

SEMESTER-V

COURSE 11: INTRODUCTION TO SOLID STATE PHYSICS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

This course aims to introduce students to the fundamental principles of solid-state physics, including crystal structures, bonding, electrical and magnetic properties, and superconductivity. Emphasis will be given to theoretical understanding and experimental applications in real-world materials.

LEARNING OUTCOMES:

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

1. Understand the structure and classification of solids and determine crystal structures using lattice parameters and Miller indices.
2. Apply Bragg's Law and diffraction techniques to determine crystal structure and analyze reciprocal lattices.
3. Gain insight into dielectric behaviour of materials including polarization, dielectric constant, and dispersion relations.
4. Differentiate between magnetic materials and understand magnetic susceptibility, hysteresis, and energy loss.
5. Explore the phenomenon of superconductivity, its theoretical background, and practical applications.

UNIT I: CRYSTAL STRUCTURE AND BONDING

(9 hrs)

Types of solids: Crystalline and amorphous, Unit cell, lattice, basis – 1D, 2D, and 3D lattices, Bravais lattices (3D) and seven crystal systems, Miller indices – Planes and directions in crystals, Common crystal structures: Simple cubic, BCC, FCC packing fraction and coordination number. Types of bonding in solids: Ionic, covalent, metallic, molecular, and van-der Waals

UNIT II: X-RAY DIFFRACTION AND CRYSTAL STRUCTURE DETERMINATION

(9 hrs)

X-ray generation and properties (brief review), Bragg's Law – Derivation and physical meaning Laue's method and powder diffraction method (qualitative), Applications in structure determination, Reciprocal lattice – Concept and construction (2D and 3D)

UNIT III: DIELECTRIC PROPERTIES OF SOLIDS

(9 hrs)

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius-Mosotti Equation. Classical Theory of Electric Polarizability. Cauchy and Sellmeier relations. Complex Dielectric Constant.

UNIT IV: MAGNETISM IN SOLIDS

(9 hrs)

Dia, Para, Ferri and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss. Soft, Hard magnetic materials and their application.

UNIT V: SUPERCONDUCTIVITY

(9 hrs)

Introduction to Superconductivity, Experimental results-critical temperature, critical magnetic field, Meissner effect, London's Equation and Penetration Depth, Isotope effect, Type I and Type II superconductors, BCS theory, High T_C Superconductors. Applications of superconductors

REFERENCE BOOKS:

1. BSc Physics, Vol.4, Telugu Akademy, Hyderabad.
2. Introduction to Solid State Physics – Charles Kittel
3. Solid State Physics – S.O. Pillai, New Age International
4. Solid State Physics – R.L. Singhal, Kedarnath Ramnath
5. Solid State Physics – P.K. Palanisamy, Scitech Publications
6. Elements of Solid-State Physics – J.P. Srivastava
7. Fundamentals of Solid-State Physics – B.S. Saxena, R.C. Gupta, P.N. Saxena
8. Solid State Physics: Structure and Properties of Materials – M.A. Wahab

SEMESTER-V

COURSE 11: INTRODUCTION TO SOLID STATE PHYSICS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

To provide hands-on experience and simulations that enable students to visualize and experimentally verify the structural, dielectric, magnetic, and superconducting properties of solids using modern tools and techniques. This practical component helps reinforce theoretical concepts from the Solid-State Physics syllabus through real and virtual lab investigations

LEARNING OUTCOMES:

On successful completion of this practical course, students will be able to:

1. Determine the crystal structure of solids using powder diffraction data and verify Bragg's Law using simulation tools.
2. Visualize and analyze common crystal structures such as SC, BCC, FCC, and HCP using software tools like VESTA.
3. Identify Miller indices of crystallographic planes and directions in a cubic crystal system using hands-on models.
4. Measure and interpret the dielectric constant and understand dispersion behavior through Cauchy and Sellmeier relations.
5. Investigate magnetic properties including magnetic susceptibility and hysteresis behavior in ferromagnetic materials.
6. Demonstrate and understand the key experimental observations related to superconductivity, including the Meissner effect and critical parameters.

Minimum of 6 experiments to be done and recorded

1. **Determination of Crystal Structure Using Powder XRD Data**
Analyze diffraction peaks to identify crystal system and lattice constants.
2. **Verification of Bragg's Law using Simulation**
Simulate diffraction pattern and verify the Bragg condition $n\lambda=2d\sin\theta$
3. **Visualization of Crystal Structures (SC, BCC, FCC, HCP) using VESTA Software**
Explore unit cell geometry and atomic positions.
4. **Indexing of Planes and Directions in a Cubic Crystal using Models**
Understand Miller indices with 3D models or interactive tools.
5. **Calculation of Packing Fraction for Cubic Structures using Models or Spreadsheet**
Compute atomic packing efficiency for SC, BCC, FCC structures.
6. **3D Paper Models or Software-based Visualization of Miller Indices**
Use CrystalMaker, VESTA, or handmade cutouts for hkl planes.
7. **Manual Calculation of d-Spacings and 2θ Values for NaCl or KCl Crystals**
Apply Bragg's law calculations using data tables or Excel.
8. **Measurement of Dielectric Constant of Solid Materials**
Use parallel plate capacitors with different dielectrics and an LCR meter.

9. **Measurement of Capacitance of a Parallel Plate Capacitor with Various Dielectrics**
Explore effect of dielectric materials on capacitance.
10. **Simulation of Dispersion Curves using Cauchy and Sellmeier Relations**
Model wavelength dependence of refractive index using Python or Excel.
11. **Simulation of Complex Dielectric Function (ϵ' and ϵ'') vs Frequency**
Use computational tools to analyze dielectric response.
12. **Measurement of Magnetic Susceptibility using Quincke's Method**
Determine susceptibility using liquid column displacement.
13. **Measurement of Magnetic Susceptibility using Gouy's Method**
Use a balance and a magnet to measure force on a sample.
14. **Study of B-H Curve and Hysteresis Loop of a Ferromagnetic Material**
Plot magnetization versus magnetic field and observe hysteresis.
15. **Visualization of Ferromagnetic Domains (Using MOKE Images or Simulation)**
View domain patterns and switching behavior under field.
16. **Demonstration of Meissner Effect and Superconductivity (Real or Simulated)**
Show magnetic levitation or expulsion in superconductors.
17. **Simulation of London Penetration Depth vs Temperature**
Model how superconducting properties change near T_c .
18. **Virtual Lab: Superconductivity & Meissner Effect (Amrita/PhET/MIT)**
Explore superconducting concepts via interactive platforms.
19. **Measurement of Dielectric Constant of Solids using Low-cost Setups**
Combine affordable dielectrics, LCR meters, and manual measurements.
20. **Simulation of Bragg Diffraction with Adjustable Wavelength and Lattice Spacing**
Hands-on interaction with diffraction geometry and conditions.

SEMESTER-V

COURSE 12 A: ELECTRONIC INSTRUMENTATION

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

To introduce fundamental measurement principles, sensor technologies, signal conditioning, and electronic measurement tools. This course prepares students to operate, analyze, and troubleshoot basic instrumentation systems in physics and electronics laboratories.

LEARNING OUTCOMES:

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

1. Describe the basic characteristics of a measurement system and types of errors.
2. Classify and explain working principles of various sensors and transducers.
3. Design and analyze signal conditioning circuits using op-amps and filters.
4. Explain the operation of ADCs, DACs, and various display systems.
5. Use CRO/DSOs and signal generators to measure and analyze waveforms.

UNIT I: BASICS OF MEASUREMENTS

(9 hrs)

Measurement system: block diagram - Characteristics: Accuracy, precision, sensitivity, resolution, repeatability - Errors: Systematic, random, gross – causes and minimization - Standards of measurements: Primary, secondary, working standards

UNIT II: SENSORS AND TRANSDUCERS

(9 hrs)

Classification: Active vs passive, analog vs digital - Temperature sensors: Thermistor, RTD, thermocouple - Displacement sensors: LVDT, capacitive and resistive types - Strain gauge and piezoelectric transducers – principle and applications

UNIT III: SIGNAL CONDITIONING

(9 hrs)

Operational amplifier as signal conditioning element - Instrumentation amplifiers – basic configuration and applications - Bridge circuits: Wheatstone, Kelvin bridge – measurement of resistance - RC filters – low pass, high pass, band pass and band stop

UNIT IV: CONVERTERS AND DISPLAYS

(9 hrs)

ADC: Successive approximation, flash ADC – block diagrams and timing - DAC: Weighted resistor and R-2R ladder type - Digital displays: Seven-segment, dot matrix, LCD - Display drivers and interfacing concepts

UNIT V: SIGNAL OBSERVATION TOOLS

(9 hrs)

Cathode Ray Oscilloscope (CRO): Block diagram, CRT, vertical and horizontal deflection - Time base generator and triggering - Use of CRO in amplitude, frequency, and phase measurement - Function generators, signal generators – applications

Textbooks / References:

1. H.S. Kalsi – *Electronic Instrumentation*, Tata McGraw-Hill
2. A.K. Sawhney – *Electrical and Electronic Measurements and Instrumentation*, Dhanpat Rai
3. J. Helfrick & W.D. Cooper – *Modern Electronic Instrumentation and Measurement Techniques*, PHI
4. Albert D. Helfrick – *Instrument Transducers*, PHI
5. B.C. Nakra & K.K. Chaudhry – *Instrumentation, Measurement and Analysis*, McGraw-Hill

Student Activities for Electronic Instrumentation

1. **Sensor showcase:** Bring a working/defunct sensor from household gadgets and explain its type and function.
2. **Mini poster/chart:** “How an LVDT Works” or “ADC vs DAC in Real Devices.”
3. **CRO Skill Check:** Identify parts of a CRO and demonstrate triggering.
4. **Circuit Simulation Task:** Simulate filters or ADC circuits using free tools (Falstad, Proteus).
5. **Viva Drill:** Identify sensor types from specifications or photos.
6. **Hands-on Signal Generator:** Explore all waveform settings and applications.
7. **Build a Basic Digital Thermometer (Group Project)** using thermistor + op-amp.
8. **Quiz:** Based on bridge circuits, filtering ranges, and oscilloscope measurements.
9. **Function Generator Demo:** Connect to CRO, vary frequency, and record waveform changes.
10. **Sensor Datasheet Reading:** Interpret ratings, sensitivity, and output formats.

SEMESTER-V

COURSE 12 A: ELECTRONIC INSTRUMENTATION

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

To provide practical experience in using sensors, bridges, filters, and waveform measuring tools essential for real-time signal acquisition and processing in electronics and physics labs.

LEARNING OUTCOMES:

1. Operate and test temperature, displacement, and strain sensors.
2. Measure resistance using bridge circuits with calibration.
3. Construct and evaluate signal conditioning circuits such as filters and amplifiers.
4. Use CROs and function generators for time- and frequency-domain measurements.
5. Understand and implement ADC/DAC conversion and digital display interfaces.

Minimum of 6 experiments to be done and recorded

1. **Study of Thermistor or RTD characteristics:** Resistance vs temperature.
2. **Displacement measurement using LVDT:** Calibration and sensitivity analysis.
3. **Wheatstone bridge and Kelvin bridge:** Resistance measurement and balancing.
4. **Strain gauge measurement:** Bridge configuration and deformation sensitivity.
5. **RC filter circuits:** Design and test low-pass, high-pass, and band-pass filters.
6. **Instrumentation amplifier using op-amp:** Gain measurement and noise rejection.
7. **Analog to Digital Converter (ADC):** Using a basic ADC chip or simulation.
8. **Digital to Analog Converter (DAC):** Design using weighted resistor or R-2R ladder.
9. **Seven-segment display interfacing:** Display digits using BCD counter or logic circuit.
10. **Cathode Ray Oscilloscope (CRO):** Frequency and amplitude measurement of waveforms

SEMESTER-V

COURSE 12 B: SOLAR ENERGY AND ITS APPLICATIONS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

The objective of the course on Solar Energy and Its Applications is to provide students with a comprehensive understanding of solar energy technologies, their principles, and their applications. The course aims to develop students' knowledge and skills in harnessing solar energy for various purposes, including electricity generation, heating, and cooling.

LEARNING OUTCOMES:

After successful completion of the course, the student will be able to:

1. Understand Sun structure, forms of energy coming from the Sun and its measurement.
2. Acquire a critical knowledge on the working of thermal and photovoltaic collectors.
3. Demonstrate skills related to callus culture through hands on experience
4. Understand testing procedures and fault analysis of thermal collectors and PV modules.
5. Comprehend applications of thermal collectors and PV modules

UNIT - I: BASIC CONCEPTS OF SOLAR ENERGY

(9hrs.)

Spectral distribution of solar radiation, Solar constant, zenith angle and Air-Mass, standard time, local apparent time, equation of time, direct, diffuse and total radiations. Pyrheliometer - working principle, direct radiation measurement, Pyranometer-working Principle, diffuse radiation measurement, Distinction between the two meters.

UNIT - II: SOLAR THERMAL COLLECTORS

(9hrs.)

Solar Thermal Collectors-Introduction, Types of Thermal collectors, Flat plate collector – liquid heating type, Energy balance equation and efficiency, Evacuated tube collector, collector overall heat loss coefficient, Definitions of collector efficiency factor, collector heat-removal factor and collector flow factor, Testing of flat-plate collector, solar water heating system, natural and forced circulation types. Concentrating collectors, Solar cookers, Solar dryers, Solar desalinators.

UNIT - III: FUNDAMENTALS OF SOLAR CELLS

(9hrs.)

Semiconductor interface, Types, homo junction, hetero junction and Schottky barrier, advantages and drawbacks, Photovoltaic cell, equivalent circuit, output parameters, conversion efficiency, quantum efficiency, Measurement of I-V characteristics, series and shunt resistance, their effect on efficiency, Effect of light intensity, inclination and temperature on efficiency

UNIT -IV: TYPES OF SOLAR CELLS AND MODULES

(9hrs.)

Types of solar cells, Crystalline silicon solar cells, I-V characteristics, poly-Si cells, Amorphous silicon cells, Thin film solar cells-CdTe/CdS and CuInGaSe₂/CdS cell configurations, structures, advantages and limitations, Multi junction cells – Double and triple junction cells. Module fabrication steps, Modules in series and parallel, Bypass and blocking diode

UNIT – V: SOLAR PHOTOVOLTAIC SYSTEMS

(9hrs.)

Energy storage in PV systems, Energy storage modes, electrochemical storage, Batteries, Primary and secondary, Solid-state battery, Molten solvent battery, lead acid battery and dry batteries, Mechanical storage – Flywheel, Electrical storage – Super capacitor

References:

1. Solar Energy Utilization by G. D. Rai, Khanna Publishers
2. Solar Energy- Fundamentals, design, modelling and applications by G.N. Tiwari, Narosa Publications, 2005.
3. Solar Energy-Principles of thermal energy collection & storage by S.P. Sukhatme, TataMcGraw Hill Publishers, 1999.
4. Science and Technology of Photovoltaics, P. Jayarama Reddy, CRC Press (Taylor & Francis Group), Leiden & BS Publications, Hyderabad, 2009.
5. Solar Photovoltaics- Fundamentals, technologies and applications, Chetan Singh Solanki, PHI Learning Pvt. Ltd.,
6. Web sources suggested by the teacher concerned and the college librarian including reading material.
 - (a) https://courses.edx.org/c4x/DelftX/ET.3034TU/asset/solar_energy_v1.1.pdf
 - (b) [https://www.sku.ac.ir/Datafiles/BookLibrary/45/John%20A.%20Duffie,%20William%20A.%20Beckman\(auth.\)-Solar%20Engineering%20of%20Thermal%20Processes,%20Fourth%20Edition%20\(2013\).pdf](https://www.sku.ac.ir/Datafiles/BookLibrary/45/John%20A.%20Duffie,%20William%20A.%20Beckman(auth.)-Solar%20Engineering%20of%20Thermal%20Processes,%20Fourth%20Edition%20(2013).pdf)

SEMESTER-V

COURSE 12 B: SOLAR ENERGY AND ITS APPLICATIONS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

The objective of the practical course on Solar Energy and Its Applications is to provide students with hands-on experience and practical skills in working with solar energy systems, performing measurements and analysis, and implementing solar energy projects. The course aims to develop students' proficiency in solar energy system installation, maintenance, performance analysis, and practical application.

LEARNING OUTCOMES:

On successful completion of this practical course, students shall be able to:

1. List out and identify various components of solar thermal collectors and systems, solar photovoltaic modules and systems.
2. Learn the procedures for measurement of direct, global and diffuse solar radiation, I -V characteristics and efficiency analysis of solar cells and modules.
3. Demonstrate skills acquired in evaluating the performance of solar cell / module in connecting them appropriately to get required power output.
4. Acquire skills in identification and elimination of the damaged panels without affecting the output power in a module / array.
5. Perform procedures and techniques related to general maintenance of solar thermal and photovoltaic modules.

Practical (Laboratory) Syllabus:

Minimum of 6 experiments to be done and recorded

1. Measurement of direct radiation using pyrliometer.
2. Measurement of global and diffuse radiation using pyranometer.
3. Evaluation of performance of a flat plate collector
4. Evaluation of solar cell / module efficiency by studying the I – V measurements.
5. Determination of series and shunt resistance of a solar cell / module.
6. Determination of efficiency of two solar cells / modules connected in series.
7. Determination of efficiency of two solar cells / modules connected in parallel.
8. Study the effect of input intensity on the performance of solar cell / module.
9. Study the influence of cell / module temperature on the efficiency.
10. Study the effect of cell / module inclination on the efficiency.

Lab References:

1. Solar Photo voltaic- Alab training manual, C.S. Solanki et al., Foundation Books Publishers, 2012.

2. Laboratory Manual on Solar thermal experiments, HP Garg, TC Kandpal, Narosa Publishing House 2000.
3. Web sources suggested by the teacher concerned.
<https://renewablelab.niu.edu/experiments/solarPanel> Development of simple solar hot water collector: <https://www.youtube.com/watch?v=WP8H5IOTwYU>
<https://www.instructables.com/Solar-Water-Heater-From-Scratch/>

Suggested Co-Curricular Activities

1. Training of students by related industrial/ technical experts using guest lectures/ invited talks.
2. Assignments (including technical assignments like identifying components of a solar hot water and solar photovoltaic systems and their handling, operational techniques and maintenance procedures with safety and security)
3. Seminars, Group discussions, Quiz, Debates etc. on related topics.
4. Preparation of videos on thermal and photovoltaic systems and technical procedures.
5. Collection of brochures/figures/photos related to products and applications of solar energy and organizing them in a systematic way in a file.
6. Making a (i) solar panel (ii) solar light (iii) solar cooker (iv) solar oven (v) sola inverter at Home.
7. Visits to nearby solar thermal system as well as solar photovoltaic power stations, firms, research organizations etc.

SEMESTER-V

COURSE 12 C: FUNDAMENTALS OF NANOSCIENCE

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

The objective of this course is to introduce undergraduate students to the fundamental principles of nanoscience and nanotechnology, focusing on the unique properties of materials at the nanoscale and their widespread applications. The course aims to build conceptual understanding of size-dependent behavior, types of nanomaterials, characterization tools, and real-life applications, while also addressing ethical and societal considerations.

LEARNING OUTCOMES:

After successful completion of this course, students will be able to:

1. **Define nanoscience and nanotechnology** and explain the significance of nanoscale dimensions and surface-to-volume ratio in determining material behavior.
2. **Describe how physical and chemical properties change at the nanoscale**, including quantum effects, optical and thermal properties, and compare them with bulk material properties.
3. **Classify various types of nanomaterials** based on their dimensions (0D to 3D), composition, and synthesis, and understand the influence of size and shape on their functionality.
4. **Identify common tools used in nanoscience**, such as electron microscopes and light-based techniques, and explain their role and limitations in characterizing nanoscale materials.
5. **Recognize the applications of nanotechnology in everyday life**, including consumer products, packaging, environment, and healthcare, while reflecting on ethical and safety issues related to nanoscience.

UNIT I: INTRODUCTION TO NANOSCIENCE

(9 hours)

What is nanoscience and nanotechnology?, The nanoscale: Understanding size and dimensions, Importance of surface-to-volume ratio, Historical milestones in nanotechnology, Everyday examples of nanotechnology

UNIT II: PROPERTIES AT THE NANOSCALE

(9 hours)

Size-dependent properties (color, melting point), Quantum effects and quantum confinement, Mechanical and thermal properties of nanomaterials, Electrical and optical behavior at nanoscale, Comparison with bulk materials

UNIT III: TYPES OF NANOMATERIALS

(9 hours)

Zero-dimensional (nanoparticles), 1D (nanowires), 2D (graphene), 3D (nanocomposites), Common nanomaterials: Metals, oxides, carbon-based, Natural vs. synthetic nanomaterials, Role of shape and size in applications, Introduction to hybrid materials

UNIT IV: TOOLS FOR NANOSCIENCE

(9 hours)

Basic idea of microscopes (SEM, TEM, AFM), Simple spectroscopy (UV-Vis, color changes), Measuring particle size (light scattering), Importance of imaging at nanoscale, Limitations of nanoscale measurements

UNIT V: NANOSCIENCE IN DAILY LIFE

(9 hours)

Nanotechnology in consumer products (e.g., sunscreen, clothing), Nanotechnology in food and packaging, Environmental benefits of nanotechnology, Safety and ethical concerns, Future potential of nanoscience

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat
2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat
3. Nanotechnology: Principles and Practices" by Sulabha K. Kulkarni
4. Introduction to Nanoscience" by S.M. Lindsay

Suggested Student Activities:

1. Presentation/Poster: Key milestones and Nobel Prizes in nanoscience.
 2. Simulation Activity: Demonstrate size-dependent properties using available virtual labs or videos (e.g., melting point variation).
 3. Virtual tour/video review: TEM/SEM working principles or nanoscale imaging.
 4. Material Research Project: Find and present current nanomaterials used in industries (e.g., carbon nanotubes, quantum dots).
- Debate or discussion: Ethics and risks of nanotechnology in consumer products or healthcare.

SEMESTER-V

COURSE 12 C: FUNDAMENTALS OF NANOSCIENCE

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

The objective of this practical course is to introduce students to basic experimental techniques in nanoscience using simple, low-cost, and visually engaging methods. Through hands-on activities, students will explore the synthesis, observation, and characterization of nanoparticles and nanomaterials. The course emphasizes conceptual understanding, safety, observation skills, and the connection between nanoscale phenomena and real-world applications.

LEARNING OUTCOMES:

After successful completion of this course, students will be able to:

1. **Synthesize and observe nanoparticles** using chemical and green synthesis methods and identify visual indicators such as color changes due to size-dependent optical effects.
2. **Demonstrate basic techniques** for preparing nanoparticle suspensions and thin films, and explore nanoparticle interaction with light, including scattering and fluorescence.
3. **Compare particle sizes** using mechanical grinding and visualize differences through simple tools or software-based image analysis.
4. **Analyze basic physical properties** of nanomaterials such as settling behavior and surface tension using simple measurement techniques.
5. **Relate experimental results** to nanoscale behavior and interpret the significance of observed changes in color, texture, or optical response.
6. **Use digital tools** (e.g., ImageJ) to simulate nanoscale imaging and understand the role of characterization in nanoscience research.
7. **Follow safe and responsible laboratory practices** while handling nanoparticle materials and conducting experiments.

A minimum of 6 of the following experiments to be recorded

1. **Color Change in Silver Nanoparticles**
Synthesize silver nanoparticles using silver nitrate and sodium citrate; observe color change.

Equipment: Beakers, hot plate, stirrer.
2. **Green Synthesis with Plant Extract**
Use leaf extract (e.g., mint) to make silver nanoparticles; note color shift.

Equipment: Beakers, hot plate, filter paper.
3. **Grinding for Nanoparticle Size Reduction**
Use a mortar and pestle to grind charcoal or chalk; compare sizes.

Equipment: Mortar, pestle, sieves.

4. Observing Light Scattering with Nanoparticles

Shine a laser pointer through a nanoparticle solution to observe scattering.

Equipment: Laser pointer, glass vial, nanoparticle solution.

5. Making a Nanoparticle Suspension

Disperse zinc oxide (ZnO) powder in water and observe settling behavior.

Equipment: Beakers, stirrer, ZnO powder.

6. Simple Thin Film Preparation: Drop-cast a nanoparticle solution (e.g., ZnO) on a glass slide to form a thin film. Equipment: Glass slides, pipette, nanoparticle solution.

7. UV Light Interaction with Nanoparticles: Expose ZnO nanoparticles to UV light and observe fluorescence. Equipment: UV lamp, ZnO nanoparticles, dark room.

8. Surface Tension of Nano fluids

Measure surface tension of a nanoparticle-water mix using the drop-count method.

Equipment: Pipette, beaker, balance.

9. Paper-Based Nanoparticle Coating

Coat filter paper with silver nanoparticles and observe color or texture changes.

Equipment: Filter paper, nanoparticle solution, brush.

10. Simulating Nanoscale Imaging

Use free software (e.g., ImageJ) to analyze nanoparticle images from online sources.

Equipment: Computer with software.

SEMESTER-V

COURSE 12 D: SOLAR, THERMAL AND PHOTOVOLTAIC CONVERSION

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE

To provide students with a comprehensive understanding of solar energy fundamentals, solar radiation principles, thermal and photovoltaic energy conversion systems, and their practical applications, while equipping them with the knowledge to analyze system performance and explore sustainable solar-based solutions for real-world energy needs.

LEARNING OUTCOMES

Upon successful completion, students will be able to:

1. Describe the solar radiation parameters and use instruments to measure solar radiation.
2. Differentiate between flat plate and concentrating collectors based on design and performance.
3. Explain various solar thermal systems like water heating, cooking, and greenhouses.
4. Analyze the structure, working, and efficiency of different types of solar cells.
5. Design small PV systems and assess the challenges in solar energy applications and maintenance.

UNIT-I: SOLAR RADIATION

(9 hours)

Structure of Sun, Spectral distribution of solar radiation, Solar constant, Concept of declination, hour angle, inclination angle, zenith angle, azimuth angle, tilt angle, angle of incidence, Measurement of solar radiation using pyranometer and pyrliometer, Estimation of direct and diffused radiation

UNIT-II: FLAT PLATE AND CONCENTRATING COLLECTORS

(9 hours)

Solar collectors – classification, Flat plate collectors: construction, working, energy balance equation, efficiency, factors affecting performance, Advantages, disadvantages and applications

Concentrating collectors: classification, design, performance analysis, Comparison between flat plate and concentrating collectors, Paraboloidal dish collector

UNIT-III: SOLAR THERMAL APPLICATIONS

(9 hours)

Solar hot water system (SHWS): natural and forced circulation types, Space heating: active and passive methods, Space cooling concepts, Solar cookers: box type, paraboloidal dish type, advanced cookers, Solar furnace, greenhouse

UNIT-IV: SOLAR PHOTOVOLTAIC CELL FABRICATION**(9 hours)**

Photovoltaic effect, Fabrication and characteristics of solar cells, Equivalent circuit, energy losses, and efficiency, Classification of solar cells, Production of single crystal silicon: Czochralski (CZ) and Float Zone (FZ) methods, Thin film solar cells: CdTe/CdS, Multi-junction solar cells.

UNIT-V: SOLAR PHOTOVOLTAIC MODULES AND APPLICATIONS (9 hours)

PV module formation: series and parallel connection of cells, Mismatch issues, use of bypass and blocking diodes, Design and fabrication of PV modules, Current, voltage and power characteristics of PV module Stand-alone PV system Grid-connected and hybrid PV systems, Installation, operation, and maintenance

Reference Books

1. *Solar Energy Utilization* – G.D. Rai, Khanna Publishers
2. *Non-Conventional Energy Resources* – B.H. Khan, McGraw Hill
3. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput, S. Chand
4. *Solar Photovoltaics: Fundamentals, Technologies and Applications* – Chetan Singh Solanki, PHI
5. *Science and Technology of Photovoltaics* – P. Jayarama Reddy, BS Publications
6. *Solar Energy: Principles of Thermal Collection and Storage*, Sukhatme, S. P., & Nayak, J. K. Tata McGraw-Hill.
7. *Solar Photovoltaics: Fundamentals, Technologies and Applications*, Chetan Singh Solanki PHI Learning Pvt. Ltd.
8. *Principles of Solar Engineering*, D. Yogi Goswami & Frank Kreith CRC Press.
9. *Solar Energy: Fundamentals and Applications*, H.P. Garg & J. Prakash – Tata McGraw-Hill.
10. *Photovoltaic Systems Engineering*, Messenger, R., & Ventre, J. – CRC Press.

SEMESTER-V

COURSE 12 D: SOLAR, THERMAL AND PHOTOVOLTAIC CONVERSION

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE

To provide hands-on experience in the measurement, analysis, and evaluation of solar thermal and photovoltaic systems, enabling students to understand their real-world performance and operation.

LEARNING OUTCOMES

1. Measure and interpret solar radiation using appropriate instruments.
2. Analyze the efficiency and performance of solar collectors and PV panels.
3. Examine the electrical characteristics of solar photovoltaic modules under different conditions.
4. Assess the impact of installation parameters such as tilt angle, shading, and wiring configuration.
5. Demonstrate understanding of solar tracking, diode protection, and energy losses in PV systems.

Minimum of 6 experiments to be done and recorded

Practicals List

1. Measurement of direct solar radiation using pyrheliometer/pyranometer
2. Measurement of efficiency of a solar flat plate collector
3. Performance testing of a solar cooker unit
4. Study of solar cell characteristics
5. Effect of tilt angle on efficiency of a solar photovoltaic panel
6. Study on solar photovoltaic panels in series/parallel combination
7. I-V and P-V characterization of a solar PV module under varying illumination
8. Estimation of shadowing and mismatch losses in PV modules
9. Study of bypass and blocking diodes in a PV module
10. Solar tracking vs. fixed mounting performance (simulation or demo)
11. Thermal analysis of a solar water heater using temperature sensors
12. Performance comparison of box-type and paraboloidal solar cookers

SEMESTER-V

COURSE 12 E: FUNDAMENTALS OF PYTHON AND NUMERICAL METHODS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

The primary objective of this course is to equip students with the fundamental knowledge and practical skills in Python programming, focusing on its application in scientific computing and data analysis. Students will learn to leverage Python's powerful libraries for numerical operations, data manipulation, visualization, and solving common scientific and engineering problems using numerical methods.

LEARNING OUTCOMES:

1. Students will master Python fundamentals including data structures and control flow.
2. Students will proficiently use NumPy, Pandas, and Matplotlib for scientific computing and data visualization.
3. Students will be able to create diverse plots for experimental data and perform curve fitting.
4. Students will also apply essential numerical methods like integration and solving ordinary differential equations.
5. Student will develop Python codes to implement these numerical techniques for problem-solving.

UNIT-I: PYTHON FUNDAMENTALS

(9 hrs)

Introduction to Python programming language, variables, data types (integers, floats, strings, booleans), Operators (arithmetic, comparison, logical), Input/Output functions, Basic data structures: Lists, Tuples, Dictionaries and control flow: Conditional statements (if, elif, else), Loops (for, while), Break and continue statements (conditionals and loops), Functions: Defining and calling functions, Arguments, return values, Local and global variables

UNIT-II: PYTHON MODULES FOR SCIENTIFIC COMPUTING

(9 hrs)

NumPy and its components, Pandas DataFrames and its components, Matplotlib and its components, SciPy and its components, SymPy and its components, Jupyter Notebook, Seaborn for statistical plots.

UNIT-III: DATA VISUALIZATION

(9 hrs)

Data importing and exporting, types of plots: line, scatter, histograms, contour, writing of program to plot experimental physics data (at least 3 data sets covering different experiments), customization of plots: labels, titles, legends, axes limits, colors, markers, line styles, curve fitting using SciPy

UNIT-IV: NUMERICAL METHODS

(9 hrs)

Basic statistics: mean, median, standard deviation, Numerical integration methods: Riemann sums, the trapezoidal rule, and Simpson's 1/3 rule, Solving ordinary differential equations (ODEs) using Euler and Runge-Kutta (2nd and 4th order) methods.

UNIT-V: PYTHON CODES FOR NUMERICAL METHODS

(9 hrs)

Developing codes for solving simple problems using Euler and Runge-Kutta methods employing `scipy.integrate.solve_ivp`. Developing codes for solving simple problems using Riemann sums, the trapezoidal rule, and Simpson's rule employing `scipy.integrate.quad`.

REFERENCE BOOKS:

1. "Python Crash Course: A Hands-On, Project-Based Introduction to Programming" by Eric Matthes
2. "A Primer on Scientific Programming with Python" by Hans Petter Langtangen
3. "Python for Data Analysis" by Wes McKinney
4. "Numerical Python: Scientific Computing and Data Science Applications with NumPy, SciPy and Matplotlib" by Robert Johansson
5. "Numerical Methods in Engineering with Python" by Jaan Kiusalaas
6. "Python Programming And Numerical Methods: A Guide For Engineers And Scientists" by Qingkai Kong, Tim Miller, and Steven L. Brunton
7. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas

STUDENT ACTIVITIES:

UNIT-I: Python Fundamentals

Students will engage in basic programming challenges to practice control flow and data structure manipulation, and participate in "Fix the Bug" exercises to enhance debugging skills.

UNIT-II: Python Modules for Scientific Computing

Activities focus on performing NumPy array operations and Pandas DataFrame manipulations, alongside exploring Jupyter Notebooks to reproduce scientific plots.

UNIT-III: Data Visualization

Students will complete experimental data plotting assignments and undertake curve fitting mini-projects using SciPy to visualize and analyze data.

UNIT-IV: Numerical Methods

Activities include manual calculation comparisons with code for integration and ODEs, and an analysis of different numerical methods to assess accuracy and efficiency.

UNIT-V: Python Codes for Numerical Methods

Students will develop Python codes for numerical methods, including simulating physical systems with ODEs and calculating complex integrals using `scipy.integrate` functions.

SEMESTER-V

COURSE 12 E: FUNDAMENTALS OF PYTHON AND NUMERICAL METHODS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

This course aims to introduce students to fundamental Python programming concepts, including data types, control flow, data structures, and basic functions. It also provides an initial exposure to numerical computing with NumPy and data visualization using Matplotlib.

LEARNING OUTCOMES:

1. **Apply Python Fundamentals:** Students will be able to write basic Python programs using variables, input/output, conditional statements, and loops.
2. **Manipulate Data Structures:** Students will demonstrate proficiency in creating and utilizing Python lists, tuples, and dictionaries for data organization and retrieval.
3. **Perform Numerical Operations:** Students will be able to create and manipulate NumPy arrays, including performing basic matrix operations.
4. **Visualize Data:** Students will be able to generate and customize fundamental plots like line plots and histograms using Matplotlib.
5. **Develop Reusable Code:** Students will be able to define and call functions to encapsulate common tasks and improve code organization.

Minimum of 6 experiments to be conducted and recorded

1. Write a program to calculate the area and perimeter of a rectangle, taking length and width as input.
2. Create a program that determines if a given year is a leap year (divisible by 4, but not by 100 unless also divisible by 400)
3. Create a list of 5 student names and their corresponding scores (e.g., [('Alice', 85), ('Bob', 92), ...]). Store this data in a list of tuples or a list of lists.
4. Write a function `calculate_average(scores_list)` that takes a list of marks from university exam results and returns their subject wise average.
5. Create a dictionary `student_grades` where keys are student names and values are their scores. Write a function `get_grade(student_name, grade_dict)` that returns the score for a given student.
6. Create a 2D NumPy array `B` (3x3 matrix) filled with ones.
7. Create two 2x2 NumPy matrices, `M1` and `M2`, and perform matrix multiplication (`@` operator or `np.dot()`).
8. Generate a simple line plot of $y=x^2$ for x ranging from -5 to 5
9. Plot two functions on the same graph (e.g., $\sin(x)$ and $\cos(x)$) and add a legend
10. Generate 1000 random numbers from a normal distribution and create a histogram to visualize their distribution.

SEMESTER-V

COURSE 13 A: ELECTRONIC DEVICES AND CIRCUITS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

To provide students with a comprehensive understanding of semiconductor devices and their applications in biasing, amplification, regulation, and waveform generation. This course enables students to construct and analyze functional analog electronic circuits.

LEARNING OUTCOMES:

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

1. Understand the principles and techniques of transistor biasing and stabilization.
2. Explain the construction and characteristics of JFETs and MOSFETs.
3. Analyze the performance of rectifiers and filter circuits.
4. Design voltage regulators using discrete components and ICs.
5. Construct multivibrator circuits and understand waveform generation mechanisms.

UNIT I: BJT BIASING AND STABILIZATION (9 hrs)

Need for biasing, operating point (Q-point) - Load line analysis – DC and AC load lines - Biasing methods: Fixed bias, collector-to-base bias, voltage divider bias - Stability factors and thermal runaway

UNIT II: FIELD EFFECT TRANSISTORS (FETs) (9 hrs)

JFET: Construction, working, transfer characteristics - MOSFET: Enhancement and depletion mode – characteristics - Comparison of JFET and MOSFET - Applications of FETs as amplifiers and switches

UNIT III: RECTIFIERS AND FILTERS (9 hrs)

Review of diode characteristics - Rectifiers: Half-wave, full-wave (center tapped and bridge) with waveforms - Filter circuits: Capacitor filter, LC filter, π filter – working and output analysis - Ripple factor and its reduction

UNIT IV: VOLTAGE REGULATION (9 hrs)

Zener diode voltage regulator: Series and shunt regulators - Transistor series regulator – concept and design - IC voltage regulators: 78xx and 79xx series – features and applications - Concept of line and load regulation

UNIT V: MULTIVIBRATORS AND WAVEFORM GENERATORS (9 hrs)

Astable, monostable, and bistable multivibrators using BJTs – circuit diagrams and waveforms - Schmitt trigger – working and applications - Applications of multivibrators in timing and waveform shaping

Textbooks / References:

1. Millman & Halkias – *Electronic Devices and Circuits*, McGraw-Hill
2. S. Salivahanan – *Electronic Devices and Circuits*, McGraw-Hill
3. Boylestad & Nashelsky – *Electronic Devices and Circuit Theory*, Pearson
4. Thomas L. Floyd – *Electronic Devices*, Pearson
5. R.L. Gupta – *Electronics Devices and Circuits*, Katson Books

SEMESTER-V

COURSE 13 A: ELECTRONIC DEVICES AND CIRCUITS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

To develop practical skills in handling active semiconductor devices and constructing analog circuits such as bias networks, rectifiers, regulators, and waveform generators using transistors and diodes.

LEARNING OUTCOMES:

1. Design and test transistor biasing circuits for proper Q-point selection.
2. Analyze rectifier outputs and evaluate ripple factor with and without filters.
3. Build and test FET amplifiers and compare with BJT circuits.
4. Construct and test voltage regulators using Zener diodes and regulator ICs.
5. Observe multivibrator waveforms and determine timing characteristics.

Minimum of 6 experiments to be done and recorded

1. **Fixed bias and voltage divider bias circuits:** Plot DC load line and measure operating point.
2. **DC characteristics of JFET:** Plot transfer and drain characteristics.
3. **Half-wave and full-wave rectifier circuits:** Observe waveforms and measure output voltage.
4. **Bridge rectifier with capacitor filter:** Measure ripple factor and compare with theory.
5. **π filter performance in rectifier circuit:** Compare ripple reduction.
6. **Zener diode voltage regulator:** Analyze voltage regulation under load conditions.
7. **Transistor series voltage regulator:** Build and test regulated output.
8. **IC 7805 and 7812 voltage regulators:** Study line and load regulation.
9. **Astable and monostable multivibrator using BJT:** Observe output waveform using CRO.
10. **Schmitt trigger circuit using BJT:** Understand hysteresis behavior and switching.

SEMESTER-V

COURSE 13 B: LOW TEMPERATURE PHYSICS & REFRIGERATION

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

The objective of the course on Low Temperature Physics & Refrigeration is to provide students with a comprehensive understanding of the fundamental principles, concepts, and applications of low-temperature physics and refrigeration systems. The course aims to develop students' theoretical knowledge and practical skills in working with low temperatures, understanding cryogenic phenomena, and operating refrigeration systems.

LEARNING OUTCOMES:

Students after successful completion of the course will be able to

1. Identify various methods and techniques used to produce low temperatures in the Laboratory.
2. Acquire a critical knowledge on refrigeration and air conditioning.
3. Demonstrate skills of Refrigerators through hands on experience and learns about refrigeration components and their accessories.
4. Understand the classification, properties of refrigerants and their effects on environment.
5. Comprehend the applications of Low Temperature Physics and refrigeration.

UNIT-I PRODUCTION OF LOW TEMPERATURE

(9 hrs.)

Production of low temperatures-Introduction, Freezing mixtures, Joule-Thomson effect, Regenerative cooling, Different methods of liquefaction of gases, liquefaction of air, Production of liquid hydrogen and nitrogen, Adiabatic demagnetization, Properties of materials at low temperatures

UNIT-II MEASUREMENT OF LOW TEMPERATURE

(9 hrs.)

Gas thermometer and its correction and calibration, Secondary thermometers, resistance thermometers, thermocouples, Vapour pressure thermometers, Magnetic thermometers, Advantages and drawbacks of each type of thermometer.

UNIT-III PRINCIPLES OF REFRIGERATION

(9 hrs.)

Introduction to Refrigeration- Natural and artificial refrigeration , Stages of refrigeration, Types of refrigeration - Vapor compression and vapor absorption refrigeration systems, Refrigeration cycle and explanation with a block diagram, Introductory ideas on air- conditioning.

Refrigerants-Introduction, Ideal refrigerant, Properties of refrigerant, Classification of refrigerants, commonly used refrigerants, Eco-friendly refrigerants

UNIT-IV COMPONENTS OF REFRIGERATOR

(9 hrs.)

Refrigerator and its working, Block diagram, Coefficient of Performance (COP), Tons of refrigeration (TR) and Energy Efficiency Ratio (EER), Refrigerator components: Types of compressors, evaporators, condensers, and their functional aspects, defrosting in a refrigerator, Refrigerant leakage and detection

UNIT-V APPLICATIONS OF LOW TEMPERATURE & REFRIGERATION

(9 hrs.)

Applications of Low temperatures: Preservation of biological material, Food freezing, liquid nitrogen and liquid hydrogen in medical field, Superconducting magnets in MRI- Tissue ablation (cryosurgery) - Cryogenic rocket propulsion system.

Applications of refrigeration: Domestic refrigerators, Water coolers, Cold storages, Ice plants, Food preservation methods, Chemical and Process industries, Cold treatment of metals, Construction field, Desalination of water, Data centers.

References

1. Heat and Thermodynamics by Brij Lal & N. Subramanyam, S. Chand Publishers.
2. Thermal Physics by S C Garg, R M Bansal & C K Ghosh, McGrawHill Education, India
3. Heat and Thermodynamics by M M Zemansky, McGrawHill Education (India).
4. Low-Temperature Physics by Christian E. & Siegfried H., Springer.
5. Thermal Engineering by S. Singh, S. Pati, Ch:18 Introduction to Refrigeration.
6. The Physics Hyper Text Book. Refrigerators. <https://physics.info/refrigerators/>
7. Refrigeration and Air Conditioning by Manohar Prasad, New age international (P) limited, New Delhi
8. A course in Refrigeration and Air Conditioning by S.C. Arora and S. Domkundwar, Dhanpatrai and sons, Delhi

SEMESTER-V

COURSE 13 B: LOW TEMPERATURE PHYSICS & REFRIGERATION

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

The objective of the practical course on Low Temperature Physics & Refrigeration is to provide students with hands-on experience and practical skills in working with low temperatures, operating refrigeration systems, and conducting experiments in the field of low temperature physics. The course aims to develop students' proficiency in handling cryogenic equipment, performing temperature measurements, and conducting experiments at low temperatures.

LEARNING OUTCOMES:

On completion of practical course, student shall be able to

1. List out, identify and handle equipment used in refrigeration and low temperature lab.
2. Learn the procedures of preparation of Freezing Mixtures.
3. Demonstrate skills on developing various Freezing mixtures and materials and their applications in agriculture, medicine and day to day life.
4. Acquire skills in observing and measuring various methodologies of very low temperatures
5. Perform some techniques related to Refrigeration and Freezing in daily life.

Minimum of 6 experiments to be done and recorded

1. Measure the temperatures below Melting point of Ice using a thermometer available in the Lab.
2. Make a freezing mixture by adding different salts viz., Sodium chloride, Potassium Hydrate (KOH), Calcium chloride to ice in different proportions and observe the temperature changes.
3. Study the operation of a refrigerator and understand the working of different parts.
4. Study the properties of refrigerants like chlorofluorocarbons-hydrochlorofluorocarbons and record the lowest temperatures obtained.
5. Consider a simple faulty refrigerator and try to troubleshoot the simple problems by understanding its working
6. Understand the practical problem of filling the Freon Gas into the Refrigerator.
7. Get the Liquid Nitrogen or Liquid Helium from nearby Veterinary Hospital and measure their temperatures using chromel-alumel thermocouple or mercury thermometer and observe their physical properties like colour, smell etc and precautions to be taken for their safe handling.
8. Preparation of freeze drying food with Dry ice and liquid nitrogen
9. Preparation of freeze drying food with liquid nitrogen

STUDENT ACTIVITIES

Co-Curricular Activities:

(a) **Mandatory:** (*Training of students by teacher in field related skills: (lab:10 + field: 05)*)

1. **For Teacher:** Training of students by the teacher in the in the laboratory/field for a total of not less than 15 hours on the techniques/skills of Low Temperature Production, methods used and applications of Low temperatures and refrigeration in day to day life and other applications in medicine and industry.
2. **For Student:** Student shall (individually) visit (i) a small ice plant or a cold storage plant
(ii) Air Conditioner (AC) repair shop or (iii) Refrigerator repair shop to understand the construction, working principle and the trouble shooting of these devices after interacting with the technicians. **Or** Student shall observe the various thermodynamic processes taking place while working with the refrigerator and observe the leak detection in refrigeration system by different methods, air removal and charging of a refrigeration unit and testing of a refrigeration system to find out the Refrigerating capacity/Ton of refrigeration (TR) and the Power input. **Or** Student shall identify the refrigerant cylinder by color coding and standing pressure. **Or** Student shall visit the freezer aisle of a supermarket and observes the bags of different frozen fruits. Student shall write the observations and submit a hand- written Fieldwork/Projectwork not exceeding 10 pages in the given format to the teacher.
3. Max marks for Fieldwork/Project work: 05.
4. Suggested Format for Fieldwork/Project work: *Title page, student details, index page, details of place visited, observations, findings and acknowledgements.*
5. Unit tests (IE).

(b) **Suggested Co-Curricular Activities**

1. Training of students by related Factory, industrial experts.
2. Assignments (including technical assignments like identifying tools in Refrigerators, Freezers and their handling, operational techniques with safety and security)
3. Seminars, Group discussions, Quiz, Debates etc. (on related topics).
4. Preparation of videos on tools and techniques in Low Temperatures and applications.
5. Collection of material/figures/photos related to substances used in Freezing Mixtures, their Properties and availability etc., writing and organizing them in a systematic way in a file.
6. Visits to Ice plants and labs in universities, research organizations, private firms, etc.
7. Making your own mini refrigerator at home
8. Build your own water cooler with the materials available at home.
9. Making hand launched liquid nitrogen rockets

10. Experiments with Liquid nitrogen and strawberry/ banana/ lemon/ onion/ mushroom/egg etc. (*To be tried under professional supervision only*).
11. Invited lectures and presentations on related topics by field/industrial experts
12. Identification of different Ozone-depleting substances (ODS) that damage the ozone layer in the upper atmosphere.
13. Demonstration to illustrate the greenhouse effect and the role of carbon dioxide as a greenhouse gas using plastic water bottles, flood light lamp, beakers and temperature sensors and observe the temperature changes.
<https://edu.rsc.org/experiments/modelling-the-greenhouse-effect/1543.article>
<https://sealevel.jpl.nasa.gov/files/archive/activities/ts1hiac1.pdf>

SEMESTER-V

COURSE 13 C: SYNTHESIS OF NANOMATERIALS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

The objective of this course is to introduce students to the fundamental concepts and practical methods used in the synthesis of nanomaterials. Students will explore various synthesis routes—physical, chemical, and green—and learn the importance of controlling size, shape, and stability of nanoparticles. Emphasis will be placed on safe laboratory practices, low-cost techniques, and the basic chemistry behind the preparation of nanomaterials suitable for undergraduate-level understanding.

LEARNING OUTCOMES:

After successful completion of this course, students will be able to:

1. **Differentiate between top-down and bottom-up approaches** to nanomaterial synthesis and explain the importance of controlling particle size and morphology.
2. **Describe common physical synthesis techniques** such as grinding, milling, and evaporation, and evaluate their advantages and limitations in laboratory-scale applications.
3. **Apply basic chemical synthesis methods** such as chemical reduction, sol-gel, and precipitation to produce nanoparticles, and understand the roles of pH and temperature in synthesis.
4. **Perform green synthesis of nanoparticles** using natural extracts, identify the function of plant-based reducing agents, and discuss the environmental benefits and challenges of eco-friendly methods.
5. **Understand strategies to stabilize nanoparticles**, including the use of surfactants and coatings, and assess how storage conditions and solution environments affect nanoparticle stability.

UNIT I: BASICS OF SYNTHESIS

(9 hours)

What is nanomaterial synthesis?, Top-down vs. bottom-up approaches, Importance of controlling size and shape, Safety in nanomaterial preparation, Common chemicals used in synthesis

UNIT II: PHYSICAL METHODS

(9 hours)

Grinding and milling for nanoparticles, Evaporation and deposition basics, Simple mechanical methods for nanofibers, Advantages of physical methods, Low-cost physical synthesis techniques

UNIT III: CHEMICAL METHODS

(9 hours)

Chemical reduction for metal nanoparticles, Precipitation for oxide nanoparticles, Sol-gel method basics, Role of pH and temperature, Simple chemical reactions for synthesis

UNIT IV: GREEN SYNTHESIS

(9 hours)

Using plant extracts for nanoparticles, Role of natural reducing agents, Eco-friendly synthesis benefits, Examples: Silver and gold nanoparticles, Challenges in green methods

UNIT V: STABILIZING NANOMATERIALS

(9 hours)

Preventing nanoparticle clumping, Using surfactants and coatings, Storage of nanomaterials, Testing stability in solutions, Practical tips for lab synthesis

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat
2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat
3. Nanotechnology: Principles and Practices" by Sulabha K. Kulkarni – great for Indian UG level.
4. Introduction to Nanoscience" by S.M. Lindsay – clear and modern.

Student Activities:

1. Lab demo/video assignment: Synthesis of nanoparticles using sol-gel or chemical reduction method.
2. Compare and contrast chart: Physical vs. chemical vs. biological synthesis methods.
3. Prepare a flowchart: Steps in a specific synthesis technique (e.g., CVD, ball milling).
4. Literature survey: Review a journal article on a novel synthesis technique.
5. Safety audit task: Identify hazards and precautions in a nano lab

SEMESTER-V

COURSE 13 C: SYNTHESIS OF NANOMATERIALS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

The objective of this laboratory course is to introduce students to the synthesis and handling of nanomaterials through simple, cost-effective, and educational experiments. Students will gain hands-on experience in chemical, physical, and green synthesis methods and learn basic techniques for nanoparticle stabilization and thin film preparation, fostering foundational lab skills in nanoscience.

LEARNING OUTCOMES:

After successful completion of this course, students will be able to:

1. **Synthesize nanoparticles** using various methods including chemical reduction, precipitation, sol-gel, and eco-friendly green synthesis.
2. **Demonstrate physical techniques** such as manual grinding and soot collection to produce and handle nanomaterials.
3. **Apply stabilization strategies** using surfactants or additives and assess nanoparticle dispersion and aggregation behavior.
4. **Perform basic characterization-related observations**, such as color change, settling, or film formation, to infer nanoparticle size and stability.
5. **Fabricate simple nanomaterial films** using drop-casting techniques and understand their relevance in real-world applications.
6. **Follow proper laboratory practices** for the safe handling, preparation, and disposal of nanomaterial samples.

A minimum of 6 of the following to be recorded

1. Silver Nanoparticle Synthesis: Make silver nanoparticles using silver nitrate and glucose. Equipment: Beakers, hot plate, stirrer.
2. Zinc Oxide Nanoparticle Synthesis: Prepare ZnO nanoparticles using zinc acetate and sodium hydroxide. Equipment: Beakers, hot plate, oven.
3. Green Synthesis with Tea Extract: Use black tea extract to synthesize silver nanoparticles; observe color change. Equipment: Beakers, hot plate, filter paper.
4. Manual Grinding for Nanoparticles: Grind iron oxide powder with a mortar and pestle; compare particle sizes. Equipment: Mortar, pestle, sieves.
5. Precipitation of Copper Nanoparticles: Synthesize copper nanoparticles using copper sulfate and ascorbic acid. Equipment: Beakers, stirrer, hot plate.
6. Stabilizing Nanoparticles with Soap : Add soap to a nanoparticle solution and observe dispersion. Equipment: Beakers, soap solution, stirrer.

7. Making Carbon Nanoparticles from Soot: Collect candle soot and disperse in water to form a nanoparticle suspension. Equipment: Candle, beaker, ultrasonic bath (optional).
8. Simple Sol-Gel Synthesis: Prepare silica nanoparticles using a sol-gel method with sodium silicate. Equipment: Beakers, stirrer, drying oven.
9. Testing Nanoparticle Stability: Add salt to a nanoparticle solution and observe settling or clumping. Equipment: Beakers, salts, stirrer.
10. Drop-Casting Nanomaterial Films Create a thin film of ZnO nanoparticles on a glass slide by drop casting. Equipment: Glass slides, pipette, nanoparticle solution.

SEMESTER-V

COURSE 13 D: WIND, HYDRO, OCEAN AND GEOTHERMAL ENERGIES

Theory

Credits: 3

3 hrs/week

Course Objective

The objective of this course is to provide students with a comprehensive understanding of various non-conventional renewable energy systems including wind, small hydro, ocean thermal, tidal, and geothermal sources. It aims to familiarize students with the principles of energy conversion, system components, design considerations, site selection, and applications of each system. The course also emphasizes the status, potential, and challenges of these energy sources in the Indian context, promoting sustainable and environment-friendly power generation methods.

Learning Outcomes

1. Understanding of wind resources, principles of wind conversion technologies, ocean energy sources and geothermal resources.
2. Ability to understand production and application of wind, hydro, ocean and geothermal energy
3. Grid-connected & off-grid applications of wind energy, OTEC systems and thermoelectric power generation.
4. Model preparation of wind turbine and analysis of environmental impact of ocean and geothermal energy.
5. Understanding the design and functioning of wind turbines, tidal and geothermal energy systems.

UNIT-I: WIND GENERATION AND MEASUREMENT

(9 hours)

Meteorology of wind, Global wind distribution, Wind speed variation with height and statistics, Principles of wind energy conversion, Types and characteristics of Wind Energy Conversion, Systems (WECS), Wind measurement methods: Eolian features, anemometers, balloon measurements

UNIT-II: WIND ENERGY APPLICATIONS

(9 hours)

Wind turbine design: horizontal vs vertical axis, Simulation of turbine characteristics, Wind pumps: design, performance, testing, Economics and environmental impacts of wind energy, Wind energy status in India

UNIT-III: SMALL HYDROPOWER SYSTEMS

(9 hours)

Overview of micro, mini and small hydro systems, Elements of pumps and turbines, Site selection, speed and voltage regulation, Load management and tariff issues, Hybrid wind-hydro standalone systems, Small hydro potential in India

UNIT-IV: OCEAN THERMAL AND TIDAL ENERGIES**(9 hours)**

Ocean Thermal Energy Conversion (OTEC): working, site selection, Tidal energy: origin, types, technologies, Merits, limitations, and applications, Basics of wave motion and power

UNIT-V: GEOTHERMAL ENERGY**(9 hours)**

Earth's internal structure and geothermal gradients, Geothermal resource classification and extraction, Exploration and development, Applications and limitations, Geothermal energy scenario in India

Reference Books

1. *Non-Conventional Energy Sources* – G.D. Rai, Khanna Publishers
2. *Non-Conventional Energy Resources* – B.H. Khan, McGraw Hill
3. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput, S. Chand Publishers

SEMESTER-V

COURSE 13 D: WIND, HYDRO, OCEAN AND GEOTHERMAL ENERGIES

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE

The objective of this laboratory course is to experimentally explore the working principles and performance characteristics of various renewable energy systems, including wind, hydro, tidal, ocean thermal, and geothermal sources. The practical sessions aim to provide hands-on experience in measuring, analyzing, and understanding energy conversion processes and system efficiencies using models, instruments, and simulations.

LEARNING OUTCOMES

By the end of the lab course, students will be able to:

1. **Measure and analyze wind speed and turbine characteristics** using anemometers and wind turbine models.
2. **Compare the performance** of different wind turbine designs, including blade variations and rotor orientation.
3. **Demonstrate energy generation principles** from wave, tidal, and ocean thermal systems through physical models or simulations.
4. **Evaluate the efficiency** of micro-hydro systems and understand the effect of flow and turbine type.
5. **Estimate geothermal gradients** and understand the process of geothermal energy extraction using simplified data sets.
6. **Interpret the effects of environmental factors** such as wave motion, blade design, and turbine speed on renewable energy output.
7. **Appreciate the practical challenges** and limitations of implementing renewable systems in real-world scenarios.

Practical

1. Estimation of wind speed using anemometer
2. Study of wind characteristics
3. Determination of wind generator characteristics
4. Effect of number and size of blades on power output
5. Comparison of vertical and horizontal wind turbine rotors
6. Effect of wave amplitude and frequency on energy output
7. Demonstration of wind turbine model and voltage output measurement
8. Efficiency test of a small water turbine (hydro setup)
9. Simulation/demonstration of OTEC system
10. Geothermal gradient estimation using simulated data
11. Model demonstration of a tidal barrage system

SEMESTER-V

COURSE 13 E: COMPUTATIONS IN MECHANICS, WAVES AND OSCILLATIONS

Theory

Credits: 3

3 hrs/week

COURSE OBJECTIVE:

This course aims to equip students with the skills to design and implement physics simulations using Object-Oriented Programming in Python. Students will apply computational methods to model and analyze various physical phenomena, from kinematics to waves.

LEARNING OUTCOMES:

1. Students will be able to design, implement, and utilize Python classes and objects to model physical entities and build structured simulation frameworks.
2. Students will master vector operations using NumPy, calculate kinematic quantities, and plot motion graphs for systems like projectile motion.
3. Simulate Central Force Systems: Students will compute central forces and angular momentum, and simulate and visualize different types of orbits, including planetary motion.
4. Students will set up and solve differential equations for various oscillatory systems (e.g., mass-spring, pendulum, damped oscillations) and visualize their time evolution.
5. Students will be able to simulate wave propagation, interference, and standing waves, and apply Fourier analysis to decompose and interpret complex wave forms.

UNIT-I: OBJECT-ORIENTED PROGRAMMING AND SIMULATIONS (9 hrs)

Object-Oriented Programming (OOP) for Simulations: Classes, objects, attributes, methods, encapsulation, Designing Simulation Components: Creating classes for physical entities (e.g., Particle, Vector, Force), Building a Simulation Framework: Structuring code for managing multiple interacting objects and evolving the system state.

UNIT-II: KINEMATICS (9 hrs)

Creating and manipulating 1D and 2D vectors as NumPy arrays, Vector addition, subtraction, scalar multiplication, Dot product and cross product for physical quantities (e.g., work, torque - introduced as vector operations), Calculation of displacement, velocity, and acceleration using kinematic relations, Plotting position-time, velocity-time, and acceleration-time graphs, Projectile motion analysis (without air resistance): calculating range, maximum height, time of flight, Kinetic energy of translation and rotation (introduction), Gravitational potential energy (mgh) and Elastic potential energy ($\frac{1}{2} kx^2$).

UNIT-III: CENTRAL FORCES (9 hrs)

Calculation of gravitational force, plotting gravitational force as a function of distance, calculation of angular momentum using NumPy's cross product, calculation of total energy in a central force

field, Simulating elliptical, parabolic, and hyperbolic orbits, visualizing variation of time period as a function of semi major axis, visualizing law of areas.

UNIT-IV: OSCILLATIONS

(9 hrs)

Plotting of sine and cosine functions, Setting up differential equations for mass-spring system and simple pendulum (small angle approximation) as a system of first-order ODEs, Plotting displacement, velocity, and acceleration as functions of time, Combination of two mutually perpendicular SHMs (1:1 and 1:2 frequencies), Lissajous figures, Setting up ODEs for underdamped, critically damped, and overdamped oscillations, Simulating and plotting the time evolution for each damping regime.

UNIT-V: WAVES

(9 hrs)

Mathematical representation of 1D transverse and longitudinal waves, Animating wave propagation, Wave speed, wavelength, frequency relationships, Simulating constructive and destructive interference patterns, Visualizing standing waves (formed by two oppositely traveling waves), Fourier analysis: Concept of decomposing complex signals into sine and cosine components, Visualization of complex waves (Square, Saw tooth and Triangular waves) by varying number of sine and cosine waves, Perform Fast Fourier Transform on simulated wave data using `scipy.fft.fft` and `fftfreq`, Interpreting frequency spectra.

REFERENCE BOOKS:

1. "Computational Physics" by Nicholas J. Giordano and Hisao Nakanishi
2. "A First Course in Computational Physics" by Paul L. DeVries and Jian-Ke Shang
3. "Python for Data Analysis" by Wes McKinney
4. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas
5. "Principles of Physics" by Halliday, Resnick, and Walker (for general physics background on Kinematics, Central Forces, Oscillations, Waves)
6. "Classical Dynamics of Particles and Systems" by Stephen T. Thornton and Jerry B. Marion (for more advanced mechanics concepts in Kinematics and Central Forces)
7. "Vibrations and Waves" by A.P. French (for in-depth coverage of oscillations and waves)
8. "Numerical Methods in Engineering with Python" by Jaan Kiusalaas (for practical implementation of ODE solvers)
9. "Object-Oriented Programming in Python: A Guide to the Fundamentals of Object-Oriented Programming (OOP) for Developers and Aspiring Programmers" by Michael Urban (for a focused OOP reference)

STUDENT ACTIVITIES:

UNIT-I: Object-Oriented Programming and Simulations

- Activity 1: Design and implement core OOP components like Particle, Vector, and Force classes, including attributes, methods, and encapsulation for physical entities.
- Activity 2: Develop a basic Simulation framework that uses these classes to manage multiple interacting objects and evolve the system state over time steps.

UNIT-II: Kinematics

- Activity 1: Perform vector operations (addition, subtraction, dot, cross products) using NumPy, applying them to calculate physical quantities like work and torque.
- Activity 2: Simulate and plot position-time, velocity-time, and acceleration-time graphs for projectile motion, calculating range, maximum height, and time of flight, and include calculations for kinetic and potential energies.

UNIT-III: Central forces

- Activity 1: Calculate and plot gravitational force as a function of distance, and compute angular momentum using NumPy's cross product.
- Activity 2: Simulate and visualize elliptical, parabolic, and hyperbolic orbits in a central force field, demonstrating the variation of time period with the semi-major axis and the law of areas.

UNIT-IV: Oscillations

- Activity 1: Set up and solve differential equations for mass-spring systems and simple pendulums (small angle approximation) as systems of first-order ODEs, plotting their displacement, velocity, and acceleration over time.
- Activity 2: Simulate and visualize Lissajous figures from combining two mutually perpendicular SHMs, and set up ODEs for and simulate the time evolution of underdamped, critically damped, and overdamped oscillations.

UNIT-V: Waves

- Activity 1: Mathematically represent and animate 1D transverse and longitudinal wave propagation, illustrating wave speed, wavelength, and frequency relationships, as well as simulating constructive and destructive interference and standing waves.
- Activity 2: Apply Fourier analysis by visualizing the decomposition of complex waves (Square, Saw tooth, Triangular) into sine and cosine components, and perform Fast Fourier Transform (FFT) on simulated wave data using `scipy.fft` to interpret frequency spectra.

SEMESTER-V

COURSE 13 E: COMPUTATIONS IN MECHANICS, WAVES AND OSCILLATIONS

Practical

Credits: 1

2 hrs/week

COURSE OBJECTIVE:

This course aims to equip students with the practical skills to design, implement, and visualize physics simulations using Python's Object-Oriented Programming capabilities and scientific libraries. Students will apply computational methods to model and analyze various physical phenomena from mechanics to wave theory.

LEARNING OUTCOMES:

1. Students will be able to design and implement Python classes for physical entities and construct simulation frameworks to evolve system states.
2. Students will master vector operations using NumPy and simulate projectile motion, analyzing trajectories and energy.
3. Students will be able to calculate and visualize gravitational forces and simulate basic orbital mechanics.
4. Students will animate 1D wave propagation and demonstrate constructive and destructive interference patterns.
5. Students will synthesize complex waveforms by summing sine and cosine components, visualizing the approximation process.

Minimum 6 experiments to be conducted and recorded

1. Define a Particle class with initial attributes for position (2D or 3D vector, e.g., a NumPy array), velocity, acceleration, and mass.
2. Design a Simulation class that holds a list of Particle objects
3. Simulate 2-3 particles moving under constant acceleration (e.g., gravity), and store their trajectories.
4. Represent 2D force and displacement vectors as NumPy arrays.
5. Calculate the work done by a constant force moving an object along a given displacement using the dot product.
6. Simulate the trajectory of a projectile launched at a given initial velocity & angle and Plot the projectile's path (Y vs. X)
7. Write a function to calculate the gravitational force vector between two masses given their positions & masses and Plot the magnitude of gravitational force as a function of distance.
8. Write a function to generate the displacement $y(x, t)$ for a 1D transverse wave and Create an animation that shows the wave propagating along the x-axis over time
9. Superimposition of two separate 1D waves to show: Constructive interference (in-phase) and Destructive interference (out-of-phase).

10. Synthesize a square wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.
11. Synthesize a sawtooth wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.
12. Synthesize a triangular wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.