



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

M.Sc.
Applied Physics Syllabus
(Two Years Programme)

School of Applied Sciences

**Centurion University of Technology
& Management**

2022

DEPARTMENT OF PHYSICS

Code (Prefix" CUTM")	Course Title	Credit	Type (T+P+Pj)
1399	Energy Storage Materials	4	3+1+0
1400	Bio and Biomimetic 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
2377	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
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
2378	Research Methodology and IPR	4	2+0+2

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

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 to designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), supercapacitors.
- The students will also learn various types of batteries used in modern technology and the intercalation of nanomaterials inside them.

Course Outcome

- The students will be able to know the usage of nano-materials in various battery applications (Li ion battery, K ion battery, Na ion battery)
- The students will be able to know the utilization of next generation super-capacitors and its applications.
- The students will be able to understand the use of nanomaterials in fuel cells, various hydrogen storage systems, and thermoelectric materials.

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

Energy band gap calculation of a material using UV –Vis spectroscopy.

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: Energy storage density and efficiency calculation from PE loop.

Practice 3: XRD Analysis of a material having supercapacitor performance.

Module VII

(3 Hours Theory+8 Hours Practice)

Aluminium ion battery; Graphene battery; Sodium ion battery

Practice 4: Prediction of the thermodynamic properties of a material using BIOVIA Material Studio.

Practice 5: Determination of HOMO-LUMO of an energy storage material using BIOVIA Material Studio.

Practice 6: Effect of doping and its microstructural analysis towards exploring the energy storage property of material.

Total theory 30 hours and total practice 12 hours

Reference Books:

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

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

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

- The students will obtain fundamental concepts of biomaterials and their biomedical applications.
- Able to use the knowledge for higher study and research
- Able to explore the possible physics research and their applications in society and health care units.

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 (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-VII Biomimetic 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

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

- The students will be able to obtain adequate knowledge regarding several photovoltaic technologies and its various applications in nano-scale.
- The students will be able 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.
- The course will help the students to apply for various internship opportunities available in various Photovoltaic start-up organizations. Also this course is a boost for the students to apply into various R&D organizations to work as a project scholar.

Course outline

Module I

(4 Hours Theory + 4 Hours Practice)

Electro-Magnetic visible spectrum, Optical absorption, Directbandgap & indirect bandgap semiconductors, Minority carrier transport properties

Practice 1: Calculation of optical absorption coefficient of a photovoltaic material using BIOVIA Material Studio.

Practice 2: Calculation of reflectivity and optical conductivity of a photovoltaic material using BIOVIA Material Studio.

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: Calculation of electronic band gap of a photovoltaic material.

Practice 4: Calculation of real and imaginary part of dielectric function of a photovoltaic material by Biovia MS

Practice 5: VI characteristics of solar cell/module.

Practice 6: Structure analysis of multiferroic material for PV applications.

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; CO₂ 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
CUTM1402	Advanced Characterization Techniques	3-1-0	Nil

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

Upon successful completion of this course, students will be able to address following points:

- Depending on the problem or needs of each case, the student must have sufficient criteria to select the most appropriate technique, as well as the interpretation of their results.
- The knowledge gained from this subject definitely help students to optimize material research and and make ready them for higher R &D and enhance their technical knowledge for 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 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

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

- Students will capable of gaining the knowledge about different kinds of materials
- Students may aware about the structure property relation of materials
- Students may know the use of materials with response to external stimuli

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)

Nanoelectronic: 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, spin relaxation, Spin hall effect, Spin Injection.

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,

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

Textbook:

Reference Books:

1. Dielectric Phenomena in Solids by Kwan Chi Kao, Academic Press, 2004
2. 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

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 (chemical vapour 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

- Student can able to understand the knowledge on surface coating and engineering.
- Able to do surface coating and surface modification for different practical application.
- Able to pursue higher study/research on surface technology.
- Able to understand different surface coating technologies and their application.
- Able to use nano technology on surface coating for practical application

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

- Students will understand and appreciate the significance of the nanocomposites as an important class of materials.
- Students will be well equipped to design and develop nanocomposites for specialized applications.
- They will be able to predict the appropriate synthesis and application for different classes of nanocomposites
- This course will develop the career competency of students in composite materials and help them in joining R & D and industry based composite sector.

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, Nanocompositesbased 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
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 nanostructures.

Course Outcomes:

Upon successful completion of this course student should be able to:

- To familiarize about the various properties of nanostructures.
- To bring out the differences between nano and macro structures.
- To discuss applications and specific properties of nanomaterials.

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,

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

Mechanical Properties: Mechanical properties of nanocrystalline metals and alloys, Inverse Hall Petch effect. Types of indentation: Oliver & Pharr, Vickers indentation process.

Practice-1: To calculate the compressibility of a mild steel using Universal Testing Machine

Module –III (5 Hours Theory+4 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 2: Seebeck effect.

Practice 3: Study of thermodynamical properies of nanomaterials using compitational method.

Module–IV

(4 Hours Theory+2 Hours Practice).

Luminescence Properties: Fluorescence/luminescence, Photoluminescence / fluorescence, Optically excited emission Electroluminescence, Laser emission of quantum dot, Phonons in nanostructures.

Practice-4: Photoluminescence study of nanomaterials.

Module–V

(5 Hours Theory+ 2 Hours Practice)

Electronic Properties :Energy bands and gaps in semiconductors,Excitons, Conduction electrons and dimensionality Fermi gas and density of states, Semiconducting nano particles.

Practice 5-: To study the electronic properties of nanomaterials using computational technique

Module–VI

(4 Hours Theory+ 2 Hours Practice)

Optical Properties: Optical properties , Photonic crystals, Defects in photonic crystals, Optical properties of semiconductors, Quantum dots.

Practice-6: To study the absorbance and bandgap of a material using UV-Vis Spectroscopy

Module -VII (4 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 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 nanomaterials -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

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

- Students will be able to describe the structure of emerging materials at the molecular, microscopic, and macroscopic scales.
- To acquaint the student with common manufacturing processes and recent technological developments that are used in creating products.
- To promote an understanding of the relationship between material structure, processing and properties.

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 spectroscopy of 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:

- The students will be exposed to various structure specific synthesis methods, their advantages etc.
- To know about Top-down to Bottom up approach techniques.
- To optimize the methods for specific material applications.

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. Types of nanomaterials, Dendrimer and Nanoshell

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

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

Practice-1: Ball-milling 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.

Autocombustion method, Electrospinning for nanofibre synthesis

Module - IV (4 Hours Theory)

Chemical Methods (II): Microwave assisted synthesis Core-Shell nanostructure, Quantum dot (QDs) synthesis, Sonochemical, Sono-chemical method, Electro-chemical synthesis

Module-V

(6 Hours Theory)

Thermolysis Route: Flame spray pyrolysis, Flame spray Hydrolysis, solvated metal atom dispersion, solution combustion synthesis, Microwave assisted thermolysis route, Physical vapor deposition (PVD), Chemical vapor deposition (CVD).

Module VI:

(2 Hours Theory+ 2 Hours Practice)

Different Lithography Route: nanomanipulation, E beam lithography and SEM based nanolithography and nanomanipulation, Ion beam lithography, X-ray based lithography.

Optical lithography, Scanning probe lithography.

Practice 2: Structural analysis of nanomaterials

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, TiO₂, ZnO etc.

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

Practice-4: Synthesis of copper nanoparticles.

Practice-5: Ag nanoparticles synthesis.

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.BalakrishnaRao and K.Krishna Reddy, Vol I to X,
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials – Understanding Nano Science 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

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

A student who completes this course should be able to:

- 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.
- Code and execute concepts of Molecular Dynamics, Monte Carlo Methods in Molecular Dynamics and derive thermodynamic properties of materials ensuing from Classical Statistical Mechanics
- 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 Mechanics and Quantum Statistics
- Use open source software like LAMMPS, Quantum Espresso, OVITO and VMD for analysis and visualization of various types of materials and their properties

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.

The London Potential

Practice (1 hour sessions):

1. Understanding the Lennard-Jones (LJ) Potential and its Parameters
2. Simulation of Equation of State of Ideal Gases using LJ Interaction
3. Simulations of Equation of State of Ideal Gases with Buckingham and Stockmayer, London Potentials.

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 Of 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, TheHohenberg-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

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

- Upon successful completion of this course the student should be able to
- Learn using fundamental plasma parameters, under what conditions an ionised gas consisting of charged particles (electrons and ions) can be treated as a plasma to set feasible criteria on the plasma-assisted processes.
- Assess relations between the process and properties of the treated surface and/or material.
- Assess suitability of individual kinds of plasma for application in materials and surface engineering, nanomaterial production applications and in environmental technologies.
- Understand application of plasma technology for eco-friendly future "green" energy.

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. Rosnagel, 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

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

On completion of this course students will be able to

- Solve Schrodinger's equation for different systems using WKB method, Variational method and perturbation method.
- To write Python code to solve Schrodinger's equation and find energy eigen values

Course outline

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

Time independent Perturbation Theory: Energy Shifts and Perturbed Eigen states, Nondegenerate 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

Assignment2:(Any one)

- Solve the problem 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.

Assignment3:(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 of Time 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 using 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:

1. Quantum Mechanics: Concepts and Applications by Nouredine Zettili
2. Introduction to Quantum Mechanics, D J Griffith, Pearson, 2014.
3. 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

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 discuss working & applications of basic devices.

Course Outcome

After learning the course the students will be able to

- Explain different types of crystal structures in terms of the crystal lattice and the basis of constituent atoms.
- Understand the origin of energy bands in solids.
- Explain the physical characteristics such as electronic structure and optical and transport properties, and current-voltage characteristics of semiconductors.
- Apply the knowledge of semiconductors to illustrate the functioning of basic electronic devices

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 diffraction 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, ClausiusMossotti 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 superconductivity

Magnetic properties of solids; quantum theories of dia, para and ferromagnetism, 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 their 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

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

After learning the course the students will be able to

- describe and explain fundamental concepts in laser physics
- compare the function and properties of a number of common lasers
- verify properties of materials used for laser production

Course outline

Module-I (3 hours theory, 2 hours 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:

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 laser astronomy 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, 4 hours 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 laser for cutting and drilling
- Application of excimer laser Photolithography and Medical purposes

Module-IV (3 hours theory, 2 hours 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, 2 hours 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)

Elementary ideas on application of Laser in Medical Science - Medical lasers, Laser diagnostic, Laser for general surgery, Laser Dentistry

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)**

Elementary ideas on -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:

4. Lasers Theory and Applications by K. Thyagarajan and A.K. Ghatak, Mcmillan (1981)
5. Laser Fundamentals, by William T. Silfvast, Cambridge University Press, 2008.
6. Principles of Lasers, by Orazio Svelto; Springer, 2009.
7. Industrial Applications of Lasers, by K. Koebner (ed.), Wiley (1984).

RESEARCH METHODOLOGY AND IPR

Code	Subject Name	Type of course	T-P-P	Prerequisite
CUTM2378	Research Methodology and IPR	Theory + Project	2-0-2	Nil

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

Course Outcome

- 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

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; IPs of relevance to nanotechnology and few case studies.

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 Concise Guide to Writing Research Papers*, McGraw-Hill
3. Kothari CR (2016) *Research Methodology: Methods and Techniques*, New Age Pvt Ltd
4. Ganbawale RM, (2017) *Biostatistics and Research Methodology*, New Central Book Agency
5. Sinha, S.C. and Dhiman, A.K., (2002). *Research Methodology*, Ess Ess 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