Centurion
UNIVERSITY
Shaping Lives...
Empowering Communities...

School of Applied Sciences

Centurion University of Technology & Management

M.Sc. (Physics) CBCS syllabus

(2020 Admitted Batch)

(Two years programme)

2021

M.Sc. Physics

(Two years programme 2021 admitted batch)

Semester Wise Course Structure				
Semester	**Basket-1**	**Basket-2**	**Basket-3**	
Sl. No.	**CORE COURSES (16)=Total 64 Credit**	**Domain** From Same/Related Discipline Minimum (Total 20-32 Credits)**	**Skill enhancement Courses (SEC)**	**Semester wise Credits**
I	**5 Core courses**	**Nil**	**Nil**	**Minimum 20**
II	**5 Core courses**	**Nil**	**SEC - 1**	**Minimum 24**
III	**3 Core courses**	**Domain Course of minimum 20 credits up to a maximum of 32 credits**	**SEC - 2**	**Minimum 26**
IV	**3 Core courses**		**SEC - 3**	**Minimum 26**
Total				**Minimum 96**
***A student can opt any of the one domain from domain basket offered by university depending on their stream/branch *A Student will opt one or more skill courses from Skill basket as per their credit requirement. * A non-credit value-added course will be opted by students during the two-year program**				**Maximum 100**

Code (Prefix"CUTM")	**Course Title**	**Credit**	**Type (T+P+Pj)**
1399	Energy storage materials	4	3+1+0
1400	Bio and bimimetic nanomaterials	4	3+0+1
1401	Photovoltaic technology and nanocatalysts	4	3+1+0
1402	Advanced characterization techniques	4	3+1+0
1403	Smart and electronic materials	4	3+0+1
1404	Corrosion and advanced coating application	4	3+0+1
1405	Synthesis and application of nano composites	4	3+1+0
1406	Material behavior of nanostructures	4	3+1+0
1407	Emerging materials	4	3+0+1
1408	Synthesis routes of nanomaterials	4	3+1+0
1409	Computational materials science	4	2+2+0
1410	Plasma technology	4	3+0+1
1411	Essentials of nanomaterials	4	3+1+0
1412	Advanced quantum mechanics	4	2+0+2
1413	Physics of solids and semiconductors	4	3+1+0
1414	Laser technology	4	2+1+1

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.

.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Understand the usage of nano-materials in various battery applications.	PO1-3, PO2-3, PO3-1,PO7-2, PO9-2
CO2	know the utilization of next generation super-capacitors and its applications.	PO1-3, PO2-3, PO3-2, PO7-1, PO9-1
CO3	Use of nanomaterials in fuel cell, TEM system and hydrogen production	PO3-3, PO7-2, PO9-1
CO7	Understand various renewable energy sources and their use	PO7-3, PO9-1

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:

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

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1400	Bio and Biomimetic Nanomaterials	3-0-1	Nil

Course Objective

- Gain knowledge about biomaterials, their properties, behavior, interaction and use of them over in pharmaceutical science.
- The emphasis of course is to understand the physics of biomaterials in detail and to explore the wide application.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Understand the fundamental concepts of biomaterials and their biomedical applications.	PO1-3, PO2-1, PO7-3, PO9-1
CO2	Use the knowledge for higher study and research	PO1-3, PO2-2, PO7-2, PO9-2
CO7	Explore the possible physics research and their applications in society and health care units	PO2-3, PO7-3, PO9-2

Course outline

Module-I:Fundamentals **(4 Hours Theory)**

Definition of biomaterials, requirements & classification of biomaterials, Properties of biomaterials

Module-II: Metallic Implant Materials **(5 Hours Theory+ 2 Hours Assignment)**

Stainless steel, Co-based alloys, Ti and Ti-based alloys. Importance of stress-corrosion cracking.

Assignment-1: Orthopedic implants

Module-III:Polymeric Implant Materials **(5 Hours Theory+ 2 Hours Assignment)**

Classification according to thermosets, thermoplastics and elastomers. Importance of molecular structure, hydrophilic and hydrophobic surface properties, Biodegradable polymers for medical purposes

Assignment-2: Dental implants

Module-IV:Ceramic Implant Materials **(5 Hours Theory+ 2 Hours Assignment)**

Definition of bioceramics, common types of bioceramics, the importance of wear resistance and low fracture toughness

Assignment-3: Soft tissue replacement implants

Module-V: Biocompatibility & Toxicological Screening of Biomaterials (5 Hours Theory+ 2 Hours Assignment)

Biocompatibility & toxicological screening of biomaterials

Assignment-4: Percutaneous and skin implants

Module-VI: Biomimetic **(3 Hours Theory+ 2 Hours Assignment)**

Inspiration from animals, self-healing materials

Assignment-5: Vascular implants

Module-VIIBiomimetic in Photonics **(3 Hours Theory+ 2 Hours Assignment)**

Biomimetic in photonics, various applications of Biomimetic

Assignment-6: Heart valve implants

Total theory 32 hours and total project 12 hours

Text Books:

1. Biomimetic Biomaterials Structure and Applications by Andrew Ruys,

   ISBN: 9780857094162

2. Biomimetics in Photonics by Olaf Karthaus, ISBN 9781439877463

Code	**Course Title**	**T-P-Pj (Credit)**	**Prerequisite**
CUTM 1401	Photo-Voltaic Technology & Nano-Catalysis	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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	To obtain adequate knowledge regarding several photovoltaic technologies and its various applications in nano-scale.	PO1-3, PO2-3, PO3-2, PO7-2
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.	PO1-1, PO2-3, PO7-2, PO9-2
CO3	To gain various internship opportunities in Photovoltaic start-up & R &D organizations.	PO3-3, PO6-2,PO7-2, PO9-2

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, Miro Zeman.
- Nanomaterials in catalysis; Philippe Serp, KarinePhilippot.

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1402	Advanced Characterization Techniques	3-1-0	Nil

Course Objective

- The objective of the subject is that the student acquires knowledge of the different existing experimental techniques for the microstructural and physicochemical characterizations of materials.
- Students gain knowledge about the principles of various techniques.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO2	To gain sufficient criteria to select the most appropriate technique for characterization, as well as the interpretation of their results.	PO1-3, PO2-3, PO4-2, PO9-2
CO3	To optimize material research and and make ready them for higher R &D and enhance their technical knowledge for	PO3-3, PO4-2, PO6-3

	employability in handling different advanced characterization techniques.	

Course outline

Module-I **(3 Hours Theory+4 Hours Practice)**

Compositional and Structural Characterization

Principle of X-ray diffraction (XRD), Importance of Rietveld refinement in XRD (fundamental), Lattice parameters, Structure analysis, Phase identification, Crystallite size analysis using Scherrer's formula,X-ray photoelectron spectroscopy (XPS), X-ray fluorescence (XRF), Energy dispersive X-ray analysis (EDAX).

Practice-1

Crystal structure and phase identification determination by XRD (Biovia MS and phase identification by using relevant software)

Practice-2

Study on molecular spectroscopy by fluorescence instrument

Module-II **(5 Hours Theory)**

Advanced Microscopy Techniques for Nanomaterials

Field emission scanning electron microscope (FESEM), Atomic force microscopy (AFM), Scanning tunneling microscopy (STM), Transmission electron microscopy (TEM), High-resolution transmission electron microscopy (HRTEM).

Module-III **(5 Hours Theory+4 Hours Practice)**

Spectroscopic Techniques

Ultraviolet-visible spectroscopy, Photo-luminescence spectroscopy, Fourier transform infrared (FTIR) spectroscopy, Raman spectroscopy, Nuclear magnetic resonance (NMR).

Practice-3

Familiarization with the ultraviolet-visible absorption spectroscopy

Practice-4

Band gap calculation from photo-luminescence spectra

Module-IV **(4 Hours Theory)**

Nanomaterials Electrical and Magnetic Characterization Techniques

Measurement of resistivity by 4-probe method, Hall measurement, Measurement of magnetic of properties of nanomaterial (Magnetic hysteresis and dielectric properties by LCR meter),Vibrating sample magnetometer.

Module-V **(5 Hours Theory+4 Hours Practice)**

Mechanical Characterization Techniques

Elastic and plastic deformation-mechanical properties of materials, models for interpretation of nanoindentation load-displacement curves, Nanoindentation data analysis methods-Hardness testing of thin films and coatings, Mechanical properties evaluation by universal testing machine (UTM), Dynamic mechanical analysis.

Practice-5

Evaluation of mechanical properties of material by nanoindentation technique

Practice-6

Measurement of tensile strength of material by UTM

Module-VI **(4 Hours Theory)**
Physical and Optical Characterizations of Nanostructured Materials
Introduction to particle size characterization, Zeta potential measurement – Particle size analysis, specific surface area by BET analysis, Photoconductivity.

Module-VII **(4 Hours Theory)**
Thermal and Electrochemical Characterization
Differential scanning calorimeter (DSC), Differential thermal analyzer (DTA), Thermogravimetric analysis (TGA), Electrochemical analysis (Charging-discharging cyclic voltammetry).
Total theory 30 hours and total practice 12 hours

Reference Books:
1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd., 2008.
3. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
4. Nanotechnology-Basic Science and Emerging Technologies, Mick Wilson, KamaliKannangra Geoff Smith, Michelle Simons and BurkhardRaguse, Overseas Press.

Code	**Course Title**	**T-P-Pj (Credit)**	**Prerequisite**
CUTM1403	Smart and Electronic Materials	3-0-1	Nil

Course Objective

- To acquaint with various kinds of smart materials for device application
- To have the knowledge about the different types of structure of the materials which affect their properties
- To understanding the theories behind electric and magnetic properties
- To use the nanotechnology in electronics
- Application of different kinds of materials

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Capable of gaining the knowledge about different kinds of materials	PO1-3, PO2-1, PO3-1
CO2	Capable of research problem solve	PO1-1, PO2-2, PO3-1,
CO3	Understand the structure property relation of materials.	PO1-1, PO2-2, PO3-3

Course outline

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

Introduction: Overview of smart materials, Sensors and actuators, Pyroelectrics, Piezoelectrics, Electrostrictors, Magnetostrictors, Electrochromic, Shape memory alloys

Assignment-1
Application of high-k dielectric materials and Topological insulators

Module II **(4 Hours Theory+ 2 Hours Assignment)**
Structure Property Relation: Structure phase transition of different types of materials and their properties such as Perovskite structure materials, Tungsten Bronze, Aurivillius structure materials**,**

Assignment-2
Electrical properties of Pyrochloro-type Materials and hexaferrite materials

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

Multiferroic and Magneto electric Materials: Multiferroic materials, Ferroelectric materials, Ferromagnetic materials, Ferroelastic materials, requirement for multiferroic materials. Magnetoelectric material and ME coefficient

Assignment-3
Origin of magnetism, Ferro-, Antiferro-, Ferri-magnetic materials and their application
Module IV **(5 Hours Theory)**

Nanoelectroinc: Overview of nano electronics, Quantum dots, Quantum wire and Quantum well, 2D Materials: Graphene

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

Spintronics: Introduction to spintronics, Generation of Spin Polarization, Theories of spin Injection, Spin accumulation, spin relaxation, Spin current, Spin hall effect and spin dephasing,

Assignment-4
Spintronic devices and applications
Module VI **(4 Hours Theory+ 2 Hours Assignment)**

High Temperature Superconductor: Discovery and experimental facts of superconductor, High TC superconductors, High-Tc Superconducting Oxides: Structure, properties, comparison on the basis of BCS Theory, Structure and properties of Iron based High temperature superconductor

Assignment-5
Structure, properties and application of Hg and Fe based High temperature superconductor
Module VII **(5 Hours Theory+2 Hours Assignment)**

Application: Sensors (conductive sensor, capacitive sensor), Optoelectronics, Supercapacitors, Radiofrequency identification

Assignment-6
Development of solar energy devices, silicon solar technology for clean energy

Total theory 30 hours and total assignment 12 hours

Reference Books:

4. .Dielectric Phenomena in Solids by Kwan Chi Kao,Academic Press,2004
5. High Temperature Superconductivity: The Road to Higher Critical Temperature by Shin-ichi Uchida, Springer Japan 2015

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	To understand the knowledge on surface coating and engineering.	PO1-3, PO4-2,PO7-2, PO9-2
CO2	To pursue higher study/research on surface technology	PO2-3, PO5-2,PO7-1
CO3	Surface coating and surface modification for different practical application.	PO3-3, PO4-2, PO6-3, PO9-2

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, Intergranular corrosion,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
5. https://www.hindawi.com/journals/ijc/2018/4749501/

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM 1405	Synthesis and Application of Nanocomposites	3-1-0	

Course Objectives

- To provide knowledge of the advantages of using different types of nanocomposites.
- To make the students familiar with the mechanism of nanocomposites.
- To make them aware the manufacturing and testing methods of nanocomposites.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	understand and appreciate the significance of the nanocomposites as an important class of materials	PO1-3, PO2-1, PO3-1
CO2	Capable of research problem solve	PO1-1, PO2-3, PO3-1,
CO3	Understand the design and develop nanocomposites	PO1-1, PO2-1, PO3-3
CO7	Environment and Sustainability	PO1-1, PO2-2, PO3-1, PO7-3

Course content

Module-I: Introduction to Nanocomposite Materials(5 Hours Theory)

Definition of nanocomposites, Classification based on matrix and topology, Constituent of nanocomposites, General characteristics of particle reinforced composites- classification, Terminology used in fiber reinforced composites, Core-Shell nanocomposites

Module-II: Basic Constituents materials in Nanocomposites (4 Hours Theory)

Role and Selection of reinforcement materials, Glass fibers, Carbon fibers, Boron Fibers, Natural fibers, Multiphase fibers, Aramid fibers

Module-III: Fabrication of various types Nanocomposites(5 Hours Theory)

Ceramic/Metal nanocomposite Systems, Nanocomposites based on polymer matrix, Carbon carbon, Carbon-metal nanocomposites, Bio-inspired nanocomposites

Module -IV: Nanocomposite Processing Methods (4 Hours Theory+4 Hours Practice)

Nanocomposite processing: In-situ polymerization technique, Solution casting, Electro spinning, melt mixing, Filament Winding, Injection and compression molding, Vacuum bag moulding Method, Pultrusion Process

Practice 1: Synthesis of polymer nanocomposite using solution casting techniques

Practice 2: Preparation of different polymer blends using BIOVIA materials studio

Practice 3: Fabrication of nanocomposite fibers using electro spinning technique

Module -V: Mechanical Properties -Stiffness and Strength (4 Hours Theory)

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

Module -VI: Application of Nanocomposites I (4 Hours Theory+4 Hours Practice)

Application of Nanocomposites in Aerospace, Coating, Mechanical, Electrical & Electronics, Fuel cell

Practice 4: Determination of tensile properties of nanocomposite

Practice 5: Determination of Dielectric constant for a given nanocomposite material

Module -VII: Applications of Nanocomposites II (4 Hours Theory+4 Hours Practice)

Hybrid Nanocomposite materials for food packaging, graphene-carbon nanotube nanocomposite for energy storage applications, Nanocomposites for solar cells, Nano composite materials for Lithium ion battery.

Practice 6: Synthesis of Graphene Oxide by Modified Hummer's Technique

Practice 7: Studies on Dye Sensitized Solar Cell

Text Books:

- Composite Polymeric Materials – Sheldon
- Lubin - Handbook of composites – (Van Nostrand, 1982)
- Carbon Nanotube and Graphene Device Physics, by H.-S. Philip Wong (Author), DejiAkinwande (Author)
- K. Chawla, Composite Materials – Science &Engg., Springer- Veslag, New York, 1988.
- Mohr - SPIE Handbook of Technology and Engineering of Reinforced Plastics/Composites – (Van Nostrand, 1998)

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1406	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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	To familiarize about the various properties of nanostructures.	PO1-3, PO23, PO9-2
CO2	To bring out the differences between nano and macro structures.	PO2-3, PO3-1, PO9-2
CO6	To discuss applications and specific properties of nanomaterials	PO6-3, PO7-2

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	understand and appreciate the microscopic and macroscopic scales	PO1-3, PO2-3, PO3-2
CO3	Understand the manufacturing processes and recent technological developments	PO1-3, PO2-2, PO3-3, PO7-2
CO7	Environment and Sustainability	PO1-3, PO2-2, PO3-3, PO7-2

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

Total theory 30 hours and total project 12 hours

Code	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM1408	Synthesis Routes of Nanomaterials.	3-1-0	Nil

Course Objective:

- To equip the students with the concepts of synthesis routes in nanoscience that he/she needs for understanding theoretical treatment in different courses taught in this class and for developing a strong background to pursue research in Nanotechnology as a career.
- This course is intended to cover the two groups of synthesis of nanostructures namely top-down and bottom-up approach various synthesis methods, including biological methods, advantages and disadvantages etc.

Course Outcomes:

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	understand and appreciate the significance of the nanomaterials as an important class of materials	PO1-3, PO2-2, PO3-2
CO2	Capable of research problem solve	PO1-1, PO2-2, PO3-3,
CO3	Understand the design and develop nanomaterial	PO1-2, PO2-2, PO3-3, PO7-3
CO7	Environment and Sustainability	PO1-2, PO2-1, PO3-2, PO7-3

Course outline

Module-I **(4 Hours Theory)**

Introduction : Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples-Trapped particles-quantum dots and artificial atoms-quantum wires and quantum wells. Conductivity and enhanced catalytic activity compared to the same materials in the macroscopic state.

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

Physical Methods: Inert gas condensation, RF-plasma, MW plasma, Ion sputtering, Laser ablation, Laser pyrolysis, Ball milling, Molecular beam epitaxy, Electro-deposition.

Practice-1: Ball-miling method of synthesis of nanomaterials.

Module -III **(4 Hours Theory)**

Chemical Methods (I): Chemical precipitation and co-precipitation, Sol-Gel synthesis; Microemulsions synthesis, Hydrothermal, Solvothermal synthesis methods.

Module - IV **(4 Hours Theory)**

Chemical Methods (II): Microwave assisted synthesis Core-Shell nanostructure, Quantum dot (QDs) synthesis, Sonochemical, Ultraviolet, Sonication

Module-V **(6 Hours Theory)**

Thermolysis Route: Flame spray pyrolysis, Flame spray Hydrolysis, solvated metal atom dispersion, hydrothermal routes, solution combustion synthesis, reaction types, boundaries and flow, PVD, CVD.

Module VI: **(2 Hours Theory+ 2 Hours Practice)**
Different Lithography Route: M based nanolithography and nanomanipulation, E beam lithography and SEM based nanolithography and nanomanipulation, Ion beam lithography, X-ray based lithography.

Practice 2: Electron beam lithography.

Module VII (**5 Hours Theory+ 8 Hours Practice)**

Preparation of Some Special Nanomaterials: Preparation of metal nano particles like gold, silver, Iron and Copper, different types of nanooxides, TiO_2, ZnO etc.

Practice-3: Synthesis of TiO2 nanotubes by hydrothermal method.

Practice-4: Synthesis of copper nanoparticles.

Practice-5: Synthesis of gold nano particles.

Practice-6: Synthesis of ZnO nano particles by sol-gel route.

Total theory 30 hours and total practice 12 hours.

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 Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India PvtLtd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham.

4. Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; NakKim;Frank Shepherd.

Reference Books:

1. Encyclopedia of Nanotechnology by M.Balakrishna Rao 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.

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

Course Objective

- Expose the students to the challenges in the analyses of materials and how to address those challenges
- Impart practice of developing Toy Models of Molecular Dynamics, HartreeFock and Density Functional Theory in Python for small scale systems using various Pseudo-Potentials
- Hands-on training on open source tools in Molecular Dynamics (LAMMPS) and Hartree-Fock and Density Functional Theory (Quantum Espresso); Data Visualization Tools like OVITO and VMD

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Get an idea of the issues and challenges involved in calculations of atomic, molecular and bulk properties of materials and how to approach their resolution using open source classical and quantum mechanical tools	PO1-3, PO4-2, PO5-2
CO2	Code and execute concepts of Molecular Dynamics, Monte Carlo Methods in Molecular Dynamics and derive thermodynamic properties of materials ensuing from Classical Statistical Mechanics	PO2-3, PO5-2,
CO5	Code and execute concepts of HartreeFock Theory and Density Functional Theory using Python and derive various molecular and bulk material properties ensuing from electronic structure calculations involving Quantum	PO5-3

	Mechanics and Quantum Statistics	
CO6	Use open source software like LAMMPS, Quantum Espresso, OVITO and VMD for analysis and visualization of various types of materials and their properties.	PO6-3, PO9-2

Course outline

Module I **(2 Hours Theory + 3 hours Practice)**

Models of Molecular Interactions: Model Van der Waals interaction potentials between neutral atoms and molecules: The Lennard-Jones potential, Other Van der Waals Interactions: the Buckingham Potential, the Stockmayer Potential

Practice (1 hour sessions):

1. Understanding the Lennard-Jones (LJ) Potential and its Parameters
2. Python simulation of Equation of State of Ideal Gases using LJ Interaction
3. Python simulations of Equation of State of Ideal Gases with Buckingham and Stockmayer Potentials

Module II

Molecular Dynamics **(3 Hours theory + 4 hours Practice)**

Molecular Dynamics theory and numerical implementation, Statistical Ensembles and Molecular Dynamics, Diffusion and Osmosis.

Practice (1 hour sessions):

4. Thermodynamics of a Real Gas using LJ potential using Python
5. Introduction to Molecular Dynamics in LAMMPS; Visualization using OVITO & VMD
6. Simulation of Diffusion in LAMMPS
7. Simulation of Osmosis using LAMMPS

Module III

Monte Carlo Methods **(6 Hours Theory + 5 Hours Practice)**

Monte Carlo Simulations, Metropolis algorithm, 2D Ising Model and its simulation, Phase Transitions, Monte Carlo Grand Canonical (MCGC) simulation of Lennard Jones (LJ) Fluid Flow and Heat Transfer

Practice (1 hour sessions):

8. Introduction to Monte-Carlo-Metropolis Algorithm: Python Implementation
9. Simulation of 2D-Ising Model using Monte-Carlo-Metropolis algorithm
10. Simulation 0f Phase Transitions Using LAMMPS
11. Simulation of Lennard-Jones (LJ) Fluid Flow Using LAMMPS
12. Thermal Conductivity and Viscosity simulation using LAMMPS

Module IV

HartreeFock Methods: (3 Hours Theory+4 Hours Lab)

The Variational Principle, The Hartree Approximation, The Hartree-Fock Approximation, Electron Density Distribution in Many-Electron atoms and simple Di-atomic molecules, Beyond HF Theory: Coupled Cluster Approximation

Practice: (1 hour)

13. Introduction to HartreeFock Implementation in Python
14. Creation of data files and running the HF code
15. Electron Density Distribution in H, He, Li atoms
16. Electron Density Distribution in simple diatomic molecules: H2, N2, O2, CO

Module V

Density Functional Theory-I (2 Hours Theory)

Introduction to Density Functional Theory, The Hohenberg-Kohn Theorems, The Kohn-Sham Theory, Numerical Implementation

Module VI

Extensions of Density Functional Theory (2 Hours Theory)

The Local Density Approximation (LDA), The Generalized Gradient Approxiamtion (GGA) , Meta GGA, Adiabatic Connctions-Hybrid Orbitals, Perdew–Burke-Ernzerhof (PBE) Approximation, the Born-Oppenheimer Molecular Dynamics (BOMD), the Car-Parrinello Molecular Dynamics (CPMD)

Module VII (2 Hours Theory+8 Hours Practice)

Introduction to Quantum Espresso: Modules and Possibilities

Practice (1 hour sessions)

17. Introduction to Quantum Espresso software: Implementation of DFT

18. Loading Data Files and Execution of Quantum Espresso; Interpretation of Output

19. Ground State Electron Density Distributions in C, N, O using LDA

20. Ground State Electron Density Distribution in C, N, O, Si using GGA, Meta GGA, PBE

21. Ground State Properties of Simple Molecules like N2, O2, H2O, CO2

22. Material Property Simulations in DFT with LDA/GGA/Meta GGA/PBE and their various combinations

23. Liquid-Gas Phase Transition Simulations in Born-Oppenheimer Molecular Dynamics

24. Liquid-Gas Phase Transition Simulations in Car-Parrinello Molecular Dynamics

Total theory 20 hours and total practice 24 hours

Textbook:

1. Introduction to Computational Materials Science, Richard LeSar, (Cambridge University Press, 2016).
2. 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).

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	understand fundamental plasma parameters, under what conditions an ionized gas consisting of charged particles	PO1-3, PO2-2, PO3-2
CO2	Capable of research problem solve	PO1-3, PO2-2, PO3-3,
CO3	Understand the application in materials and surface engineering,	PO1-3, PO2-2, PO3-3, PO7-3
CO7	Environment and Sustainability	PO1-1, PO2-3, PO3-2, PO7-3

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	Course Title	T-P-Pj (Credit)	Prerequisite
CUTM 1411	Essentials of Nanomaterials	3-1-0	Nil

Course Objective

- Understand and use the properties of Nano-materials in diverse fields.
- Gain knowledge about the Nanomaterials, their properties, behavior, interaction and use of them over many discipline of science.
- The emphasis of the course is to understand the physics of Nanomaterials in detail and to explore the wide application.
- Highlights of the course is to provide virtual way of understanding the courses materials. Especially the application based approach.

Course outcome

COs	Course outcomes	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Understand the constituents of matter, Nanomaterials, properties and usefulness. Able to learn how to understand the basic behavior of Nanomaterials	PO1-3, PO7-2, PO9-2
CO2	Able to use the knowledge for higher study and research	PO2-3, PO3-2, PO7-1,
CO7	Able to explore the possible physics research, their applications in society and health care unit.	PO7-3, PO9-2

Course outline

Module I **(4 Hours Theory)**

Fundamentals of Nanomaterials: Introduction to Nanomaterials, Definition of Nano, Atomic Structure and atomic size, significance of nano material over micro/macro, size dependent roperties.

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

Material structure and the Nano-surface: Importance of surface at Nanoscale, Significance of Particle shape and Size in Nanomaterials, Surface to Volume Ratio, Particle orientation.
Practice 1: Polarization of light

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

Energy at the Nanoscale: Surface energy, surface energy of Liquids, surface energy of solids, Surface energy of crystallographic planes in fcc& bcc, surface energy minimization mechanism.
Practice 2: Surface tension of liquid

Module IV **(6 Hours Theory+ 6 Hours Practice)**

Nanostructured Materials : Zero Dimensional: Nano particles through homogenous nucleation; Nano particles through heterogeneous nucleation, Quantum Dots; One Dimensional: Nano wires and nano rods, Two dimensional: Fundamentals of film growth; Carbon Nanotubes. hierarchal structure, Quantum size effect and scaling law
Practice 3: Particle/wave nature of particle
Practice 4: Quantum dot
Practice 5: Quantum tunneling

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

Nano thermodynamics: Classical equilibrium in thermodynamics, Nano Thermodynamics, Modern Nano Thermodynamics. hermodynamics of surfaces: surface and interfacial energy, uses of Wulff plot.
Practice 6: Seebeck effect

Module VI **(5 Hours Theory)**

Chemical interaction at the Nanoscale: Long range and short range order forces, electrostatic forces, hydrogen bonding, Vanderwaal forces, hydrophobic forces

Module VII **(7 Hours Theory)**

Essentials of nanoscience in diverse Emerging area : Nano-electromechanical systems, Nano sensors, Nano Optics, Nano-electronics, Nano medicine, environmental, health and safety issues.

Total theory 36 hours and total practice 12 hours

Text Book:

1. Introduction to nanoscience by G.Louis Hornyak
2. Introduction to nanotechnology by C. P. Poole

References:

1. NPTEL (Nano materials)
2. MIT (Nano material)

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO5	Solve Schrodinger's equation for different systems using WKB method, Variational method and perturbation method	PO1-3, PO2-2, PO5-3
CO6	To write Python code to solve Schrodinger's equation and find energy eigen values	PO2-2, PO6-3

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:

3. Advanced Quantum Mechanics by Satyaprakash, S Chand Publications

Reference Books:

6. Quantum Mechanics: Concepts and Applications by NouredineZettili
7. Introduction to Quantum Mechanics, D J Griffith, Pearson, 2014.
8. Modern Quantum Mechanics, J.J. Sakurai, Pearson, 2013.

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	understand crystal structures in terms of the crystal lattice and the basis of constituent atoms	PO1-3, PO2-2, PO3-2
CO2	Understand the origin of energy bands in solids	PO1-3, PO2-2, PO3-3,
CO3	Understand the electronic structure and optical and transport properties	PO1-3, PO2-2, PO3-3, PO7-3
CO7	Environment and Sustainability	PO1-1, PO2-3, PO3-2, PO7-3

Course outline

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

Structure of Solids

Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell, Symmetry operations and classification of 2- and 3-dimensional Bravais lattices, point group and space group (information only). Common crystal structures- NaCl and CsCl structure, Close-packed structure, Zinc blende and Wurtzite structure, tetrahedral and octahedral interstitial sites, Spinel structure. Crystal diffraction by X-ray, Anomalous scattering. Atomic and geometric structure factors, systematic absences. Reciprocal lattice and Brillouin zone, Electron and neutron scattering by crystals (qualitative discussion)

Practice-1

V Lab: To study various crystals structures

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

Band Theory of Solids

Bloch equation, Empty lattice band, Number of states in a band, Effective mass of an electron in a band, Concept of holes, Electronic band structures in solids, Nearly free electron model.

Practice-2

Determination of band gap of semiconductor by Four probe method

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

Lattice Dynamics

Tight binding method - application to a simple cubic lattice, Band structures in copper, GaAs and silicon, 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

Optical properties of ionic crystal in the infrared region, Inelastic scattering of neutron by phonon, Lattice heat capacity, Debye and Einstein models-omparison with electronic heat capacity, Anharmonic effects in crystals - thermal expansion.

Practice-4

Determination of specific heat of solids (copper, glass and lead)

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

Dielectric Properties of Solids

Electronic, ionic and orientationalpolarisation, Static dielectric constant of gases and solids, ClaussiusMossotti relation, Complex dielectric constant and dielectric losses, Relaxation time, Debye equations, Cases of distribution of relaxation time, Cole - cole distribution parameter, Dielectric modulus, Ferroelectricity, Displacive phase transition, Landau Theory of Phase transition.

Practice-5

Determination of dielectric constant of air, glass and polystyrenes

Module VI **(4 Hours Theory)**

Imperfections in Solids

Frenkel and Schottky defects, Defects by non-stoichiometry, Electrical conductivity of ionic crystals, Classifications of dislocations, Role of dislocations in plastic deformation and crystal growth, Colour centers and photoconductivity, Luminescence and phosphors, Bragg - Williams theory, Order-disorder phenomena.

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

Semiconductors

Kronig Penny model (no derivation required). Band gap. Conductor, semiconductor (P and N type) and insulator. Conductivity of semiconductor, Mobility, Direct and indirect band gap semiconductors and their behaviour to external field, Types of semiconductors, Charge carriers, Intrinsic and extrinsic materials, Carrier concentration, Fermi Level, Electron and hole concentration equilibrium, Temperature dependence of carrier concentration, Compensation and charge neutrality. Conductivity and mobility, Effect of temperature, Doped semiconductors, Doping and high electric field.

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	Mapping COs with POs (High-3, Medium-2, Low-1)
CO1	Describe and explain fundamental concepts in laser physics	PO1-3, PO2-2, PO9-2
CO2	Compare the function and properties of a number of common lasers	PO2-3, PO3-2, PO6-2
CO3	Verify properties of materials used for laser production	PO3-3, PO6-2

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:

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

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

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

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