Scheme of Studies for Associate & BS Degree Program

Department of Physics

Abdul Wali Khan University Mardan

UPDATED

July 2023

SEMESTERWISE COURSES

	Name of Course		Credits
A. General Education Courses	**A1.** Breadth courses		
	Arts and Humanities	1. Aesthetic Studies 2. Introduction to Philosophy 3. Language and Society 4. Urdu Language and Society 5. Islamic History 6. Islamic Morals 7. Creative Arts 8. History of Pakistan 9. Pashtun Language and Society 10. Chinese Language and society 11. Classical Poetry 12. Foundations of Literary Theory & Criticism	Two subjects of 6 Credit Hours (3 C.Hs each) will be selected from the list
	Social Sciences	1. CPEC Role in Planning & Development of Pakistan 2. Current Affairs 3. Principles of Psychology 4. Introduction to Political Science 5. International Trade 6. Principles of Management 7. Cultural History of Pakistan 8. Tourism Planning and Development 9. Western Political Philosophy 10. Introduction to Social Work 11. Pakistan Movement and Political History 12. Introduction to Economics 13. Introduction to International Relations 14. Environmental Psychology 15. Muslim Political Philosophy 16. Public International Law 17. Philosophical basis of Physical Education 18. Sports Biomechanics 19. Introduction to Sociology 20. Sociology of Health 21. Gender Studies 22. Introduction to Law and Human Rights 23. Constitutional Development in Pakistan 24. Introduction to Social Anthropology	Two subjects of 6 Credit Hours (3 C.Hs each) will be selected from the list

		25. Pakistan's Foreign Policy 26. General Methods of Teaching 27. Class Assessment and Management 28. Curriculum Development 29. Introduction to Mass Communication 30. Mass Media in Pakistan 31. Introduction to Social Media 32. International Communication and Reporting 33. Muslim Struggle for Pakistan (1857 – 1947) 34. Political History of Pakistan (1947-to date	
	Natural Sciences	1. Every day Science-I 2. Every day science-II 3. Introduction to Physics 4. Introduction to Chemistry 5. Introduction to Geology 6. Geomorphology 7. Introduction to Biology 8. Introduction to Ecology 9. Introduction to Environmental Sciences 10. Introduction to Geography 11. Introduction to bio-chemistry	Two subjects of 6 Credit Hours (3 C.Hs each) will be selected from the list
	Total Sub-A1	**Courses: 06**	**18**
	A2. Functional Skills Courses		
	Expository Writing	1. English composition and comprehension (Eng-I) 2. Communication and presentation skills (Eng-II) 3. Technical report writing (Eng-III)	Three Courses of 9 C.Hs (3 Credit Hours each) will be included in Scheme of Studies by all Departments
	Quantitative Reasoning	1. Basic Mathematics 2. Introduction to Information & Communication Technology 3. Logic & Critical Reasoning 4. Statistics I 5. Statistics II 6. Calculus-I 7. Calculus-II	Two subjects of 6 Credit Hours (3 C.Hs each) will be selected from the list
	Total Sub-A2	**Courses 05**	**15**
	A3. Civilizational Courses		
		Islamic Studies/Ethics Pakistan Studies	Two subjects of 6 Credit Hours (3 C.Hs each) will be

			selected from the list
	Total Sub-A3	**Courses: 02**	**06**
B. Disciplinary courses			
	Subject foundation and major subjects	Subject 1:	03
		Subject 2:	03
		Subject 3:	03
		Subject 4:	03
		Subject 5:	03
		Subject 6:	03
		Subject 7: Research Methods	03
	Total Sub-B	**Courses: 07**	**21**
	Grand Total (A+B)		**60**

Year 3		
Semester 5		
PHY-501	Classical Mechanics	3
PHY-502	Mathematical Methods of Physics- I	3
PHY-503	Electrodynamics-I	3
PHY-504	Quantum Mechanics -I	3
PHY-505	Electronics	3
PHY-505L	Lab-V (Electronics)	2
Total		**17**
Semester 6		
PHY-551	Quantum Mechanics-II	3
PHY-552	Mathematical Methods of Physics-II	3
PHY-553	Electrodynamics-II	3
PHY-554	Thermal and Statistical Physics	3
PHY-555	Atomic & Molecular Physics	3
PHY-555L	Lab -VI (Modern Physics)	2
Total		**17**
Year 4		
Semester 7		
PHY-601	Solid State Physics-I	3
PHY-602	Nuclear Physics	3
PHY-602L	Lab-VII (Nuclear Physics)	2
PHY-6XY	Elective-I	3
PHY-6XY	Elective-II	3
Total		**14**
Semester 8		
PHY-603	Solid State Physics-II	3
PHY-6XY	Elective-III	3
PHY-6XY	Elective-IV	3
PHY-600	Project/Thesis	3
Total		**12**
Total credit hours		

Contents

PHY-301 **An Introduction to Physics**
Credit Hours: **3**

Objective

The main objective of this course is to understand the different motions of objects on a macroscopic scale and to develop simple mathematical formalisms to analyze such motions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Course Contents:

Introduction to Physics: Explore fundamental physics concepts, scientific notations, dimensional analysis, linear relationships and quadratic relationships.
Vectors: Describe types of vectors and the process to add, subtract and multiply vectors. Understand how to get a resultant vector and perform vector operations using components.
Kinematics: Differentiate between displacement and distance and speed and velocity. Determine acceleration using slope of speed and explain projectile, free fall and uniform circular motion.
Force and the Laws of Motion: Examine Newton's Laws of Motion. Explain the differences between mass, inertia and weight and describe action and reaction force pairs. Describe friction, inclined plane, the spring constant and centripetal force.
Work and Energy in Physics: Apply the work-energy theorem and describe relationship between kinetic and potential energy. Examine gravitational potential energy, conservative forces and power.
Linear Momentum in Physics: Describe the impulse-momentum change equation and apply the momentum conservation principle. Discuss elastic and inelastic collisions and isolated systems and find the centre of gravity.
Waves, Sound and Light: Define vibrations and explore wave parameters, electromagnetic waves and pitch and volume in sound waves. Discuss reflection, resonance, colour, diffraction and the Doppler Effect.
Fluids in Physics: Define density and pressure and perform calculations for hydrostatic pressure. Apply Pascal's Principle and Archimedes' Principle and use the equation of continuity and Bernoulli's equation.
Thermodynamics in Physics: Explore the relationship between temperature and heat, phase changes and heat transfer. Describe thermal expansion, the ideal gas law, entropy and the first and second laws of thermodynamics.
Electrostatics: Understand electric charge, force fields and Coulomb's Law. Solve parallel-plat capacitor problems and describe electric potential.
Circuits in Physics: Examine insulators and conductors, electric current and electrical resistance. Describe Ohm's Law and resistor-capacitor circuits. Discuss alternative current power and RLC series circuits.
The Physics of Magnetism: Explain magnetic force and how magnetic fields are created. Describe Faraday's Law of Electromagnetic Induction.
Wave Optics: Use equations to answer mirror and images questions. Examine polarizing light, single-slit and double-slit diffraction and thin film interference. See applications for the Michelson Interferometer.
Relativity: Describe classical relativity and general and special relativity. Discuss time dilation, space contraction and the interchangeable relationship between mass and energy.
Modern Physics and Nuclear Physics: Explore photons, atomic spectra, nuclear binding energy and radioactive decay. Interpret decay graphs and discuss applications of radioactive nuclides.

Recommended Books:

1. College Physics by Raymond A. Serway and Chris Vuille, Volume 10, Publisher: Cengage Learning (2014)
2. University Physics by George Arfken, Academic Press (2012)
3. Conceptual Physics by Paul G. Hewitt, Pearson Education India (2007)

PHY-401 **Mechanics**
Credit Hours: **3**

Objectives:

The main objective of this course is to understand the different motions of objects on a macroscopic scale and to develop simple mathematical formalisms to analyze such motions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Course Contents:

Vectors Overview: Vectors and scalars, Vector operators, coordinate systems and Unit Vectors, Vector – Magnitude and direction, Vector decomposition into components

Kinematics: position, velocity and acceleration, constant acceleration, vector description of motion in 2D, projectile motion.

Newton's Laws: Newton's Laws of motion, force laws, constraint forces and free body diagrams for gravity, contact forces, tension and springs, Friction

Circular Motion: Circular motion, velocity and angular velocity, uniform circular motion, tangential and radial acceleration, period and frequency of uniform circular motion. Newton's second law and Circular motion, Universal Law of gravitation.

Drag Forces, Constrains and Continuous Systems: Pulleys and constraints, Massive rope, continuous systems and Newton's second law as a differential equation, Resistive forces, capstan, drag force in fluids, free fall with air drag.

Momentum and Impulse: Momentum and Impulse, External and Internal forces and the change in momentum of a system, system of particle. Conservation of momentum, constancy of momentum and isolated systems, momentum changes and non-isolated systems, center of mass, translational motion of the center of mass.

Continuous mass Transfer: Relative velocity and recoil, reference frames, continuous mass transfer, momentum and flow of mass

Kinetic Energy and Work: The concept of energy and conservation of energy, kinetic energy, work, work energy theorem, power, work and scalar product, work done by a non-constant force along arbitrary path, work kinetic energy theorem in 3D, conservation of energy, conservative and non-conservative forces.

Potential Energy and Energy conservation: Changes in potential energy of a system, changes in potential energy and zero point of potential energy, mechanical energy and conservation of mechanical energy, change of mechanical energy for closed system with internal non-conservative forces, dissipative forces: friction, potential energy diagrams.

Collision Theory: Types of collision, Elastic collisions, center of mass reference frame.

Rotational Motion: Motion of a rigid body, two-dimensional rotational kinematics, moment of inertia, Torque, static equilibrium, rotational dynamics.

Angular momentum: Angular momentum of a point particle, angular momentum of a rigid body about a fixed axis, Torque and angular impulse.

Rotations and Translations -Rolling: Rolling Kinematics, rolling dynamics, rolling kinetic energy and angular momentum, gyroscopes

Recommended Books:

4. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
5. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. 2010.
6. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed. 2010.
7. F. J Keller, W. E. Gettys and M. J. Skove, "Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.

8. D. C. Giancoli, “Physics for Scientists and Engineers, with Modern Physics”, Addison-Wesley, 4th ed. 2008.
9. Classical Mechanics: MIT 8.01" by Peter Dourmashkin

PHY-401L LAB-I (Mechanics)

Credit Hours: 1

Theme:

Experiments with pendulums, stop watches, one-dimensional motion and verification of Newton's laws of motion, measurement of forces, speed, acceleration and linear momentum, collisions and conservation of momentum, impacts, free fall and acceleration due to gravity, gyroscopes, rotational motion, conservation of angular momentum, friction, static and dynamic equilibrium, compound pendulum, rolling motion along inclined planes, simple harmonic motion, masses attached to springs and Hooke's law, damped motion and the regimes of damping (overdamped, underdamped and critically damped), pressure in fluids, experiments demonstrating continuity, Bernoulli's principle, buoyancy and Archimedes’ principle, Atwood machine, fluid viscosity, surface tension.

PHY-402 **Electricity and Magnetism**
Pre-requisite: **Mechanics, Calculus I**
Co-requisite: **Calculus II**
Credit Hours: **3**

Objectives:

The main objective of this course is to understand the Physics of Electromagnetism and to develop simple mathematical formalisms to analyze the electromagnetic fields and interactions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Course Contents

- **Coulomb's Law:** Coulomb's Law, Charge is Quantized, Charge is Conserved
- **Electric Fields:** The Electric Field, The Electric Field Due to a Charged Particle, The Electric Field Due to a Dipole, The Electric Field Due to a Line of Charge, The Electric Field Due to a Charged Disk, A Point Charge in an Electric Field, A Dipole in an Electric Field
- **Gauss' Law:** Electric Flux, Gauss' Law, A Charged Isolated Conductor, Applying Gauss' Law: Cylindrical Symmetry, Applying Gauss' Law: Planar Symmetry, Applying Gauss' Law: Spherical Symmetry,
- **Electric Potential:** Electric Potential , Equipotential Surfaces and the Electric Field, Potential due to a Charged Particle, Potential due to an Electric Dipole, Potential due to a Continuous Charge Distribution, Calculating the Field From the Potential, Electric Potential Energy of a System of Charged Particles, Equipotential Surfaces, Potential due to a Point Charge and a Group of Point Charges, Potential due to an Electric Dipole, Potential due to a Charge Distribution, Relation between Electric Field and , Electric Potential Energy.
- **Capacitors:** Capacitance, Calculating the Capacitance, Capacitors In Parallel And In Series, Energy Stored in an Electric Field, Capacitor With a Dielectric, Dielectrics and Gauss' Law.
- **Current and Resistance:** Electric Current, Current Density, Resistance and Resistivity, Ohm's Law; Power, Semiconductors and Superconductors.
- **Circuits:** Single-loop Circuits, Multi- loop Circuits, The Ammeter and the Voltmeter, RC Circuits
- **Magnetic Fields**: Magnetic Fields and the Definition of B, Crossed Fields: Discovery of the Electron, Crossed Fields: The Hall Effect, A Circulating Charged Particle, Cyclotrons and Synchrotrons, Magnetic Force on a Current-Carrying Wire, Torque on a Current Loop, The Magnetic Dipole Moment
- **Magnetic Fields Due to Currents**: Magnetic Field Due to a Current, Force between two Parallel Currents, Ampere's Law, Solenoids and Toroids, A Current-Carrying Coil as a Magnetic Dipole
- **Induction and Inductance**: Faraday's Law and Lenz's Law, Induction and Energy Transfers, Induced Electric Fields, Inductors and Inductance, Self-Induction, RL Circuits, Energy Stored in a Magnetic Field, Energy Density of a Magnetic Field, Mutual Induction

- **Electromagnetic Oscillations and Alternating Current:** Lc Oscillations, Damped Oscillations in an RLC Circuit, Forced Oscillations of Three Simple Circuits, The Series RLC Circuit, Power in Alternating-Current Circuits, Transformers
- **Maxwell's Equations; Magnetism of Matter:** Gauss' Law for Magnetic Fields, Induced Magnetic Fields, Displacement Current, Magnets, Magnetism and Electrons, Diamagnetism, Paramagnetism, Ferromagnetism

Recommended Text Books:

1) D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley & Sons, 9th ed. 2010.
2) R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. 2010.
3) R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed. 2010.
4) F. J Keller, W. E. Gettys and M. J. Skove, "Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.
5) D. C. Giancoli, "Physics for Scientists and Engineers, with Modern Physics", Addison-Wesley

PHY-402L LAB-II (Electricity and Magnetism)

Credit Hours: 1

Theme:

Static charge and electric fields, direct and alternating currents, electrical measurement instrumentation (voltmeters, ammeters, power supplies, variable transformers, cathode ray oscilloscope, electrometer), passive electronic components (resistors, capacitors, inductors), measurement of resistance, capacitance and inductance, electromagnetic induction, inductors and transformers, motors, magnetic fields due to currents and permanent magnets, ferromagnetism and ferroelectricity, determination of hysteresis curves, determination of Curie point, magnetic susceptibility and its temperature dependence, dielectric properties measurement, mapping of magnetic fields using Hall sensors, experiments on noise, properties of the light bulb.

PHY-451 **Waves and Oscillations**
Pre-requisites: **Mechanics, Calculus II**
Credit Hours: **3**

Objective(s)

To develop a unified mathematical theory of oscillations and waves in physical systems.

Course Contents

Harmonic Oscillations:

Simple harmonic motion (SHM), Obtaining and solving the basic equations of motion x(t), v(t), a(t), Longitudinal and transverse Oscillations, Energy considerations in SHM. Application of SHM, Torsional oscillator, Physical pendulum, simple pendulum, SHM and uniform circular motion, Combinations of harmonic motions, Lissajous patterns, Damped harmonic motion, Equation of damped harmonic motion, Quality factor, discussion of its solution, Forced oscillations and resonances, Equation of forced oscillation, Discussion of its solution, Natural frequency, Resonance, Examples of resonance.

Waves in Physical Media:

Mechanical waves, travelling waves, Phase velocity of traveling waves, Sinusoidal waves, Group speed and dispersion, Waves speed, Mechanical analysis, Wave equation, Discussion of solution, Power and intensity in wave motion, Derivation & discussion, Principle of superposition (basic ideas), Interference of waves, Standing waves. Phase changes on reflection

Sound:

Properties of sound waves, travelling sound waves, the speed of sound, Power and intensity of sound waves, interference of sound waves, standing longitudinal waves, vibrating systems and sources of sound

Light:

Nature of light, visible light (Physical characteristics) light as an electromagnetic wave, speed of light in matter, physical aspects, path difference, phase difference etc. total internal reflection, The doppler effect of light.

Recommended Books

1. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
2. N.K. Bajaj, The Physics of Waves & Oscillations, Tata McGraw- Hill Publishing company Limited, 1986.
3. H. J. Pain, The Physics of Vibrations and Waves, 5th Edition 1999.

PHY-452 **Thermal Physics**
Pre-requisites: **Mechanics**
Co-requisites: **Calculus-II**
Credit Hours: **3**

Objective(s)

To understand the fundamentals of heat and thermodynamics.

Course Contents

Basic Concepts and Definitions in Thermodynamics: Thermodynamic system, Surrounding and Boundaries. Type of systems. Macroscopic and microscopic description of system. Properties and state of the substance: Extensive and Intensive properties, Equilibrium, Mechanical and Thermal Equilibrium. Processes and Cycles: Isothermal, Isobaric and Isochoric. Reversible and irreversible processes

Ideal Gases: Brownian motion, Langevin theory and Einstein theory of Brownian motion, Degrees of freedom in mono, di and triatomic molecules, Specific heat of mono, di and polyatomic gases, Critical constants, Boyles temperature, Temperature of inversion, Van der Waals equation of state, Joule's law for perfect gas, Joules coefficient, Joule-Thomson effect, Nature and origin of Van der Waal gases

Transport phenomena in gases: Mean free path, sphere of influence, transport phenomena, viscosity, thermal conductivity

Heat and Temperature: Temperature, Kinetic theory of ideal gas, Work done on an ideal gas, Review of previous concepts. Internal energy of an ideal gas: Equipartition of Energy, Intermolecular forces, Qualitative discussion, The Virial expansion, The Van der Waals equation of states

Thermodynamic Functions: Thermodynamic functions (Internal energy, Enthalpy, Gibb's functions, Entropy, Helmholtz functions), Maxwell's relations, TdS equations, Energy equations and their applications.

Thermodynamics: Zeroth Law of Thermodynamics, Consequence of Zeroth law of Thermodynamics. The state of the system at Equilibrium. First law of thermodynamics and its applications to adiabatic, isothermal, cyclic and free expansion. Second law of thermodynamics, Carnot theorem and Carnot engine. Heat engine, Diesel and Petrol engines, Refrigerators. Calculation of efficiency of heat engines. Entropy and Second law of thermodynamics, Entropy and Probability, The T-S diagram. Third law of thermodynamics, Zero-point energy

Thermometry: Heat and temperature, types of thermometers, relationships between scales, Thermoelectricity, Seebeck effect, Peltier effect, Thomson effect, Thermoelectric power, Thermoelectric thermometer

Recommended Books

1. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
2. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley, 9th ed. 2010.
3. M. W. Zemansky, "Heat and Thermodynamics", Mc Graw Hill, 7th ed. 1997.
4. M. Sprackling, "Thermal Physics" McMillan 1991.
5. B. N. Roy, "Principle of Modern Thermodynamics", Institute of Physics, London 1995.
6. Brij Lal, N. Subrahmanyam, Heat Thermodynamics and Statistical Physics, Publisher: S. Chand Limited, 2008

PHY-452L LAB-III (Heat, Waves and Sound)
Credit Hours: 1
Objective(s)
Heat: Calorimetry, heat transfer, Newton's cooling under ambient and forced convection and radiation, measurement of temperature using Si diodes, thermistors, thermocouples and RTD's, blackbodies, heat pumps and heat engines, investigation of gas laws and laws of thermodynamics, thermal conductivity by pulsed heating of a metal rod, measurement of latent heats and specific heat capacities, temperature control using PID (proportional-integral-derivative) schemes, thermal expansivity and its measurement using strain gauges.
Waves and Oscillations, Sound: Resonance in a stretched string, normal modes of oscillation, dispersion relations for mono and diatomic lattice, coupled oscillators, nonlinear oscillations exemplified by resistance-inductance-diode circuits, magnetic pendulums, accelerometers, measurement of the speed of sound under conditions of varying temperature, solitons, pendulum, waves in water, beats, super-positions of harmonic motion (Lissajous patterns), sonometer.

PHY-453 **Modern Physics**
Pre-requisites: **Mechanics, Electricity and Magnetism**
Credit Hours: **3**

Objective(s)

To understand the failure of classical physics and emergence of quantum physics

Course Contents

Special Theory of Relativity:

Inertial and non inertial frame, Postulates of Relativity, The Galilean Coordinate Transformation, The Lorentz Transformation, Derivation, Assumptions on which inverse transformation is derived, Consequences of Lorentz transformation, Relativity of time, Relativity of length, Relativity of mass, Transformation of velocity, variation of mass with velocity, mass energy relation and its importance, relativistic momentum and Relativistic energy, (Lorentz invariants) $E^2= p^2c^2+mo^2c^4$

The Twin Paradox, The Doppler Effect for Electromagnetic Waves, Relativistic Momentum, Relativistic Work and Energy, Newtonian Mechanics and Relativity

Photons: Light Waves Behaving as Particles

Historical background (from classical to modern physics), Light Absorbed as Photons: The Photoelectric Effect, Light Emitted as Photons: Production of X-rays, Measurement of the intensity of X-rays, Diffraction of X-rays and Bragg's law, single crystal X-ray spectrometer, X-ray spectrum (continuous and discrete) Moseley's law, X-ray energy level diagram, radiation less transitions, Auger effect, related problems

Light Scattered as Photons: Compton Scattering and Pair Production, Wave–Particle Duality, Probability, and Uncertainty, The Uncertainty Principle, Waves and Uncertainty, Uncertainty in Energy

Particles Behaving as Waves

Electron Waves: Davisson-Germer Experiment, J. P. Thomson Experiment, The Nuclear Atom and Atomic Spectra, Rutherford's Exploration of the Atom, The Failure of Classical Physics, Energy Levels and the Bohr Model of the Atom, The Franck–Hertz Experiment, Hydrogen Energy Levels in the Bohr Model, Planck and the Quantum Hypothesis, The Heisenberg Uncertainty Principles for Matter

Recommended Books

1. Robert M Eisberg, Fundamentals of Modern Physics, John Wiley & Sons 1961
2. Sanjiv Puri, Modern Physics, Narosa Publishing House, 2004.
3. Arthur Beiser, Concepts of Modern Physics (fifth edition) McGraw-Hill 1995
4. Robert M. Eisberg and Robert Resnick, Quantum Physics of Atoms, molecules, Solids, Nuclei and Particles, 2nd edition, John Wiley & Sons, 2002.
5. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
6. A.P. Malvino, 'Electronic Principles', Tata McGraw Hill, New Delhi (1988).
7. Hugh D. Young, Roger A. Freedman, A. Lewis Ford, University Physics with Modern Physics, 13th Edition, Addison Wesley (2012)

PHY-454 **Modern Optics**
Pre-Requisites: **Waves and Oscillations**
Credit Hours: **2**

Objective(s)

To understand the optical phenomena and their uses in physical systems

Course Contents

Geometrical Optics

Geometrical optics and its laws, sign convention, Refraction at a spherical surface, lens formula, lens formula by deviation method, two lens systems, Aberrations, Review of topics related to chromatic aberration, Chromatic aberration, Eye pieces, Fibre optics.

Polarization

Plane elliptically and circularly polarized light, Production of each type and their uses, Malus law, Polarizing angle and Brewster law, Uni-axial crystals, Induced optical effects, Optical activity in liquids

Interference

Far field approximation, Analytical treatment of interference phenomenon, point source and extended source, Typical cases of interference phenomena, (thin films, Fabry Perot & Michelson interferometer, Fresnel's biprism), Holography.

Diffraction

Huygen's principle, Fraunhofer diffraction, Fresnel diffraction, Diffraction by a single slit, Diffraction pattern of a rectangular aperture, Diffraction pattern of a circular aperture, Resolving power of lenses, Double slit diffraction pattern, Diffraction grating, Dispersing properties of prism and grating, X-ray diffraction, neutron and electron diffraction. Study of Fourier theorem and its analysis, Application to grating, Diffraction applications.

Recommended Books

1. E. Hecht, Optics, Addison – Wesley Publishing Company 1987.
2. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.

PHY-454L **LAB-IV (Modern Optics)**
Credit Hours: **1**

Objective(s)

Optics (basic and advanced) and Spectroscopy:

Sources of light including bulbs, light emitting diodes, laser diodes and gas lasers, experiments demonstrating optical phenomena such as interference, diffraction, linear motion, reflection, refraction, dispersion, Michelson interferometry, measurement of refractive index using interferometry, measurement of the speed of light, diffraction gratings and multiple-slit interference, thin film interference and Newton's rings, use of digital cameras for optics experiments, mode structure of lasers, use of spectrometers and monochromators, wavelength tuning of laser diodes, rainbows, emission spectroscopy of low-pressure gases (hydrogen), alkali spectra and fine structure, hyperfine structure of rubidium, vibrational spectrum of nitrogen, Lambert-Beer's law, optical polarization, magneto-optical Faraday rotation.

PHY-401 Mechanics

Credit Hours: Four (4)

Objectives:

The main objective of this course is to understand the different motions of objects on a macroscopic scale and to develop simple mathematical formalisms to analyze such motions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Course Contents:

Vectors Overview: Vectors and scalars, Vector operators, coordinate systems and Unit Vectors, Vector – Magnitude and direction, Vector decomposition into components

Kinematics: position, velocity and acceleration, constant acceleration, vector description of motion in 2D, projectile motion.

Newton's Laws: Newton's Laws of motion, force laws, constraint forces and free body diagrams for gravity, contact forces, tension and springs, Friction

Circular Motion: Circular motion, velocity and angular velocity, uniform circular motion, tangential and radial acceleration, period and frequency of uniform circular motion. Newton's second law and Circular motion, Universal Law of gravitation.

Drag Forces, Constrains and Continuous Systems: Pulleys and constraints, Massive rope, continuous systems and Newton's second law as a differential equation, Resistive forces, capstan, drag force in fluids, free fall with air drag.

Momentum and Impulse: Momentum and Impulse, External and Internal forces and the change in momentum of a system, system of particle. Conservation of momentum, constancy of momentum and isolated systems, momentum changes and non-isolated systems, center of mass, translational motion of the center of mass.

Continuous mass Transfer: Relative velocity and recoil, reference frames, continuous mass transfer, momentum and flow of mass

Kinetic Energy and Work: The concept of energy and conservation of energy, kinetic energy, work, work energy theorem, power, work and scalar product, work done by a non-constant force along arbitrary path, work kinetic energy theorem in 3D, conservation of energy, conservative and non-conservative forces.

Potential Energy and Energy conservation: Changes in potential energy of a system, changes in potential energy and zero point of potential energy, mechanical energy and conservation of mechanical energy, change of mechanical energy for closed system with internal non-conservative forces, dissipative forces: friction, potential energy diagrams.

Collision Theory: Types of collision, Elastic collisions, center of mass reference frame.

Rotational Motion: Motion of a rigid body, two-dimensional rotational kinematics, moment of inertia, Torque, static equilibrium, rotational dynamics.

Angular momentum: Angular momentum of a point particle, angular momentum of a rigid body about a fixed axis, Torque and angular impulse.

Rotations and Translations -Rolling: Rolling Kinematics, rolling dynamics, rolling kinetic energy and angular momentum, gyroscopes

Recommended Books:

10. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
11. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. 2010.

12. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), “University Physics with Modern Physics”, Addison-Wesley-Longman, 13th International ed. 2010.
13. F. J Keller, W. E. Gettys and M. J. Skove, “Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.
14. D. C. Giancoli, “Physics for Scientists and Engineers, with Modern Physics”, Addison-Wesley, 4th ed. 2008.
15. Classical Mechanics: MIT 8.01" by Peter Dourmashkin

PHY-401L LAB-I (Mechanics)

Credit Hours: One (1)

Theme:

Experiments with pendulums, stop watches, one-dimensional motion and verification of Newton's laws of motion, measurement of forces, speed, acceleration and linear momentum, collisions and conservation of momentum, impacts, free fall and acceleration due to gravity, gyroscopes, rotational motion, conservation of angular momentum, friction, static and dynamic equilibrium, compound pendulum, rolling motion along inclined planes, simple harmonic motion, masses attached to springs and Hooke's law, damped motion and the regimes of damping (overdamped, underdamped and critically damped), pressure in fluids, experiments demonstrating continuity, Bernoulli's principle, buoyancy and Archimedes’ principle, Atwood machine, fluid viscosity, surface tension.

MATH-301F Foundation Mathematics

Credit Hours: A non-credit course (compulsory for medical students)

Objectives

This is a bridging course, compulsory for pre-medical students, studying BS Physics. The aim of this course is to bring pre-medical students at par with pre-engineering students. In this course the students will focus on understanding basic concepts of mathematics frequently used in physics majors

Course Contents

Basic Arithmetic

Basic idea of fraction, Addition, subtraction, multiplication and divisions of fractions, decimals, percentages, ratios, rules of arithmetic, surds

Functions and Graphs

Introduction to functions, linear functions, polynomial functions, exponential and logarithmic functions, trigonometric functions, hyperbolic functions, composition of functions, inverse functions

Algebra

Powers or indices, logarithms, expanding and removing brackets, pascal's triangle and binomial theorem, factorizing quadratics, linear equations in one variable, completing the squares, quadratic equations, simultaneous linear equations, solving inequalities, cubic equations, simplifying algebraic fractions, polynomial division, partial fraction

Geometry

Properties of straight-line segment, the gradient of a straight-line segment, equations of straight lines, the geometry of a circle, conic sections, polar co-ordinates

Trigonometry

Pythagoras theorem, Trigonometric ratios in a right-angled triangle, trigonometric ratios of an angle of any size, measurements in radians, trigonometric equations, triangle formulae, cosec, sec and cot, the addition formulae, the double angle formulae

Differentiation

Differentiation from first principles, differentiation power of x, differentiating sines and cosines, differentiating logs and exponentials, using a table of derivatives, the quotient rule, the product rule, the chain rule, parametric differentiation, differentiation by taking logarithms, implicit differentiation, tangent and normal, maxima and minima

Integration

Integration as summation, integration as reverse of differentiation, integration using table of anti-derivatives, integration by parts, integration by substitution, integration of algebraic fractions, integration using trigonometric formulae, finding areas by integration

Recommended Books

1. Hugh Neill and Douglas Quadling, Advanced Mathematics, Cambridge University Press 2004.
2. F.Sc. textbook for Mathematics.

PHY-402 Electricity and Magnetism

Pre-requisite: **Mechanics, Calculus I**
Co-requisite: **Calculus II**
Credit Hours: **Four (4)**

Objectives:

The main objective of this course is to understand the Physics of Electromagnetism and to develop simple mathematical formalisms to analyze the electromagnetic fields and interactions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Course Contents

- **Coulomb's Law:** Coulomb's Law, Charge is Quantized, Charge is Conserved
- **Electric Fields:** The Electric Field, The Electric Field Due to a Charged Particle, The Electric Field Due to a Dipole, The Electric Field Due to a Line of Charge, The Electric Field Due to a Charged Disk, A Point Charge in an Electric Field, A Dipole in an Electric Field
- **Gauss' Law:** Electric Flux, Gauss' Law, A Charged Isolated Conductor, Applying Gauss' Law: Cylindrical Symmetry, Applying Gauss' Law: Planar Symmetry, Applying Gauss' Law: Spherical Symmetry,
- **Electric Potential:** Electric Potential , Equipotential Surfaces and the Electric Field, Potential due to a Charged Particle, Potential due to an Electric Dipole, Potential due to a Continuous Charge Distribution, Calculating the Field From the Potential, Electric Potential Energy of a System of Charged Particles, Equipotential Surfaces, Potential due to a Point Charge and a Group of Point Charges, Potential due to an Electric Dipole, Potential due to a Charge Distribution, Relation between Electric Field and , Electric Potential Energy.
- **Capacitors:** Capacitance, Calculating The Capacitance, Capacitors In Parallel And In Series, Energy Stored in an Electric Field, Capacitor With a Dielectric, Dielectrics and Gauss' Law.
- **Current and Resistance:** Electric Current, Current Density, Resistance and Resistivity, Ohm's Law; Power, Semiconductors and Superconductors;
- **Circuits:** Single-loop Circuits, Multi- loop Circuits, The Ammeter and the Voltmeter, RC Circuits
- **Magnetic Fields**: Magnetic Fields and the Definition of B, Crossed Fields: Discovery of the Electron, Crossed Fields: The Hall Effect, A Circulating Charged Particle, Cyclotrons and Synchrotrons, Magnetic Force on a Current-Carrying Wire, Torque on a Current Loop, The Magnetic Dipole Moment
- **Magnetic Fields Due to Currents**: Magnetic Field Due to a Current, Force between two Parallel Currents, Ampere's Law, Solenoids and Toroids, A Current-Carrying Coil as a Magnetic Dipole
- **Induction and Inductance**: Faraday's Law and Lenz's Law, Induction and Energy Transfers, Induced Electric Fields, Inductors and Inductance, Self-Induction, RL

Circuits, Energy Stored in a Magnetic Field, Energy Density of a Magnetic Field, Mutual Induction

- **Electromagnetic Oscillations and Alternating Current:** Lc Oscillations, Damped Oscillations in an RLC Circuit, Forced Oscillations of Three Simple Circuits, The Series RLC Circuit, Power in Alternating-Current Circuits, Transformers
- **Maxwell's Equations; Magnetism of Matter:** Gauss' Law for Magnetic Fields, Induced Magnetic Fields, Displacement Current, Magnets, Magnetism and Electrons, Diamagnetism, Paramagnetism, Ferromagnetism

Recommended Text Books:

6) D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley & Sons, 9th ed. 2010.
7) R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. 2010.
8) R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed. 2010.
9) F. J Keller, W. E. Gettys and M. J. Skove, "Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.
10) D. C. Giancoli, "Physics for Scientists and Engineers, with Modern Physics", Addison-Wesley,

PHY-402L LAB-II (Electricity and Magnetism)

Credit Hours: One (1)

Theme:

Static charge and electric fields, direct and alternating currents, electrical measurement instrumentation (voltmeters, ammeters, power supplies, variable transformers, cathode ray oscilloscope, electrometer), passive electronic components (resistors, capacitors, inductors), measurement of resistance, capacitance and inductance, electromagnetic induction, inductors and transformers, motors, magnetic fields due to currents and permanent magnets, ferromagnetism and ferroelectricity, determination of hysteresis curves, determination of Curie point, magnetic susceptibility and its temperature dependence, dielectric properties measurement, mapping of magnetic fields using Hall sensors, experiments on noise, properties of the light bulb.

PHY-451 Waves and Oscillations

Pre-requisites: **Mechanics, Calculus II**
Credit Hours: **Three (3)**

Objective(s)

To develop a unified mathematical theory of oscillations and waves in physical systems.

Course Contents

Harmonic Oscillations:
Simple harmonic motion (SHM), Obtaining and solving the basic equations of motion x(t), v(t), a(t), Longitudinal and transverse Oscillations, Energy considerations in SHM. Application of SHM, Torsional oscillator, Physical pendulum, simple pendulum, SHM and uniform circular motion, Combinations of harmonic motions, Lissajous patterns, Damped harmonic motion, Equation of damped harmonic motion, Quality factor, discussion of its solution, Forced oscillations and resonances, Equation of forced oscillation, Discussion of its solution, Natural frequency, Resonance, Examples of resonance.
Waves in Physical Media:
Mechanical waves, Travelling waves, Phase velocity of traveling waves, Sinusoidal waves, Group speed and dispersion, Waves speed, Mechanical analysis, Wave equation, Discussion of solution, Power and intensity in wave motion, Derivation & discussion, Principle of superposition (basic ideas), Interference of waves, Standing waves. Phase changes on reflection
Sound:
Properties of sound waves, travelling sound waves, the speed of sound, Power and intensity of sound waves, interference of sound waves, standing longitudinal waves, vibrating systems and sources of sound
Light:
Nature of light, visible light (Physical characteristics) light as an electromagnetic wave, speed of light in matter, physical aspects, path difference, phase difference etc. total internal reflection, The doppler effect of light.

Recommended Books

4. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
5. N.K. Bajaj, The Physics of Waves & Oscillations, Tata McGraw- Hill Publishing company Limited, 1986.
6. H. J. Pain, The Physics of Vibrations and Waves, 5th Edition 1999.

PHY-452 Thermal Physics

Pre-requisites: **Mechanics**
Co-requisites: **Calculus-II**
Credit Hours: **Three (3)**

Objective(s)
To understand the fundamentals of heat and thermodynamics.

Course Contents
Basic Concepts and Definitions in Thermodynamics: Thermodynamic system, Surrounding and Boundaries. Type of systems. Macroscopic and microscopic description of system. Properties and state of the substance: Extensive and Intensive properties, Equilibrium, Mechanical and Thermal Equilibrium. Processes and Cycles: Isothermal, Isobaric and Isochoric. Reversible and irreversible processes
Ideal Gases: Brownian motion, Langevin theory and Einstein theory of Brownian motion, Degrees of freedom in mono, di and triatomic molecules, Specific heat of mono, di and polyatomic gases, Critical constants, Boyles temperature, Temperature of inversion, Van der Waals equation of state, Joule's law for perfect gas, Joules coefficient, Joule-Thomson effect, Nature and origin of Van der Waal gases
Transport phenomena in gases: Mean free path, sphere of influence, transport phenomena, viscosity, thermal conductivity
Heat and Temperature: Temperature, Kinetic theory of ideal gas, Work done on an ideal gas, Review of previous concepts. Internal energy of an ideal gas: Equipartition of Energy, Intermolecular forces, Qualitative discussion, The Virial expansion, The Van der Waals equation of states
Thermodynamic Functions: Thermodynamic functions (Internal energy, Enthalpy, Gibb's functions, Entropy, Helmholtz functions), Maxwell's relations, TdS equations, Energy equations and their applications.
Thermodynamics: Zeroth Law of Thermodynamics, Consequence of Zeroth law of Thermodynamics. The state of the system at Equilibrium. First law of thermodynamics and its applications to adiabatic, isothermal, cyclic and free expansion. Second law of thermodynamics, Carnot theorem and Carnot engine. Heat engine, Diesel and Petrol engines, Refrigerators. Calculation of efficiency of heat engines. Entropy and Second law of thermodynamics, Entropy and Probability, The T-S diagram. Third law of thermodynamics, Zero-point energy
Thermometry: Heat and temperature, types of thermometers, relationships between scales, Thermoelectricity, Seebeck effect, Peltier effect, Thomson effect, Thermoelectric power, Thermoelectric thermometer

Recommended Books
7. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
8. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley, 9th ed. 2010.
9. M. W. Zemansky, "Heat and Thermodynamics", Mc Graw Hill, 7th ed. 1997.
10. M. Sprackling, "Thermal Physics" McMillan 1991.
11. B. N. Roy, "Principle of Modern Thermodynamics", Institute of Physics, London 1995.
12. Brij Lal, N. Subrahmanyam, Heat Thermodynamics and Statistical Physics, Publisher: S. Chand Limited, 2008

PHY-452L LAB-III (Heat, Waves and Sound)

Credit Hours: Four (1)

Objective(s)

Heat: Calorimetry, heat transfer, Newton's cooling under ambient and forced convection and radiation, measurement of temperature using Si diodes, thermistors, thermocouples and RTD's, blackbodies, heat pumps and heat engines, investigation of gas laws and laws of thermodynamics, thermal conductivity by pulsed heating of a metal rod, measurement of latent heats and specific heat capacities, temperature control using PID (proportional-integral-derivative) schemes, thermal expansivity and its measurement using strain gauges.

Waves and Oscillations, Sound: Resonance in a stretched string, normal modes of oscillation, dispersion relations for mono and diatomic lattice, coupled oscillators, nonlinear oscillations exemplified by resistance-inductance-diode circuits, magnetic pendulums, accelerometers, measurement of the speed of sound under conditions of varying temperature, solitons, pendulum, waves in water, beats, super-positions of harmonic motion (Lissajous patterns), sonometer.

PHY-453 Modern Physics

Pre-requisites: **Mechanics, Electricity and Magnetism**
Credit Hours: **Three (3)**

Objective(s)

To understand the failure of classical physics and emergence of quantum physics

Course Contents

Special Theory of Relativity:

Inertial and non inertial frame, Postulates of Relativity, The Galilean Coordinate Transformation, The Lorentz Transformation, Derivation, Assumptions on which inverse transformation is derived, Consequences of Lorentz transformation, Relativity of time, Relativity of length, Relativity of mass, Transformation of velocity, variation of mass with velocity, mass energy relation and its importance, relativistic momentum and Relativistic energy, (Lorentz invariants) $E^2= p^2c^2+mo^2c^4$

The Twin Paradox, The Doppler Effect for Electromagnetic Waves, Relativistic Momentum, Relativistic Work and Energy, Newtonian Mechanics and Relativity

Photons: Light Waves Behaving as Particles

Historical background (from classical to modern physics), Light Absorbed as Photons: The Photoelectric Effect, Light Emitted as Photons: Production of X-rays, Measurement of the intensity of X-rays, Diffraction of X-rays and Bragg's law, single crystal X-ray spectrometer, X-ray spectrum (continuous and discrete) Moseley's law, X-ray energy level diagram, radiation less transitions, Auger effect, related problems

Light Scattered as Photons: Compton Scattering and Pair Production, Wave–Particle Duality, Probability, and Uncertainty, The Uncertainty Principle, Waves and Uncertainty, Uncertainty in Energy

Particles Behaving as Waves

Electron Waves: Davisson-Germer Experiment, J. P. Thomson Experiment, The Nuclear Atom and Atomic Spectra, Rutherford's Exploration of the Atom, The Failure of Classical Physics, Energy Levels and the Bohr Model of the Atom, The Franck–Hertz Experiment, Hydrogen Energy Levels in the Bohr Model, Planck and the Quantum Hypothesis, The Heisenberg Uncertainty Principles for Matter

Recommended Books

8. Robert M Eisberg, Fundamentals of Modern Physics, John Wiley & Sons 1961
9. Sanjiv Puri, Modern Physics, Narosa Publishing House, 2004.
10. Arthur Beiser, Concepts of Modern Physics (fifth edition) McGraw-Hill 1995
11. Robert M. Eisberg and Robert Resnick, Quantum Physics of Atoms, molecules, Solids, Nuclei and Particles, 2nd edition, John Wiley & Sons, 2002.
12. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.
13. A.P. Malvino, 'Electronic Principles', Tata McGraw Hill, New Delhi (1988).
14. Hugh D. Young, Roger A. Freedman, A. Lewis Ford, University Physics with Modern Physics, 13^{th} Edition, Addison Wesley (2012)

PHY-454 Modern Optics

Pre-Requisites: **Waves and Oscillations**
Credit Hours: **Two (2)**

Objective(s)
To understand the optical phenomena and their uses in physical systems

Course Contents
Geometrical Optics
Geometrical optics and its laws, sign convention, Refraction at a spherical surface, lens formula, lens formula by deviation method, two lens systems, Aberrations, Review of topics related to chromatic aberration, Chromatic aberration, Eye pieces, Fibre optics.
Polarization
Plane elliptically and circularly polarized light, Production of each type and their uses, Malus law, Polarizing angle and Brewster law, Uni-axial crystals, Induced optical effects, Optical activity in liquids
Interference
Far field approximation, Analytical treatment of interference phenomenon, point source and extended source, Typical cases of interference phenomena, (thin films, Fabry Perot & Michelson interferometer, Fresnel's biprism), Holography.
Diffraction
Huygen's principle, Fraunhofer diffraction, Fresnel diffraction, Diffraction by a single slit, Diffraction pattern of a rectangular aperture, Diffraction pattern of a circular aperture, Resolving power of lenses, Double slit diffraction pattern, Diffraction grating, Dispersing properties of prism and grating, X-ray diffraction, neutron and electron diffraction. Study of Fourier theorem and its analysis, Application to grating, Diffraction applications.

Recommended Books
1. E. Hecht, Optics, Addison – Wesley Publishing Company 1987.
2. Halliday, D. Resnick, Krane, Physics, Vol. I & II, John Wiley, 5th ed. 1999.

PHY-454L LAB-IV (Modern Optics)

Credit Hours: One **(1)**

Objective(s)

Optics (basic and advanced) and Spectroscopy:

Sources of light including bulbs, light emitting diodes, laser diodes and gas lasers, experiments demonstrating optical phenomena such as interference, diffraction, linear motion, reflection, refraction, dispersion, Michelson interferometry, measurement of refractive index using interferometry, measurement of the speed of light, diffraction gratings and multiple-slit interference, thin film interference and Newton's rings, use of digital cameras for optics experiments, mode structure of lasers, use of spectrometers and monochromators, wavelength tuning of laser diodes, rainbows, emission spectroscopy of low-pressure gases (hydrogen), alkali spectra and fine structure, hyperfine structure of rubidium, vibrational spectrum of nitrogen, Lambert-Beer's law, optical polarization, magneto-optical Faraday rotation.

PHY-501 Classical Mechanics

Pre-requisites: **Mechanics**
Credit Hours: **Three (3)**

Course Contents

Review of Newtonian Mechanics: Frame of reference, orthogonal transformations, angular velocity and angular acceleration, Newton's laws of motion, Galilean transformation, conservation laws, systems of particles, motion under a constant force, motions under variable force, time-varying mass system.
The Lagrange Formulation of Mechanics and Hamilton Dynamics: Generalized co-ordinates and constraints, D-Alembert's principle and Lagrange's Equations, Hamilton's principle, integrals of motion, non-conservative system and generalized potential, Lagrange's multiplier method, the Hamiltonian of a dynamical system, canonical equations, canonical transformations, Poisson brackets, phase space and Liouville's theorem.
Central Force Motion: The two-body problem, effective potential and classification of orbits, Kepler's laws, stability of circular orbits, hyperbolic orbits and Rutherford scattering, center of mass co-ordinate system, scattering cross-sections.
Motion in Non- inertial Systems: Accelerated translational co -ordinate system, dynamics in rotating co-ordinate system, motion of a particle near the surface of the earth.
The Motion of Rigid Bodies: The Euler angles, rotational kinetic energy and angular momentum, the inertia tensor, Euler equations of motion, motion of a torque-free symmetrical top, stability of rotational motion.

Recommended Books

1. T. L. Chow, "Classical Mechanics", John Wiley, 1995.
2. T. Kibble and F. Berkshire, "Classical Mechanics", World Scientific, 5th ed. 2004.

PHY-502 Mathematical Methods of Physics-I

Pre-requisite: **Mechanics, Differential Equations, Linear Algebra**
Credit Hours: **(Three) 3**

Objective(s)

To develop the mathematical background of student in vectors, tensors, matrices and some of their uses in the world of physics, to give basic understanding of group theory and complex variables used in physics.

Course Contents

Vector Analysis

Review of vectors Algebra, Vector operations, Physical significance of DEL operator, Line integrals, Surface and Volume Integrals, Gradient of a scalar, Divergence of a vector , Directional derivatives and gradients, Curl of a vector , Gauss's divergence theorem, Green's theorem, Vector differentiation and gradient, Vector integration, , Stokes's Curl theorem, , Cartesian coordinates systems, Polar coordinates systems, Spherical polar and Cylindrical coordinates systems.

Matrices:

Determinants, Matrices, Linear vector spaces, orthogonal matrices, Hermitian matrices, Unitary Matrices, Orthogonalization, Eigenvalues and eigenvectors of matrices, , Similarity transformations, Diagonalization of matrices.

Complex Variables:

Complex numbers , Functions of a complex variable, analytic functions of complex variables, De Moivre's theorem, Taylor and Laurent series, Cauchy Riemann conditions and analytic functions, Cauchy integral theorem, Cauchy integral formula, Euler's formula, harmonic functions, complex integration, Contour integrals, singularities and residues, residue theorem.

Recommended Books

1. G. Arfken, Mathematical Physics, 2nd ed, Academic Press, 1970.
2. Dass H.K, R. Verma, 2011, 6th Edition, Mathematical Physics, S. Chand& Company Ltd. New Delhi.
3. E. Butkov, Mathematical Physics, Addison-Wesley 1968.
4. Pipes and Harvill, Applied Mathematics for Engineers and Physicists, McGraw Hill, 1971.
5. M. L. Boas, Mathematical Methods in Physical Sciences, John Wiley & Sons, New York (1989)
6. M. R. Speigel, Complex Variables Schaum's Outline Series, McGraw Hill 1979

PHY-503 Electrodynamics-I

Pre-requisites: **Electricity and Magnetism, Calculus-II**
Credit Hours: **Three (3)**

Course Contents

Review of Calculus: vector algebra and calculus, Cartesian coordinates spherical coordinates.
The Dirac Delta Function: Review of vector calculus using example of Dirac Delta function, the divergence of r/r^2, the one -dimensional and the three-dimensional Dirac delta functions. The theory of vector fields: the Helmoholtz theorem, potentials.
Electrostatics: The electric field: introduction, Coulomb's law, the electric field, continuous charge distributions. Divergence and curl of electrostatic fields: field lines, flux and Gauss's law, the divergence of Electric field, applications of Gauss's law, the curl of Electric field. Electric potential: introduction to potential, comments on potential, Poisson's equation and Laplace's equation, the potential of a localized charge distribution, summary, electrostatics boundary conditions, Work and energy in electrostatics: the work done to move a charge, the energy of a point charge distribution, the energy of a continuous charge distribution, comments on electrostatic energy. Conductors: basic properties, induced charges, surface charge and the force on a conductor, capacitors.
Special Techniques: Laplace's equation: introduction, Laplace's equation in one, two and three dimensions, boundary conditions and uniqueness theorems.
The Method of Images: The classic image problem, induced surface charge, force and energy, other image problems.
Multi- pole Expansion: Approximate potential at large, the monopole and dipole terms, origin of coordinates in multi-pole, expansions, the electric field of a dipole.
Electric Fields in Matter: Polarization: dielectrics, induced dipoles, alignment of polar molecules, polarization. The field of a polarized object: bound charges, physical interpretation of bound charges, and the field inside a dielectric. The electric displacement: Gauss's law in the presence of dielectrics, a deceptive parallel, boundary conditions. Linear Dielectrics: susceptibility, permittivity, dielectric constant, boundary value problems with linear dielectrics, energy in dielectric systems, forces on dielectrics.

Recommended Books

1. D. J. Griffiths, "Introduction to Electrodynamics", Prentice Hall, 3rd ed. 1999.
2. P.C. Lorrain & D.R. Corson, 'Electromagnetic Fields and Waves', W.H. Freeman & Co., New York.
3. Ritze, Millford & Chiristy, Foundation of Electromagnetic Theory.4th edition
4. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Press, 5th ed. 2009.
5. F. Melia, "Electrodynamics", University of Chicago Press, 2001.
6. Hearld J and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed. 2011.

PHY-504 Quantum Mechanics-I

Pre-requisites: **Modern Physics**
Credit Hours: **Three (3)**

Course Contents

1. Historical motivation: wave-particle duality, photo-electric effect, instability of atoms, black body catastrophe.
2. Observables and operators, postulates of mechanics, measurement problems, the state function and expectation values, Schrödinger wave equation.
3. Time-independent Schrödinger equation and one-dimensional problems, stationary states, superposition principle, free particles, infinite and finite square well, harmonic oscillator, and delta-function potential.
4. Hilbert space, Dirac notation, linear transformations, discrete and continuous basis vectors, hermitian and unitary operators.
5. Compatible observables, commutators, uncertainty principle, minimum uncertainty states.
6. Time development of state functions, symmetries and conservation laws, conservation of parity, operators for time and space translations.
7. Waves incident on potential barrier, reflection and transmission coefficients, WKB method.
8. Quantum mechanics in three-dimensions, cartesian and spherical forms of Schrodinger equation, separation of variables
9. Rotational symmetry, angular momentum as a generator of rotations, spherical harmonics and their properties. Completeness and orthonormality properties.

Recommended Books

1. Introductory Quantum Mechanics, by Richard L. Liboff, publisher: Addison Wesley; 4th Edition, (2002).
2. Introduction to Quantum Mechanics, by David J. Griffiths, publisher: Pearson Prentice Hall, 2nd Edition (2005).
3. Quantum Physics by Stephen Gasiorowicz, publisher: Willey International, 3rd Edition

PHY-505 Electronics

Pre-requisites: **Modern Physics**
Credit Hours: **Three (3)**

Course Contents

The Semiconductor Diode: Metals, insulators and semiconductors, Conduction in Silicon and Germanium, The forbidden energy gap, n and p type semiconductors, the junction diode, diode voltage-current equation, Zener diodes, light emitting diodes, photodiodes, capacitance effects in the pn junction.

The Diode as Rectifier and Switch: The ideal diode model, the half wave rectifier, the full wave rectifier, the bridge rectifier, measurement of ripple factor in the rectifier circuit, the capacitor filter, the ∏ filter, the ∏-R filter, the voltage doubling rectifier circuit, rectifying AC voltmeters, diode wave clippers, diode clampers.

Circuit Theory and Analysis: Superposition theorem, Thevenin's Theorem, Norton's Theorem, Model for circuit, one port and two-port network, Hybrid parameter equivalent circuit, Power in decibels.

The Junction Transistor as an Amplifier: Transistor voltage and current designations, the junction transistors, the volt-ampere curve of a transistor, the current amplification factors, the load line and Q point, the basic transistor amplifiers, the common emitter amplifier, the trans-conductance gm, performance of a CE amplifier, relation between Ai and Av, the CB amplifier, the CC amplifier, comparison of amplifier performance.

DC Bias for the Transistor: Choice of Q point, variation of Q point, fixed transistor bias, the four resistor bias circuit, design of a voltage feedback bias circuit, Common emitter, common collector, common base biasing.

Field Effect Transistor: What is /field effect transistor, JFET: Static characteristics of JFET, Metal oxide semiconductor Field Effect Transistor (MOSFET of IGFET): enhancement and depletion mode, FET biasing techniques, Common drain, common source and common gate, fixed bias and self-bias configurations, Universal JFET bias curve, Darlington pair.

Operational Amplifiers: The integrated amplifier, the differential amplifier, common mode rejection ratio, the operational amplifier, summing operation, integration operation, comparator, milli-voltmeter.

Recommended Books

1. Thomas L. Floyd, "Electronics Fundamentals: Circuits, Devices and Applications", Prentice Hall, 8th ed., 2009.
2. B. Grob, "Basic Electronics", McGraw-Hill, Tch ed. 1997.
3. B. Streetman and S. Banerjee "Solid State Electronics Devices", Prentice Hall, 6th ed. 2005.
4. Bar-lev, "Semiconductor and Electronics Devices", Prentice Hall, 3rd ed. 1993.
5. D. H. Navon and B. Hilbert, "Semiconductor Micro-devices and Materials", CBS College Publishing, 1986.
6. P. Malvino, "Electronic Principles", McGraw-Hill, 7th ed. 2006.
7. R. T. Paynter, "Introductory Electric Circuits", Prentice Hall, 1998.

PHY-505L LAB-V (Electronics)

Credit Hours: Two (2)

Electronics: DC voltages and current measurement, simple DC circuits, generating and analyzing time-varying signals, opamps and comparators, amplifier design, RC transients, filters, frequency response, LC circuits, resonance, transformers, diodes, modulation and radio reception, MOSFET characteristics and applications, principles of amplification, bipolar transistors and amplifiers, digital logic circuits, gates and latches, D-flip flops and shift registers, JK flip-flops and ripple counters.

PHY-551 Quantum Mechanics-II

Pre-requisites: **Quantum Mechanics-I**

Credit Hours: **Three (3)**

Course Contents

1. Motion of a particle in a central potential. Separation of variables, effective potential, solution for the Coulomb problem. Spectrum of the hydrogen atom.
2. Spin as an internal degree of freedom, intrinsic magnetic moment, intrinsic angular momentum, spin-orbit interaction and total angular momentum.
3. Identical particles: Many-particle systems, system of distinguishable noninteracting particles, systems of identical particles, symmetrization postulate, Pauli exclusion principle and the periodic table.
4. Time-independent perturbation theory: Nondegenerate perturbation theory, degenerate perturbation theory.
5. The variational principle: Variational theorem, variational approximation method, the ground state of helium atom.
6. The WKB approximation: WKB wave functions, general connection rules across a classical turning point, tunneling.
7. Systems of Identical Particles: Identical particles, Permutation operators, The symmetrization postulate, difference between bosons and fermions, Pauli's exclusion principle, many-electrons atom and their electronic configurations, energy levels of the helium atom, configurations, terms, multiplets, spin isomers of hydrogen (ortho and parahydrogen)
8. Time-dependent perturbation theory: A perturbed two-level system, perturbation by an electromagnetic wave, transition into a continuum of states-Fermi's golden rule, Oscillator strengths, selection rules.
9. Scattering: Classical scattering theory, quantum scattering theory, partial wave analysis, phase shifts, the Born approximation.

Recommended Books

1. *Introductory Quantum Mechanics*, by Richard L. Liboff, publisher: Addison Wesley; 4th Edition, (2002).
2. *Introduction to Quantum Mechanics*, by David J. Griffiths, publisher: Pearson Prentice Hall, 2nd Edition (2005).
3. *Quantum Physics, by* Stephen Gasiorowicz, publisher: John Wiley, 3rd Edition (2005).

PHY-552 Mathematical Methods of Physics-II

Pre-requisite: **Mathematical Methods of Physics-I**
Credit Hours: **Three (3)**

Objective(s)

To give the understanding of Differential equations and their uses in Physics, Introduction to special functions, Fourier Series, Fourier Transforms, Solution of Boundary value problems and their uses.

Course Contents

Special Functions:
Gamma functions, Beta functions, Bessel functions, generating function, recurrence relation, Spherical Bessel functions, Legendre polynomials, Associated Legendre polynomials, Hermite polynomials.
Fourier series:
Definition and general properties, Fourier series of various physical functions, complex form of Fourier series, uses and application of Fourier series, Parseval's theorem
Integral Transforms:
Integral transform, Fourier transform, Fourier cosine transform,Fourier sine transform, Convolution theorem, Elementary Laplace transform and its applications, Fourier transform of derivatives, Inverse Laplace Transform, Laplace transform of derivatives. Physical significance along with examples of Fourier and Laplace transforms, Integral transform solution of partial differential equations,
Differential Equations in Physics:
First and second order linear differential equations, Partial differential equations of theoretical physics, Separation of variables, Homogeneous differential equations, Frobenius series solution of differential equations, Nonhomogeneous differential equations. Applications of partial differential equations

Recommended Books

1. G. Arfken, Mathematical Physics, 2nd ed, Academic Press, 1970.
2. Dass H.K, R. Verma, 2011, 6th Edition, Mathematical Physics, S. Chand& Company Ltd. New Delhi.
3. E. Butkov, Mathematical Physics, Addison-Wesley 1968.
4. Pipes and Harvill, Applied Mathematics for Engineers and Physicists, McGraw Hill, 1971.
5. M. L. Boas, Mathematical Methods in Physical Sciences, John Wiley & Sons, New York (1989)
6. M. R. Speigel, Complex Variables Schaum's Outline Series, McGraw Hill 1979

PHY-553 Electrodynamics-II

Pre-requisites: **Electromagnetic Theory-I**
Credit Hours: **Three (3)**

Motivation

This course is the second part of the core level undergraduate course on Electromagnetic Theory and a previous knowledge of Electromagnetic Theory I is expected.

Course Contents

Magnetostatics: The Lorentz Force law: magnetic fields, magnetic forces, currents. The Biot-Savart Law: steady currents, the magnetic field of a steady current. The divergence and curl of B: straight-line currents, the divergence and curl of B, applications of Ampere's law, comparison of magnetostatics and electrostatics. Magnetic Vector Potential: the vector potential, summary, magnetic boundary conditions, multi-pole expansion of the vector potential.
Magnetic Fields in Matter: Magnetization, diamagnets, paramagnets, ferromagnets, torques and forces on magnetic dipoles, effect of a magnetic field on atomic orbits, magnetization. The Field of a Magnetized Object: bound currents, physical interpretation of bound currents, and the magnetic field inside matter. The auxiliary field H: Ampere's law in magnetized materials, a deceptive parallel, boundary conditions. Linear and nonlinear media: magnetic susceptibility and permeability, ferromagnetism.
Electrodynamics: Electromotive force: Ohm's law, electromotive force, motional emf, electromagnetic induction: Faraday's law, the induced electric field, inductance, energy in magnetic fields, Maxwell's equations: electrodynamics before Maxwell, how Maxwell fixed Ampere's law, Maxwell's equations, magnetic charges, Maxwell's equations in matter, boundary conditions.
Conservation Laws: Charge and energy: the continuity equation, Poynting's theorem, momentum: Newton's third law in electrodynamics, Maxwell's stress tensor, conservation of momentum, angular momentum.
Electromagnetic Waves: Waves in one dimension: the wave equation, sinusoidal waves, boundary conditions, reflection and transmission, polarization, electromagnetic waves in vacuum: the wave equation for E and B, monochromatic plane waves, energy and momentum in electromagnetic waves, electromagnetic waves in matter: propagation in linear media, reflection and transmission at normal incidence, reflection and transmission at oblique incidence, absorption and dispersion: electromagnetic waves in conductors, reflection at a conducting surface, the frequency dependence of permittivity, guided waves: wave guides, the waves in a rectangular wave guide, the coaxial transmission line.
Potentials and Fields: The potential formulation: scalar and vector potentials, gauge transformations, Coulomb gauge and Lorentz gauge, continuous distributions: retarded potentials, Jefimenko's equations, point charges: Lienard-Wiechert potentials, the field of a moving point charge.
Radiation, Dipole Radiation: What is radiation, electric dipole radiation, magnetic dipole radiation, radiation from an arbitrary source, point charges: power radiated by a point charge, radiation reaction, the physical basis of the radiation reaction.

Recommended Books

1. D. J. Griffiths, "Introduction to Electrodynamics", Prentice Hall, 3rd ed. 1999.
2. P.C. Lorrain & D.R. Corson, 'Electromagnetic Fields and Waves', W.H. Freeman & Co., New York.

3. Ritze, Millford & Chiristy, Foundation of Electromagnetic Theory.4th edition
4. M. N. O. Sadiku, ”Elements of Electromagnetics”, Oxford University Press, 5th ed. 2009.
5. F. Melia, “Electrodynamics”, University of Chicago Press, 2001.
6. Hearld J and W. Muller-Kristen, “Electrodynamics”, World Scientific Publishing, 2nd ed. 2011.

PHY-554 Thermal and Statistical Physics

Pre-requisites: **Heat & Thermodynamics, Calculus-II**
Credit Hours: **Three (3)**

Course Contents

Review of Classical Thermodynamics: States, macroscopic vs. microscopic, "heat" and "work", energy, entropy, equilibrium, laws of thermodynamics, Equations of state, thermodynamic potentials, temperature, pressure, chemical potential, thermodynamic processes (engines, refrigerators), Maxwell relations, phase equilibria.
Thermal Radiations: Black body radiation, Rayleigh-Jeans theory, Planck distribution, free energy of a photon gas, Stefan-Boltzmann formula, phonons, Solar Spectrum, Electromagnetic Spectrum
Foundation of Statistical Mechanics: Phase Space, Trajectories in Phase Space, Conserved Quantities and Accessible Phase Space, Macroscopic Measurements and Time Averages, Ensembles and Averages over Phase Space, Liouville's Theorem, The Ergodic Hypothesis, Equal a priori Probabilities. Specification of the state of a system, concept of ensembles, elementary probability calculations, distribution functions, statistical interpretation of entropy (Boltzmann theorem).
Statistical Ensembles: Microcanonical ensemble, canonical ensemble and examples (e.g., paramagnet), calculation of mean values, calculation of partition function and its relation with thermodynamic quantities, the grand canonical ensemble and examples (e.g. adsorption), calculation of partition function and thermodynamic quantities.
Simple Applications of Ensemble Theory: Monoatomic ideal gas in classical and quantum limit, Gibb's paradox and quantum mechanical enumeration of states, equipartition theorem and examples (ideal gas, harmonic oscillator), specific heat of solids, quantum mechanical calculation of para-magnetism.
Quantum Statistics: Indistinguishability and symmetry requirements, Maxwell-Boltzmann statistics, Bose-Einstein and photon statistics, Fermi-Dirac statistics (distribution functions, partition functions). Examples: polyatomic ideal gas (MB), black body radiation (photon statistics), conduction electrons in metals (FD), Bose condensation (BE).
Systems of Interacting Particles: Lattice vibrations in solids, van der Waals gas, mean field calculation, ferromagnets in mean field approximation.

Recommended Books

1. F. Reif, "Fundamentals of Statistical and Thermal Physics", Waveland Pr Inc, 2008.
2. W. Brewer, F. Schwabl, "Statistical Mechanics", Springer, 2nd ed. 2006.
3. T. L. Hill, "Statistical Mechanics", World Scientific Publishing Company, (2004).
4. K. Huang, "Statistical Mechanics", John Wiley, 2nd ed. 1987.
5. Brij Lal, N. Subrahmanyam, Heat Thermodynamics and Statistical Physics, Publisher: S. Chand Limited, 2008

PHY-555 Atomic and Molecular Physics

Pre-requisites: **Quantum Mechanics I**
Co-requisite: **Quantum Mechanics II**
Credit Hours: **Three (3)**

Objective(s)

To provide an introduction to the structure and spectra of atoms and molecules. To prepare students for more advanced courses on Physics of Atoms, Molecules and Photons.

Course Contents

One Electron Atoms: Review of Bohr Model of Hydrogen Atom, Reduced Mass, Atomic Units and Wavenumbers, Energy Levels and Spectra, Schrodinger Equation for One-Electron Atoms, Quantum Angular Momentum and Spherical Harmonics, Electron Spin, Spin -Orbit interaction. Levels and Spectroscopic Notation, Lamb Shift, Hyperfine Structure and Isotopic Shifts. Rydberg Atoms.
Interaction of One -Electron Atoms with Electromagnetic Radiation: Radiative Transition Rates, Dipole Approximation, Einstein Coefficients, Selection Rules, Dipole Allowed and Forbidden Transitions. Metastable Levels, Line Intensities and Lifetimes of Excited States, Shape and Width of Spectral Lines, Scattering of Radiation by Atomic Systems, Zeeman Effect, Linear and Quadratic Stark Effect.
Many-Electron Atoms: Schrodinger Equation for Two-Electron Atoms, Para and Ortho States, Pauli's Principle and Periodic Table, Coupling of Angular Momenta, L-S and J-J Coupling. Ground State and Excited States of Multi-Electron Atoms, Configurations and Terms.
Molecular Structure and Spectra: Structure of Molecules, Covalent and Ionic Bonds, Electronic Structure of Diatomic Molecules, Rotation and Vibration of Diatomic Molecules, Born -Oppenheimer Approximation. Electronic Spectra, Transition Probabilities and Selection Rules, Frank-Condon Principle, H2+ and H2. Effects of Symmetry and Exchange. Bonding and Anti-bonding Orbitals. Electronic Spin and Hund's Cases, Nuclear Motion: Rotation and Vibrational Spectra (Rigid Rotation, Harmonic Vibrations). Selection Rules. Spectra of Triatomic and Polyatomic Molecules, Raman Spectroscopy, Mossbauer Spectroscopy.

Recommended Books

1. C. J. Foot, "Atomic Physics", Oxford University Press, 2005.
2. B. H. Bransden and C. J. Joachain, "Physics of Atoms and Molecules", Pearson Education, 2nd ed. 2008.
3. W. Demtroder, "Atoms, Molecules and Photons", Springer, 2nd ed. 2010.
4. C. N. Banwell and E. M. McCash, "Fundamentals of Molecular Spectroscopy", McGraw-Hill, 4th ed. 1994.
5. J. M. Hollas, "Basic Atomic & Molecular Spectroscopy", John Wiley, 2002.

PHY-555L LAB-VII (Modern Physics)

Credit Hours: Three (2)

Modern Physics

- Photoelectric effect,
- Frank- Hertz's quantization of energy levels,
- Determination of Planck's constant (e.g. using a light bulb),
- Verification of Moseley's law using X-ray fluorescence,
- Compton effect
- Millikan's experiment for determination of charge of electron
- Measurement of electrical conductivity by two-probe and four-probe methods, band gap estimation of intrinsic and extrinsic semiconductors, carrier lifetimes and mobilities, Hall effect and its application in measuring magnetic fields, thermoelectric effects.

PHY-600 Project

Credit Hours: Three (3)

Objective(s)

To train students in relevant field and thesis writing, finally presenting the research project carried out.

PHY-601 Solid State Physics-I

Pre-requisites: **Quantum Mechanics I, Statistical Mechanics**

Credit Hours: **Three (3)**

Course Contents

Structure of Solids:

Crystal Lattice, Basis & Translation vectors, Unit cell & Wigner Seitz unit cell, Symmetry operations, Point groups & Space groups, Bravais lattice in 2D & 3D, Fundamental types of lattices, Lattice directions & Planes, Interplanar spacing, Density of atoms in crystal plane, Simple & Closed packed crystal structures, Structure of diamond, Zinc Blend (ZnS) & Sodium Chloride structures.

Defects in Crystals:

Crystal imperfections, Thermodynamics of Point defects, Schottky & Frenkel defects, Dislocations in Solids, edge dislocation, Screw dislocation Slip and plastic deformation, Stacking faults, color centers, and grain Boundaries, volumetric defects.

Atomic Bonding:

Interatomic forces & types of bonding, Ionic bonds, Binding energy in ionic crystals, Covalent bonds, Hydrogen bonds, Metallic bonds, Van der Waals bonds, Electronegativity

Crystal diffraction and reciprocal lattice:

Diffraction of X-rays, Neutrons and electrons from crystals, Bragg's law, Laue method, rotating crystal method, Powder methods, Reciprocal lattice, Reciprocal lattice to SC, BCC, FCC, Brillouin Zone, Miller Indices for directions & planes, Atomic packing factor.

Lattice Vibrations:

Vibration of One-Dimensional Monoatomic & Diatomic Lattices, Phonons, Momentum of Phonons, Vibrational modes of crystals, Optical modes in ionic crystals, Lattice heat capacity, Classical model, Einstein model, Density of state in one, two and three dimensions, Fermi energy, Debye model of heat capacity.

Recommended Books

1. C. Kittle, Introduction to Solid State Physics, 7th Ed. By, Kohn Wiley, 1996.
2. N. M. W. Ashcroft and N. D. Mermin, Solid State Physics, 1976.
3. Pillai S. O., 'Solid State Physics', 6th edition, New Age International Limited Publishers, 2006
4. Rohrer G. S., 'Structure and Bonding in Crystalline Materials', Cambridge University Press, 2001
5. M. A. Omar, Elementary Solid State Physics, Pearson Education 2000.
6. M. A. Wahab, Solid State Physics, Narosa Publishing House, 1999.
7. R. K. Puri, Solid State Physics, S. Chand & Co. Ltd, Ram Nagar, New Delhi-110055.
8. Smith, W.F., 'Principles of Materials Science and Engineering', McGraw Hill, 1996
9. Shackelford, J.F., 'Introduction to Materials Science for Engineers', Maxwell Macmillan Publishing Co., 1992

PHY-602 Nuclear Physics

Pre-Requisites: **Modern Physics**
Credit Hours: **Three (3)**

Objective(s)

To understand the nuclear structure using different nuclear models. To understand the nature of nuclear forces. To give understanding of radioactivity and nuclear reactions.

Course Contents

History: Starting from Bacqurel's discovery of radioactivity to Chedwick's neutron.
Basic Properties of Nucleus: Nuclear size, mass, binding energy, nuclear spin, magnetic dipole and electric quadrupole moment, parity and statistics.
Nuclear Forces: Yukawa's theory of nuclear forces. Nucleon scattering, charge independence and spin dependence of nuclear force, isotopic spin.
Nuclear Models: Liquid drop model, Fermi gas model, Shell model, Collective model.
Theories of Radioactive Decay: Theory of Alpha decay and explanation of observed phenomena, measurement of Beta ray energies, the magnetic lens spectrometer, Fermi theory of Beta decay, Neutrino hypothesis, theory of Gamma decay, multipolarity of Gamma rays, Nuclear isomerism.
Nuclear Reactions: Conservation laws of nuclear reactions, Q-value and threshold energy of nuclear reaction, energy level and level width, cross sections for nuclear reactions, compound nucleolus theory of nuclear reaction and its limitations, direct reaction, resonance reactions, Breit-Wigner one level formula including the effect of angular momentum.

Recommended Books

1. E. Segre, "Nuclei and Particles", Bejamin-Cummings, 2nd ed. 1977.
2. Kaplan, "Nuclear Physics", Addison-Wisely, 1980.
3. Green, "Nuclear Physics", McGraw-Hill, 1995.
4. K. S. Krane, "Introducing Nuclear Physics", John Wiley, 3rd ed. 1988.
5. B. Povh, K. Rith, C. Scholtz, F. Zetsche, "Particle and Nuclei", 1999.

PHY-602L LAB-VI (Nuclear Physics)

Credit Hours: **Two (2)**

- Characteristic of G.M Counter
- To find Half value Thickness of Al and Fe
- Determination of mass absorption Co-efficient
- Half value Thickness of Lead
- Inverse square's law
- To find operating voltage
- Determination of linear absorption Co-efficient
- Verification of absorption law of Gamma radiation
- Verification of absorption law of Alpha-radiation
- Verification of absorption law of Beta radiation
- Pulse height analysis of Gamma radiation sources (using scintillation detector)

PHY-603 Solid State Physics-II

Pre-requisites: **Solid State Physics I**
Credit Hours: **Three (3)**

Course Contents

Free Electron Theory of Solid:
Drude-Lorentz theory of free electron model, Electrical conductivity, resistivity, Thermal conductivity, Specific conductivity, Wiedmann-Franz law, Hall Effect, The Sommerfeld theory of electrons, Energy levels of electron in 1D & 3D potential box, Ground-state energy of electron gas.

Band Theory of Solids:
General theory of electrons in a periodic potential, Bloch theorem, Kronig-Penney model, Nearly Free electron approximation, and tight binding approximation.

Dielectrics and Ferroelectrics:
Maxwell Equations, Dipole moment, Polarization, Dielectric Polarizability & Susceptibility, Clausius-Mossotti Relation, Mechanisms of Dielectric Polarization, Electronic, ionic and Orientational polarization, Ferroelectrics & Phase Transitions, Ferroelectric crystals & its Classification, Thermodynamic theory of Ferroelectric transition, Ferroelectric Domains, Piezoelectricity.

Diamagnetism and Paramagnetism:
Atomic theory of magnetism, The quantum numbers, Orbital and spin magnetic moments of electrons, Classification of magnetic materials, Dia-, Para- & Ferromagnetism, Langevin's theory of Dia- and Para-magnetism, Ferromagnetism, Domain & Weiss theory of Ferromagnetism, Antiferromagnetism & Ferrimagnetism.

Semiconductors:
Semiconductors, Theory of semiconductors, Extrinsic semiconductors, Mobility of current carriers, Minority carriers, Life time, Surfaces, Contacts Semiconductor devices; Theory of p.n. junctions, tunneling, p-n junction devices and their circuit models.

Recommended Books

1. C. Kittle, Introduction to Solid State Physics, 7th Ed. By, Kohn Wiley, 1996.
2. N. M. W. Ashcroft and N. D. Mermin, Solid State Physics, 1976.
3. Pillai S. O., 'Solid State Physics', 6th edition, New Age International Limited Publishers, 2006
4. Rohrer G. S., 'Structure and Bonding in Crystalline Materials', Cambridge University Press, 2001
5. M. A. Omar, Elementary Solid State Physics, Pearson Education 2000.
6. M. A. Wahab, Solid State Physics, Narosa Publishing House, 1999.
7. R. K. Puri, Solid State Physics, S. Chand & Co. Ltd, Ram Nagar, New Delhi-110055.
8. Smith, W.F., 'Principles of Materials Science and Engineering', McGraw Hill, 1996
9. Shackelford, J.F., 'Introduction to Materials Science for Engineers', Maxwell Macmillan Publishing Co., 1992

PHY-651 Computational Physics

Credit Hours: Three (3)

Objective(s)

To introduce the basics of computational physics and enable students to solve physical problems computationally.

Course Contents

Programming in Python: Values and Data Types, Operators and Operands, Function Calls, Data Types, Type conversion functions, Variables, Variable Names and Keywords, Choosing the Right Variable Name, Statements and Expressions, Order of Operations, Reassignment, Updating Variables, Hard Coding, Input

Turtle Graphics: Turtle Program, Little Turtles, Instances: A Herd of Turtles, Object Oriented Concepts, Repetition with a For Loop, A Few More Turtle Methods and Observations, Summary of Turtle Methods, Modules, The random module

Errors: Syntax errors, Runtime Errors, Semantic Errors, Know the Error Messages, Incremental Programming, Common Turtle Errors

List and Strings: Sequences, Strings and Lists, Index Operator, Disambiguating: Creation Vs Indexing, Length, The Slice Operator, Concatenation and Repetition, Count and Index, Splitting and Joining Strings

Iteration: Introduction to Iteration, The *for* Loop, Flow of Execution of the *for* Loop, Strings and *for* loops, Lists and *for* loops, The Accumulator Pattern, Traversal and the *for* loop (By Index), Naming Variables in *for* Loops, Printing Intermediate Results, Keeping Track of the Iterator Variable and Iterable

Boolean Expressions: Turtles and Conditionals, Boolean Values and Boolean Expressions, Logical operators, The *in* and *not in* operators, Precedence of Operators

Conditional Execution: Conditional Execution (Binary Selection), Omitting the *else* Clause (Unary Selection), Nested conditionals, Chained conditionals, Setting Up Conditionals, The Accumulator Pattern with Conditionals

Sequence Mutation: Transforming Sequences, Mutability, List Element Deletion, Objects and References, Aliasing, Cloning Lists

Methods on Strings and Lists: Mutating Methods, Append versus Concatenate, Non-mutating Methods on Strings

Accumulating Lists and Strings: The Accumulator Pattern with Lists, The Accumulator Pattern with Strings, Accumulator Pattern Strategies

Recommended Book(s)

1. Python: The Fundamentals of Python Programming, by Paul Jones
2. Python Crash Course: A hands Project-based Introduction to Programming, by Eric Matthes
3. How to Think Like a Computer Scientist: Learning with Python, by Allen Downey, Jeffrey Elkner, Chris Meyers

PHY-652 Environmental Physics

Credit Hours: Three (3)

Objective(s)

To become familiar with the essentials of environment and Global climate. To learn to use spectroscopy for environments.

Course Contents

Introduction to the Essentials of Environmental Physics: The economic system, living in green house, enjoying the sun, Transport of matter, Energy and momentum, the social and political context.
Basic Environmental Spectroscopy: Black body radiation, The emission spectrum of sun, The transition electric dipole moment, The Einstein Coefficients, Lambert – Beer's law, The spectroscopy of bi-molecules, Solar UV and life, The ozone filter.
The Global Climate: The energy Balance, (Zero-dimensional Greenhouse Model), elements of weather and climate, climate variations and modeling.
Transport of Pollutants: Diffusion, flow in reverse, ground water. Flow equations of fluid Dynamics, Turbulence, Turbulence Diffusion, Gaussian plumes in air, Turbulent jets and planes.
Noise: Basic Acoustics, Human Perceptions and noise criteria, reducing the transmission of sound, active control of sound.
Radiation: General laws of Radiation, Natural radiation, interaction of electromagnetic radiation and plants, utilization of photo synthetically active radiation.
Atmosphere and Climate: Structure of the atmosphere, vertical profiles in the lower layers of the atmosphere, Lateral movement in the atmosphere, Atmospheric Circulation, cloud and Precipitation, The atmospheric greenhouse effect.
Topo Climates and Micro Climates: Effects of surface elements in flat and widely unduling areas, Dynamic action of seliq. Thermal action of selief.
Climatology and Measurements of Climate Factor: Data collection and organization, statistical analysis of climatic data, climatic indices, General characteristics of measuring equipment. Measurement of temperature, air humidity, surface wind velocity, Radiation balance, precipitation, Atmospheric Pressure, automatic weather stations.

Recommended Books

1. E.t Booker and R. Van Grondelle, "Environmental Physics", John Wiley, 3rd ed. 2011.
2. G. Guyot, "Physics of Environment and Climate", John Wiley, 1998.

PHY-653 Laser Physics

Pre-requisite: **Quantum Mechanics-II, Atomic and Molecular Physics**

Credit Hours: **Three (3)**

Objective(s)

Develop fundamental concepts about lasers. Learn the principles of spectroscopy of molecules and semi-conductors6. Understand the optical resonators and laser system. Applications of lasers.

Introductory Concepts: Interference, diffraction nd polarization, Spontaneous Emission, Absorption, Stimulated Emission, Pumping Schemes, Absorption and Stimulated Emission Rates, Absorption and Gain Coefficients, Properties of Laser Beam: Monochromaticity, Coherence, Directionality, Brightness, beam divergence,

Spectroscopy of Molecule and Semiconductors: Electronic Energy Levels, Molecular Energy Levels, Level Occupation at Thermal Equilibrium, Stimulated Transition, Boltzmann's statistics

Optical Resonators: Plane Parallel (Fabry-Perot) Resonator, Concentric (Spherical) Resonator, Confocal, Resonator, Generalized Spherical Resonator, Stable Resonators, Unstable Resonators, Wave Reflection and Transmission at a Dielectric Interface, Stability Condition Standing and Traveling Waves in a two Mirror Resonator, Longitudinal and Transverse Modes in a Cavity, Multilayer Dielectric Coatings, Fabry-Perot Interferometer. Small Signal Gain and Loop Gain

Pumping Processes: Optical pumping: Flash lamp and Laser, Threshold Pump Power, pumping efficiency, Electrical Pumping: Longitudinal Configuration and Transverse Configuration, Gas Dynamics Pumping, Chemical Pumping.

Continuous Wave (CW) and Pulsed Lasers: Rate Equations, Threshold Condition and Output Power, Optimum Output Coupling, Laser Tuning, Oscillation and Pulsations in Lasers, Q-Switching and Mode-Locking Methods, Phase Velocity, Group Velocity, and Group-Delay Dispersion, Line broadening.

Lasers Systems: Solid State Lasers: Ruby Laser, Nd: YAG & Nd: Glass Lasers

Laser Applications: Material Processing: Surface Hardening, Cutting, Drilling, Welding etc. Holography, Laser Communication, Medicine, Defense Industry, Atmospheric Physics.

Recommended Books

1. W. T. Silfvast, "Laser Fundamentals", Cambridge University Press, 2nd ed. 2008.
2. O. Svelto, "Principles of Lasers", Springer, 5th ed. 2009.
3. J. Eberly and P. Milonni, "Lasers Physics", John Wiley, 2nd ed. 2010.
4. Laser systems and applications by Richa Verma,
5. Lasers and optoelectronics fundamentals, devices and applications by Anil Kumar Maini

PHY-654 Concepts of Nanophysics and Nanotechnology

Pre-requisite: **Solid State Physics, Quantum Mechanics**
Credit Hours: **Three (3)**

Objective(s)

This course provides the basic concepts of physics at the nanoscale and its application towards nanotechnology. After successful completion of the course students will acquire the knowledge about:

- To discuss various physical properties observed between nanoscale and macroscale materials.
- To discuss quantum phenomena observed at the nanoscale.
- To explain why nanotechnology is an enabling technology.
- To discuss about the fabrication methods involved in the formation of nanomaterials.
- To describe basic concepts of the quantum effects important for nano-electronical devices.

Course Contents

Introduction to Nanophysics and Nanotechnology:
What is nanophysics and nanotechnology, scaling laws and limits to smallness, Feynman talks on small structures, Nano scale dimension, why is this length scale so important? Evolution of Nanotechnology, Important ways in which nanoscale materials differs from macroscale materials

Quantum Nature of the Nano World:
Wave particle duality, Energy quanta, Uncertainty principle, De Broglie relation, Bohr model of the nuclear atom, Schrodinger's equation, Quantum tunneling, Quantum confinement, Classification of nanomaterials, The trapped particles in one, two and three dimensions, Quantum transport in nanostructures: Ballistic electron transport, quantized conductance, coulomb blockade, single electron transistor

Fabricating Nano Structures:
Top-down and Bottom-up approaches, Lithography (photo and electron beam), Physical and Chemical Methods for Producing Nano-Objects: Mechanical, vapor deposition, co-precipitation, sol-gel, hydrothermal, microemulsion and electrospinning methods

Nanoscale Objects:
Nanotubes and the crystalline forms of carbon, Graphene: Structure, production, physical and electronic properties of graphene, Fullerenes and carbon nanotubes: Structure, production, and physical and electronic properties of fullerenes and carbon nanotubes, Plasmonic Quantum dots: Production, physical and optical properties of gold and silver nanoparticles

Nanotechnology the Road Ahead:
Nanostructure innovation, Quantum Informatics, Energy solutions

Recommended Books

1. "Nanophysics & Nanotechnology: An introduction to modern concepts in nanoscience", Edward L. Wolf, WILLEY-VCH Verlag GmbH and Co, 2004.
2. "Introduction to Nanoscience", S. Lindsay, Oxford University Press, 2009.
3. "Introduction to Nanoscience and Nanotechnology", C. Binns, Willey, 2010.
4. "Introduction to nanotechnology", Ch. Poole Jr., F. J. Owens, John Wiley & Sons E, 2003.

PHY-655 Particle Physics

Pre-requisites: **Quantum Mechanics-II, Nuclear Physics**
Credit Hours: **Three (3)**

Course Contents

Introduction to Elementary Particles: Fundamental building blocks and their interactions. Quantum Electrodynamics. Quantum Chromodynamics. Weak interactions. Decays and conservation laws.
Relativistic Kinematics: Lorentz transformations. Four-Vectors. Energy and momentum. Particle collisions. Mandelstam variables.
Symmetries: Symmetries and conservation laws, Spin and orbital angular momentum. Flavour symmetries. Parity. Charge conjugation. CP Violation. Time reversal and TCP Theorem.
Quantum Electrodynamics: Klein-Gordon equation. Dirac equation. Solution of Dirac equation. Bilinear covariants. Feynman rules for QED. Casimir's trick. Cross sections & lifetimes.
Neutrino Oscillations: Solar neutrino problem. Oscillations, Neutrino masses. PMNS mixing matrix.
Gauge Field Theories: Lagrangian in Relativistic Field Theory. Gauge Invariance. Yang-Mills Theory. The mass terms. Spontaneous symmetry breaking. Higgs mechanism. Higgs boson. Grand Unification. Supersymmetry. Extra dimensions. String theory. Dark energy. Dark Matter.

Recommended Books

1. D. Griffiths, "Introduction to Elementary Particles", Wiley-VCH, 2nd ed. 2008.
2. F. Halzen and A.D. Martin, "Quarks and Leptons: An introductory course in modern Particle Physics", John Wiley, 1984.
3. D. H. Perkins, "Introduction to High-Energy Physics", Cambridge University Press, 4th ed. 2000.
4. V. D. Barger and R. J. N. Phillips, "Collider Physics", Addison-Wesley, 1996.

PHY-656 Materials Characterization Techniques

Credit Hours: Three (3)

Objectives

This course provides a detailed account of some common experimental techniques in physics research. It introduces the basic working principles, the operational knowhow, and the strength and limitations of the techniques.

Contents

Optical Microscopy

Reflected light microscopy, using transmission mode, polarized light microscopy, using optical microscope, resolution and imaging, sample preparation for metals, ceramics and polymers.

Electron Microscopy

SEM gun construction, magnetic lenses, electron detectors, SEM imaging parameters, high resolution microscopy, electron gun parameters, imaging parameters, basic sample preparation**,** energy dispersive spectroscopy

Electro-optics of the TEM (lenses, lens aberrations), Image formation and imaging modes in TEM, Diffraction theory and Diffraction patterns, Dark and bright field imaging, Image interpretation, High resolution microscopy and Lattice imaging, TEM Sample preparation

Scanning Probe Microscopy

Introduction to scanning probe microscopy, Tip surface interaction, modes of operation, the scanner, tip and cantilever, feedback, artefacts from scanner, tip and others. Scanning Tunneling microscopy.

X-ray Diffraction Techniques

X-rays, production and measurements of x-rays, Bragg's law, Single crystal diffraction, determining lattice parameters accurately, relationship between crystalline structure and x-ray data, powder diffraction, phase identification, textured samples.

Raman Spectroscopy

Basic theory and principles of Raman spectroscopy, absorption and scattering, Ryleigh scattering, stokes and anti-stokes, lattice modes, number and symmetry of vibrations, some basic examples of interpreting Raman data.

Fourier Transform Infrared Spectroscopy

Basic theory and concepts of FTIR and its applications.

Recommended Books

1. R Haynes, *Optical microscopy of materials*, Kluwer Academic Publishers, 1984
2. Ludwig Reimer, *Scanning Electron Microscopy*, Physics of Image Formation and Microanalysis, Springer-Verlag Berlin Heidelberg, 1998
3. Meyer, Hug and Bennewitz, *Scanning Probe Microscopy: The Lab on a Tip*, Springer, 2003
4. Williams and Carter, *Transmission Electron Microscopy* Kluwer/Plenum Press, 1996 to 2004
5. B. D. Cullity and S. R. Stock, *Elements of X-ray Diffraction*, 3rd edition, Prentice Hall, 2001
6. Ewen Smith, Geoffrey Dent, Modern Raman Spectroscopy – A Practical Approach, John Wiley & Sons Ltd, 2005.

PHY-657 Introduction to Materials Science

Credit Hours: Three (3)

Objective(s)

To understand the important aspects of materials. Moving towards microstructures.

Course Contents

Introduction:
Classification of Materials; Metals; Ceramics; Polymers; Composites; Semiconductors; Biomaterials; Smart and Nanomaterials; Properties and Uses of these Materials.
Diffusion:
Diffusion Mechanisms, Factors That Influence Diffusion, Other Diffusion Paths
Microstructure and Phase Diagram:
Microstructure and microscopy, pressure vs. temperature phase diagrams, temperature vs. composition phase diagrams, equilibrium, thermodynamic functions, variation of Gibbs energy with temperature and composition, general features of equilibrium phase diagrams, solidification, diffusion mechanisms, nucleation of a new phase, phase diagrams of Fe-C system and other important alloys, materials fabrication.
Mechanical Behavior of Materials:
Normal stress and normal strain, shear stress and shear strain, elastic deformation, plastic deformation, Young's modulus, shear modulus, Poisson's ratio, elastic strain energy, thermal expansion, estimate of the yield stress, dislocations and motion of dislocations, slip systems, dislocations and strengthening mechanisms, fracture mechanics, ductile fracture, brittle fracture, Griffith criterion, ductile fracture, toughness of engineering materials, the ductile-brittle transition temperature, cyclic stresses and fatigue, creep.
Corrosion and Degradation of Materials:
Electrochemical Considerations, Corrosion Rates, Prediction of Corrosion Rates, Passivity, Environmental Effects, Forms of Corrosion, Corrosion Environments, Corrosion Prevention, Oxidation, Swelling and Dissolution, Bond Rupture, Weathering.
Applications and Processing of Metal Alloys:
Types of metal alloys, Ferrous and Non-Ferrous Alloys, Refractory Metals, Super Alloys

Recommended Books

1. W. D. Callister, "Materials Science and Engineering: An Introduction", Wiley, 7th ed. 2006.
2. W. D. Callister and D. G. Rethwisch "Fundamentals of Materials Science and Engineering: An Integrated Approach", Wiley, 4th ed. 2012.

PHY-658 Plasma Physics

Pre-requisite: **Electromagnetic Theory-II, Waves and Oscillations**
Credit Hours: **Three (3)**

Objective(s)

To learn about the importance of the plasma along with the basic concept of plasma. To know fluid description of the plasma.

Course Contents

Introduction: Plasma - An Ionized Gas, Plasmas are Quasi-Neutral
Plasma Shielding: Elementary Derivation of the Boltzmann Distribution, Plasma Density in Electrostatic Potential, Debye Shielding, Plasma-Solid Boundaries (Elementary), The 'Plasma Parameter, Occurrence of Plasmas, Different Descriptions of Plasma, Equations of Plasma Physics
Motion of Charged Particles in Fields: Different conditions of B and E, Drift Due to Gravity or Other Forces, Curvature Drift, Vacuum Fields, Toroidal Confinement of Single Particles, Force on an Elementary Magnetic Moment Circuit, Mirror Trapping, Pitch Angle, Polarization Drift, Finite Larmor Radius
Collisions in Plasmas: Binary Collisions between Charged Particles, Frames of Reference, Scattering Angle, Differential Cross-Section for Scattering by Angle, Relaxation Processes, Energy Loss, Cut-offs Estimates, Momentum Loss, 'Random Walk' in Angle, Thermal Distribution Collisions, Applications of Collision Analysis, Energetic ('Runaway') Electrons, Plasma Resistivity (DC), Diffusion, Energy Equilibration
Fluid Description of Plasma: Particle Conservation (In 2-d Space), Fluid Motion, Lagrangian & Eulerian Viewpoints, Momentum (Conservation) Equation, Pressure Force, Momentum Equation: Eulerian Viewpoint, Effect of Collisions, Two-fluid Equations, Two-fluid Equilibrium: Diamagnetic Current, Reduction of Fluid, Approach to the Single Fluid Equations, Heuristic Derivation/Explanation, Maxwell's Equations for MHD Use, MHD Equilibria, θ-pinch, Z-pinch, 'Stabilized Z-pinch', Some General Properties of MHD Equilibria, Pressure & Tension, Magnetic Surfaces, 'Current Surfaces', Low β equilibria: Force-Free Plasmas, Toroidal Equilibrium, Plasma Dynamics, Flux Conservation, Field Line Motion, General Principles Governing Instabilities
Electromagnetic Waves in Plasmas: General Treatment of Linear Waves in Anisotropic Medium, Simple Case. Isotropic Medium, General Case (k in z-direction), High Frequency Plasma Conductivity, Zero B-field Case, Cold Plasma Waves (Magnetized Plasma), Dispersion Relation, Hybrid Resonances; Perpendicular Propagation, Whistlers, Thermal Effects on Plasma Waves, Refractive Index Plot, Including the Ion Response, Electrostatic Approximation for (Plasma) Waves, Alfven Waves, Non-uniform Plasmas and Wave Propagation, Two Stream Instability, Kinetic Theory of Plasma Waves, Vlasov Equation, Linearized Wave Solution of Vlasov Equation, Landau's Original Approach (1946), Dispersion Relation, Direct Calculation of Collisionless Particle Heating, Physical Picture, Damping Mechanisms, Ion Acoustic Waves and Landau Damping, Alternative Expressions of Dielectric Tensor Elements, Electromagnetic Waves in Unmagnetized Vlasov Plasma, Experimental Verification of Landau Damping.

Recommended Books

1. Chen, F. F. Introduction to Plasma Physics. 2nd ed. Plenum Press, 1995. ISBN: 9780306307553.

2. Shohet, J. L. The Plasma State. Burlington, MA: Academic Press, 1971. ISBN: 9780126405507.
3. Hazeltine, R. D., and F. L. Waelbroeck. The Framework of Plasma Physics. NewYork, NY: HarperCollins Publishers, 1998. ISBN: 9780738200477.
4. Clemmow, P. C., and J. P. Dougherty. Electrodynamics of Particles and Plasmas. NewYork, NY: Perseus Books, 1989. ISBN: 9780201515008.
5. Krall, N. A., and A. W. Trivelpiece. Principles of Plasma Physics. New York, NY: McGraw-Hill, 1973. Reissued by San Francisco Press, 1986. ISBN: 9780911302585.
6. T. J. M. Boyd and J. J. Sanderson, “The Physics of Plasmas”, Cambridge University Press, 2003.

PHY-659 Special Theory of Relativity

Credit Hours: Three (3)

Contents

Relativity before Einstein: Inertial frames, Galilean relativity, Form invariance of Newton's Laws, Galilean transformation, Non-inertial frames, Galilean velocity addition, Getting wet in the rain

Electromagnetism, light and absolute motion: Particle and wave interpretations of light, Measurement of c, Maxwell's theory → electromagnetic waves, Maxwell waves ↔ light.

Search for the aether: Properties of the aether, Michelson-Morley experiment, Aether drag & stellar aberration

Precursors of Einstein: Lorentz and Poincar´e, Lorentz contraction, Lorentz invariance of electromagnetism

Principles of relativity: Postulates, Resolution of Michelson-Morley experiment, Need for a transformation of time.

Intertial systems, clock and meter sticks, reconsidered: Setting up a frame, Synchronization, Infinite family of inertial frames

Lorentz transformation: The need for a transformation between inertial frames, Derivation of the Lorentz transformation

Immediate consequences: Relativity of simultaneity, Spacetime, world lines, events, Lorentz transformation of events

Algebra of Lorentz transformations: β, γ, and the rapidity, η. Analogy to rotations
Inverse Lorentz Transformation

Length contraction: Proper length, Careful measurements of length → length contraction, Is length contraction real?

Time dilation: Proper time, Careful measurements of duration → time dilation, Is time dilation real? Examples, Time dilation as a measured phenomenon, Duality between length contraction and time dilation

Intervals, causality, etc.: Invariance of the interval under Lorentz transformation, Spacelike, time like, and light like intervals, Causality: The Future, the Past, and Elsewhere, Minkowski space and coordinate systems

The Doppler Effect: Frequencies, Longitudinal Doppler effect, Transverse Doppler effect, Doppler effect for arbitrary motion, Comparison with non-relativistic Doppler effect, Visual appearance of objects at relativistic velocities.

Acceleration in special relativity: The meaning of acceleration in the context of special relativity, Lorentz transformation of acceleration, Proper acceleration, "Hyperbolic" motion, Time in an accelerating frame

The twin paradox: The twin at rest, The twin in motion, The result and the experimental verification with accelerated particles, The confusion, The resolution

Constructing relativistic momentum and energy: Derivation from "physical construction", Rest mass, Reality of the rest energy, Examples of mass ⇔ energy, Relation between momentum, energy and rest mass: $E^2 - p^2 c^2 = {}_m2\ {}_c4$, Massless particles, Pressure of light

Relativistic decays and collisions: A → 2B in A rest frame, Photon emission and absorption, Doppler shift and Mossbauer effect, Compton scattering

Properties of objects under Lorentz transformation: Invariants and things that change, The instantaneous rest frames, The proper time as a Lorentz invariant, Four vectors, Definition through transformation properties, The four vectors as a vector in Minkowski space

Another four vector: the four velocity: The Lorentz transformation of energy and momentum, E and p form a four vector, Examples: boosting a particle at rest; boosting from the center of mass to the lab

The invariant scalar product: Invariance of the interval as a property of four vectors, $E^2 - p^2c^2 = m^2c^4$ again, Invariance of $p_a \cdot p_b$, Incompleteness of special relativity, Non-inertial reference frames

Recommended Books

1. Resnick, Robert. *Introduction to Special Relativity*. New York, NY: Wiley, 1968. ISBN: 9780471717256.
2. French, Anthony Philip. *Special Relativity*. New York, NY: Norton, 1968. ISBN: 9780393097931.
3. Einstein, Albert A. *Relativity: The Special and the General Theory*. New York, NY: Three Rivers Press/Random House, 1995. ISBN: 9780517884416

PHY-660 Introduction to Scintillation Materials

Credit Hours: Three (3)

Objectives

1. To understand the scintillation mechanism involved in scintillation materials.
2. To understand the interaction of radiation with scintillation materials
3. To know the requirement of scintillation materials in different applications.

Course Contents

Historical background of scintillators, Types of scintillators, Scintillator and Scintillations, Applications of scintillation materials, Growth of single crystal scintillators, Basic Principles and Processes, Physical mechanism of scintillation, Creation of electron hole pairs, Excitation and emission of luminescence centers, Intrinsic Luminescence of Inorganic Scintillators, Excitonic luminescence, Core to valance transition, Scintillation Materials, Halides, Oxides and Oxides systems, Interaction of Ionization radiation with scintillators i.e. High energy photons, Charged particles, Neutral particles, General characteristics of inorganic scintillators, derivation of light yield, Duration of scintillation pulse, Afterglow, Basic mechanism of defects formation and their effect on scintillation performance of a scintillator.

Recommended Books

1. Physical Process in Inorganic Scintillators, Piotr, A. Rodnyi, CRC Press, Boca Raton New York 1997.
2. Inorganic Scintillators for Detector Systems, Springer-Verlag Berlin Heidelberg 2006.
3. Inorganic Scintillators for Modern and Traditional Applications, M. Globus, B. Grinyov, J. K. Kim, Institute for single crystals Ukrain-Kharkiv, 2005.

PHY-661 Radiation Physics

Objectives

1. To learn basics of different radiations
2. To learn radiation interaction with matter

Course contents

Review of atomic physics, Review of nuclear physics, Types of radiation and their characteristics, Penetrating power of radiations, Range of different radiation in matter and factors affect the range, particle range relations, Bragg Peak and Proton Therapy, Natural and Man-made sources of radiations, Transition probabilities. Radioactivity and Radioactive Decay, Activity and Laws of Decay, Serial Radioactive Decay, Interaction of gamma-rays with Matter and photonuclear interactions, Interaction cross sections, Attenuation Gamma Rays, Electron capture, conversion electron, characteristic and bremsstrahlung x-rays, Auger electrons, Interaction of neutrons with matter- Elastic and inelastic scattering and cascade reactions, radiative capture, charged-particle emission. Interactions of charged particles with matter- Elastic, inelastic: excitation, ionization, and bremsstrahlung. Semi-classical derivation of Bethe's formula of stopping power. Radiation effects on matter.

Recommended Books

1. Radiation Detection and Measurements, 4^{th} Ed., Glen F Knoll, John Wiley & Sons.
2. Measurement & Detection of Radiation, 4^{th} Ed., Nicholas Tsoulfanidis Sheldon Landsberger, CRC Press, Taylor & Francis Group, 2015.
3. The Physics of Radiation Therapy, F. Khan, 3^{rd} Ed, Lippincott, Williams and Wilkins, Baltimore, MD, 2003.
4. Atoms, Radiation, and Radiation Protection, James E. Turner 3^{rd} Ed., Wiley-VCH Verlag GmbH & Co. KGaA, 2000

PHY-662 Physics of MRI

Objectives

- General objective of the course is to enhance students' skills use and understanding of the physics of Nuclear Magnetic Resonance.
- Specific objectives are as under
- Understanding of underlying principles in Magnetic Resonance Imaging
- Ability to apply the principles for analysis of MR images and contrast agents.

Course contents

A Preview, Nuclear Magnetization, and the Bloch Equation, The Quantum Mechanical Basis of Precession and Excitation, Thermal Equilibrium and Longitudinal Relaxation. Signal Detection Concepts, Introductory Signal Acquisition Methods, Free Induction Decay, Spin Echoes, Inversion Recovery and Spectroscopy. One Dimensional Fourier Imaging, k Space and Gradient Echoes, Multi-Dimensional Fourier Imaging and Slice Excitation. NMR Signal, T-1 and T-2 Quantification Methods in MR Imaging. Introduction to MRI Coils and Magnets. Contrast Agents.

Recommended Books

1. Magnetic Resonance Imaging: Physical Principles and Sequence Design, E. Mark, Robert W. Brown, Michael R. Thompson, Ramesh. V. Willy, 1999.
2. Handbook of MRI Pulse Sequences, 1st ed., Bernstein, K. F. King, X. J. Zhoa, Academic press, 2004
3. MRI : the Basics, Rah H. ashemi, William G. Bradley, ChristopherJ. Lisanti, 2nd edition. Lippincott Williams & Wilkins

PHY-663 Radiation Detection

Learning Outcomes

By the end of the course, the student must be able to explain interaction processes of ionizing radiation and matter, explain the type of radiation detectors and assess/evaluate the detection system and method required for a specific measurement.

Contents

Radiation Sources

- Units and Definitions
- Fast Electron Sources
- Heavy Charged Particle Sources
- Sources of Electromagnetic Radiation
- Neutron Sources

Radiation Interactions

- Interaction of Gamma Rays
- Interaction of Heavy Charged Particles
- Interaction of Fast Electrons
- Interaction of Neutrons

Gas filled Detectors

- Principle and operating characteristics of ionization chambers
- Proportional Counter
- Geiger Mueller Counter

Scintillation Detector Principles

- Scintillation mechanism in organic scintillators
- Scintillation mechanism in inorganic scintillators

Semiconductor Diode Detectors

- Semiconductor Properties
- The Action of Ionizing Radiation in Semiconductors
- Semiconductors as Radiation Detectors
- Different Types of Semiconductor Detectors

Recommended Books

1. Radiation Detection and Measurements, 4th Ed., Glen F Knoll, John Wiley & Sons.
2.Measurement & Detection of Radiation, 4th Ed., Nicholas Tsoulfanidis Sheldon Landsberger, CRC Press, Taylor & Francis Group, 2015.
3. Physics and Engineering of Radiation Detection, 2nd Ed. Syed Naeem Ahmed, Elsevier Amsterdam, Netherlands, 2015
4. Practical Gamma-ray Spectrometry, 2nd Edition, Gordon Gilmore, John Wiley & Sons, 2008.

PHY-664 Physics of Semiconductors

Course Objectives:

This course will help to acquire basic knowledge of semiconductors and related physics.

Course Contents:

Physics of semiconductors: Energy bands in solids; intrinsic and extrinsic semiconductors, doping and carriers; Transport phenomena in semiconductors (drift, mobility, conductivity and diffusion); non-equilibrium transport; Optical processes in semiconductors; Modem semiconductor structures; Junctions (Ohmic and Schottky).

Semiconductor Devices: PN-Diode (forward and reverse bias transport); Bipolar junction transistor (BJT); Field Effect Transistors (FETs); Optoelectronic devices; Light Emitting Diodes (LED); Laser Diodes (LD); Photodetectors; Solar cells; Electro-optic devices.

Recommended Books:

1. Solid State Electronic Devices by B. G. Streetman, (Prentice-Hall, 1995).
2. Semiconductor Devices–An Introduction by Jasprit Singh, (McGraw-Hill, Inc., 1994).
3. Physics of Semiconductor Devices by Michael Shur, (Prentice Hall, Inc., 1990).
4. Semiconductors and Electronic Devices by A. Bar-Lev, (Prentice Hall, 1985).
5. Physics of Semiconductor Devices by S. M. Sze, (John Wiley, 1981).
6. Physics and Technology of Semiconductor Devices by A. S. Grove, (John Wiley, 1967).
7. Physics of Semiconductors by J. L. Moll, McGraw-Hill, Inc., (1964).
8. Semiconductors by R. A. Smith, 2nd ed., (Cambridge University Press, 1979).
9. Semiconductor Device Fundamentals by R. F. Pierret, (Addison Wesley, 1996).

PHY-665 Luminescent Materials

Objective:

Fundamentals of luminescence, Characteristics of Luminescence, Theoretical model and mechanism of luminescence, Experimental techniques of luminescence measurements , Absorption and luminescence spectroscopy, Spectroscopic components, radiative and nonradiative processes, Energy Transfer, cross relaxation(CR), Photoluminescence, Classification of photoluminescence in solids, Band to band luminescence, Wannierexciton luminescence, Characteristics of localized center luminescence, Extrinsic luminescence of unlocalized type, Extrinsic luminescence of localized type, luminescence of rare earth/lanthanides(RE/Ln^{3+}) doped materials, Thermoluminescence, Thermoluminescence model, Thermoluminescence mechanism, Methods of analysis, Applications.

Recommended Books:

1. Luminescence Materials, G. Blasse, B. C. Grabmaier, Springer-Verlag, 1994.
2. Luminescence of Solids, D. R. Vij, Plenum Press New York, 1998.
3. Luminescence, From Theory to Applications, R. Ronda (WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2008.

PHY-666 Digital Electronics

Objective(s):

- To learn the basics of digital electronics such a as Boolean Algebra,
- To develop logic circuit using the Boolean Algebra,
- To understand the computer interface and micro-controller along with the embedded systems.

Contents

Review of Number Systems: Binary, Octal and Hexadecimal number system, their interconversion, concepts of logic, truth table, basic logic gates.

Boolean Algebra: De Morgan's theorem, simplification of Boolean expression by Boolean Postulates and theorem, K-maps and their uses. Don't care condition, Different codes. (BCD,

ASCII, Gray etc.). Parity in Codes

IC Logic Families: Basic characteristics of a logic family. (Fan in/out, Propagation delay time, dissipation, noise margins etc. Different logic-based IC families (DTL, RTL, ECL, TTL, CMOS) Combinational Logic Circuit: Logic circuits based on AND — OR, OR-AND, NAND, NOR Logic. gate design, addition, subtraction (2 's compliments, half adder, full adder, half subtractor, full subtractor encoder, decoder, PLA. Exclusive OR gate.

Sequential Logic Circuit: Flip-flops clocked RS-FF, D-FF, T-F F, JK-FF, Shift Register,

Counters (Ring, Ripple, up-down, Synchronous) A/D and D/A Converters

Memory Devices: ROM, PROM, EAPROM, EE PROM, RAM, (Static and dynamic) Memory mapping techniques

Recommended Books:

1. M. M. Mano, "Digital Logic and Computer Design", Prentice Hall, 1995.
2. R. Tokheim, "Digital Electronics", McGraw Hill, 7th ed. 2007.
3. B. B. Brey, "The Intel Microprocessors: Architecture, Programming and Interfacing", Merril, 2 nd ed. 1991.

PHY-666 Computational Physics II

Objective(s)

To enable students applying the computational methods to physical problems.

Course Contents

Files: Working with Data Files; Reading a File; Alternative File Reading Methods; Iterating over lines in a file; Finding a File in a Filesystem; Writing Text Files; Using *with* for Files; Recipe for Reading and Processing a File

CSV Output: CSV Format; Reading in data from a CSV File, Writing data to a CSV File, Tips on Handling Files

Dictionary Mechanics: Dictionaries, Getting Started with Dictionaries, Dictionary operations, Dictionary methods, Aliasing and Copying

Dictionary Accumulation: Accumulating Multiple Results in a Dictionary, Accumulating Results from a Dictionary, Accumulating the Best Key, When to Use a Dictionary

Function Basics: Introduction to Functions, Function Definition, Function Invocation, Function Parameters; Returning a Value from a Function; Decoding a Function; A function that accumulates

Local and Global Variables: Variables and parameters (local), Global Variables, Functions calling other Functions (Composition), Flow of Execution Summary; Print vs. Return; Passing Mutable Objects; Side Effects

Tuples: Tuple Packing; Tuples as Return Values; Tuple Assignment with Unpacking; Unpacking Tuples as Arguments to Function Calls

While Loop: The *while* Statement; The Listener Loop; Randomly Walking Turtles; Break and Continue, Infinite Loops

Advance Function: Optional Parameters; Keyword Parameters; Anonymous functions with lambda expressions; Programming with Style

Sorting Basics: Introduction: Sorting with Sort and Sorted; Optional Reverse parameter; Optional key Parameter

Sorting Dictionaries, Breaking Ties: Sorting a Dictionary; Breaking Ties: Second Sorting, Using a Lambda Expression

Packages for Solving the Physical Problems: NumPy, SciPy and Matplotlib, Learning Physics with Pylab, Data analysis with Pylab and SciPy, Numerical Integration (solving ordinary differential equations on the computer), Using and creating code packages

Recommended Book(s)

Python: The Fundamentals of Python Programming, by Paul Jones

Python Crash Course: A hands Project-based Introduction to Programming, by Eric Matthes

How to Think Like a Computer Scientist: Learning with Python, by Allen Downey, Jeffrey Elkner, Chris Meyers