CH112	PHYSICS FOR CHEMICAL ENGINEERING	L	T	P	C	Int	Ext
		3	-	-	3.0	40	60

Semester I [First Year]

COURSE OUTLINE:

This course introduces the physical principles that underpin chemical engineering practice, covering oscillations and ultrasonics, wave optics, quantum mechanics, electromagnetic theory and semiconductor physics, and materials science with nanotechnology. It matters because vibrational and wave phenomena, quantum-level material behaviour, electromagnetic principles, and nanoscale material properties directly influence process instrumentation, reaction engineering, and materials selection in the chemical process industry. It builds on Semester 1 mathematics and science and prepares students for higher-semester courses such as Chemical Process Instrumentation, Materials Science for Chemical Engineers, and Nanotechnology in Process Engineering within the Chemical Engineering curriculum.

COURSE OBJECTIVES:

1. To develop a conceptual and mathematical understanding of oscillatory motion, damping, resonance, and ultrasonic wave production/detection relevant to chemical process instrumentation.
2. To develop an understanding of interference, diffraction, and polarization phenomena in wave optics and their applications in optical measurement.
3. To introduce the foundational postulates of quantum mechanics and explain the inadequacy of classical mechanics in describing microscopic phenomena.
4. To explain Maxwell's equations and the electrical behaviour of semiconductors, including the Hall effect, relevant to electromagnetic and sensor applications.
5. To introduce crystal structure, crystal defects, and nanomaterials â€" their classification, synthesis, and applications in chemical engineering.

COURSE OUTCOMES:

After successful completion of the course, the students are able to

CO	Course Outcome	RBTL
CO1	analyze damped and forced oscillatory systems and explain the production and detection of ultrasonic waves and their role in chemical engineering.	Analyze (BL4)
CO2	explain the principles of interference, diffraction, and polarization, and apply them to determine optical parameters such as wavelength, refractive index, and optical rotation.	Apply (BL3)
CO3	interpret the postulates of quantum mechanics, including the de Broglie hypothesis, uncertainty principle, and SchrÃ¶dinger's equation, to explain microscopic phenomena. 2 2	Understand (BL2)
CO4	analyze Maxwell's equations and semiconductor properties, including the Hall effect, and evaluate electromagnetic wave propagation.	Analyze (BL4)
CO5	evaluate crystal structures, crystal defects, and nanomaterial synthesis methods for applications in chemical engineering materials.	Evaluate (BL5)

CO - PO / PSO Mapping

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

UNIT I [CO:1] **(9)**

Oscillations and Ultrasonics

Simple harmonic motion: differential equation and solution, Damped harmonic oscillator: equation and solution, Over-damped, critically damped, and under-damped conditions, Energy and power dissipation; quality factor, Resonance: concept and examples, Production of ultrasonics: magnetostriction method, Production of ultrasonics: piezoelectric method, Detection of ultrasonics: Kundt's tube and quartz crystal methods, Role of ultrasonics in chemical engineering (basic concept)

AI Integration with Contents:

1.Simulation tools to plot displacement-time responses of damped and forced oscillators for varying damping/driving parameters.

2.AI/ML-based signal-analysis tools to model ultrasonic transducer response for varying frequency and process-medium parameters.

Unit Learning Outcomes:

1.Analyze the response of damped and forced harmonic oscillators and relate resonance behaviour to process-equipment vibration.

2.Explain the production and detection of ultrasonic waves and their relevance to non-invasive process monitoring in chemical engineering.

Practical Examples for In-Class Explanation:

1.Plotting the amplitude-vs-driving-frequency curve of a forced oscillator to illustrate resonance and its sharpness.

2.Explaining how ultrasonic waves are used for level/flow measurement in a chemical process vessel.

Exercise / Practice Problems:

1.Derive the quality factor of a damped harmonic oscillator given its damping coefficient and natural frequency.

2.Determine the resonance frequency of a forced oscillator given its mass, stiffness, and damping.

3.Calculate the wavelength of ultrasonic waves in a given medium from the frequency and velocity of propagation.

UNIT II [CO:2] **(9)**

Wave Optics

Interference: superposition principle, coherence, Young's double-slit experiment, Thin-film interference (reflection geometry); Newton's rings - formation, Newton's rings: derivation for diameters; applications - wavelength and refractive index determination, Diffraction: concept, Fresnel and Fraunhofer diffraction, Fraunhofer diffraction: single slit, N-slit diffraction (plane transmission diffraction grating); dispersive and resolving power of a grating, Polarization: basic concept, Malus's law, double refraction, Polaroids and applications; optical activity (optical rotation and specific rotation).

AI Integration with Contents:

1.Use of simulation tools (e.g., PhET/MATLAB-Python scripts) to generate and visualize interference and diffraction patterns for varying parameters.

2.AI-assisted image-analysis of Newton's-ring photographs to automatically extract ring diameters and compute wavelength/refractive index.

Unit Learning Outcomes:

1.Derive expressions for the diameters of Newton's rings and relate them to wavelength/refractive index measurement.

2.Apply Malus's law and the concept of optical activity to determine the specific rotation of a given solution.

Practical Examples for In-Class Explanation:

1.Working out the fringe spacing of a Young's double-slit setup for a given wavelength and slit separation.

2.Explaining how a polarimeter uses optical rotation to determine the concentration of an optically active solution (e.g., sugar solution).

Exercise / Practice Problems:

1.Calculate the wavelength of light from given Newton's-ring diameters and the radius of curvature of the lens.

2.Determine the angular positions of diffraction minima for a single slit of given width and wavelength.

3.Calculate the specific rotation of a solution given its observed rotation, concentration, and path length.

UNIT III [CO:3] **(9)**

Quantum Mechanics

Inadequacy of classical mechanics: black body radiation, Photoelectric effect, Compton effect, de Broglie hypothesis and matter waves, Heisenberg's uncertainty principle, Verification of the uncertainty principle: single-slit diffraction experiment, Schrodinger's time-independent wave equation, Physical significance of the wave function (psy); particle in a one-dimensional infinite potential well, Basic concept of quantum tunnelling.

AI Integration with Contents:

1.Simulation tools to plot black-body spectral radiance curves and Compton-shift data for varying scattering angles.

2.Use of computational notebooks (Python) to numerically solve and visualize wave functions for a particle in a potential well.

Unit Learning Outcomes:

1.Explain the photoelectric and Compton effects as evidence for the particle nature of light.

2.Apply Schrdinger's equation to a particle in a one-dimensional box and interpret the resulting wave functions.

Practical Examples for In-Class Explanation:

1.Calculating the stopping potential in a photoelectric-effect experiment for a given frequency of incident light.

2.Solving for the energy levels of a particle in an infinite potential well of given width.

Exercise / Practice Problems:

1.Calculate the de Broglie wavelength of a given particle moving at a specified velocity.

2.Determine the Compton shift in wavelength for a photon scattered at a given angle.

3.Derive the energy eigenvalues for a particle in a one-dimensional infinite potential well.

UNIT IV [CO:4] **(9)**

Electromagnetic Theory and Semiconductor Physics

Maxwell's equations: integral form, Maxwell's equations: differential form, Physical significance of Maxwell's equations, Electromagnetic wave equation in free space; velocity of electromagnetic waves, Poynting vector, Semiconductors: intrinsic and extrinsic types, Fermi level concept in semiconductors, Concentration of electrons and holes in an intrinsic semiconductor, Hall effect: expression for the Hall coefficient and its applications.

AI Integration with Contents:

1.AI-assisted electromagnetic field simulators (FEM tools with ML-optimized meshing) to visualize field

distributions from Maxwell's equations.

2.Use of simulation/ML tools to plot Fermi-level position and carrier-concentration trends for varying doping levels.

Unit Learning Outcomes:

1.Derive Maxwell's equations in integral and differential forms and interpret their physical significance.

2.Analyze carrier concentration and the Hall effect to characterize a given semiconductor sample.

Practical Examples for In-Class Explanation:

1.Deriving the wave equation for the electric field in free space from Maxwell's equations.

2.Determining the type and concentration of majority carriers from Hall-effect measurement data.

Exercise / Practice Problems:

1.Derive the expression for the velocity of electromagnetic waves in free space from Maxwell's equations.

2.Calculate the Poynting vector for a given electromagnetic plane wave.

3.Determine the Hall coefficient and carrier concentration from given Hall-voltage data.

UNIT V [CO:5] **(9)**

Materials Science and Nanotechnology

Fundamental definitions in crystallography: lattice, basis, unit cell, unit cell parameters, Bravais lattices (types of crystal systems), Atomic packing factor for the simple cubic (SC) structure, Atomic packing factor for BCC and FCC structures, Crystal defects: point defects, Crystal defects: line and planar defects, Introduction to nanomaterials: classification, Size-dependent properties of nanomaterials, Synthesis methods (top-down and bottom-up: ball milling, sol-gel) and applications of nanomaterials in engineering.

AI Integration with Contents:

1.Use of crystal-structure visualization/simulation software to build and rotate SC, BCC, and FCC unit cells interactively.

2.AI/ML-based literature-mining or property-prediction tools to relate nanomaterial size to property changes.

Unit Learning Outcomes:

1.Determine the atomic packing factor of SC, BCC, and FCC crystal structures and classify common crystal defects.

2.Explain nanomaterial classification, size-dependent properties, and top-down/bottom-up synthesis methods.

Practical Examples for In-Class Explanation:

1.Computing the atomic packing factor of an FCC unit cell for a given atomic radius.

2.Explaining how the sol-gel method is used to synthesize metal-oxide nanoparticles for catalytic applications.

Exercise / Practice Problems:

1.Calculate the atomic packing factor of a BCC structure given the relation between atomic radius and lattice parameter.

2.Classify a given set of crystal imperfections as point, line, or planar defects with justification.

3.Compare the top-down and bottom-up approaches to nanomaterial synthesis with one example of each.

LEARNING RESOURCES:

TEXT BOOK(s):

1. Avadhanulu, M. N., & Kshirsagar, P. G. (2019). A textbook of engineering physics (11th ed.). S. Chand Publishing.
2. Rajendran, V. (2020). Engineering physics (2nd ed.). McGraw Hill Education.

REFERENCE BOOK(s):

1. Callister, W. D., & Rethwisch, D. G. (2020). Materials science and engineering: An introduction (10th ed.). Wiley.
2. Kittel, C. (2004). Introduction to solid state physics (8th ed.). Wiley.
3. Poole, C. P., & Owens, F. J. (2003). Introduction to nanotechnology. Wiley.
4. Griffiths, D. J. (2017). Introduction to electrodynamics (4th ed.). Cambridge University Press.

WEB RESOURCES:

1. National Programme on Technology Enhanced Learning. (n.d.). Engineering physics. NPTEL. https://nptel.ac.in
2. National Programme on Technology Enhanced Learning. (n.d.). Nanoscience and nanotechnology. NPTEL. https://nptel.ac.in
3. MIT OpenCourseWare. (n.d.). Physics for chemical engineering related courses. https://ocw.mit.edu