SEMESTER-VI

COURSE 14 A: ANALOG AND DIGITAL ELECTRONICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

To develop a unified understanding of analog signal processing using operational amplifiers and the principles of digital logic design, enabling students to analyze and implement both analog and digital circuits in real-life applications.

LEARNING OUTCOMES:

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

1. Design and analyze advanced op-amp circuits such as log amplifiers, detectors, and waveform generators.
2. Apply Boolean algebra to simplify digital expressions and construct logic circuits.
3. Implement practical combinational circuits including adders, encoders, and multiplexers.
4. Understand the operation of flip-flops, counters, and shift registers.
5. Differentiate between logic families and apply memory devices in simple digital systems.

UNIT I: ADVANCED OP-AMP APPLICATIONS (9 hrs)

Log and antilog amplifiers – circuit design and working - Peak detector and sample-and-hold circuits - Schmitt trigger – hysteresis and switching characteristics - Timer IC 555 – internal block diagram, astable and monostable operation

UNIT II: BOOLEAN ALGEBRA AND LOGIC SIMPLIFICATION (9 hrs)

Basic laws and theorems of Boolean algebra - DeMorgan's theorems – statement and verification - Logic gates: Symbols, truth tables, logic expressions - SOP and POS forms, simplification using Boolean laws

UNIT III: COMBINATIONAL LOGIC CIRCUITS (9 hrs)

Half adder and full adder – circuit, truth table, logic diagrams - Multiplexers, demultiplexers – working principles and applications - Encoders and decoders – design and uses - Implementation of Boolean expressions using multiplexers

UNIT IV: SEQUENTIAL CIRCUITS AND FLIP-FLOPS (9 hrs)

Latches and flip-flops: SR, JK, D, T – truth tables and characteristic equations - Edge-triggered and level-triggered flip-flops - Counters: Asynchronous and synchronous – binary and mod-N counters - Shift registers – SIPO, PISO, ring and Johnson counters

UNIT V: MEMORY DEVICES AND LOGIC FAMILIES (9 hrs)

Classification of memories: ROM, RAM, PROM, EPROM – working principles - TTL and CMOS logic families – characteristics, comparison - Noise margin, fan-in, fan-out - Interfacing TTL with CMOS and vice versa

Textbooks / References:

1. R.P. Jain – *Modern Digital Electronics*, McGraw-Hill.
2. Operational Amplifiers and Linear ICs, David A. Bell, 3rd Edition, 2011
3. D. Roy Choudhury & Shail Jain – *Linear Integrated Circuits*, New Age
4. Morris Mano – *Digital Logic and Computer Design*, Pearson
5. Thomas L. Floyd – *Digital Fundamentals*, Pearson
6. M.M. Mano & Ciletti – *Digital Design*, Pearson

Student Activities for Analog and Digital Electronics

1. **Logic gate truth table race**: Time-based group challenge for filling truth tables.
2. **Build your own digital lock** using basic gates or flip-flops.
3. **Mini project**: Design a basic traffic light controller using counters and logic gates.
4. **Boolean expression challenge**: Simplify and implement using NAND/NOR only.
5. **IC datasheet analysis**: Read and present features of IC 7400, 74138, or 555 timer.
6. **Schmitt trigger behavior demonstration** with varying input voltages.
7. **Poster presentation**: “TTL vs CMOS Logic Families.”
8. **Simulation**: Use Logic.ly, Tinkercad, or Falstad to simulate logic circuits.
9. **Classroom quiz**: Rapid-fire on memory types and logic circuit features.
10. **Sequential logic clock design**: Create a timing circuit using flip-flops and counters.

SEMESTER-VI

COURSE 14 A: ANALOG AND DIGITAL ELECTRONICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To provide hands-on experience in designing analog and digital circuits using op-amps, logic gates, and digital ICs, allowing students to observe, test, and troubleshoot various signal processing and logic control systems

LEARNING OUTCOMES:

1. Construct and analyze analog op-amp circuits like log amplifiers and Schmitt triggers.
2. Simplify Boolean expressions and implement them using logic gates.
3. Design and verify the behavior of adders, multiplexers, and encoders.
4. Build sequential circuits using flip-flops and observe timing behaviors.
5. Interface digital ICs from different logic families and use memory components.

Minimum of 6 experiments to be done and recorded

1. **Logarithmic and antilogarithmic amplifiers** using op-amps.
2. **Peak detector and sample-and-hold circuit**: Observe input/output waveforms.
3. **Astable and monostable multivibrator** using IC 555 timer.
4. **Schmitt trigger circuit** using op-amp or digital IC.
5. **Verification of Boolean laws and DeMorgan's theorems** using logic gates.
6. **Design and implementation of half-adder and full-adder** using basic gates or ICs.
7. **Multiplexer and demultiplexer circuits** using 74153, 74138, etc.
8. **Flip-flop circuits (SR, JK, D)**: Setup using ICs and verify truth tables.
9. **Ripple counter and mod-N counter implementation**.
10. **Shift register using 7495 or equivalent**: Observe sequence and modes.

SEMESTER-VI

COURSE 14 B: VACUUM TECHNOLOGY

Theory | **Credits: 3** | **3 hrs/week**

Course Objective:

The primary objective of this course is to provide a comprehensive understanding of the principles, design, operation, and applications of vacuum systems across different pressure regimes. The course aims to equip students with foundational knowledge of gas behavior in vacuum, pumping mechanisms, measurement techniques, leak detection methods, and the wide-ranging industrial and scientific uses of vacuum technology. Emphasis is placed on both theoretical aspects and practical considerations in selecting and operating vacuum systems for research and industrial environments.

Learning outcomes

1. **Understand** the fundamental principles of vacuum, vacuum ranges, gas laws, and characteristics of low to medium vacuum systems and pumps.
2. **Explain** the design, operation, and limitations of high and ultra-high vacuum systems including advanced pumps and materials used.
3. **Identify and compare** various vacuum pressure measurement methods and select appropriate gauges based on vacuum levels and system requirements.
4. **Apply** leak detection techniques to diagnose, troubleshoot, and maintain the integrity of vacuum systems.
5. **Explore and analyze** diverse industrial, scientific, and emerging applications of vacuum technology across multiple domains including thin films, space, and semiconductor processing.

UNIT I: INTRODUCTION AND LOW TO MEDIUM VACUUM SYSTEMS (9 hours)

Introduction to Vacuum: History, Definition of vacuum and vacuum ranges (low, medium, high, ultra-high), Gas laws (Ideal gas law, mean free path, Knudsen number), Surface phenomena in vacuum; Gas Flow in Vacuum Systems, Low to Medium Vacuum Pumps: Mechanical pumps: Rotary vane, Diaphragm pumps, Scroll pumps, Liquid ring pumps, Working principles, characteristics, merits & limitations, Back streaming and oil contamination

UNIT II: HIGH AND ULTRA-HIGH VACUUM SYSTEMS (9 hours)

High Vacuum Pumps: Diffusion pumps: Operation, oil backstreaming, traps, Turbomolecular pumps: Design, speed, limitations; Ultra-high Vacuum Pumps: Ion pumps: Sputter-ion, getter-ion, Titanium sublimation pumps, Cryopumps and sorption pumps; Pumping System Design: Pump combinations (e.g., rotary + diffusion pump), Pumping station layout and material selection, Vibration isolation, cleanliness, and bake-out

UNIT III: VACUUM MEASUREMENT SYSTEMS **(9 hours)**

Basic Concepts: Importance of pressure measurement, Units: Torr, Pascal, mbar; Gauges for Low and Medium Vacuum: Bourdon gauge, McLeod gauge, Thermocouple and Pirani gauges; Gauges for High and Ultra-High Vacuum: Ionization gauges (Hot cathode and cold cathode), Bayard-Alpert gauge; Calibration and Gauge Selection: Accuracy, sensitivity, limitations, Gauge calibration methods

UNIT IV: LEAK DETECTION TECHNIQUES **(9 hours)**

Importance of Leak Detection: Effects of leaks on vacuum quality and stability; Common Leak Types: Real and virtual leaks, Permeation and desorption; Leak Detection Methods: Pressure rise method, Halogen leak detector, Helium mass spectrometer leak detection (MSLD), Ultrasonic and bubble test techniques; Leak Testing Setup: Sensitivity, resolution, and quantitative leak rate analysis, Troubleshooting leak problems in vacuum systems

UNIT V: APPLICATIONS OF VACUUM TECHNOLOGY **(9 hours)**

Industrial Applications: Vacuum coating (PVD, CVD, sputtering, evaporation), Vacuum metallurgy and degassing, Electron beam welding; Scientific Applications: Particle accelerators, Scanning Electron Microscopy (SEM), TEM, Surface science and thin film research; Semiconductor and Space Applications: Vacuum in semiconductor fabrication (etching, lithography), Vacuum insulation and thermal shielding in space tech; Emerging and Miscellaneous Applications: Food packaging, Vacuum drying, freeze drying, Vacuum tube devices, lighting technology

Recommended Textbooks & References

1. Vacuum Science and Technology by V.V. Rao, T.B. Ghosh, and K.L. Chopra – Allied Publishers
2. Vacuum Technology by A. Roth – North-Holland (Elsevier)
3. Handbook of Vacuum Technology by Karl Jousten – Wiley-VCH
4. NPTEL Course:
   Vacuum Technology and Process Applications – Prof. V. Vasudeva Rao, IIT Kharagpur
   View Course

5. Manufacturers' Manuals & Videos:
   Pfeiffer, Edwards, and Agilent vacuum systems (operation, leak detection, maintenance)

6. Online Simulations and Virtual Labs:
   nanohub.org

   vlabs.iitb.ac.in – Virtual Experiments on Pumps and Pressure Gauges

SEMESTER-VI

COURSE 14 B: VACUUM TECHNOLOGY

Practical **Credits: 1** **2 hrs/week**

Course Objective:

To impart practical knowledge of vacuum generation, measurement, and leak detection techniques essential for thin film deposition, material processing, and analytical instrumentation.

Learning Outcomes: After completing this course, students will be able to:

1. Understand and operate vacuum pumps and pressure gauges.
2. Measure vacuum levels using appropriate sensors and methods.
3. Identify flow regimes and evaluate pump-down characteristics.
4. Detect and interpret common vacuum system leaks and conductance limitations.
5. Maintain and troubleshoot basic vacuum systems safely.

Minimum of 6 experiments to be done and recorded

Experiment 1: Demonstration of Vacuum using a Bell Jar and Rotary Pump

- Objective: To demonstrate creation of low vacuum using a bell jar and observe pressure reduction.
- Apparatus: Bell jar, rotary vane pump, vacuum gauge, rubber seal.
- Procedure: Evacuate air from the bell jar and observe physical changes (e.g., bursting balloon, water boiling at room temperature).
- Concepts: Low vacuum creation, pressure vs. boiling point, pressure gauge reading.

Experiment 2: Calibration of a Pirani Gauge

- Objective: To calibrate a Pirani gauge using known pressures.
- Apparatus: Pirani gauge, vacuum system with pressure control, reference gauge.
- Procedure: Record gauge readings at known pressures and plot calibration curve.
- Concepts: Gauge sensitivity, thermal conductivity-based pressure sensing.

Experiment 3: Estimation of Pumping Speed of a Rotary Pump

- Objective: To measure the pumping speed of a rotary pump.
- Apparatus: Rotary pump, vacuum chamber, vacuum gauge, stopwatch.
- Procedure: Record pressure vs. time and use gas law relations to estimate speed.
- Concepts: Pumping speed, pressure decay analysis.

Experiment 4: Measurement of Pressure Using McLeod Gauge

- Objective: To measure low pressure using a McLeod gauge.
- Apparatus: McLeod gauge, vacuum pump.
- Procedure: Compress a known gas volume and read pressure.
- Concepts: Boyle’s law, precision pressure measurement.

Experiment 5: Leak Detection using Bubble Method

- Objective: To detect leaks in a vacuum system using soap solution.
- Apparatus: Vacuum tubing system, pump, soap solution.
- Procedure: Apply soap to joints and observe bubbles while evacuating.
- Concepts: Leak identification, pressure loss due to leaks.

Experiment 6: Observation of Mean Free Path Effects

- Objective: To demonstrate changes in mean free path at low pressures.
- Apparatus: Small gas discharge tube, variable pressure chamber.
- Procedure: Observe discharge glow as pressure decreases.
- Concepts: Mean free path, gas discharge, low-pressure physics.

Experiment 7: Vacuum Distillation or Water Boiling at Low Pressure

- Objective: To show that water boils at lower temperatures under vacuum.
- Apparatus: Bell jar, beaker with water, vacuum pump.
- Procedure: Evacuate bell jar and observe boiling of water at room temp.
- Concepts: Vapor pressure, pressure-temperature relation.

Experiment 8: Determination of Outgassing Rate

- Objective: To measure the rate of pressure rise due to outgassing.
- Apparatus: Sealed vacuum chamber, pressure gauge.
- Procedure: Pump down chamber, isolate, and record pressure rise over time.
- Concepts: Outgassing, gas desorption from surfaces.

Experiment 9: Study of Pressure Rise with and without Cold Trap

- Objective: To compare pressure stability with/without cold trap.
- Apparatus: Cold trap (liquid nitrogen), vacuum line, gauge.
- Procedure: Monitor pressure over time in both configurations.
- Concepts: Vapor capture, pressure maintenance, oil backstreaming control.

Experiment 10: Simple Thin Film Deposition by Thermal Evaporation in Vacuum

- Objective: To deposit a thin metal film using a basic thermal evaporator setup.
- Apparatus: Evaporation chamber, resistive heater (tungsten filament), metal wire (e.g., Al), glass substrate.
- Procedure: Evacuate chamber, heat metal to evaporation, observe film on glass.
- Concepts: Vacuum coating, deposition, evaporation rate.

SEMESTER-VI

COURSE 14 C: CHARACTERIZATION OF NANOMATERIALS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To introduce students to the fundamental principles and practical applications of nanomaterial characterization techniques, enabling them to understand and analyze key structural, optical, surface, electrical, and magnetic properties using both experimental methods and digital tools, while appreciating the role of characterization in linking nanoscale features to material behavior and functionality.

LEARNING OUTCOMES

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

1. **Explain** the need for nanomaterial characterization and the differences between bulk and nanoscale properties.
2. **Describe** the basic principles and applications of optical, structural, surface, electrical, and magnetic characterization techniques.
3. **Interpret** experimental data from techniques such as UV-Vis spectroscopy, XRD, SEM, and DLS for analyzing nanoparticle properties.
4. **Apply** software tools like ImageJ and Origin to analyze images, spectra, and patterns related to nanomaterial properties.
5. **Recognize** the limitations and challenges in nanoscale measurement and data interpretation.

UNIT I: NEED OF CHARACTERIZATION (9 hours)

Need for characterization: structure–property relationships in nanomaterials, Key parameters: particle size, shape, distribution, crystallinity, and surface area, Differences between bulk and nanoscale behavior, Role of characterization in synthesis validation and application suitability

Classification of techniques: microscopic, spectroscopic, surface, and property-based, Introduction to qualitative vs. quantitative methods, Overview of limitations and challenges in nanoscale measurement

UNIT II: OPTICAL CHARACTERIZATION TECHNIQUES (9 hours)

Visual cues: color change due to nanoparticle size (e.g., silver/gold nanoparticles), UV-Visible Spectroscopy: absorption peak shifts and size estimation, Fluorescence Spectroscopy: emission behavior of quantum dots, ZnO nanoparticles, Dynamic Light Scattering (DLS): principle and interpretation of size distribution, Tyndall Effect and Light Scattering: basic demonstrations

Cost-effective classroom/lab setups for basic optical analysis

UNIT III: STRUCTURAL AND SURFACE ANALYSIS TECHNIQUES (9 hours)

X-ray Diffraction (XRD): basic principles, Bragg's law, and crystallite size estimation using Scherrer's formula, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM): image interpretation, magnification limits (conceptual level)

Atomic Force Microscopy (AFM): surface topography and roughness (introductory idea)

Brunauer–Emmett–Teller (BET) Method: surface area measurement (overview)

Particle size estimation using mechanical sieving and limitations

UNIT IV: ELECTRICAL AND MAGNETIC PROPERTIES (9 hours)

Electrical conductivity in nanomaterials: size effects and measurement basics, Four-Point Probe Method: concept and application in resistivity measurement, I-V Characteristics of nanomaterials (introductory level), Magnetic properties: basic concepts of paramagnetism, superparamagnetism in nanoparticles, Use of Vibrating Sample Magnetometer (VSM): basic working

UNIT V: DIGITAL TOOLS AND SOFTWARE FOR ANALYSIS (9 hours)

ImageJ: measuring particle size, area, and shape from microscope images, Origin/Excel: plotting UV-Vis spectra, XRD patterns, and thermal curves, Simulated datasets for spectrum analysis (UV-Vis, XRD, Fluorescence), Basics of software-based pattern fitting and peak identification

Online repositories for open-access nanomaterial datasets, Introduction to nanomaterial databases and visualization tools (e.g., NanoHUB simulations)

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. Characterization of Nanostructures by Klaus D. Sattler

4. Materials Characterization by Yang Leng

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COURSE 14 C: CHARACTERIZATION OF NANOMATERIALS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The objective of this laboratory course is to provide hands-on experience with simple, cost-effective experimental techniques for characterizing the properties of nanomaterials. Through a series of guided experiments, students will explore optical, electrical, magnetic, thermal, and surface characteristics of nanoparticles using basic lab tools and freely available software.

LEARNING OUTCOMES:

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

1. **Identify and interpret optical characteristics** of nanoparticles through color changes, light scattering, and UV fluorescence.
2. **Test basic electrical and magnetic properties** of nanomaterials using simple instruments like multimeters and magnets.
3. **Perform particle size analysis** using sieve methods and image processing software (e.g., ImageJ).
4. **Conduct surface property experiments** such as dye adsorption to understand surface area effects in nanomaterials.
5. **Analyze simulated X-ray diffraction patterns** using free tools (e.g., VESTA) to understand the crystal structure of nanoparticles.
6. **Observe thermal behavior of nanomaterials** through heating experiments and interpret physical changes like color and mass.
7. **Utilize digital tools** to analyze microscope images and spectra, enabling deeper insight into nanoparticle morphology and behavior.
8. **Practice safe laboratory procedures** while working with nanomaterials and associated equipment.

A minimum of 6 experiments of the following to be recorded

1. Color Analysis of Nanoparticles
   Compare colors of different nanoparticle solutions (e.g., Ag, Au) visually.

   Equipment: Beakers, nanoparticle solutions.

2. Light Scattering with a Laser Pointer
   Use a laser pointer to observe scattering in a nanoparticle solution.

   Equipment: Laser pointer, glass vial, nanoparticle solution.

3. UV Lamp Fluorescence Test
   Expose ZnO nanoparticles to UV light and observe glowing effect.

Equipment: UV lamp, ZnO nanoparticles.

4. Simple Conductivity Test
   Measure conductivity of a nanoparticle film using a multimeter.

   Equipment: Multimeter, glass slide with nanoparticle film.

5. Magnetic Property Test
   Test magnetic behavior of iron oxide nanoparticles using a magnet.

   Equipment: Magnet, Fe3O4 nanoparticles, beaker.

6. Sieve Analysis for Particle Size
   Use sieves to estimate size of ground nanoparticles (e.g., charcoal).

   Equipment: Sieves, mortar, pestle.

7. Dye Adsorption for Surface Area
   Adsorb a dye (e.g., methylene blue) on ZnO nanoparticles to estimate surface area.

   Equipment: Beakers, dye, UV-Vis spectrophotometer (optional).

8. Simulating XRD Patterns
   Use free software (e.g., VESTA) to simulate X-ray diffraction of nanomaterials.

   Equipment: Computer with software.

9. Thermal Test of Nanoparticles   Heat ZnO nanoparticles in an oven and observe color or weight change. Equipment: Oven, balance, ZnO nanoparticles.
10. Image Analysis with Software   Use ImageJ to analyze provided nanoparticle images for size and shape. Equipment: Computer with software.

SEMESTER-VI

COURSE 14 D: ENERGY STORAGE AND CONVERSION SYSTEMS

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE

The objective of this course is to introduce students to the principles, classifications, and applications of various energy storage systems and direct energy conversion technologies. It aims to provide foundational knowledge on mechanical, electrochemical, thermal, and magnetic energy storage, along with direct conversion devices like thermoelectric, thermionic, MHD generators, and fuel cells. The course emphasizes the role of these technologies in modern and sustainable energy systems.

LEARNING OUTCOMES

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

1. Understand the need for energy storage and differentiate between various storage technologies including mechanical, chemical, thermal, and electrical.
2. Explain the working principles and applications of different battery systems such as lead-acid, Ni-Cd, and lithium-ion batteries.
3. Describe the construction, operation, and comparison of capacitors, supercapacitors, and SMES, and their relevance in high-power energy applications.
4. Analyze the functioning and performance of direct energy conversion devices such as thermoelectric, thermionic, and magneto hydro dynamic generators.
5. Comprehend the design, classification, and efficiency of fuel cells, and identify suitable applications and limitations of various fuel cell types.

UNIT-I: ENERGY STORAGE (9 hours)

Importance of energy storage, Flywheel, electrical and magnetic storage, Capacitors, electromagnets, Thermo-chemical, photochemical, biochemical, and electrochemical storage, Fossil and synthetic fuels, hydrogen as storage.

UNIT-II: BATTERIES (9 hours)

Battery classification: primary vs secondary, MnO_2 batteries, lead-acid, Ni-Cd, lithium-ion, Battery applications

UNIT-III: SUPER CAPACITORS AND SMES (9 hours)

Superconducting Magnet Energy Storage (SMES), Concept and types of supercapacitors: EDLCs, pseudocapacitors, hybrids, Differences between capacitors, supercapacitors, and batteries

UNIT-IV: DIRECT ENERGY CONVERSION DEVICES (9 hours)

Thermoelectric generators: Seebeck effect, efficiency, Thermionic generators: construction, efficiency, Magneto Hydro Dynamic (MHD) generators: working and performance

UNIT-V: FUEL CELLS (9 hours)

Fuel cell concept and classification, Alkaline, phosphoric acid, PEM, molten carbonate, solid oxide fuel cells, Efficiency and characteristics, Applications and limitations

Reference Books

1. *Fundamentals of Energy Storage* – J. Jensen, B. Sorensen
2. *Electrochemical Power Sources* – P. Peregrines
3. *Supercapacitors: Materials, Systems, and Applications* – F. Beguin & E. Frackowiak
4. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput
5. *Non-Conventional Energy Resources* – B.H. Khan

SEMESTER-VI

COURSE 14 D: ENERGY STORAGE AND CONVERSION SYSTEMS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide students with practical exposure to various energy storage technologies, fuel cell operations, and direct energy conversion systems, enabling hands-on understanding of their characteristics, efficiency, and real-world applications.

LEARNING OUTCOMES

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

1. Analyze charge–discharge behavior of batteries (lead-acid, lithium-ion, Ni-Cd) and capacitors through real-time measurements.
2. Evaluate fuel cell performance under varying load and temperature conditions using voltage–current characteristics.
3. Construct and test simple electrochemical systems, such as primary batteries and thermoelectric modules.
4. Demonstrate and interpret the Seebeck effect using thermocouple and Peltier modules.
5. Simulate or observe direct energy conversion devices, such as MHD generators, and understand their potential in renewable energy systems.

A minimum of 6 experiments to be performed and recorded

Practical list

1. Charge-discharge characteristics of storage batteries
2. Charging/discharging behavior of capacitors
3. Charging of Ni-Cd battery using solar PV
4. Performance estimation of a fuel cell
5. Temperature dependence of fuel cell efficiency
6. Voltage-current characteristics of fuel cells
7. Construction and testing of a simple lemon battery (primary battery demo)
8. Determination of internal resistance and efficiency of a lead-acid battery
9. Study of charging characteristics of a lithium-ion battery
10. Observation of Seebeck effect using thermocouple setup
11. Testing of a thermoelectric module (TEC1 – Peltier/Seebeck module)
12. Simulation or model demonstration of a Magneto Hydro Dynamic (MHD) generator

SEMESTER-VI

COURSE 14 E: COMPUTATIONS IN OPTICS, HEAT AND THERMODYNAMICS

Theory	Credits: 3	3 hrs/week

COURSE OBJECTIVE:

This course aims to equip students with computational skills to model, analyze, and visualize fundamental concepts in optics, thermodynamics, and quantum theory. Students will learn to implement and simulate key physical phenomena using programming techniques.

LEARNING OUTCOMES:

1. Students will be able to computationally apply Snell's Law, trace ray paths, and define optical components as objects to analyze image formation and lens systems.
2. Students will be able to simulate and visualize interference patterns, calculate maxima/minima positions, and plot intensity distributions for various wave experiments.
3. Students will be able to write functions to determine maxima/minima for single-slit and grating diffraction, visualize spectra, and calculate grating resolving power.
4. Students will be able to compute and visualize Maxwell's velocity distribution, plot P-V and T-S diagrams, and calculate thermodynamic efficiencies and potentials.
5. Students will be able to computationally model and graphically compare spectral distributions from Wien's, Rayleigh-Jeans, and Planck's laws, and calculate energy density using the Stefan-Boltzmann law.

UNIT-I: RAY OPTICS (9 hrs)

Write functions to calculate the refracted angle using Snell's Law and the reflected angle, Visualize ray paths and image formation graphically, write functions to calculate resultant focal length of two lenses separated by a distance, Defining lenses and mirrors as objects with properties (focal length, curvature, position).

UNIT-II: ABERRATIONS AND INTERFERENCE (9 hrs)

Visualization of chromatic aberration, Computer positions of maxima, minima and fringe width in Young’s double-slit experiment, Plot the intensity distribution for Young's double-slit experiment, Create a 2D heatmap or contour plot of the interference pattern produced by two point sources, visualization of Newton’s rings.

UNIT-III: DIFFRACTION (9 hrs)

Write functions to compute positions of maxima and minima in Fraunhoffer diffraction due to single slit and diffraction grating. Visualize the spectrum of white light using diffraction grating, calculation of resolving power of grating, write function to calculate wavelength of light using diffraction grating.

UNIT-IV: THERMODYNAMICS **(9 hrs)**

Calculation and visualization of Maxwell's distribution of molecular velocities, Write functions to graphically represent P-V diagrams and T-S diagrams, Write function to compute efficiency of Carnot engine, Write function to calculate Thomson's cooling, write function to calculate thermodynamic potentials (Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy).

UNIT-V: QUANTUM THEORY OF RADIATION **(9 hrs)**

Write functions to calculate spectral distributions using Wien's displacement law, Rayleigh-Jeans law, Planck's quantum theory, Graphical comparison of Wien's displacement law, Rayleigh-Jeans law, Planck's quantum theory of radiation, calculation of energy density Stephan-Boltzmann law as a function of temperature.

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. "Optics" by Eugene Hecht
5. "Computational Photonics: An Introduction with MATLAB/Python" by Marek S. Wartak
6. "Thermodynamics and an Introduction to Thermostatistics" by Herbert B. Callen
7. "Thermal Physics" by Ralph Baierlein
8. "Thermal Physics" by Daniel V. Schroeder
9. "Concepts of Modern Physics" by Arthur Beiser
10. "Quantum Mechanics: Concepts and Applications" by Nouredine Zettili
11. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas

STUDENT ACTIVITIES

UNIT-I: Ray Optics

- Activity 1: Write functions to calculate refracted and reflected angles using Snell's Law, then visualize light ray paths and image formation through lenses and mirrors graphically.
- Activity 2: Define lenses and mirrors as objects with properties like focal length and curvature, then write functions to calculate the resultant focal length of multiple lenses.

UNIT-II: Aberrations and Interference

- Activity 1: Visualize chromatic aberration and write functions to compute positions of maxima, minima, and fringe width for Young's double-slit experiment, then plot the intensity distribution.
- Activity 2: Create 2D heatmaps or contour plots of interference patterns from two point sources, and visualize Newton's rings.

UNIT-III: Diffraction

- Activity 1: Write functions to compute and visualize the positions of maxima and minima for Fraunhofer diffraction from single slits and diffraction gratings, including the visualization of white light spectra.
- Activity 2: Implement functions to calculate the resolving power of a grating and determine the wavelength of light using diffraction grating principles.

UNIT-IV: Thermodynamics

- Activity 1: Calculate and visualize Maxwell's distribution of molecular velocities, and write functions to graphically represent P-V and T-S diagrams for thermodynamic processes.
- Activity 2: Write functions to compute the efficiency of a Carnot engine, calculate Thomson's cooling, and determine various thermodynamic potentials (Internal Energy, Enthalpy, Helmholtz Free Energy, Gibbs Free Energy).

UNIT-V: Quantum Theory of Radiation

- Activity 1: Write functions to calculate and graphically compare the spectral distributions from Wien's displacement law, Rayleigh-Jeans law, and Planck's quantum theory.
- Activity 2: Calculate and visualize the total energy density as a function of temperature using the Stefan-Boltzmann law.

SEMESTER-VI

COURSE 14 E: COMPUTATIONS IN OPTICS, HEAT AND THERMODYNAMICS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

This course aims to develop students' ability to computationally model and visualize fundamental phenomena in optics, thermodynamics, and quantum radiation theory. Students will implement core physics principles through programming to analyze and interpret physical systems.

LEARNING OUTCOMES:

1. Model Ray Optics Systems: Students will be able to write functions to apply Snell's Law and calculate reflection, and compute equivalent focal lengths for multi-lens systems.
2. Analyze and Visualize Interference Patterns: Students will be able to calculate intensity distributions for Young's double-slit experiment and generate 2D plots of interference patterns.
3. Compute and Plot Diffraction Phenomena: Students will be able to write functions to determine intensity and angles for single-slit diffraction and diffraction gratings.
4. Simulate and Graph Thermodynamic Processes: Students will be able to visualize Maxwell's velocity distributions and plot P-V diagrams for thermodynamic cycles like the Carnot cycle.
5. Compare Quantum Radiation Laws: Students will be able to computationally implement and graphically compare Wien's, Rayleigh-Jeans, and Planck's laws for spectral radiance.

Minimum of 6 experiments to be conducted and recorded

1. Write a function snell_law(n1, n2, theta_i) to calculate the refracted angle
2. Write a function reflect_angle(theta_i) to calculate the reflected angle.
3. Write a function calculate_resultant_focal_length(lens1, lens2, separation) that computes the equivalent focal length for two thin lenses separated by a distance d.
4. Write a function to calculate the intensity at a point on a screen for Young's double-slit setup, given wavelength, slit separation, and screen distance.
5. Generate a 2D heatmap or contour plot of the interference pattern, clearly showing regions of high and low intensity.
6. Write a function to calculate the intensity for single-slit diffraction given slit width, wavelength, and angle.
7. Write a function to calculate the diffraction angles for different orders (m) and wavelengths passing through a grating.
8. Plot the distribution for different temperatures (e.g., 300K, 600K) and for different gases (e.g., Hydrogen, Oxygen) on the same graph, observing the shift in peak velocity.
9. Plot the P-V diagram for a complete Carnot cycle (two isothermal and two adiabatic processes).
10. Write functions to calculate the spectral radiance (or energy density) as a function of wavelength for Wien's, Rayleigh-Jeans, and Planck's laws.

SEMESTER-VI

COURSE 15 A: ELECTRONIC COMMUNICATION SYSTEMS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To provide students with a comprehensive understanding of the principles, techniques, and components used in electronic communication systems, including analog and digital modulation, antennas, wave propagation, and modern communication technologies such as fiber optics, microwaves, and satellite communication.

LEARNING OUTCOMES

After successful completion, students will be able to:

1. Describe types and characteristics of antennas and propagation mechanisms.
2. Explain and differentiate AM, FM, and pulse modulation techniques.
3. Analyze transmitter and receiver block diagrams for analog and digital systems.
4. Design and simulate basic modulator and detector circuits.
5. Apply communication principles in optical, satellite, and digital transmission systems.

UNIT-I ANTENNAS AND WAVE PROPAGATION (9hrs)

Antenna - Effective resistance - Efficiency - Directive gain - Bandwidth, Beam width and polarization - Dipole - Folded dipole - Arrays - Yagi - Uda - Helical - Discone - Parabolic - Dish Antennas - Ground wave, sky wave and space ware propagation - Skip distance - Maximum usable frequency.

UNIT-II AMPLITUDE MODULATION (9hrs)

Modulation - Needs for Modulation - Types of Modulation - Amplitude Modulation Generation and detections circuits - Balanced Modulator - DSB/SC and SSB Modulation - VSB modulation. Block diagram of AM Radio transmitter and super heterodyne Receiver.

UNIT-III FREQUENCY MODULATION (9hrs)

Frequency Modulation - Definition - Derivation of Modulated wave - Generation of FM - Varactor diode and Reactance tube Modulators, Detectors - Balanced slope detector, Foster Seeley discriminator, and ratio detector, Block diagram of FM transmitter and receiver.

UNIT-IV PULSE MODULATION (9hrs)

Pulse Modulation - Sampling theorem - PAM, PWM, PCM - quantizing, sampling, coding, decoding, quantization error, delta modulation and adaptive delta modulation.

UNIT-V DIGITAL COMMUNICATION **(9hrs)**

Multiplexing - FDM, TDM, CDMA - ASK, FSK, PSK
Advantages of Digital Communication, Introduction to Microwave, Fiber optic, Satellite Communications

Text Books

1. Electronic Communication Systems - *George Kennedy*, McGraw Hill Book Company, 4/e, 2005.
2. Communication Engineering - *T.G. Palanivelu*, Anuradha Publicatons, 1/e, 2002.
3. Communication System - *Roddy & Coolen*, 4/e, Pearson Education, 2005.
4. Principles of Communication Engineering - *Anok Singh*, 4/e, Sathyaprakasam Publications, 2004.
5. Electronic Communication Systems *Wayne Tomasi*, 4/e, Pearson Education, 2004.

Student Activities

1. **Model Making:** Build simple antennas (dipole, Yagi) using rods or wires.
2. **Circuit Assembly:** Construct AM or FM transmitters using breadboard and discrete components.
3. **Simulations:** Use Python/Matlab/Scilab for visualizing AM/FM/PCM waveforms.
4. **Poster Presentation:** Compare analog and digital modulation in communication history.
5. **Mini Project:** Design a simple radio receiver or a simulated digital communication system.
6. **Group Assignment:** Trace signal path in an FM radio or DTH system with block diagrams.

SEMESTER-VI

COURSE 15 A: ELECTRONIC COMMUNICATION SYSTEMS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE

To provide practical experience in various analog and digital modulation techniques and their applications in communication systems.

LEARNING OUTCOMES:

By completing the lab, students will be able to:

1. Design and construct basic analog and digital modulation/demodulation circuits.
2. Use simulation tools to generate and analyze modulated waveforms.
3. Compare performance of various modulation schemes.
4. Understand block-level implementation of communication systems.
5. Relate antenna performance to theoretical parameters.

Minimum of 6 experiments to be done and recorded

1. **Amplitude Modulation (AM) and Demodulation**
2. **Frequency Modulation (FM) and Demodulation**
3. **Simulation of AM and FM Signals *(using Python/Scilab/Matlab)***
4. **Pulse Amplitude Modulation (PAM): Generation and Detection**
5. **Pulse Width Modulation (PWM): Generation and Detection**
6. **Pulse Code Modulation (PCM): Generation, Sampling, and Reconstruction**
7. **Delta Modulation and Adaptive Delta Modulation**
8. **Amplitude Shift Keying (ASK): Generation and Detection**
9. **Frequency Shift Keying (FSK): Generation and Detection**
10. **Phase Shift Keying (PSK): Generation and Detection**
11. **Observation of Antenna Radiation Patterns *(Dipole and Yagi – Simulation or Demonstration)***
12. **Construction and Testing of a Simple AM or FM Radio Receiver**

SEMESTER-VI

COURSE 15 B: MATERIALS FOR INDUSTRIAL APPLICATIONS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVES

To provide an overview of materials used in industrial applications, their classification, properties, and methods of fabrication and characterization, enabling students to relate material science concepts to practical engineering systems.

LEARNING OUTCOMES

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

1. **Classify engineering materials** (metals, ceramics, polymers, composites) and describe their atomic structures, bonding types, and physical properties including mechanical, electrical, thermal, magnetic, and optical behavior.
2. **Analyze the structure and properties of metals and alloys**, interpret phase diagrams (e.g., iron–carbon), explain heat treatment processes, and understand corrosion mechanisms and preventive methods.
3. **Describe the structure, processing, and applications of ceramics and polymers**, and compare their mechanical and thermal characteristics for industrial use.
4. **Differentiate types of composite and smart materials**, understand their fabrication methods, and evaluate their applications in advanced technologies such as aerospace, biomedical, and automotive sectors.
5. **Apply principles of material selection** using performance criteria, cost, and availability; utilize Ashby charts and databases at a basic level; and evaluate real-world case studies involving material choices for specific applications.

UNIT I: FUNDAMENTALS OF ENGINEERING MATERIALS (9 Hours)

Classification: Metals, Ceramics, Polymers, Composites, Atomic structure and bonding in solids, Crystalline vs. amorphous solids; defects in crystals, Mechanical properties: Stress-strain, toughness, hardness, ductility, Electrical, thermal, magnetic, and optical properties overview

UNIT II: METALS AND ALLOYS (9 Hours)

Ferrous metals: Types of steel, cast iron – uses in industry, Non-ferrous metals: Aluminum, copper, titanium – applications, Phase diagrams (Iron-Carbon), alloying principles, Heat treatment: Annealing, quenching, tempering, Corrosion mechanisms and prevention (coatings, plating)

UNIT III: CERAMICS AND POLYMERS **(9 Hours)**

Ceramics: Structure, properties, manufacturing (sintering, vitrification), Applications: Refractories, abrasives, dielectrics, Polymers: Thermoplastics vs. thermosets, Examples: Nylon, PVC, PTFE, Bakelite, Polycarbonate, Mechanical and thermal behavior of polymers

UNIT IV: COMPOSITES AND SMART MATERIALS **(9 Hours)**

Types of composites: Fiber-reinforced, metal/ceramic matrix, Fabrication techniques: Hand lay-up, pultrusion, resin transfer molding, Applications: Aerospace, automotive, biomedical, construction, Smart materials: Shape memory alloys, piezoelectric, magnetostrictive materials

UNIT V: MATERIALS SELECTION AND CASE STUDIES **(9 Hours)**

Criteria for material selection: Performance, cost, durability, availability, Ashby charts and material databases (introductory level), Case studies: Automotive components, Power plant materials, Packaging (metal, plastic, bio-degradable), Biomedical materials (implants, prosthetics)

Text Books & References

1. *Materials Science and Engineering* – William D. Callister
2. *Introduction to Materials Science for Engineers* – James F. Shackelford
3. *Engineering Materials: Properties and Selection* – Kenneth G. Budinski
4. NPTEL Courses on Materials Science
5. TTTI Modules on Material Selection in Industry

Suggested Student Activities:

1. Material Identification Task: Classify given samples (metals, ceramics, polymers, composites) based on their observable properties.
2. Case Study: Analyze material choice in a common product (e.g., engine block, prosthetic implant, or smartphone casing).
3. Simple hardness or tensile strength demo: Use school-level setups or virtual tools.
4. Poster/Presentation: Emerging materials in aerospace or biomedical industries.
5. Factory or lab visit report: Interaction with an industrial process involving materials (e.g., foundry, welding unit, polymer lab).

SEMESTER-VI

COURSE 15 B: MATERIALS FOR INDUSTRIAL APPLICATIONS

Practical **Credits: 1** **2 hrs/week**

Course Objective:

The objective of this practical course is to provide hands-on experience in testing and analyzing the mechanical, thermal, electrical, and structural properties of various engineering materials. Students will develop experimental skills relevant to industrial applications, including characterization of metals, polymers, composites, and smart materials. The course aims to bridge theoretical knowledge with real-world materials behavior and processing techniques.

Learning Outcomes:

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

1. Perform tensile and hardness tests to evaluate the mechanical properties of materials.
2. Analyze the effect of heat treatment on the hardness of steel and interpret microstructural changes using optical microscopy.
3. Measure and compare electrical resistivity and thermal conductivity of different materials.
4. Conduct corrosion testing and understand the degradation behavior of metals in corrosive environments.
5. Fabricate simple composite samples and perform basic testing on polymer materials.
6. Demonstrate the shape memory effect in NiTi alloys and understand its significance in advanced materials.
7. Apply safe laboratory practices and document experimental results with scientific accuracy

Minimum of 6 experiments to be done and recorded

List of Practical

1. Stress-strain analysis (tensile test)
2. Hardness testing (Rockwell, Brinell)
3. Heat treatment and hardness variation in steel
4. Microstructure observation using optical microscopy
5. Electrical resistivity of metals and semiconductors
6. Thermal conductivity comparison of materials
7. Simple polymer mechanical testing
8. Composite fabrication using hand lay-up method
9. Corrosion testing in saline solution
10. Demonstration of shape memory effect in NiTi alloy

SEMESTER-VI

COURSE 15 C: APPLICATIONS OF NANOMATERIALS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To introduce students to the diverse and interdisciplinary applications of nanotechnology across key sectors such as electronics, energy, healthcare, environment, and consumer goods, while fostering an understanding of its societal impact, ethical considerations, and future directions.

Learning Outcomes

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

1. **Explain** how nanomaterials are used in modern electronics, including displays, sensors, and flexible devices.
2. **Describe** the role of nanotechnology in enhancing energy generation, storage, and efficiency through advanced materials.
3. **Discuss** biomedical applications of nanotechnology, including drug delivery, diagnostics, and antimicrobial coatings.
4. **Analyze** how nanotechnology contributes to environmental sustainability through purification, sensing, and green innovations.
5. **Evaluate** the societal, ethical, and economic implications of nanotechnology, and recognize its global trends and challenges.

UNIT I: NANOTECHNOLOGY IN ELECTRONICS *(9 hours)*

Role of nanomaterials in display technologies (e.g., OLED, quantum dots), Nanoscale materials in sensors and transistors, Carbon-based conductive materials: Graphene, CNTs, and their electrical properties, Introduction to flexible and printable electronics using nanomaterials

Emerging trends in nanoelectronics: miniaturization and performance enhancement

UNIT II: NANOTECHNOLOGY IN ENERGY *(9 hours)*

Application of nanomaterials in photovoltaic cells (e.g., TiO_2, perovskite nanoparticles), Nanostructured electrodes in lithium-ion and solid-state batteries, Role of nanomaterials in supercapacitors and hydrogen storage, Thermo-reflective and energy-efficient nanocoatings, Nanotechnology for renewable and clean energy systems

UNIT III: NANOTECHNOLOGY IN HEALTH *(9 hours)*

Targeted drug delivery using liposomes, dendrimers, and polymeric nanoparticles, Use of gold and silver nanoparticles in diagnostics and biosensors, Antibacterial and antiviral nanocoatings for medical devices, Toxicological aspects and biocompatibility of nanomaterials, Examples of nanomedicine in commercial healthcare products

UNIT IV: NANOTECHNOLOGY FOR ENVIRONMENT ***(9 hours)***

Nanomaterials for water purification: adsorption, photocatalysis, and filtration, Air filtration and pollutant breakdown using nanocatalysts, Use of nanosensors for detecting environmental contaminants, Waste treatment and recycling aided by nanomaterials, Principles and examples of green nanotechnology

UNIT V: NANOTECHNOLOGY IN SOCIETY ***(9 hours)***

Everyday nanotech products: textiles, cosmetics, food packaging, Economic impact and affordability of nanotechnology-based goods, Ethical, legal, and safety issues in nanotechnology development, Promoting public awareness and responsible nanotechnology education, Global trends, policies, and future directions in nanotechnology

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. **Introduction to Nanotechnology** – Charles P. Poole Jr. and Frank J. Owens

4. **Nanotechnology: Principles and Practices**– Sulabha K. Kulkarni

5. **Nanotechnology for Beginners**– Nan Yao and Zhong Lin Wang

SEMESTER-VI

COURSE 15 C: APPLICATIONS OF NANOMATERIALS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide students with hands-on experience in applying nanotechnology to real-world problems in energy, environment, healthcare, and electronics. The experiments aim to demonstrate basic concepts of nanomaterials and their functional properties using simple, low-cost setups.

LEARNING OUTCOMES:

At the end of this course, students will be able to:

1. **Demonstrate basic fabrication and testing techniques** for nanomaterial-based devices and coatings.
2. **Perform simple experiments** to understand energy harvesting, antibacterial activity, and environmental cleanup using nanomaterials.
3. **Test and analyze functional properties** such as conductivity, UV protection, and sensing behavior of nanoparticle-coated surfaces.
4. **Develop simple prototypes** such as filters, sensors, or coatings using nanocomposites.
5. **Interpret experimental results** and relate them to scientific principles in nanotechnology.

A minimum of 6 experiments of the following to be recorded

1. Simple Solar Cell Model
   Make a basic solar cell using TiO_2 nanoparticles and fruit juice dye.

   Equipment: Glass slides, TiO_2, multimeter, fruit juice.

2. Dye Removal with Nanoparticles
   Use ZnO nanoparticles to remove dye from water under sunlight.

   Equipment: Beakers, ZnO, dye, sunlight.

3. Antibacterial Test of Silver Nanoparticles Test silver nanoparticles on a paper disc against bacterial growth (e.g., on agar). Equipment: Agar plates, silver nanoparticles, incubator.
4. Nanoparticle-Coated Fabric Coat cotton fabric with ZnO nanoparticles and test water repellency. Equipment: Cotton, ZnO nanoparticles, beaker.
5. Simple Nanosensor Model
   Use silver nanoparticles on paper to detect ammonia (color change).

   Equipment: Paper, ammonia solution, nanoparticles.

6. Conductive Nanoparticle Film
   Create a carbon nanoparticle film and test its conductivity with a multimeter.

   Equipment: Multimeter, glass slide, carbon nanoparticles.

7. Nanoparticle Water Filter
   Make a filter with nanoparticle-coated paper and test dye removal.

   Equipment: Filter paper, nanoparticles, dye solution.

8. Battery Model with Nanomaterials
   Build a simple battery using carbon nanoparticles as an electrode.

   Equipment: Multimeter, carbon, zinc, electrolyte.

9. UV-Protective Coating
   Coat a paper with ZnO nanoparticles and test UV blocking with a UV lamp.

   Equipment: UV lamp, ZnO, paper.

10. Nanocomposite Preparation   Mix ZnO nanoparticles with glue to make a nanocomposite and test its strength. Equipment: Glue, ZnO, mold, balance.
    Implementation Notes

SEMESTER-VI

COURSE 15 D: BIOMASS AND HYDROGEN ENERGIES

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

This course aims to introduce students to the fundamental principles and technologies involved in the generation and utilization of bioenergy and hydrogen energy. It covers biomass resources, biogas production, gasification, biofuels, and hydrogen as alternative energy carriers. The course emphasizes the role of these renewable sources in achieving sustainable and eco-friendly energy solutions.

LEARNING OUTCOMES

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

1. Identify various biomass resources and explain their conversion routes such as thermochemical, biochemical, and physical methods.
2. Understand the design, operation, and efficiency of different biogas plant models and recognize the factors affecting gas production.
3. Explain the gasification process and distinguish it from combustion and pyrolysis, including its application in waste-to-energy conversion.
4. Classify biofuels and describe their sources, production methods, advantages over fossil fuels, and their current status in India.
5. Understand the significance of hydrogen as a clean fuel, its production and storage techniques, and its applications in energy systems.

UNIT-I: BIOMASS RESOURCES (9 hours)

Definition and sources, Photosynthesis, Biomass conversion: physical, incineration, thermochemical, biochemical, Biomass properties and applications

UNIT-II: BIOGAS PRODUCTION (9 hours)

Biogas plants and components, Floating drum, Janatha, and Deenabandhu models, Factors affecting biogas generation, Applications and troubleshooting

UNIT-III: GASIFICATION AND WASTE-TO-ENERGY (9 Hours)

Definition and need for gasification, Comparison with combustion and pyrolysis, Advantages of gasification for biomass utilization, Fixed Bed Gasifiers (Updraft and downdraft configurations, Working principle, structure, and temperature zones), Waste-to-Energy Technologies: Urban Solid Waste: Segregation, drying, shredding for fuel, Liquid Waste: Anaerobic digestion, biogas production

UNIT-IV: BIOFUELS **(9 Hours)**

What are biofuels? Classification: first, second, and third-generation biofuels, Benefits over fossil fuel, Ethanol as a Biofuel: Raw materials, Production methods: fermentation and distillation (basic process); Biodiesel: Sources: vegetable oils, animal fats, waste cooking oil, Transesterification Process (basic) Properties of biodiesel; Producer Gas Composition Properties and calorific value, E85 Fuel, Biofuel Scenario in India

UNIT-V: HYDROGEN ENERGY **(9 Hours)**

Introduction to Hydrogen Energy Why hydrogen? Role in clean energy Physical and chemical properties of hydrogen, Advantages and Disadvantages, Hydrogen Production Techniques: Electrolysis of Water, Thermochemical water splitting (concept only), Hydrogen Storage Methods: Compressed Gas Cylinders, Liquid Hydrogen Tanks, Solid-State Storage (Hydrides); Applications of Hydrogen Energy: Fuel cells (brief mention), Hydrogen as fuel for vehicles and industry

Reference Books

1. *Bio Energy Technology* – David Boyles
2. *Non-Conventional Energy Sources* – G.D. Rai
3. *Non-Conventional Energy Resources* – B.H. Khan
4. *Biogas Technology – A Practical Handbook* – K.C. Khandelwal & S.S. Mahdi

SEMESTER-VI

COURSE 15 D: BIOMASS AND HYDROGEN ENERGIES

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide hands-on experience and practical understanding of biomass properties, biogas and biofuel production, gasification systems, and hydrogen energy technologies. This lab enables students to correlate theoretical concepts with real-world renewable energy applications.

LEARNING OUTCOMES

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

1. **Determine key physical properties** of biomass such as calorific value, moisture content, and bulk density.
2. **Demonstrate the working principles** of biogas plants and fixed bed gasifiers using models or simulations.
3. **Analyze the effect of feedstock characteristics** on biogas yield through experiments or data-based simulations.
4. **Prepare biodiesel from vegetable oil** using basic chemical processes and assess its physical properties like flash point.
5. **Understand the principles of hydrogen production** through electrolysis and evaluate its energy density using simple demonstrations.

A minimum of 6 experiments to be performed and recorded

Practical

1. Determination of Calorific Value of Biomass Samples
2. Measurement of Moisture Content and Bulk Density of Biomass
3. Demonstration of a Mini Biogas Plant (Floating Drum or Deenabandhu Model)
4. Effect of Feedstock Type on Biogas Yield (Data/Simulation-Based)
5. Model Demonstration of a Fixed Bed Gasifier (Updraft/Downdraft)
6. Segregation and Calorific Estimation of Urban Waste Samples
7. Preparation of Biodiesel from Vegetable Oil (Basic Transesterification Process)
8. Determination of Flash Point of Ethanol and Biodiesel
9. Hydrogen Production by Electrolysis of Water
10. Demonstration or Simulation of Hydrogen Balloon for Energy Density Concept

SEMESTER-VI

COURSE 15 E: COMPUTATIONS IN ELECTRICITY, MAGNETISM, ELECTROMAGNETIC THEORY AND MODERN PHYSICS

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

This course aims to computationally model and visualize fundamental concepts in electricity, magnetism, electromagnetic theory, spectroscopy, and quantum mechanics. Students will develop programming skills to solve complex physics problems and interpret their results graphically.

LEARNING OUTCOMES:

1. Students will be able to calculate and visualize electric and magnetic field lines, and analyze the behavior of currents in AC/DC circuits.
2. Students will compute Lorentz force, self/mutual inductance, and analyze electromagnetic wave properties including reflection and transmission at interfaces.
3. Students will be able to calculate atomic properties, determine spectral terms using different coupling schemes, and analyze Raman spectra.
4. Students will compute de Broglie wavelengths, uncertainty principle limits, and visualize atomic orbitals and quantum well wave functions.
5. Students will be able to numerically determine eigenvalues and visualize wave functions for basic quantum systems like the 1D infinite potential well.

UNIT-I: ELECTRICITY, VARYING AND ALTERNATING CURRENTS (9hrs)

Calculation of intensity of electric field due to uniformly charged solid sphere and spherical shell, visualization of electric field lines due to point charge, Write function to express relationship between D, E and P, Calculation of potential due to a uniformly charged solid sphere, Representations of Growth and decay of currents in LR, CR, LCR circuits, representation of variation of impedance in LCR series and parallel resonant

UNIT-II: MAGNETISM (9hrs)

Visualization of magnetic field lines, Calculation of magnetic field induction due to (i) long straight wire, (ii) circular loop and (iii) solenoid, visualization of field as a function of distance, Write function to compute Hall coefficient and carrier concentration.

UNIT-III: ELECTROMAGNETIC THEORY (9hrs)

Calculation of Lorentz Force on a point charge, Calculation of Self- inductance of a long solenoid, Magnetic Energy density, Mutual inductance of a pair of coils, Coefficient of Coupling, Calculation of Visualization of Electric and Magnetic components of electromagnetic waves, Calculate the reflection and transmission coefficients for an EM wave incident normally on an interface between two dielectric media.

UNIT-IV: SPECTROSCOPY (9hrs)

Calculation for radius, energy and wave number of Bohr's atomic model, visualization of Bohr's atomic structure, write function to calculate quantum number associated with vector atom model, write function to calculate spectral terms in L-S coupling and j-j coupling, Calculation of Raman Shift, position of stokes lines and anti-stokes lines.

UNIT-V: MATTER WAVES AND QUANTUM MECHANICS (9hrs)

Calculation of de Broglie wavelength and visualization of variation of wavelength with mass and velocity, calculation of uncertainty in Heisenberg uncertainty principle, visualization of atomic orbitals (s, p and d), computation of eigen values of an eigen value equation, visualization of wave functions and energy levels of 1-D infinite potential well.

REFERENCE BOOKS:

1. "A First Course in Computational Physics" by Paul L. DeVries and Jian-Ke Shang
2. "Python for Data Analysis" by Wes McKinney
3. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas
4. Computational Electromagnetics with MATLAB" by Matthew N.O. Sadiku (While MATLAB focused, the numerical methods and principles are highly relevant and transferable to Python)
5. NumPy: https://numpy.org/doc/stable/user/index.html (Essential for vector operations, arrays)
6. Matplotlib: https://matplotlib.org/stable/users/index.html (For all plotting and visualization)
7. SciPy: https://docs.scipy.org/doc/scipy/reference/ (For numerical integration, ODE solvers, FFT)
8. Pandas: https://pandas.pydata.org/pandas-docs/stable/user_guide/index.html (If you include data handling in experiments beyond basic arrays)
9. Jupyter Notebook Documentation: https://jupyter-notebook.readthedocs.io/en/stable/ (For learning to use the interactive environment)
10. Python Official Documentation: https://docs.python.org/3/ (General Python language reference)
11. ComPADRE Physics Education Resources: https://www.compadre.org/physics/ (A vast collection of physics education resources, including computational tools and simulations. Search for topics related to E&M, Quantum, etc.)
12. Online Courses (e.g., Coursera, edX, MIT OpenCourseware):
13. Many universities offer free or audit options for computational physics, electromagnetism, and quantum mechanics courses that often provide lecture notes, problem sets, and sometimes even Python code examples. Searching for "computational electromagnetism" or "computational quantum mechanics" on these platforms can yield good supplementary material.

14. "The Feynman Lectures on Physics" (Online Edition): https://www.feynmanlectures.caltech.edu/ (Volume II covers Electromagnetism. While not computational, it provides profound conceptual understanding.)

STUDENT ACTIVITIES:

UNIT-I: Electricity, Varying and Alternating Currents

- Activity 1: Write functions to calculate and visualize electric field lines for point charges, and intensity of electric fields for uniformly charged solid spheres and spherical shells.
- Activity 2: Develop simulations to represent the growth and decay of currents in LR, CR, and LCR circuits, and visualize the variation of impedance in LCR series and parallel resonance.

UNIT-II: Magnetism

- Activity 1: Visualize magnetic field lines for various current configurations (long straight wire, circular loop, solenoid) and plot field strength as a function of distance.
- Activity 2: Write functions to compute the Hall coefficient and carrier concentration from simulated or given experimental data, demonstrating their relationship.

UNIT-III: Electromagnetic Theory

- Activity 1: Write functions to calculate the Lorentz force on a point charge and determine self-inductance of a solenoid, magnetic energy density, and mutual inductance/coefficient of coupling for coils.
- Activity 2: Visualize the electric and magnetic components of electromagnetic waves in 2D or 3D, and calculate reflection and transmission coefficients for EM waves incident normally on dielectric interfaces.

UNIT-IV: Spectroscopy

- Activity 1: Calculate and visualize the radius, energy, and wave number for Bohr's atomic model, and write functions to determine quantum numbers for the vector atom model.
- Activity 2: Write functions to calculate spectral terms in L-S and j-j coupling schemes, and compute Raman shift, positions of Stokes and anti-Stokes lines for given molecular parameters.

UNIT-V: Matter waves and quantum mechanics

- Activity 1: Calculate de Broglie wavelength and visualize its variation with mass and velocity, and compute the uncertainty in position/momentum according to Heisenberg's principle.
- Activity 2: Visualize the spatial distribution of atomic orbitals (s, p, and d), and computationally determine eigenvalues and visualize wave functions and energy levels for a 1-D infinite potential well.

SEMESTER-VI

COURSE 15 E: COMPUTATIONS IN ELECTRICITY, MAGNETISM, ELECTROMAGNETIC THEORY AND MODERN PHYSICS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE

This course aims to develop students' computational skills to model, simulate, and visualize fundamental concepts across classical electromagnetism, atomic physics, and quantum mechanics. Students will learn to apply numerical methods and programming to solve complex physical problems.

LEARNING OUTCOMES:

1. Students will be able to calculate and visualize electric fields and simulate the transient behavior of RC and LR circuits.
2. Students will compute and plot magnetic fields from various current configurations and simulate the Lorentz force on moving charges in electromagnetic fields.
3. Students will calculate and visualize reflection and transmission coefficients for EM waves at interfaces.
4. Students will be able to calculate and visualize properties of the Bohr atom and determine wavenumber positions for Raman spectroscopy.
5. Students will compute de Broglie wavelengths, demonstrate the Heisenberg Uncertainty Principle, visualize atomic orbitals, and model wave functions/energy levels for basic quantum systems.

Minimum 6 experiments to be conducted and recorded

1. Write a function to calculate the electric field vector E at a given point due to a point charge at the origin.
2. Use this function to compute and visualize the electric field lines for a single positive point charge in 2D.
3. For an RC circuit, simulate the charging of a capacitor and the decay of current when discharging. Plot current vs. time and voltage across capacitor vs. time.
4. For an LR circuit, simulate the growth of current when a switch is closed and its decay when the voltage source is removed. Plot current vs. time.
5. Write a function to calculate the magnetic field magnitude due to a long straight current-carrying wire as a function of perpendicular distance. Plot the field's dependence.
6. Write a function to calculate the magnetic field magnitude along the axis of a circular current loop. Plot the field's dependence on axial distance.
7. Simulate the 3D trajectory of a charged particle (given initial position, velocity, charge, mass) using numerical integration of its equations of motion.
8. Write functions to calculate the reflection coefficient (R) and transmission coefficient (T) for normal incidence of an EM wave from medium 1 to medium 2.

9. Plot R and T as functions of the ratio of refractive indices (n_2/n_1).
10. Write functions to calculate the orbital radius (rn), energy (En), and wavenumber for transitions ($1/\lambda$) for the hydrogen atom.
11. Visualize the first few Bohr orbits (e.g., n=1,2,3,4) as concentric circles.
12. Write a function to calculate the wavenumber positions of Stokes and anti-Stokes lines given the excitation wavenumber and molecular vibrational wavenumbers.
13. Write a function to calculate the de Broglie wavelength for objects of varying mass and velocity (e.g., a thrown ball vs. an electron). Visualize the extreme differences in scale.
14. Given an uncertainty in position (Δx), calculate the minimum uncertainty in momentum (Δp) and vice-versa. Plot the relationship between Δx and Δp.
15. Use 3D plotting to visualize the isosurfaces of the probability density for a selected s, p, and d orbital.
16. Write functions to calculate the energy eigenvalues En and normalized wave functions ψ_n (x) for the first few quantum states (n=1,2,3,4) in a 1D infinite potential well of given width.
17. Plot each wave function $\psi_n(x)$ and its corresponding probability density $|\psi_n(x)|^2$.