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(i) Introduction to Electromagnetic Theory [L : 3; T:1; P : 0 (4 credits)]

Pre-requisites (if any)	Mathematics course with vector calculus

Detailed contents:

Module 1: Electrostatics in vacuum (8 lectures)

Calculation of electric field and electrostatic potential for a charge distribution; Divergence and curl of electrostatic field; Laplace's and Poisson's equations for electrostatic potential and uniqueness of their solution and connection with steady state diffusion and thermal conduction; Practical examples like Farady's cage and coffee-ring effect; Boundary conditions of electric field and electrostatic potential; method of images; energy of a charge distribution and its expression in terms of electric field.

Module 2: Electrostatics in a linear dielectric medium (4 lectures)

Electrostatic field and potential of a dipole. Bound charges due to electric polarization; Electric displacement; boundary conditions on displacement; Solving simple electrostatics problems in presence of dielectrics – Point charge at the centre of a dielectric sphere, charge in front of a dielectric slab, dielectric slab and dielectric sphere in uniform electric field.

Module 3: Magnetostatics(6 lectures)

Bio-Savart law, Divergence and curl of static magnetic field; vector potential and calculating it for a given magnetic field using Stokes' theorem; the equation for the vector potential and its solution for given current densities.

Module 4: Magnetostatics in a linear magnetic medium (3 lectures)

Magnetization and associated bound currents; auxiliary magnetic field ; Boundary conditions on and. Solving for magnetic field due to simple magnets like a bar magnet; magnetic susceptibility and ferromagnetic, paramagnetic and diamagnetic materials; Qualitative discussion of magnetic field in presence of magnetic materials.

Module 5: Faraday's law (4 lectures)

Faraday's law in terms of EMF produced by changing magnetic flux; equivalence of Faraday's law and motional EMF; Lenz's law; Electromagnetic breaking and its applications; Differential form of Faraday's law expressing curl of electric field in terms of time-derivative of magnetic field and calculating electric field due to changing magnetic fields in quasi-static approximation; energy stored in a magnetic field.

Module 6: Displacement current, Magnetic field due to time-dependent electric field and Maxwell's equations (5 lectures) Continuity equation for current densities; Modifying equation for the curl of magnetic field to satisfy continuity equation; displace current and magnetic field arising from time-dependent electric field; calculating magnetic field due to changing electric fields in quasi-static approximation. Maxwell's equation in vacuum and non-conducting medium; Energy in an electromagnetic field; Flow of energy and Poynting vector with examples. Qualitative discussion of momentum in electromagnetic fields.

Module 7: Electromagnetic waves (8 lectures)

The wave equation; Plane electromagnetic waves in vacuum, their transverse nature and polarization; relation between electric and magnetic fields of an electromagnetic wave; energy carried by electromagnetic waves and examples. Momentum carried by electromagnetic waves and resultant pressure. Reflection and transmission of electromagnetic waves from a non-conducting medium-vacuum interface for normal incidence.

Suggested Text Books

(i) David Griffiths, Introduction to Electrodynamics

Suggested Reference Books:

(i) Halliday and Resnick, Physics

(ii) W. Saslow, Electricity, magnetism and light

Laboratory - Introduction to Electromagnetic Theory[L: 0; T:0 ; P : 3 (1.5 credits)]

Choice of experiments from the following:

Experiments on electromagnetic induction and electromagnetic breaking; LC circuit and LCR circuit; Resonance phenomena in LCR circuits; Magnetic field from Helmholtz coil;
Measurement of Lorentz force in a vacuum tube.

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(ii) Introduction to Mechanics [L : 3; T:1; P : 0 (4 credits)]

Pre-requisites (if any)	High-school education

Detailed contents:

Module 1: (8 lectures)

Transformation of scalars and vectors under Rotation transformation; Forces in Nature; Newton's laws and its completeness in describing particle motion; Form invariance of Newton's Second Law; Solving Newton's equations of motion in polar coordinates; Problems including constraints and friction; Extension to cylindrical and spherical coordinates

Module 2: (7 lectures)

Potential energy function; F = - Grad V, equipotential surfaces and meaning of gradient; Conservative and non-conservative forces, curl of a force field; Central forces; Conservation of Angular Momentum; Energy equation and energy diagrams; Elliptical, parabolic and hyperbolic orbits; Kepler problem; Application: Satellite manoeuvres;

Module 3: (5 lectures)

Non-inertial frames of reference; Rotating coordinate system: Five-term acceleration formula.
Centripetal and Coriolis accelerations; Applications: Weather systems, Foucault pendulum;

Module 4: (6 lectures)

Harmonic oscillator; Damped harmonic motion – over-damped, critically damped and lightly-damped oscillators; Forced oscillations and resonance.

Module 5: (5 lectures)

Definition and motion of a rigid body in the plane; Rotation in the plane; Kinematics in a coordinate system rotating and translating in the plane; Angular momentum about a point of a rigid body in planar motion; Euler's laws of motion, their independence from Newton's laws, and their necessity in describing rigid body motion; Examples.

Module 6: (7 lectures)

Introduction to three-dimensional rigid body motion — only need to highlight the distinction from two-dimensional motion in terms of (a) Angular velocity vector, and its rate of change and (b) Moment of inertia tensor; Three-dimensional motion of a rigid body wherein all points move in a coplanar manner: e.g. Rod executing conical motion with center of mass fixed — only need to show that this motion looks two-dimensional but is three-dimensional, and two-dimensional formulation fails.

Suggested Reference Books

(i) Engineering Mechanics, 2nd ed. -MK Harbola
(ii) Introduction to Mechanics - MK Verma
(iii) An Introduction to Mechanics -D Kleppner& R Kolenkow
(iv) Principles of Mechanics - JL Synge & BA Griffiths
(v) Mechanics - JP Den Hartog
(vi) Engineering Mechanics - Dynamics, 7th ed. - JL Meriam
(vii) Mechanical Vibrations - JP Den Hartog
(viii)Theory of Vibrations with Applications - WT Thomson

Course Outcomes

To be uploaded

 Laboratory - Introduction to Mechanics[L : 0; T:0 ; P : 3 (1.5 credits)] Suggested list of experiments from the following:

Coupled oscillators;

Experiments on an air-track;

Experiment on moment of inertia measurement, Experiments with gyroscope;

Resonance phenomena in mechanical oscillators.

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(iii) Quantum Mechanics for Engineers[L : 3; T:1; P : 0 (4 credits)]

Pre-requisites (if any)	Mathematics course on differential equations and linear algebra)

Detailed contents :

Module 1: Wave nature of particles and the Schrodinger equation (8 lectures)

Introduction to Quantum mechanics, Wave nature of Particles, Time-dependent and time-independent Schrodinger equation for wavefunction, Born interpretation, probability current, Expectation values, Free-particle wavefunction and wave-packets, Uncertainty principle.

Module 2: Mathematical Preliminaries for quantum mechanics (4 lectures)

Complex numbers, Linear vector spaces, inner product, operators, eigenvalue problems, Hermitian operators, Hermite polynomials, Legendre's equation, spherical harmonics.

Module 3: Applying the Schrodinger equation (15 lectures)

Solution of stationary-state Schrodinger equation for one dimensional problems– particle in a box, particle in attractive delta-function potential, square-well potential, linear harmonic oscillator.

Numerical solution of stationary-state Schrodinger equation for one dimensional problems for different potentials

Scattering from a potential barrier and tunneling; related examples like alpha-decay, field-ionization and scanning tunneling microscope

Three-dimensional problems: particle in three dimensional box and related examples, Angular momentum operator, Rigid Rotor, Hydrogen atom ground-state, orbitals, interaction with magnetic field, spin Numerical solution stationary-state radial Schrodinger equation for spherically symmetric potentials.

Module 4: Introduction to molecular bonding (4 lectures)

Particle in double delta-function potential, Molecules (hydrogen molecule, valence bond and molecular orbitals picture), singlet/triplet states, chemical bonding, hybridization

Module 5: Introduction to solids (7 lectures)

Free electron theory of metals, Fermi level, density of states, Application to white dwarfs and neutron stars, Bloch's theorem for particles in a periodic potential, Kronig-Penney model and origin of energy bands

Numerical solution for energy in one-dimensional periodic lattice by mixing plane waves.

Suggested Text Books

(i) Eisberg and Resnick, Introduction to Quantum Physics

Suggested Reference Books

(i) D. J. Griffiths, Quantum mechanics
(ii) Richard Robinett, Quantum Mechanics
(iii) Daniel McQuarrie, Quantum Chemistry

Course Outcomes

To be uploaded

Laboratory - Quantum Mechanics for Engineers[L: 0; T:0 ; P : 3 (1.5 credits)] Suggested list of experiments from the following:

Frank-Hertz experiment; photoelectric effect experiment; recording hydrogen atom spectrum

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(iv) Oscillations, waves and optics [L : 3; T:1; P : 0 (4 credits)]

Pre-requisites (if any)	(i) Mathematics course on Differential equations (ii) Introduction to Electromagnetic theory

Detailed contents :

Module 1: Simple harmonic motion, damped and forced simple harmonic oscillator (7 lectures)

Mechanical and electrical simple harmonic oscillators, complex number notation and phasor representation of simple harmonic motion, damped harmonic oscillator – heavy, critical and light damping, energy decay in a damped harmonic oscillator, quality factor, forced mechanical and electrical oscillators, electrical and mechanical impedance, steady state motion of forced damped harmonic oscillator, power absorbed by oscillator.

Module 2: Non-dispersive transverse and longitudinal waves in one dimension and introduction to dispersion (7 lectures)

Transverse wave on a string, the wave equation on a string, Harmonic waves, reflection and transmission of waves at a boundary, impedance matching, standing waves and their Eigen frequencies, longitudinal waves and the wave equation for them, acoustics waves and speed of sound, standing sound waves.

Waves with dispersion, water waves, superposition of waves and Fourier method, wave groups and group velocity.

Module 3: The propagation of light and geometric optics (10 lectures)

Fermat's principle of stationary time and its applications e.g. in explaining mirage effect, laws of reflection and refraction, Light as an electromagnetic wave and Fresnel equations, reflectance and transmittance, Brewster's angle, total internal reflection, and evanescent wave. Mirrors and lenses and optical instruments based on them, transfer formula and the matrix method.

Module 4: Wave optics (6 lectures)

Huygens' principle, superposition of waves and interference of light by wave front splitting and amplitude splitting; Young's double slit experiment, Newton's rings, Michelson interferometer, Mach-Zehnder interferometer.

Farunhofer diffraction from a single slit and a circular aperture, the Rayleigh criterion for limit of resolution and its application to vision; Diffraction gratings and their resolving power

Module 5: Lasers (8)

Einstein's theory of matter radiation interaction and A and B coefficients; amplification of light by population inversion, different types of lasers: gas lasers (He-Ne, CO_2), solid-state lasers(ruby, Neodymium), dye lasers; Properties of laser beams: mono-chromaticity, coherence, directionality and brightness, laser speckles, applications of lasers in science, engineering and medicine.

Suggested Reference Books

(i) Ian G. Main, Oscillations and waves in physics
(ii) H.J. Pain, The physics of vibrations and waves
(iii) E. Hecht, Optics
(iv) A. Ghatak, Optics
(v) O. Svelto, Principles of Lasers

Laboratory - Oscillations, waves and optics [L : 0; T:0 ; P : 3 (1.5 credits)] Suggested list of experiments from the following:

Diffraction and interference experiments (from ordinary light or laser pointers); measurement of speed of light on a table top using modulation; minimum deviation from a prism.

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