develop the ability for innovative laser applications and research.

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2	-	2	2	2	2	-	1	3	2	3

CO2	3	3	3	2	2	-	2	2	2	2	-	1	3	2	3
CO3	3	3	3	2	2	-	2	2	2	2	-	1	3	2	3
CO4	-	3	2	2	2	-	2	2	2	2	-	1	3	2	3
CO5	-	3	2	2	2	-	2	2	2	2	-	1	3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module-I (3 hours theory,2hours practice, 2 hours Assignment)
Laser Fundamentals:Spontaneous and stimulated emission, Absorption, Einstein's coefficients, Active medium, population inversion, laser-pumping, Laser gain, metastable state, condition for light amplification.Solid state laser:Ruby Laser.

Practice1:

Building and operating a Diode laser pumped Nd:YAG laser. Measure its efficiency and spiking effects to be demonstrated OR Any other Laser to explain the operation of Lasers

Assignment 1:

Neodymium Glass Lasers – Construction, Properties and Applications.

Module-II (3 hours theory, 2 hours Assignment)
Liquid Lasers: Principle of, Main components of Laser, Levels of laser action, Continuous Wave Lasers, construction and working of Dye laser.

Assignment 2: (Any one)

- Application of Tuning in Dye laserastronomy as a laser guide star
- Alexandrite Lasers application in dermatology – Working, Properties and Applications in industrial like medical field
- Model-Locked Ring Dye laser application for Optical Data Storage

Module-III (3 hours theory,4hours practice, 2 hours Assignment)
Gas Laser: Principle, working and usefulness of gas laser. He-Ne laser. Lasing Action in Ion Lasers, construction and operation of ion lasers

Practice2: Determine the wavelength and angular spread of He-Ne laser using plane diffraction grating**.**
Practice 3: Argon Ion Laser spectrum- Operating and selecting various wavelengths for a single line operation in an Argon Laser.

Assignment 3:(Any one)

- Application of Krypton ion laser in medicine
- Application of Copper vapour laser for entertainment purposes
- Application of He-Cadmium laser – Working, Properties and Applications

- Industrial application of Carbon dioxide laserfor cutting and drilling
- Application of excimers laser Photolithography and Medical purposes

Module-IV (3 hours theory,2hours practice, 2 hours Assignment)
Semiconductor Laser:Principle of semiconductor laser diode, threshold frequency, difference between a diode and laser diode, Characteristics of semiconductor lasers, Semiconductor diode lasers, LED versus Laser diode.

Practice 4: Operating characteristics of a Semiconductor diode lasers- measuring its threshold current, output power versus current etc.

Assignment 4:(Any one)

- Application of heterojunction structures to optical devices
- Application of Homojunction lasers
- Application of Quantum well lasers for applications in optical information processing

Module-V (3 hours theory,2hours practice, 2 hours Assignment)
Laser applications: Material processing with lasers, Interaction mechanism, Lattice heating, Material processing mechanism.
Practice 5: Drilling process with laser – Either Physical lab or virtual lab.
Practice 6: Cutting and Welding process with laser – Either Physical lab or virtual lab.

Assignment 5: Industrial application of laser - Material processing with lasers

Module-VI (3 hours theory,2 hours Assignment)
Application of Laser in Medical Science - Medical lasers, Laser diagnostic, Laser for general surgery, Laser in medicine.

Assignment 6: (Any one)

- Understanding the properties of GaN for Laser application by Density Functional theory using Biovia Material Studio
- Understanding the properties of InGaN for Laser application by Density Functional theory using Biovia Material Studio
- Understanding the properties of GaAs for Laser application by Density Functional theory using Biovia Material Studio
- Understanding the properties of AlGaAs for Laser application by Density Functional theory using Biovia Material Studio

Module-VII (3 hours theory,2 hours Assignment)
Laser in Optical Communication: Optical source for fiber optical communication, Essential characteristics of Laser in fibre optic communication.

Assignment 6:(Any one)
- Understanding the properties of “Tungsten oxide-based mediums”for Laser application by using Biovia Material Studio
- Understanding the properties of “sapphire crystals usually doped with titanium particles”for Laser application by using Biovia Material Studio

Textbook:

1. Laser Principles, Types and Application by KR Nambiar, New Age International.

Reference Books:

1. Lasers Theory and Applications by K. Thyagarajan and A.K. Ghatak, Mcmillan (1981)

2. Laser Fundamentals, by William T. Silfvast, Cambridge University Press, 2008.

3. Principles of Lasers, by OrazioSvelto; Springer, 2009.

4. Industrial Applications of Lasers, by K. Koebner (ed.), Wiley (1984).

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM 1404	Corrosion and advanced coating applications	3-0-1	Nil

Course Objective

- To impart knowledge on surface coating and engineering of nanomaterials and their applications.
- Role of surface coating and surface modification technologies in obtaining required surface characteristics (mechanical, chemical, thermal, electrical, electronic, optical) of a product.
- Learn about different surface coating technologies (chemicalvapour deposition, physical vapour deposition, electro-deposition, thermal spray, etc).
- Substrate technology and its significance in obtaining high performance coating. Various methods for evaluating the performance of the coating.

Course outcome

COs	Course outcomes
CO1	To understand the knowledge on surface coating and engineering.
CO2	To pursue higher study/research on surface technology
CO3	Surface coating and surface modification for different practical application.
CO4	Demonstrate the ability to select appropriate coating materials and methods for specific applications based on considerations such as material compatibility, environmental conditions, and performance requirements
CO5	Apply knowledge and skills acquired in the course to real-world scenarios by solving corrosion and coating-related problems

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2			2			2	2	3	2	3
CO2	3	3	3	2	2			2			2	2	3	2	3
CO3	3	3	3	2	2			2			2	2	3	2	3

CO4	-	3	2	2	2			2			2	2	3	2	3
CO5	-	3	2	2	2			2			2	2	3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module I **(4 Hours Theory+2 Hours Assignment)**
Introduction to surface engineering fundamentals: Introduction to surface science, Surface degradation, corrosion, importance of corrosion, Corrosion studies: Atmospheric, Galvanic, Pitting, Crevice corrosion, Intergranularcorrosion,Stress corrosion & cracking

Assignment-1
Corrosion effects on degrading the properties of materials

Module II **(4 Hours Theory+ 2 Hours Assignment)**

Surface preparation methods: Surface cleaning and finishing processes, Electrochemical, Mechanical- Sand blasting, Hydroblasting, Vapor phase degreasing
Assignment-2
Surface preparation for advanced coating applications

Module III **(5 Hours Theory+ 4 Hours Assignment)**

Advanced coating practices: Cold spray, Sputter deposition, Electrolysis techniques, Physical vapor deposition(PVD), Chemical Vapor deposition (CVD), Carburising, Aluminizing
Assignment-3
Current and advanced coating technologies for industrial applications
Assignment-4
Coating surface characterization techniques

Module IV **(3 Hours Theory)**

Plasma coating: Plasma deposition, Sputtering, Plasma spray mechanisms & applications, Laser processing.

Module V **(5 Hours Theory+ 2 Hours Assignment)**

Characterization of coating: Physical characterization and porosity, Assessment of coating hardness, Assessment of friction and wear of coating, Assessment of surface roughness and thickness of Coating, Assessment of Adhesion of coating
Assignment-5
Coating for wear resistant applications

Module VI **(4 Hours Theory+2 Hours Assignment)**

Application-I : Wear resistant coating. Thermal barrier coating, CVD Diamond coated tool, Biomedical coatings
Assignment-6
Advanced coating applications

Module VII **(5 Hours Theory)**

Application-II: Super hydrophobic application, Coating in semiconductor, Zinc coating, Coating for marine atmosphere,Antireflective Coating

Total theory 30 hours and total Assignment 12 hours

Text Book:

1. Advanced Coating Materials book Online ISBN:9781119407652 |DOI:10.1002/978111940765
2. Advanced Surface Coating Techniques for Modern Industrial Applications by Supriyo Roy (Haldia Institute of Technology, India) and Goutam Kumar Bose (Haldia Institute of Technology, India)

References:

1. https://nptel.ac.in/courses/112/105/112105053/
2. https://link.springer.com/book/10.1007%2F978-94-017-0631-5
3. http://home.ufam.edu.br/berti/nanomateriais/8403_PDF_CH13.pdf
4. https://www.azom.com/article.aspx?ArticleID=17081

https://www.hindawi.com/journals/ijc/2018/4749501/

Code	**Course Title**	**T-P-Pj (Credit)**	**Prerequisite**
CUTM 1401	Photo-Voltaic Technology and nanocatalysist	3-1-0	Basics of Nanomaterials & Physics of Semiconductor Devices

Course Objective

- This course will educate students on the design, working of photo voltaic technology and use of materials in nanoscale in these photovoltaics.
- This course will provide the study of several types of nanocatalysts for various industrial applications.

Course outcome

COs	Course outcomes
CO1	To obtain adequate knowledge regarding several photovoltaic technologies and its various applications in nano-scale.
CO2	To gain significant knowledge about industrial catalytic processes and catalysts at nano-levels which helps them to apply for several industrial applications and help them for higher research and employability.

CO3	To gain various internship opportunities in Photovoltaic start-up & R &D organizations.
CO4	Identify and differentiate between various types of photovoltaic cells, such as silicon-based, thin-film, and emerging photovoltaic technologies.
CO5	Develop research skills in designing experiments related to photovoltaic technology and nanocatalysis.

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	2	2								3	2	3
CO2	3	2	3	2	2								3	2	3
CO3	3	3	3	2	2								3	2	3
CO4	-	3	2	2	2								3	2	3
CO5	-	3	2	2	2								3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module I **(4 Hours Theory + 4 Hours Practice)**
Electro-Magnetic visible spectrum, Optical absorption, Direct bandgap & indirect bandgap semiconductors, Minority carrier transport properties

Practice 1: To calculate the sun position at a given place and time and thereby study the variation in power production in a solar photovoltaic panel with respect to the change in incidence angle.
Practice 2: Learn how to assess the solar energy potential of a site

Module II **(4 Hours Theory + 8 Hours Practice)**
Surface and interface recombination; PN junctions and transport of charge carriers; Solar cell parameters; Photo current & spectral responses; Types of different generation of PV systems: 1st, 2nd, 3rd generation PV systems
Practice 3 : Find the GHI using the pyranometer data and assess the feasibility of a solar PV station in the area

Practice 4: Learn how to assess the solar energy potential of a site using a pyrheliometer.

Practice 5: To measure the outlet and inlet temperatures of the parabolic trough collector as a function of angle of incidence of solar radiation.

Practice 6: To measure the outlet and inlet temperatures and flow rate of the parabolic trough collector as a function of flow rate variation.

Module III **(4 Hours Theory)**
Si photovoltaics; Thin film solar cell production; Nano coating on photovoltaics; ;CdTe PV systems

Module IV **(6 Hours Theory)**
CIGs PV Systems; Dye-sensitized solar cell; III-V multi junction solar cells; Organic solar cell; OPV working principles; Perovskite solar cell;

Module V **(3 Hours Theory)**
Quantum dots based solar cells; Nanowire based solar cells; Carbon nanomaterials based solar cells,

Module VI **(5 Hours Theory)**
Nano catalyst production; Use of graphene as nano catalytic applications; Artificial photosynthesis; CO_2 conversion;

Module VII **(4 Hours Theory)**
Photocatalysis; Au nanoparticle as effective catalyst; Hydrogen production using nanocatalyst, Nano titanium oxide as photocatalyst.
Total theory 30 hours and total practice 12 hours

Reference Books:

- Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems; Olindo Isabella, Klaus Jäger, Arno Smets, René van Swaaij, MiroZeman.
- Nanomaterials in catalysis; Philippe Serp, KarinePhilippot.

Code	**Course Title**	**T-P-Pj (Credit)**	**Prerequisite**
CUTM 1399	Energy Storage Materials	3-1-0	Basics of Nanomaterials

Course Objective

- This course will educate the students the concepts and operation of accessible energy storage systems, significance of energy storage in current scenario, reason and transfer of efficiency losses in different energy storage systems.
- This course is designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), super capacitors.
- The students will also learn various types of batteries used in modern technology and the intercalation of nanomaterials inside them.

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Course outcome

COs	Course outcomes
CO1	Understand the usage of nano-materials in various battery applications.
CO2	know the utilization of next generation super-capacitors and its applications.
CO3	Use of nanomaterials in fuel cell including Solid state fuels
CO4	Understand various renewable energy sources and their use
CO5	Develop research skills in the field of energy storage materials and apply knowledge of energy storage materials to real-world applications

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
CO2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
CO3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

***High-3, Medium-2, Low-1**

Course outline

Module I **(4 Hours Theory)**

Nanotechnology in energy research, Fossil fuels, Nanotechnology in fuel production, Renewable energy sources; Advantages of renewable energy sources.

Module II **(4 Hours Theory)**

Thermoelectric materials (bulk), Thermoelectric materials (in nanoscale), Thermoelectric nanocomposites, Applications of thermoelectric nano materials

Module III **(6 Hours Theory + 2 Hours Practice)**

Supercapacitors, Types of supercapacitors, Design of supercapacitors, Carbon based materials for supercapacitors, Necessary parameters for supercapacitors, Applications.

Practice-1

To learn the specific charge/discharge characteristics of a supercapacitor through experimental testing of a remote triggered ultracapacitor battery supercapacitor

Module IV **(6 Hours Theory)**

Fuel Cells: Low temperature fuel cells; High temperature fuel cells; Catalysts for fuel cells and electrolytes; Solid oxide fuel cells; Applications

Module V **(4 Hours Theory)**

Semiconductor based Hydrogen production; Selection of nanomaterials for energy harvesting and storage applications; Other significant materials for Hydrogen storage; Thermal energy storage systems

Module VI **(3 Hours Theory+ 4 Hours Practice)**

Batteries: Lithium ion battery; Nanomaterials in Li ion battery; Nanomaterials in K ion battery

Practice 2: To learn the specific charge/discharge characteristics of a Lithium- ion (Li- ion) battery through experimental testing of a remote triggered Li- ion Battery

Practice 3: To learn the specific charge/discharge characteristics of a Lithium- Polymer (Li-Po) battery through experimental testing of a remote triggered Li- Po Battery.

Module VII **(3 Hours Theory+8 Hours Practice)**
Aluminium ion battery; Graphene battery; Sodium ion battery

Practice 4: To learn the specific charge/discharge characteristics of a Lead Acid battery through experimental testing of a remote triggered Lead Acid Battery

Practice 5: To learn the specific charge/discharge characteristics of a Nickel Metal Hydride (NiMH) battery through experimental testing of a remote triggered NiMH Battery

Practice 6: To learn the specific charge/discharge characteristics of a Nickel-Cadmium (Ni-Cad) battery through experimental testing of a remote triggered Ni-Cad battery.

Total theory 30 hours and total practice12 hours

Reference Books:

5. Robert A. Huggins; Energy Storage, Fundamentals, Materials and Applications
6. KunihitoKoumoto , Takao Mori ; Thermoelectric Nanomaterials
7. Electrochemical Supercapacitors for Energy storage and delivery; Aiping Yu, Victor Chabot, and Jiujun Zhang.

Code	**Course Title**	**T-P-Pj (Credit)**	**Prerequisite**
CUTM1410	Plasma Technology	3-0-1	Nil

Course Objective

- To explore the fourth state of matter, Plasma.
- To understand fundamental characteristics of plasma, various plasma generation methods, various applications of plasma technology in nanomaterial synthesis, energy production and storage, medicine/health care, etc.
- To acquire comprehensive knowledge of how plasmas are utilized for different types of materials processing specially in nanotechnology and developing advanced materials

Course outcome

COs	Course outcomes
CO1	understand fundamental plasma parameters, under what conditions an ionized gas consisting of charged particles

CO2	Capable of research problem solve
CO3	Understand the application in materials and surface engineering,
CO4	Understand the complex interactions between plasma and materials
CO5	Evaluate Environment and Sustainability of Plasma Technology

Course outline

Module-I **(5 Hours Theory)**
Fundamentals of Plasma Physics
Plasma-the fourth state of matter, Plasma parameters, Debye length, Plasma sheath, Plasma oscillations & frequency, Saha's theory of thermal ionization, Concept about plasma equilibrium and types of plasma (only classification), Plasma classification on basis of temperature and pressure (only fundamental)

Module-II **(6 Hours Theory+ 2 Hours Assignment)**
Plasma Production Techniques
DC discharges, Glow discharge, I-V characteristic of electrical discharge, Paschen curve, Arc discharge, Transferred and non-transferred arcs, RF discharge, Capacitively and inductively coupled plasmas, Microwave discharge, Vacuum arcs
Assignment-1
Gases break-down, Paschen Curves, Advanced plasma generation techniques

Module-III **(3 Hours Theory+ 2 Hours Assignment)**
Plasma Diagnostics
Basic plasma diagnostics: electric probes (single and double), Optical emission spectroscopy (basic idea), Laser based diagnostics
Assignment-2
Plasma diagnostic for understanding the basic plasma

Module-IV **(4 Hours Theory+ 2 Hours Assignment)**
Plasma Etching, Spraying and Atomization processes
Etching, Plasma cleaning, Surfactants removal, Non transferred plasma torches, Advanced plasma atomization process
Assignment-3
Advanced plasma atomization for nano material production

Module-V **(5 Hours Theory+ 2 Hours Assignment)**
Plasma Sputtering Deposition Processes
Introduction of thin film coatings by plasma,Plasma-Enhanced Chemical Vapor Deposition (PECVD), Physical vapor deposition (PVD), Pulsed laser deposition (PLD), Plasma nitriding
Assignment-4
Surface treatment and thin film coating by advanced plasma techniques

Module-VI **(4 Hours Theory+ 2 Hours Assignment)**
Plasma Melting, Cutting and welding
Arc plasma melting, Synthesis of nanomaterials (Al_2O_3 and SiC) by plasma reactor/furnace, Plasma cutting, Plasma Welding
Assignment-5
Plasma cutting and welding

Module-VII **(3 Hours Theory+ 2 Hours Assignment)**

Special Plasma Applications
Controlled thermo-nuclear fusion: the green technology-Tokamaks (fundamental), Plasma waste processing (Plasma pyrolysis), Biomedical and health applications
Assignment-6
Plasma Technology: An emerging clean and green energy technology for future

Total theory 30 hours and total assignment class 12 hours

Reference Books:

1. Principles of Plasma Discharges and Materials Processing, M. A. Lieberman and A. J.. Lichtenberg (John Wiley and Sons, 2005)
2. Introduction to Plasma Physics and Controlled Fusion, 3rd edition, Francis F. Chen, (Springer, 2018)
3. Plasma Technology, B. Gross, B. Greyz and K. Miklossy, (Iliffe Books Ltd., London, 1968).
4. Handbook of Advanced Plasma Processing Techniques, Eds. R.J. Shul and S.J. Pearton.
5. Fundamentals of Plasma Physics, J. A. Bittencourt, Springer-Verlag New York Inc., 2004.
6. Handbook of Plasma Processing Technology: Fundamental, Etching, Deposition and Surface Interactions, S. M. Rossnagel, J. J. Cuomo, W. D. Westwood, (Noyes Publications, 1990) SAP 4005 Plasma Processing of Materials.

Code	Subject Name	Type of course	T-P-P	Prerequisite
CUTM1412	Advanced Quantum Physics	• Theory & Project	2-0-2	Nil

Course Objective

- Learn methods to solve Schrodinger's equation by WKB method, Variational method and perturbation method.
- Learn Practical application of these methods to real time problems
- Learn to apply these methods to solve several problems.

Course outcome

COs	Course outcomes
CO1	Apply the principles of advanced quantum mechanics to various physical systems, including atoms, molecules, solids, and quantum field theory
CO2	Explore the fundamentals of quantum information theory and quantum computing
CO3	Develop research skills in quantum physics, including the ability for simulations to explore advanced quantum phenomena and their applications.
CO4	Solve Schrodinger's equation for different systems using WKB method, Variational method and perturbation method
CO5	To write Python code to solve Schrodinger's equation and find energy Eigen values

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3

CO1	3	2	2	2	2	-	-	-	-	-	-	--	3	2	3
CO2	3	3	2	2	3	-	-	-	-	-	-	-	3	2	3
CO3	2	3	2	3	3	-	-	-	-	-	-	-	3	2	3
CO4	3	3	2	2	2	-	-	-	-	-	-	-	3	2	3
CO5	3	3	2	2	3	-	-	-	-	-	-	-	3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module-I (Theory 4 hours, Project 2 hours)

Time independent Perturbation Theory:Energy Shifts and Perturbed Eigen states, Nondegenrate and degenerate perturbation theory, spin orbit coupling.

Assignment1:(Any one)

- Develop solution for shifting and splitting of spectral lines of atoms - The Stark Effect
- Develop solution for shifting and splitting of spectral lines of atoms - Zeeman Effect

Module -II (Theory 4 hours + Project 2 hours)

Pictures of quantum mechanics: The Schrodinger picture, The Heisenberg picture, The interaction picture.
Variational Methods**:** General formalism, Ground State of One-Dimensional Harmonic Oscillator, First Excited State of One-Dimensional Harmonic Oscillator

Assignment 2:(Any one)

- Solve theproblem for Tunneling of a particle through a Potential Barrier
- Find out the energy of ground state and first excited states of Harmonic oscillator

Module -III (Theory 4 hours + Project 2 hours)

WKB Approximation**:** General Formalism, Validity of WKB Approximation Method, Bound States for Potential Wells with no rigid walls.

Assignment 3:(Any one)

- Gamow's theory of alpha decay – Finding solution with WKB method
- Find out the energy of particle in Bound States for Potential Wells with One Rigid Wall
- Find out the time taken for a can of soft drink at room temperature to topple spontaneously- applications of quantum tunneling

Module -IV (Theory 4 hours + Project 2 hours)

Time Dependent Perturbation Theory**:** Introduction,Transition Probability, Transition Probability for Constant Perturbation, Transition Probability for Harmonic Perturbation, Adiabatic Approximations, Sudden Approximations.

Assignment 4:

- Calculate the transition probability rate for an excited electron that is excited by a photon from the valence band to the conduction band in a direct band-gap semiconductor by using

Fermi golden rule.

Module -V **(Theory 4 hours + Project 2 hours)**

Applications ofTime Dependent Perturbation Theory**:** Interaction of Atoms with Radiation, classical treatment of incident radiation, Transition Rates for Absorption and Emission of Radiation,
Assignment 5:(Any one)

- Light absorption and emission - mathematical formulation using electric dipole radiation
- The quantum mechanical selection rules for electric dipole transitions
- Find out expression for transition rates within the dipole approximation

Module -VI **(8 project sessions 2 hours each)**

Assignment 6:(Any one)
Group Project

1. One-electron phenomena in strong Laser fields – derivation and Python programming**-** application of adiabatic approximation
2. Two-electron phenomena in strong Laser fields **-** application of adiabatic approximation
3. Fermi's golden rule applied to find tunneling current of a scanning tunneling microscope
4. Derivation and Python programming for bound states for potential wells with two rigid walls
5. Ground state of Hydrogen atom - solve using Python programming.
6. Study of the neutron quantum states in the gravity field - Python programming
7. Find an expression for electric-dipole two-photon absorption selection rules and use it to summarize the rules for two photons of unequal frequency.
8. Simulation using Python programming for tunneling through a potential barrier
9. Quantum harmonic oscillator using Python
10. Gamow's theory of alpha decay – solution and simulation sing python
11. Time taken for a can of soft drink at room temperature to topple spontaneously- applications of quantum tunneling - Python programming.

Total theory 20 hours and total project 26 hours

Textbook:

1. Advanced Quantum Mechanics by Satyaprakash, S Chand Publications

Reference Books:

8. Quantum Mechanics: Concepts and Applications by NouredineZettili
9. Introduction to Quantum Mechanics, D J Griffith, Pearson, 2014.

Modern Quantum Mechanics, J.J. Sakurai, Pearson, 2013.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1409	**Computational Materials Science**	**2-2-0**	**Nil**

Total theory 30 hours and total project 12 hours

Course Objective

- To teach the fundamental definitions, concepts, and tools of Computational Materials Science, and how they are applied to address materials modeling challenges.
- To impart practical skills in developing computational models using Molecular Dynamics (MD), Hartree-Fock (HF), and Density Functional Theory (DFT) approaches for simulating physical and electronic behavior.
- To provide students with hands-on training in open-source and commercial software tools, including Python-based coding, Biovia Materials Studio, and Quantum ESPRESSO, for performing calculations, visualization, and analysis of material systems.

Course outcome

COs	Course outcomes
CO1	Define and explain key concepts of interatomic potentials, cohesive energy, statistical ensembles, and basic principles of Hartree and Hartree-Fock approximations.
CO2	Apply molecular dynamics and Monte Carlo simulation techniques using standard algorithms (e.g., Verlet, Metropolis) to model simple systems and predict material behavior.
CO3	Analyze electronic structures and total energy calculations using Density Functional Theory, identifying the effect of k-points, basis sets, and exchange-correlation functionals.
CO4	Evaluate the accuracy and limitations of DFT results for vibrational frequencies, magnetic properties, and adsorption behavior on surfaces using slab models.
CO5	Design and execute a simulation-based mini-project combining MD, Monte Carlo, or DFT techniques to investigate a materials problem such as diffusion, surface adsorption, or phase transition.

	PO1	**PO2**	**P03**	**P04**	**P05**	**P06**	**P07**	**P08**	**P09**	**P010**	**PO11**	**P012**	**P013**
CO1	3	2	2					3		2	1	1	
CO2	2	3	2		1			2		2		1	
CO3	3	2	3									2	
CO4	2	2	3		1					2	1	1	
CO5	**3**	2	3		3					2	2	3	

Course outline

Module I **(4 Hours Theory)**

Introduction to computational materials science: Cohesive Energy, Modelling & Simulation, Basic forms of interatomic interactions (pair potentials, The Lennard-Jones potential, Morse Potential, Brenner Model, Tersoff Model)

Practice -1 Introduction to Python-variables, data types
Practice -2 Python-Loops
Practice -3 Python-Modules (NumPy ,SciPy)
Practice -4 Python-Plotting
Practice -5 Model and visualize Brenner Model &Tersoff Model.
Practice -6 Model and visualize Lennard-Jones potential and Morse Potential

Module II

Molecular Dynamics **(4 Hours Theory)**

Statistical Ensembles used in Molecular Dynamics (NVT, NVE, NPT), Thermostat (Andersen's method, Berendsen thermostat, Nose-Hoover thermostat), Boundary Conditions. MD Methodology (Verlet algorithm, Velocity Verlet algorithm), Force Field, Diffusion.

Practice -7 Simulate water molecules at room temperature using NVT ensemble and analyze the structural and dynamic properties
Practice -8 Simulate water molecules at room temperature using NPT ensemble and analyze the structural and dynamic properties

Module III

Monte Carlo Methods and Hartree Approximation **(5 Hours Theory)**

Monte Carlo Simulations, Metropolis algorithm, 2D Ising Model and its simulation, The Variational Principle, The Hartree Approximation.

Practice-9 Investigate how different water molecules adsorb in various sites of a nanoporous host like CNT using Forcite module of BIOVIA MS
Practice-10 Investigate how different methane molecules adsorb in various sites of a nanoporous host like CNT using Forcite module of BIOVIA MS
Practice -11 VariationalPrinciple – Ground State Compute and compare total ground state energy of molecules H_2, He, or LiH using Hartee mechanism of BIOVIA MS.
Practice -12 Comparative Study of Electron Density in Isoelectronic materials: O^{2-}, F^{-}, and Ne
Practice -13 Electron Density Mapping and Visualization in simple polar and non-polar molecules like H_2O, NH_3, and CH_4

Module IV

Density Functional Theory-I **(4 Hours Theory)**

The Hartree-Fock Approximation, Periodic structures, supercells, and lattice parameters, K Points, Energy Cutoffs, Geometry Optimization.

Practice -14 Electron Density Distribution in H, He, Li atoms.
Practice -15 Electron Density Distribution in simple diatomic molecules: H2, N2, O2, CO
Practice -16 Prediction of Lattice Parameters of AlAs using CASTEP of BIOVIA Material Studio.
Practice-17 Visualize and compare electron density of atoms like Be, Ne, Ar using $DMol^3$ module of BIOVIA MS.

Module V

Density Functional Theory-II **(4 Hours Theory)**

Density Functional Theory (From Wave Functions to Electron Density), TheHohenberg-Kohn Theorems, The Kohn-Sham Equations, Exchange Correlation Functionals (LDA, GGA, PBE).

Practice -18 Optical Properties Si and Ge (Indirect band gap SC)
Practice -19 Optical Properties ZnO and GaAs (Direct band gap SC)
Practice -20 Optical Properties GaN and SnO2, $BaTiO_3$ (wide band gap SC)

Module VI

Extensions of Density Functional Theory **(4 Hours Theory)**

DFT for Surfaces of Solids (Slab Models, Surface Relaxation, Adsorbates on Surfaces)

Practice -21 Adsorption of CO onto a Pd (110) Surface
Practice -22 Adsorption of NH_3 onto a Pt(111) Surface

Module VII **(3 Hours Theory)**

DFT Calculations of Vibrational Frequencies, Electronic Structure, Magnetic Properties.

Practice -23 redicting the Thermodynamic properties of Ge using BIOVIA MS
Practice -24 Band gap prediction of ZnO in DFT using BIOVIA MS
Practice -25 Density of States of AlAs using DMol3 using BIOVIA MS.
Practice -26Simulating Electron transport with DFTB+

Total theory 28 hours and total practice 52 hours

Textbook:

2. Introduction to Computational Materials Science, Richard LeSar, (Cambridge University Press, 2016).
3. Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory. Attila Szabo, Neil S Ostlund. (Dover Publications Inc. 1996).

Reference Books:

Computational Materials Science: An Introduction. June Gunn Lee, (CRC Press, 2011).

CourseTitle: InstrumentationTechniques **Course Code:** CUTM 4526 **Contact Hours:** 40 (Theory: 20 hours, Practical: 20 hours)

1. Course Objectives:

This course is designed for postgraduate students from diverse science backgrounds. The primary objective is to provide a comprehensive understanding of the principles, instrumentation, and applications of modern analytical techniques. It aims to equip students with the necessary skills to select and apply appropriate instrumental methods for qualitative and quantitative analysis in their respective research areas.

2. CourseOutcomes (COs):

Upon successful completion of this course,studentswillbeableto:

COs	Course outcomes
CO1	Explain the working principles and applications of various modern analytical instruments.
CO2	Select suitable instrumental techniques for solving specific chemical analysis problems.
CO3	Perform experimental analysis using instruments with accuracy, precision, and safety.
CO4	Analyze and interpret experimental data to draw meaningful scientific conclusions.
CO5	Integrate instrumental methods into research and industrial applications for problem-solving and innovation.

CO, PO, PSO Mapping Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2		1	3	2	2			3	2	3	2	
CO2	2	3	3	2		3	2	2	2		2	2	3	3	2
CO3	3	2	3		2	2	3	3	2		3	2	3	2	3
CO4	2	3	3	2		2	2	2	2		2	1	3	3	2
CO5	3	2	3	3	2	2	3	1	3		2	2	3	3	3

Theory(20Hours)

ModuleI:Fundamentalsof Instrumentation& DataAnalysis(3 Hours)

- Introduction:Classificationofinstrumentalmethods.
- BasicComponents&Performance:Transducers,detectors,signalprocessors.Accuracy, precision, sensitivity, resolution.
- Errors&DataHandling: Systematicandrandomerrors,statisticalanalysis.
- SignalsandNoise:Sourcesofnoise,signal-to-noiseenhancementtechniques.

Module II: UV-Visible & Luminescence Spectroscopy (4 Hours)

- UV-VisibleSpectroscopy:Principles(Beer-LambertLaw),instrumentation,and applications.
- Fluorescence & Phosphorescence Spectroscopy: Theory of molecular luminescence, instrumentation, and applications.
- Photoluminescence (PL) Spectroscopy: Principles of luminescence in semiconductors and nanomaterials, instrumentation, and applications in materials characterization.

ModuleIII:Vibrational&RamanSpectroscopy(3Hours)

- Infrared (IR/FTIR) Spectroscopy: Principles of molecular vibrations, instrumentation, sample handling, and applications in functional group identification.
- RamanSpectroscopy:TheoryofRamanscattering,instrumentation(lasers,filters, detectors), and applications, including comparison with IR spectroscopy.

ModuleIV:ChromatographicSeparationTechniques(3Hours)

- Principles:Adsorption,partition,ion-exchange,andsize-exclusionmechanisms.
- GasChromatography (GC):Principle,instrumentation(columns, detectors).
- High-PerformanceLiquidChromatography(HPLC):Principle,instrumentation(pumps, columns, detectors).

ModuleV:MassSpectrometry(MS)(3Hours)

- Principles:Ionization,fragmentation,mass-to-chargeratio.
- Instrumentation:Ionsources(EI,CI),massanalyzers(quadrupole,time-of-flight).
- HyphenatedTechniques:IntroductiontoGC-MSandLC-MSforstructuralelucidation.

Module VI: Electron Microscopy Techniques (2 Hours)

- Principles, instrumentation, and applications:Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).
- ElementalAnalysis:EnergyDispersiveX-raySpectroscopy(EDS)coupledwithSEM/TEM.

ModuleVII:X-rayBasedAnalyticalTechniques(2Hours)

- X-rayDiffraction(XRD):Bragg'sLaw,principlesofpowderXRD,andapplicationsin crystal structure identification.
- X-rayFluorescence(XRF):Principles,instrumentation,andapplicationsinnon-destructive elemental analysis.
- X-rayPhotoelectronSpectroscopy(XPS):Principles,instrumentation,andapplications for determining surface elemental composition and chemical states.

PartB:Practicals(20Hours)

Atotalof10experiments(2hourseach)istobeperformed.

1. Performerroranalysisonagivendataset,includingcalculationofabsolute,relative, and percentage errors.
2. Calculatethemean,standarddeviation,andvarianceforasetofexperimental measurements.
3. Determine the λ_max of $KMnO_4$ and verify the Beer-Lambert Law using a UV-VisSpectrophotometer.
4. IdentifythefunctionalgroupsinagivenorganicsampleusingFTIRspectroscopy.
5. Determinetheelementalcompositionofasolid/liquidsampleusingX-rayFluorescence (XRF) spectroscopy (data analysis).
6. Separate a mixture of amino acids or plant pigments (any material) using Paper/Thin Layer Chromatography and determine their $R_f$values.
7. Analyzethevibrationalmodesofamaterial(e.g.,carbonnanotubes,siliconwafer)from a given Raman spectrum (data analysis).
8. Determine the elemental composition and chemical states of a surface from a givenXPS spectrum (data analysis).
9. DemonstrationofGasChromatography(GC)fortheseparationofamixtureofvolatile compounds (data analysis).

10. DemonstrationofHigh-PerformanceLiquidChromatography(HPLC)(dataanalysis).
11. Analyzethe surfacemorphology of agiven sampleusingprovided SEMmicrographs.
12. Determine the crystal structure and lattice parameters from a given powder XRD pattern.

3. RecommendedBooks:

Textbooks:

1. Singh, D.K., Pradhan, M. and Materny, A. eds., 2021. *Modern techniques of spectroscopy: basics, instrumentation, and applications*. Singapore: Springer.
2. Hawkes,P.W.andSpence,J.C.eds.,2019.*Springerhandbookofmicroscopy*.Springer Nature.
3. Kumar, C.S., Singh, M.M. and Krishna, R., 2023. *Advanced Materials Characterization: Basic Principles, Novel Applications, and Future Directions*. CRC Press.

References:

1. Pavia, D. L., Lampman, G. M., Kriz, G. S., & Vyvyan, J. R. (2014). *Introduction toSpectroscopy*. Cengage Learning.
2. Goldstein,J.I.,etal.(2017).*ScanningElectronMicroscopyandX-rayMicroanalysis*. Springer.
3. Briggs,D.,&Seah,M.P.(1990).*PracticalSurfaceAnalysis,AugerandX-rayPhotoelectron Spectroscopy*. Wiley.

Syllabus:ScientificComputingusingMATLAB (CUTM4527)

Credits: 1-2-1 (T-P-P: 1 Theory, 2 Practice, 1 Project)

ContactHours:12Theory,22Practice,11Project Sessions

- Course Objectives

Thiscourseaimstoequippostgraduatestudentsinthephysicalandmathematicalscienceswith essential computational skills using the MATLAB environment. The primary objective is to empower students to apply numerical methods and data analysis techniques to solve complex scientificproblems,visualizeresultseffectively,andautomateresearchtasks.Bytheendofthe course, students will be proficient in using MATLAB as a powerful tool for computation, modeling, and analysis, including an introduction to its machine learning capabilities.

- 2. Course outcomes

COs	Course outcomes
CO1	Navigate and utilize the MATLAB Integrated Development Environment (IDE) with confidence
CO2	Develop and debugstructuredprogramsusingMATLABscriptsandfunctions
CO3	Process,analyze,andvisualizescientificdatatoextractmeaningfulinsightsandcreate publication-quality graphics
CO4	Apply basic signal, image, and machine learning techniques to relevant datasets using MATLAB toolboxes
CO5	Independently design and execute a computational project from problem formulation to final presentation

CO, PO, PSO Mapping Matrix

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	–	–	–	1			2	2	3	1	3	–	2
CO2	3	3	2	2	–	2			3	2	2	–	3	2	3
CO3	3	3	2	2	2	2			3	2	2	2	3	3	2
CO4	3	2	1	–	–	–			2	1	3	2	2	3	2
CO5	3	3	3	3	2	2			3	3	3	2	3	3	2

4. CourseStructureandSessionDistribution

Module	ModuleTitle	Theory Sessions	Practice Sessions	Project Sessions
1	IntroductiontotheMATLAB Environment	2	4	0
2	ProgrammingFundamentalsin MATLAB	2	4	0

3	DataHandling,Analysis,and Visualization	1	4	0
4	NumericalMethodsforScientists	3	4	0
5	Introduction to Signal and Image Processing	1	3	0
6	Machine Learning using MATLAB	3	3	1
7	Project Work and Advanced Topics	0	0	10
	Total	12	22	11

Module1:IntroductiontotheMATLABEnvironment

- Theory:MATLABIDE(CommandWindow,Workspace,Editor,HelpBrowser),basic syntax, defining variables. [2 Hours]
- PracticeSessions(1-4):
    1. Aim: TofamiliarizewiththeMATLABIDEbycalculatingtheenergyofa photon using Planck's equation (E=hν). [1 Hour]
    2. Aim:Tocreateandmanipulatevectorsrepresentingpositionin3Dspace (Physics) and matrices for linear transformations. [1 Hour]
    3. Aim:Tounderstandelement-wiseoperations for stoichiometriccalculations in a chemical reaction. [1 Hour]
    4. Aim:Togenerateandcustomizea2Dplotofaprojectile'strajectory.[1Hour]

Module 2: Programming Fundamentals in MATLAB

- Theory:Scriptfilesvs.functions,functiondefinitionandcalling,controlflow(if-elseif- else, switch), loops (for, while), logical operators. [2 Hours]
- PracticeSessions(5-8):
- 5.Aim:Towriteauser-definedfunctiontocalculatethepHfromagivenhydrogenion concentration. [1 Hour]
- 6.Aim:To implement control flow to determine the phase of water (solid, liquid, gas) based on temperature and pressure inputs. [1 Hour]
- 7. Aim:TouseaforlooptocalculatethetermsofaTaylorseriesexpansionfora function like sin(x) [1 Hour]
- 8.Aim: To use a struct to store properties of chemical elements (e.g., name, symbol, atomic number, mass) [1 Hour].

Module3:Data Handling,Analysis,andVisualization

- Theory:Importingandexportingdata(CSV,TXT,Excel),datatypes,descriptive statistics. [1 Hour]

- PracticeSessions(9-12):
- 9.Aim:Toimportexperimentaldatafromaspectrometer(.csvfile)intotheMATLAB workspace. [1 Hour]
- 10.Aim:Toperformdescriptivestatisticalanalysis(mean,median,standarddeviation) on a set of experimental measurements. [1 Hour]
- 11.Aim:Tocreateasemi-log plotto analyzefirst-orderreactionkinetics(Chemistry). [1 Hour]

QUANTUM COMPUTING

Subject Name	Code	Type of course	T-P-Pj (Credit)	Prerequisite
QUANTUM COMPUTING	**CUTM4525**	**Theorv +Practice+ Project**	**1-2-1**	Linear Algebra, Basic Quantum Mechanics, Classical Computing Concepts

Objective

- Build conceptual understanding of quantum mechanics as it applies to computation, including superposition, entanglement, and quantum gates.
- Familiarize students with quantum algorithms such as Deutsch-Jozsa, Grover's Search, and Shor's algorithm.
- Introduce quantum programming using tools like Qiskit, enabling students to simulate and implement quantum circuits on classical and quantum simulators.

Course outcome

After completion of the course, students will be able to

Course Outcome to Program Outcome Mapping:

Cos	Course outcomes
CO1	Understand the fundamental concepts of quantum mechanics that form the basis of quantum computation, including qubits, superposition, entanglement, and quantum measurement.
CO2	Analyze and design quantum circuits using quantum logic gates and evaluate the behavior of basic quantum algorithms such as Deutsch-Jozsa, Grover's, and Shor's algorithms.
CO3	Apply quantum programming frameworks (e.g., Qiskit) to simulate quantum circuits and perform quantum computations on real or simulated quantum processors.
CO4	Solve scientific and computational problems using quantum approaches in domains such as optimization, cryptography, and quantum chemistry.
CO5	Demonstrate critical thinking, teamwork, and communication skills through mini-projects or case studies involving interdisciplinary applications of quantum computing.

Course Outcome to Program Outcome Mapping:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1		1	1	3	1	2	2			1		3	3	3	2
CO2	1	2		2		1	1			2	1	1	2	1	3
CO3	3		2		1	2	2			1	1	2	1	1	3
CO4	2		2		2					2	2		2	3	2
CO5	2	1		1		1	1			2		1	2	1	1

***High-3, Medium-2, Low-1**

Course outline

Course Outline

Module 1: Foundations of Quantum Computing (T-2Hrs | P-4Hrs | Pj-1Hr)

Theory (2 Hrs.)

- **Motivation & Overview**
  - Why Quantum Computing? Moore's Law & Classical Limits.
  - Classical vs Quantum Computation: Bits vs Qubits.
  - Applications Landscape (Medicine, AI, Cryptography).
- **Essential Linear Algebra& Complex Numbers**
  - Complex number and its Polar Representation
  - Vectors, Linear Independence,VectorSpace, Oorthonormal Basis.Unitary Matrix.
- **Qubits, Quantum States & Dirac Notation**
  - Quantum State, Wave function, State vectors in Hilbert space
  - Bra-Ket Notation: Inner,Outer, Tensor Products,Nnormalization
  - Phase and Pprobability Aamplitudes, Superposition&Entanglement
  - Measurement: Projective measurement, Born rule, Quantum state collapse
  - Bloch Sphere representation of Qubits

Practice (4 Hrs.)

- Single Qubit state visualization using Bloch Sphere
- Hands-on with simple state preparations using Qiskit

Project 1 (1Hrs.)

- Simulation and visualization of basic quantum states

Module 2: Quantum Gates & Circuits (T-2Hrs | P-6Hrs | Pj-1Hrs)

Theory (3 Hrs.)

- Single Qubit Gates: Identity (I), Pauli Gates (X, Y, Z),HadamardGate (H), General Phase Gate R(ϕ), Phase (S)&$S^\dagger$, T& $T^\dagger$, Rotation Gates (R_x,R_y,R_z)
- Matrix representations, Circuit symbols, Bloch sphere Action
- Multi-Qubit Systems: Tensor Product, BasisStates, StateSpace Growth
- **Multi-QubitGates:** CNOT, CZ, SWAP,iSWAP,Toffoli (CCNOT), Fredkin (CSWAP) Gates.
- Quantum Entanglement: Bell states, GHZ states, Non-locality (EPR paradox, Bell inequalities)
- Arbitrary n-QubitUnitaries (U_2^n): Representation and Decomposition
- Universality of Quantum Gates

- Introduction to Quantum Circuit Design and Simulation (Basics of Quantum Circuits, Circuit Elements, Circuit Design Principles, Quantum Measurements and Simulation Concepts)

Practice (6 Hrs.)

- Visualize multi-qubit state vectors through Q-Sphere.
- Implement single qubit gates: X, Y, Z, H, R(ϕ), S, $S^\dagger$, T, $T^\dagger$, R_x,R_y,R_z.
- Implement single qubit gates: CNOT, CZ, SWAP,iSWAP,Toffoli (CCNOT), Fredkin (CSWAP) Gates
- Create quantum circuits producing Bell states and GHZ States
- Decomposearbitrary unitary gates (1-2 Qubits)

Project 2 (1 Hrs.)

- Design and implement custom gate sequences and analyze output states

Module 3: Quantum Communication Protocols (T-2Hrs | P-4Hrs | Pj-1Hr)

Theory (2 Hrs.)

- No-Cloning Theorem, Quantum Teleportation Protocol
- Superdense Coding
- Quantum Cryptography: BB84, Quantum Key Distribution (QKD), Post-quantum cryptography overview

Practice (4 Hrs.)

- Simulate Quantum Teleportation and Superdense Coding.
- QKD Simulation using BB84 Protocol

Project 3 (1 Hrs.)

- Simulate Teleportation on State Vector Simulator and Real Quantum Computer.

Module 4: Quantum Algorithms-I (T-2Hrs | P-4Hrs | Pj-1Hrs)

Theory (1 Hr.)

- Quantum Parallelism, Quantum Interference.
- Deutsch-Jozsa Algorithm, Oracle Concept, Grover's Algorithm and Amplitude Amplification

Practice (4 Hrs.)

- Simulate Deutsch-Jozsa algorithm.
- Simulate Grover's algorithm for a small database.

Project 4 (2 Hrs.)

- Developing Quantum Oracles for Specific Search Problems: Design, Testing, and Evaluation.

Module 5: Quantum Algorithms-II (T-2Hrs | P-4Hrs | Pj-1Hrs)

Theory (2 Hrs.)

- Quantum Fourier Transform (QFT)
- Period Finding and Integer Factorization
- Shor's Algorithm

Practice (4 Hrs.)

- Implement and simulate QFT

- Implement and simulate Shor's algorithm

Project 5 (1 Hr.)

- Quantum Fourier Transform and Its Applications in Period Finding and Integer Factorization

Module 6: Quantum Error Correction & Noise (T-2Hrs | P-4Hrs | Pj-1Hr)

Theory(2 Hrs)
- Quantum Decoherence and Errors
- Types of Noise Affecting Qubits
- Classical Error Correction Analogies
- Quantum Error Correcting Codes: Bit-flip, Phase-flip, Shor's 9-qubit, Surface Code

Practice (4 Hrs)
- Error simulation using QiskitAer
- Demonstration of 3-qubit repetition code

Project 6(1 Hr)
- Simulation of Quantum Error Correction Codes on Noisy Quantum Devices Using Qiskit

Module 7: Quantum Programming & Applications (T-2Hrs | P-4Hrs | Pj-1Hr)

Theory:
- Quantum Programming Languages (Qiskit (IBM), Cirq (Google), Braket (AWS), PennyLane, Q#)
- Applications of Quantum Computing
- Quantum Machine Learning (Variational Circuits, QNNs)
- Quantum Chemistry (Hamiltonian simulation, Variational Quantum Eigen solver)
- Optimization (QAOA, MaxCut)
- Current **Quantum Hardware and Roadmaps (**NISQ devices vs. Fault-tolerant devices)

Practice:

Advanced circuit building
Simulate H_2 molecule energy using VQE
Hybrid quantum-classical workflows (e.g., VQE, QAOA)

Project 6 (1 Hr.)

Capstone project: Implementation of a Real-world application-based project

Assessment Scheme:

Component	Weightage
Theory Exams	30%
Lab Assignments	20%
Module Projects	20%
Final Capstone Project	30%

Textbooks and References

Textbooks:

1. Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum

Information, 10th Anniversary Edition, Cambridge University Press, 2010. ISBN: 978-1107002173

Chapters:1 (Art. 1.1, 1.2, 1.3, 1.4, 1.5),2 (Art. 2.1–2.9),4 (Art. 4.1–4.10),5 (Art. 5.1–5.3),6 (Art. 6.1–6.8),7 (Art. 7.1–7.3),8 (Art. 8.1),10 (Art. 10.1–10.9),12 (Art. 12.1–12.3)

2 Jack D. Hidary, *Quantum Computing: An Applied Approach*, 2nd Edition, Springer, 2021. ISBN: 978-3030239213

Chapters:1 (Art. 1.1, 1.2),2 (Art. 2.1–2.4),3 (Art. 3.1–3.3),4 (Art. 4.1–4.3),5 (Art. 5.1–5.2),6 (Art. 6.1–6.6),7 (Art. 7.1–7.3),8 (Art. 8.1, 8.3),11 (Art. 11.1–11.2),
12 (Art. 12.1–12.2)

References:

1. **Eric R. Johnston, NicHarrigan, Mercedes Gimeno-Segovia**, *Programming Quantum Computers: Essential Algorithms and Code Samples*, O'Reilly Media, 2019.
   - ISBN: 978-1492039686

   Chapters: 1 (Art. 1.1–1.3), 2 (Art. 2.1–2.2), 3 (Art. 3.1–3.4), 4 (Art. 4.1–4.3), 5 (Art. 5.1–5.4), 6 (Art. 6.1–6.3), 7 (Art. 7.1–7.2)

2. **Sarah Kaiser & Christopher Granade**, *Learn Quantum Computing with Python and Q#*, Manning Publications, 2021.
3. **Thomas G. Wong**, *Introduction to Classical and Quantum Computing*, Springer, 2022.
4. **Qiskit Textbook** (Open Source):*"Learn Quantum Computing using Qiskit"*, IBM Quantum(https://qiskit.org/learn/)

IBM Quantum Lab: https://quantum-computing.ibm.com

CUTM 2378: RESEARCH METHODOLOGY AND IPR

Subject Name	Code	Type of course	T-P-Pr (Credit)
Research Methodology and IPR	CUTM 2378	Theory+Project	**(2-0-2)**(04)

Objective

- To develop an appropriate framework for research studies
- To develop an understanding of various research designs and techniques.
- To identify various sources of information for literature review and data collection.
- To develop an understanding of the ethical dimensions of conducting applied research.
- To Demonstrate enhanced Scientific writing skills
- warn the common mistakes in the field of research methodology.
- To make expertise in academic writing, patenting
- Search, select and critically analyse research articles and papers
- Formulate and evaluate research questions
- Develop the ability to apply the methods while working on a research project work
- Describe the appropriate statistical methods required for a particular research design
- Choose the appropriate research design and develop appropriate research hypothesis for a research project

Course outcome

COs	Course outcomes
CO1	Develop skills in research design, and creating a structured research plan
CO2	Gain proficiency in data collection methods, statistical analysis, and interpretation of research findings
CO3	Understand and adhere to ethical principles in research ensuring compliance with ethical guidelines and regulations.
CO4	Acquire knowledge of IPR concepts and understand their importance in protecting intellectual property generated through research.
CO5	Explore strategies for managing and commercializing intellectual property to maximize the value of research outcomes

Course Outcome to Program Outcome Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	3	3								3	2	3
CO2	3	3	3	3	3								3	2	3
CO3	-	3	2	3	3								3	2	3
CO4	2	3	2	3	2								3	2	3
CO5	3	2	3	2	3								3	2	3

***High-3, Medium-2, Low-1**

Course outline

Module 1:Elementary Research Methodology

Research Concept, Objective, characteristics, Steps and Significance of Research, Arbitrary and Scientific Research, Research approaches. Types of research: Historical, Descriptive, Analytical, Case Study, Quantitative vs. qualitative, Conceptual, Empirical Action Research, Research Methods vs Methodology. Research Problems: Selection and definition of the research problems, formulating a research problem, identifying variables and Constructing hypothesis; Choosing a mentor, lab and research question; maintaining a lab notebook; Selection of problems - stages in the execution of research

Module II: Academic Writing and Presentation

Technical writing skills - types of reports; layout of a formal report; standard of Journal (Impact Factor, Citation Index), Scientific writing skills - importance of communicating science; problems while writing a scientific document; plagiarism, software for plagiarism; scientific publication writing: elements of a scientific paper including abstract, introduction, materials & methods, results, discussion, references; drafting titles and framing abstracts; publishing scientific papers - peer review process and problems, recent developments such as open access and non-blind review; characteristics of effective technical communication; scientific presentations; ethical issues; scientific misconduct.

Module III: Scientific communication skills

Concept of effective communication- setting clear goals for communication; determining outcomes and results; barriers to effective communication; non-verbal communication- importance of body language, power of effective listening; Presentation skills - formal presentation skills; preparing and presenting using over-head projector, PowerPoint; defending interrogation; scientific poster preparation & presentation; participating in group discussions; Computing skills for scientific research - web browsing for information search.

Module IV: Introduction to IPR

Introduction to intellectual property; types of IP: patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications, protection of new GMOs; IP as a factor in R&D; Intellectual property protection strategies for nanotechnology.

Module V: Types of Patents

Basics of patents: types of patents; Indian Patent Act 1970; recent amendments; WIPO Treaties; Budapest Treaty; Patent Cooperation Treaty (PCT) and implications; filing of a patent application; role of a Country Patent Office; precautions before patenting-disclosure/non-disclosure - patent application- forms and guidelines including those of National Bio-diversity Authority (NBA) and other regulatory bodies, fee structure, time frames; types of patent applications: provisional and complete specifications.

PROJECTS

1. Write a review article and submit to a journal
2. Write a book chapter/ book for publishing
3. Write an original article for a journal

Books:

1. Geoffrey Marczyk, David DeMatteo, David Festinger (2005) ***Essentials of Research Design and Methodology***, John Wiley & Sons, Inc.
2. Carol Ellison (2010) ***McGraw-Hill's ConcisevGuide to WritingvResearch Papers***, McGraw-Hill
3. Kothari CR (2016) ***Research Methodology: Methods and Techniques***, New Age Pvt Ltd
4. Ganbawale RM, (2017) ***Bioststistics and Research Methodology***, New Central Book Agency
5. Sinha, S.C. and Dhiman, A.K., (2002). ***Research Methodology***, EssEss Publications. 2 volumes.
6. Trochim, W.M.K., (2005). ***Research Methods: the concise knowledge base***, Atomic Dog Publishing. 270p.
7. Wadehra, B.L. (2000). ***Law relating to patents, trademarks, copyright designs and geographical indications***. Universal Law Publishing.

8. Neuman, W.L. (2008). ***Social research methods: Qualitative and quantitative approaches,*** Pearson Education