SCHEME OF STUDY
BECHELOR OF SCIENCE (BS) /ASSOCIATE DEGREE PROGRAME (ADP) IN PHYSICS

(For the session in 2024 and onwards)

HOD,
Department of Physics,
University of Lakki Marwat

DEPARTMENT OF PHYSICS, UNIVERSITY OF LAKKI MARWAT, LAKKI MARWAT

LIST OF CONTENTS

Annexure-A

BS (4-Year) Program in Physics

Degree Awarded:	BS in Physics
Entrance Requirements:	HSSC (Pre-Engineering/Pre-Medical) or equivalent with at least 45% marks
Duration of the Program:	4 years (8 Semesters)
Semester duration:	16-18 weeks
Total Credit Hours:	**130-138**
Total Marks:	**5300**

In the course code number:

XYZ

X represents year of study,
, Y represents semester
Z represents appearance of the course.

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The BS Scheme of Studies: Main Structure

S. No.	Categories	Requirement of HEC 2023 Policy (Credit Hours)	Number of Courses	Credit Hours
1	General Education Cluster	30	12	30
2	Interdisciplinary/Allied Courses	12	04	12
4	Major Courses + Laboratories	72	28+7	90
5	Project+ Internship	06	02	06
Total		**120**	**46**	**138**

General Education Cluster		**Interdisciplinary / Allied Requirement**	
Title	**Cr. Hrs**	**Title**	**Cr. Hrs**
1. Functional English*	**3**	**1.** Calculus-I	**3**
2. Natural Science	**3**	**2.** Calculus-II	**3**
3. Introduction to Information and Communication Technology (ICT)*	**3**	**3**. Linear Algebra	**3**
4. Islamic Studies/ Ethics*	**2**	**4.** Ordinary Differential Equations	**3**
5. Art and Humanities	**2**		
5. Expository Writing*	**3**		
6. Quantitative Reasoning-I*	**3**		
7. Entrepreneurship*	**2**		
8. Civics and Community Engagement*	**2**		
9. Social Sciences	**2**		
10. Ideology and Constitution of Pakistan*	**2**		
11. Quantitative Reasoning-II*	**3**		
Total	**30**	**Total**	**15**

*HEC designed model courses may be used by the university

Major Courses		Capstone Project + Field Experience		Laboratories + Seminars	
Title	**Cr Hrs.**	**Title**	**Cr Hrs.**	**Title**	**Cr Hrs.**
1. Mechanics	**3**	**1.** Project	**3**	**1.** Laboratory I	**1**
2. Electricity and Magnetism	**3**	**2.** Internship (In Summer Break)	**3**	**2.** Laboratory II	**1**
3. Rotational Dynamics	**3**			**3.** Laboratory III	**I**
4. Introduction to Astronomy	**3**			**4.** Laboratory IV	**1**
5. Heat and Thermodynamics	**3**			**5.** Laboratory V	**1**
6. Waves and Oscillations	**3**			**6.** Laboratory VI	**1**
7. Modern Physics	**3**			**7.** Laboratory VII	**1**
8. Optics	**3**				
9. Fluid Dynamics	**2**				
10. Electronics-I	**3**				
11. Electronics-II	**3**				
12. Mathematical Methods for Physics-I	**3**				
13. Mathematical Methods for Physics-II	**3**				
14. Electrodynamics-I	**3**				
15. Electrodynamics-II	**3**				
16. Introductory Classical Mechanics	**3**				
17. Introductory Statistical Physics	**3**				
18. Nuclear Physics	**3**				
19. Quantum Mechanics-I	**3**				
20. Quantum Mechanics-II	**3**				
21. Computational Physics	**3**				
22. Solid State Physics-I	**3**				
23. Solid State Physics-II	**3**				
24. Atomic & Molecular Physics	**3**				
25. Elective I	**3**				
26. Elective II	**3**				
27. Elective III	**3**				
28. Elective IV	**3**				
Total	**83**		**06**		**07**

Art and Humanities		Natural Sciences		Social Sciences		Quantitative Reasoning	
Title	**Cr. Hrs.**	**Title**	**Cr. hrs**	**Title**	**Cr. hrs**	**Title**	**Cr. hrs**
Foreign Language	**2**	What is Science?	**3**	A Science of Society-I	**2**	Exploring Quantitative Skills	**3**
Urdu Advance	**2**	The Science of Global Challenges	**3**	A Science of Society-II	**2**	Tools for Quantitative Reasoning	**3**
History to English Literature	**2**	Principle of Animal life	**3**	Introduction to Economics	**2**		
Classical Drama	**2**	Diversity of Plants	**3**	Introduction to Psychology	**2**		
Classical Poetry	**2**	Introduction to Geography	**3**	Principles of Management	**2**		
Introduction to English Literature	**2**	Basic Health and Physical Science	**3**	Introduction to Political Science	**2**		
Introduction to Law	**2**	Everyday Science	**3**	Introduction to International Relations	**2**		
Pre-Islamic History	**2**	Environmental Science	**3**	History of ancient Civilization	**2**		
Islamic Jurisprudence	**2**	Geo-Physics	**3**	Civilizations	**2**		
		Physical Chemistry		Media and Mass Communication	**2**		
				Archeology Basics	**2**		
				Culture Tourism	**2**		

Foreign Language (Chinese, Korean, German, Arabic, Spanish, French, Persian)

Scheme of Study for BS Physics (4-Year) Program

The requirement for the BS degree in Physics is 138 credit hours of approved undergraduate courses. Out of these 138 credit hours, at least 90 credit hours must be from physics courses. Semester wise detail is given in the following tables.

Semester-I				
Codes	**Title of the Courses**	**Cr. Hrs.**	**Marks**	**Remarks**
	Functional English	3	100	Gen Ed-I (English-I)
	Everyday Science	3	100	Gen Ed-II
	Islamic Studies / Ethics	2	100	Gen Ed-III
	Calculus-I	3	100	Interdisciplinary / Allied Requirement
Phys-111	Mechanics	3	100	Major Course
Phys-112	Rotational Dynamics	3	100	Major Course
Phys-111L	Lab-I	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	
Semester-II				
Codes	**Title of the Courses**	**Cr Hrs.**	**Marks**	**Remarks**
	Expository Writing (English)	3	100	Gen Ed-IV (English-II)
	Exploring Quantitative Skills	3	100	Gen Ed-V
	Introduction to Law	2	100	Gen Ed-VI
	Calculus-II	3	100	Interdisciplinary / Allied Requirement
Phys-121	Electricity and Magnetism	3	100	Major Course
Phys-122	Waves and Oscillations	3	100	Major Course
Phys-122L	Lab-II	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	
Semester-III				
	Title	**Cr Hrs**	**Marks**	**Remarks**
	Introduction to Economics/Political Science	2	100	Gen Ed-VII
	Ideology and Constitution of Pakistan	2	100	Gen Ed-VIII
	Civics and Community Engagement	2	100	Gen Ed-IX
	Entrepreneurship	2	100	Gen Ed-X
	Linear Algebra	3	100	Interdisciplinary / Allied Requirement
Phys-231	Heat and Thermodynamics	3	100	Major Course
Phys-232	Modern Physics	3	100	Major Course
Phys-233L	Lab-III	1	100	Major Course
	Semester's Credit Hours	**18**	**800**	
Semester-IV				
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
	Tools for Quantitative Reasoning	3	100	Gen Ed-XI
	Introduction to Information and Communication Technology (ICT)	3	100	Gen Ed-XII
	Ordinary Differential Equations	3	100	Interdisciplinary / Allied Requirement
Phys-241	Optics	3	100	Major Course
Phys -242	Introduction to Astronomy	3	100	Major Course
Phys-243	Fluid Dynamics	2	100	Major Course
Phys-244L	Lab-IV	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	
Semester-V				
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
Phys-351	Mathematical Methods for Physics-I	3	100	Major course

Phys-352	Electrodynamics-I	3	100	Major course
Phys-353	Electronics-I	3	100	Major course
Phys-354	Classical Mechanics	3	100	Major course
Phys-355	Statistical Physics	3	100	Major course
Phys-355L	Lab-V	1	100	Major course
	Semester's Credit Hours	**16**	**600**	
		Semester-VI		
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
Phys-361	Mathematical Methods for Physics-II	3	100	Major course
Phys-362	Electrodynamics-II	3	100	Major course
Phys-363	Electronics-II	3	100	Major course
Phys-364	Quantum Mechanics-I	3	100	Major course
Phys-365	Nuclear Physics	3	100	Major course
Phys-366L	Lab-VI	1	100	Major course
	Semester's Credit Hours	**16**	**600**	
		Semester-VII		
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
Phys-471	Quantum Mechanics-II	3	100	Major course
Phys-472	Solid State Physics-I	3	100	Major course
Phys-473	Atomic and Molecular Physics	3	100	Major course
Phys-474	Computational Physics	3	100	Major course
	Elective-I / Minor	3	100	Major course / Optional
Phys-477L	Lab-VII	1	100	Major Course
	Semester's Credit Hours	**16**	**600**	
		Semester-VIII		
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
Phys-481	Solid State Physics-II	3	100	Major course
	Elective-II / Minor	3	100	Major course / Optional
	Elective-III / Minor	3	100	Major course / Optional
	Elective-IV / Minor	3	100	Major course / Optional
Phys-482	Project	3	100	Project
	Semester's Credit Hours	**15**	**500**	
Phys-475	Internship	3	100	Field Experience (In summer break)
Total Credit Hours		**138**		

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ELECTIVE COURSES

S. No	Course Code	Course Name	Credit hours
1.	Phys 401	Plasma Physics	03
2.	Phys 402	Surface Physics	03
3.	Phys 403	Fluid Dynamics	03
4.	Phys 404	Methods of Experimental Physics	03
5.	Phys 405	Environmental Physics	03
6.	Phys 406	Quantum Information Theory	03
7.	Phys 407	Introduction to Quantum Computing	03
8.	Phys 408	Quantum Field theory	03
9.	Phys 409	Particle Physics	03
10.	Phys 410	Analogue Electronics	03
11.	Phys 411	Experimental Techniques in Particle and Nuclear Physics	03
12.	Phys 412	LASER	03
13.	Phys 413	Renewable Sources of Energy	03
14.	Phys 414	Fundamentals of Optoelectronics	03
15.	Phys 415	Laser Engineering	03
16.	Phys 416	Introduction to Photonics	03
17.	Phys 417	Introduction to Nanosciences and Nanotechnology	03
18.	Phys 418	Quantum Optics	03
19.	Phys 419	Research Methodology	03
20.	Phys 421	Advanced Experimental Techniques	03
21.	Phys 424	Biophysics	03
22.	Phys 425	Materials For Green Energy	03
23.	Phys 426	Introduction to Material Science	03
24.	Phys 427	Density Functional Theory	03
25.	Phys 428	Simulation and Computational Physics	03

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BS PHYSICS FOUNDATION COURSES

Note: Other than Physics Courses are provided in Appendix I.

Phys-111 **MECHANICS** **Credit Hours: 03**

Objectives: To understand the different motions of objects on a macroscopic scale and to develop simple mathematical formalisms to analyze such motions.

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:

1. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8^{th} ed. 2010.
2. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13^{th} International ed. 2010.

Phys-111L **LAB-I (Mechanics)** **Credit Hours: 01**

Pre-requisites: Mechanics

Objective(s): To understand the experimentally Mechanics

Course outline: 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.

Phys-112 **ROTATIONAL DYNAMICS** **Credit Hours: 03**

Pre-requisites: Mechanics

Objective(s): To understand the fundamentals of rotational motion

Contents: Vector Product of Two Vectors, Centre of Mass, Motion of Centre of Mass, Moment of Inertia, Theorems of Parallel and Perpendicular Axis, Rolling Motion, Angular Velocity and Angular Acceleration, Linear Momentum of System of Particles, Torque and Angular Momentum, Equilibrium of a Rigid Body, Angular Momentum in Case of Rotation About a Fixed Axis, Dynamics of Rotational Motion About a Fixed Axis, Kinematics of

Rotation Motion about a Fixed Axis, Rotational kinematic vectors, Moment of Inertia, Equilibrium and Elasticity.

Recommended Books:

1. J. Pain, “The Physics of Vibrations and Waves”, John Wiley, 6th ed. 2005.
2. P. French, “Vibrations and Waves”, CBS Publishers (2003).

Phys-122L ELECTRICITY AND MAGNETISM Credit Hours: 03

Pre-requisite: Mechanics, Calculus I

Objectives: To understand the Physics of Electromagnetism and to develop simple mathematical formalisms to analyze the electromagnetic fields and interactions.

Contents: Electric charge (properties/quantization/conservation), Coulombs law in free space, Electric field due to discrete/continuous charges distributions, Electric dipole, Electric flux, Gauss’s law and its applications, Electric potential due to discrete/continuous charges distributions, Work and Electric potential energy, Capacitors and capacitance, Capacitance for various geometries, Capacitance with Dielectrics, Electric Current, current density, Resistance and resistivity, Microscopic and macroscopic forms of Ohm’s Law, Energy transfer in electric circuit, Power in electric circuits, Calculating current in a single loop and multiple loop by using Kirchhoff laws, Circuit analysis, Growth and decay of current in RC-circuits and its analytical treatment. Magnetic field, Magnetic forces on a single point charge/current carrying conductor, Torque on a current carrying loop and magnetic dipole, Biot & Savart Law and its analytical treatment and application, Ampere’s law and its applications, Electromagnetic induction and its laws, Inductance, Inductance for various configurations, LR circuits, Growth and decay of current in RL circuits, Electromagnetic Oscillation (Qualitative and Quantitative analysis using differential equations), Forced electromagnetic oscillations and resonance, Alternating current circuits, Single loop RLC circuits (series and parallel), Power in AC circuits and phase angles, Maxwell's equations (integral/differential forms), Electromagnetic waves, Poynting vector, Magnetic properties of materials.

Recommended Books:

1. D. Halliday, R. Resnick and J. Walker, “Fundamentals of Physics”, John Wiley & Sons, 11th 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.

Phys-122L **LAB-II (Electricity and Magnetism)** **Credit Hrs: 01**

Pre-requisites: Electricity and Magnetism

Objective(s): To understand the fundamentals of Electricity and Magnetism

Course outline:

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.

Phys-122 **WAVES AND OSCILLATIONS** **Credit Hours: 03**

Pre-requisites: Mechanics, Calculus II

Objective(s): To understand the fundamentals of oscillations and waves

Contents: Harmonic Oscillator Equation, Complex Number Notation, Simple Pendulum, Transverse Waves: Transverse Standing Waves, Normal Modes, General Time Evolution of a Uniform String, Phase velocity, Group Velocity. Longitudinal Waves: Spring Coupled Masses, Sound Waves in an Elastic Solid, Sound Waves in an Ideal Gas, Traveling Waves: Standing Waves in a Finite Continuous Medium, Traveling Waves in an Infinite Continuous Medium, Energy Conservation, Reflection and Transmission at Boundaries, Electromagnetic Waves, Wave Pulses: Multi-Dimensional Waves: Plane Waves, Three-Dimensional Wave Equation, Waveguides, Cylindrical Waves, Interference and Diffraction of Waves: Double-Slit Interference, Single-Slit Diffraction.

Recommended Books:

1. J. Pain, “The Physics of Vibrations and Waves”, John Wiley, 6^{th} ed. 2005.
2. P. French, “Vibrations and Waves”, CBS Publishers (2003).

Phys-231 **HEAT AND THERMODYNAMICS** **Credit Hours: 03**

Pre-requisites: Mechanics

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

Contents: Basic Concepts and Definitions in Thermodynamics, Properties and state of the substance, Extensive and Intensive properties, Equilibrium, Mechanical and Thermal Equilibrium, Processes and Cycles: Isothermal, Isobaric and Isochoric., Zeroth Law of Thermodynamics, Consequence of Zeroth law of, Thermodynamics. The state of the system at Equilibrium, Heat and Temperature: Temperature, Kinetic theory of ideal gas, Work done on an ideal gas, Internal energy of an ideal gas: Equipartition of Energy, Intermolecular forces, Qualitative discussion, The Virial expansion, The Van der Waals equation of state. Thermodynamics: First law of thermodynamics and its applications to adiabatic, isothermal, cyclic and free expansion. Reversible and irreversible processes, Second law of thermodynamics, Carnot theorem and Carnot engine. Heat engine, Refrigerators, Calculation of efficiency of heat engines, Thermodynamic temperature scale: Absolute zero, Entropy, Entropy in reversible process, Entropy in irreversible process, Entropy and Second law of thermodynamics, Entropy and Probability. Thermodynamic Functions: Thermodynamic functions (Internal energy, Enthalpy, Gibb's functions, Entropy, Helmholtz functions), Maxwell's relations, TdS equations, Energy equations and their applications. Low Temperature Physics, Joule-Thomson effect and its equations. Thermoelectricity: Thermocouple, Seabeck's effect, Peltier's effect, Thomson effect, Introduction to Statistical Mechanics: Statistical distribution and mean values, Mean free path and microscopic calculations of mean free path. Distribution of Molecular Speeds, Distribution of Energies, Maxwell distribution, Maxwell Boltzmann energy distribution, Internal energy of an ideal gas, Brownian Motion Legvaian equation, Qualitative description.

Recommended Books:

1. D. Halliday, R. Resnick and K. Krane, "Physics", John Wiley, 5^{th} ed. 2002.
2. M. W. Zemansky, "Heat and Thermodynamics", Mc Graw Hill, 7^{th} ed. 1997.

Phys-233L **LAB-III (Heat and Thermodynamics)** **Credit Hrs: 01**

Course outline:

Heat: Calorimetric, 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.

Phys-232	**MODERN PHYSICS**	**Credit Hours: 03**

Pre-requisites: Mechanics, Electricity and Magnetism.

Objective(s): To understand the non-classical aspects of Physics, the emphasis is on the applications of Quantum Physics in microscopic-scale Physics, atomic and molecular structure and processes.

Contents: Motivation for Non--Classical Physics: Quantum interference, black body radiation and ultraviolet catastrophe, Planck's quantization. Photoelectric effect, Compton effect, production and properties of X-rays, diffraction of X-rays, concept of matter waves, de Broglie relationship, electrons are waves, electron diffraction, particulate nature of matter, contributions of Faraday (atoms exist), Thomson (electron exists), Rutherford (nucleus exists) and Bohr (quantization of energies inside an atom), wave packets and wave groups, dispersion, Heisenberg uncertainty principle, direct confirmation of quantization through Franck-Hertz experiment and spectroscopy, working of electron microscopes. Quantum Mechanics in One Dimension: The concept of a wave function, time independent Schrodinger equation and interpretation of the equation, solving the Schrodinger equation for a free particle, for a particle inside an infinite box, relationship between confinement and quantization, working of a CCD camera. Concept of tunneling, reflection and transmission of wave functions from barriers, applications: radioactivity, scanning tunneling microscope, decay of black holes. The Hydrogen atom, orbitals, angular momentum and its quantization, orbital magnetism, Zeeman effect, concept of spin, Pauli’s exclusion principle, Building of the periodic table, magnetic resonance and MRI, why is iron magnetic? White dwarfs and neutron stars. From Atoms to Molecules and Solids: Ionic bonds, covalent bonds, hydrogen bonds, molecular orbitals, how crystals are different from amorphous solids? Why and how do metals conduct electricity? Bands in solids, semiconductors, introduction to ED's and lasers, in traducing graphene. Nuclear Structure: Size and structure of nucleus, nuclear forces, radioactivity and nuclear reactions, radiocarbon dating.

Recommended Books:

1. Concepts of Modern Physics, Sixth Edition by Arthur Beiser
2. D. Halliday, R. Resnick and J. Walker, “Fundamentals of Physics”, John Wiley & Sons, Latest ed. 2010.
3. R. A. Serway and J. W. Jewett, “Physics for Scientists and Engineers”, Golden Sunburst Series, 8th ed. 2010.
4. 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.

Phys-241 **OPTICS** **Credit Hours: 03**

Pre-Requisites: Waves and Oscillations

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

Contents: Huygens’ Principle, Fermat’s Principle, Laws of Reflection and Refraction, Refraction at a Spherical Surface, Thin Lenses, Newtonian Equation for a Thin Lens. Ray Transfer Matrices, Thick Lens, Significance of System Matrix Elements, Cardinal Points of an Optical System with examples, Optical Instruments including Simple Magnifiers, Telescopes and Microscopes, Chromatic and Monochromatic Aberrations, Spherical Aberrations, Coma, Distortion, Stops, Pupils, Windows. Superposition & Interference: Standing Waves, Beats, Phase and Group Velocities, Two-Beam and Multiple-Beam Interference, Thin Dielectric Films, Michelson and Fabry-Perot Interferometers, Resolving Power, Free-Spectral Range. Jones Matrices, Production of Polarized Light, Dichroism, Brewster’s Law, Birefringence, Double Refraction. Fraunhofer Diffraction: from a Single Slit, Rectangular and Circular Apertures, Double Slit, Many Slits, Diffraction Grating, Dispersion, Resolving Power Blazed Gratings. Fresnel Diffraction: Zone Plates, Rectangular Apertures, Cornu’s Spiral Coherence & Holography: Temporal Coherence, Spatial Coherence, Holography of a Point object and an Extended Object Laser Basics: Stimulated Emission, Population Inversion, Resonators, Threshold and Gain, Multi-layered Dielectric Films.

Recommended Books:

1. F. Pedrotti, L. S. Pedrotti and L. M. Pedrotti, “Introduction to Optics”, Pearson Prentice Hall, 3rd ed. 2007.
2. E. Hecht and A. Ganesan, “Optics”, Dorling Kindersley, 4th ed. 2008.
3. M. V. Klein and T. E. Furtak, “Optics”, John Wiley, 2nd ed. 1986.
4. K. K Sharam, “Optics: Principles and Applications”, Academic Press, 2006.
5. C. A. Bennett, “Principles of Physical Optics”, John Wiley, 2008.

PHYS-244L **LAB-IV (Modern Physics)** **Credit Hrs: 02**

Course outline:

- 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.

Phys-243 **FLUID DYNAMICS** **Credit Hours: 02**

Pre-Requisites: Mechanics

Objective (s): To be able to analyze the problems related to elementary Fluid Dynamics especially for incompressible flow.

Contents:

Introductory concept: Fluid mass and weight, viscosity, viscous drag, compressibility, vapor pressure, surface tension.

Fluid statics: Pressure, hydrostatics and aerostatics, forces on plane and curved surfaces, Manometer, Buoyancy and Archimedes principle.

Elementary Fluid Dynamics: Stream lines, Bernoulli's equation along the streamline and across the streamline, Application of Bernoulli's equation, Static, stagnation, total pressure, Pitot tube.

Fluid Kinematics: Velocity fluid, acceleration fluid, control volume, Material derivative, Reynolds transport theorem. Finite control volume analysis: Conservation of mass for control volume, Derivation and application of linear momentum equation, Derivation and application of energy equation, Differential form of continuity equation.

Recommended Books:

1. D. Halliday, R. Resnick and J. Walker, “Fundamentals of Physics”, John Wiley & Sons, Latest ed. 2010.
2. 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.

Phys -242 **INTRODUCTION TO ASTRONOMY** **Credit Hours: 03**

Pre-requisites: Mechanics

Objectives: To understand the basic concept of Modern Astronomy new perspective, that astronomy gives us on ourselves and our planet.

Contents: Our Place in the Universe, Discovering the Universe for Yourself, The Science of Astronomy, Making Sense of the Universe, Understanding Motion, Energy, and Gravity. The components of the universe (stars, planets and galaxies), the scale of the universe, a brief historical guide to the study of astronomy, the Cosmic Messenger, Formation of Planetary Systems, Earth and the Terrestrial Worlds, Earth as a Planet, the Moon and Mercury, Asteroids, Comets,and Dwarf Planets, Their Nature, Orbits, and Impacts, Our Star. The Sun's energy source. Nuclear fusion. Structure of the Sun. Solar activity. The Sun - Earth connection. Properties of stars. Spectroscopic classification. The Hertzsprung-Russell diagram. Types of stars. Evolution of low and high mass stars. Multiple stars. Star clusters. Milky Way Galaxy Size and structure of the Milky Way. The disk, bulge and halo. Orbits of stars. The galactic centre. Recycling of Material in the Galaxy The interstellar medium. Molecular clouds. Star formation. Planetary nebulae. White Dwarfs. Supernovae. Neutron stars and black holes.

Recommended Books:

1. J. Bennett, M. Donahue, N Schneider, M. Voit, "The essential cosmic perspective" 6th ed. 1998.
2. L. Jones, "Observation Exercises in Astronomy" 1st ed. 2011.
3. E. E. Prather; T. F. Slater; J. P. Adams, G. Brissenden, "Lecture Tutorials for Introductory.

Phys-351 MATHEMATICAL METHODS FOR PHYSICS-I Credit Hours: 03

Pre-requisite: Mechanics, Ordinary Differential Equations, Linear Algebra

Objective(s): **U**nderstanding of vector analysis and complex variables and their use in Physics

Contents: 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 Texts:

1. Mathematical Methods for Physicists, by Arfken & Weber, publisher:Academic Press; 7th Edition, (2012)
2. Mathematical Methods for Physics and Engineering, by K. F. Riley, M.P. Hobson, and S.
3. J. Bence, Cambridge University Press, 3rd Edition (2006)
4. Mathematical Method for Scientists and Engineers, by Donald A. McQuarrie, University Science Books, California (2003).

Phys-352 **ELECTRODYNAMICS-I** **Credit Hours: 03**

Pre-requisites: Electricity and Magnetism, Calculus-II

Objective(s): Understanding and use of Electrodynamics in Physics

Contents: Differential/integral calculus; Orthogonal coordinate systems (Cartesian/cylindrical/ spherical); Electrostatics in free space: Electrostatic force/field/potential/energy for discrete (a single point charge/a collection of point source charges) and continuous (line/surface/volume) charge distributions, Divergence/curl of E, Electrostatic boundary conditions (on E, V, and D), Conductors, Capacitors; Boundary value problems: Solutions of Laplace's equation for various symmetries (Cartesian/ cylindrical/spherical), Method of Images for various symmetries; Electric monopole/ dipole/quadrupole/octopole etc., Electric dipole moment for line/surface/volume charge; Electrostatics in matter: Polarization P, Bound surface/volume charge, Electric displacement D, Gauss's law for D & P−differential/integral forms and its uses/applications, Electric susceptibility/permittivity/relative permittivity; Electric line/surface/volume currents I/K/J, Equation of continuity.

Recommended Books:

1. D. J. Griffiths, "Introduction to Electrodynamics" Prentice Hall, 3rd ed. 1999.
2. M. N. O. Sadiku" Elements of Electromagnetics" Oxford University Press, 5th ed. 2009.
3. F. Melia, "Electrodynamics", University of Chicago Press, 2001.
4. Hearld J and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed.

2011.

Phys-353 **ELECTRONICS-I** **Credit Hours: 03**

Pre-requisites: No pre-requisite

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 transconductance g_m, performance of a CE amplifier, relation between A_i and A_v, 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", MacGraw Hill, Tch ed. 1997.
3. B. Streetman and S. Banerjee "Solid State Electronics Devices" Prentice Hall, 6th ed. 2005.
4. A. Bar-lev, "Semiconductor and Electronics Devices", Prentice Hall, 3rd ed. 1993.

Phys-354 **CLASSICAL MECHANICS** **Credit Hours: 03**

Pre-requisites: Mechanics

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, nonconservative 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, 5^{th} ed. 2004.

Phys-355 STATISTICAL PHYSICS Credit Hours: 03

Pre-requisites: Heat and Thermodynamics, Calculus-II, Probability and Statistics

Contents: Review of thermodynamics: Mathematical formulation of first and second law of thermodynamics, Maxwell's relation, Reduction of derivatives, General conditions of equilibrium. Partition Function: Partition Function, Relations of partition function with thermo dynamical variables, examples (collection of simple harmonic oscillators, Half spin paramagnet. Basic Principles of statistical Mechanics: Microscopic and macroscopic states, Phase Space, Ensemles, Liouvillie theorem, Formation of Micro canonical, Canonical and Grand canonical partition function. Maxwell distribution of molecular speed: Probability of the particle in quantum state, Density of states in k-space, single particle density of states in energy, Maxwell-Boltzman Distribution Function, Validity of Maxwell-Boltzman statistics, Evaluation of constants α and β, Maxwell Speed distribution function. Theory of ideal Fermi System: Fermi-Dirac Distribution Function, Examples of the Fermi system (free electron theory of metals, Electrons in stars, electrons in white dwarf stars). Theory of Bose System:

Bos-Einstein Distribution Function, Black body radiation, the photon gas, ideal bose gas model of liquid helium, Einstein's model of vibration in solids, Debye's model of vibration in solids.

Advanced Topics: Fluctuations, Bose-Einstein Condensation, Introduction to density matrix approach.

Recommended Books:

1. F. Mandl, Statistical Physics, ELBS/John Willey, 2nd Ed. 1988.
2. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, 1965.
3. A.J. Pointon, Introduction to Statistical Physics, Longman 1967.
4. C. Kittel, Elements of Statistical Physics, John Wiley 1958.

Phys-355L LAB-V (Waves and oscillation, sound) Credit Hrs: 01

Pre-requisites: Waves and Oscillation.

Objective(s): To understand different aspect of wave and oscillation, sound.

Course outline:

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, Lorentz pendulum, waves in water, beats, superposition's of harmonic motion (Lissajous patterns), sonometer.

Phys-361 MATHEMATICAL METHODS FOR PHYSICS-II Credit Hours: 03

Pre-requisite: Mathematical Methods of Physics-I

Objective(s): **U**nderstanding of Fourier series, Fourier transform, special functions, differential equation and their use in Physics

Contents: Fourier series: Fourier series and analysis, use and application to physical systems. orthogonality and orthonormality, complete sets of functions, Gibbs phenomenon, discrete and continuous Fourier transforms. The Gamma Function: Gamma function and its properties, Digamma and Polygamma functions, Stirling's series, The Beta function, Incomplete Gamma function. Legendre Functions: Legendre equation, Associated Legendre functions, Hermite equation and polynomials, Laguerre equation and associated polynomials, Bessel's equation and solutions, spherical Bessel functions. Hermit Function, Bessel Function. Differential Equations, First order differential equations, general solution by integration, uniqueness property. Second order differential equations with constant coefficients, Euler linear equations, Series Solution of Differential Equations: power series method, ordinary and singular points of differential equations, series solution by Frobenius' method, Wronskian, uniqueness.

Recommended Texts:

1. Mathematical Methods for Physicists, by Arfken & Weber, publisher: Academic Press; 7th Edition, (2012)
2. Mathematical Methods for Physics and Engineering, by K. F. Riley, M.P. Hobson, and S. J. Bence, Cambridge University Press, 3rd Edition (2006)
3. Mathematical Method for Scientists and Engineers, by Donald A. McQuarrie, University Science Books, California (2003).

Phys-362 **ELECTRODYNAMICS-II** **Credit Hours: 03**

Pre-requisites: Electricity and Magnetism, Calculus-II

Contents: 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 waveguide.

Recommended Books:

2. D. J. Griffiths, "Introduction to Electrodynamics" Prentice Hall, 3rd ed. 1999.M. N. O. Sadiku" Elements of Electromagnetics" Oxford University Press, 5th ed.2009.
3. F. Melia, "Electrodynamics", University of Chicago Press, 2001.
4. Hearld J and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed. 2011.

Phys-363 **ELECTRONICS-II** **Credit Hours: 03**

Pre-requisites: Electronics-I

Objective(s): To learn the basics of digital electronics such as Boolean Algebra, logic circuit, computer interface and micro-controller along with embedded systems

Contents: Review of Number Systems: Binary, Octal and Hexadecimal number system, their inter-conversion, 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-FF, 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. Micro Computers: Computers and its types, all generation of computers, basic architecture of computer, micro processor (ALU, UP Registers, Control and Time Section). Addressing modes, Instruction set and their types, Discussion on 8085/8088, 8086 processor family, Intel Microprocessor Hierarchy. Micro-controller/ Embedded System: Introduction to Embedded and microcontroller based systems, The Microprocessor and microcontroller applications and environment, microcontroller characteristics, features of a general purpose microcontroller, Microchip Inc and PIC microcontroller, Typical Microcontroller examples:, Philips 80C51 & 80C552 and Motorola 68Hc05/08, Interfacing with peripherals.

Recommended Books:

2. Thomas L. Floyd, "Electronics Fundamentals: Circuits, Devices and Applications" Prentice Hall, 8th ed. 2009.
3. B. Grob, "Basic Electronics", MacGraw Hill, Tch ed. 1997.
4. B. Streetman and S. Banerjee "Solid State Electronics Devices", , Prentice Hall, 6th ed. 2005.
5. A. Bar-lev, "Semiconductor and Electronics Devices", Prentice Hall, 3rd ed. 1993.

Phys-364 **QUANTUM MECHANICS-I** **Credit Hours: 03**

Pre-requisites: Modern Physics

Contents: Waves and Particles: Introduction to the fundamental ideas of quantum mechanics: Electromagnetic waves and photon, material particles and matter waves, quantum description of a particle, wave packets, particle in a time-independent scalar potential, order of magnitude of the wavelength associated with material particles, constraints imposed by uncertainty relations, one-dimensional Gaussian wave packet: Spreading of the wave packet, stationary states of a particle in one-dimensional square potential, behavior of a wave packet at a potential step. The Mathematical Tools of Quantum Mechanics: One-particle wave function space, state space, Dirac notation, representations in the state space, observable, representations, review of some useful properties of linear operators, unitary operators, study of the $\{|r\rangle\}$ and $\{|p\rangle\}$ representations, some general properties of two observable, Q and P, whose commutator is equal to iħ, the two-dimensional infinite well. The Postulates of Quantum Mechanics:

Statement of the postulates and their physical interpretation, the physical implications of the Schrodinger equation, the superposition principle, particle in an infinite potential well, study of the probability current in some special case, root-mean-square deviations of two conjugate observables, the density and evolution operators, Schrodinger and Heisenberg pictures, Gguge invariance, bound states of a particle in a potential well of arbitrary shape, unbound states of a particle in the presence of a potential well or barrier of arbitrary shape, quantum properties of a particle in a one-dimensional periodic structure. Application of The Postulates to Simple Cases: Spin ½ And Two-Level Quantum Systems: Spin ½ particles, quantization of the angular momentum, illustration of the postulates in the case of a spin ½, general study of two level systems, Pauli matrices, diagonalization of a 2×2 hermitian matrix, System of two spin ½ particles, Spin ½ density matrix, Spin ½ particle in a static magnetic field and a rotating field, Magnetic resonance. The One-Dimensional Harmonic Oscillator: Importance of the harmonic oscillator in physics, eigenvalues and eigenstates of the Hamiltonian, mean value and root-mean-square deviations of X and P in state $|\varphi_n\rangle$, Some examples of harmonic oscillators, study of the stationary states in the $\{|r\rangle\}$ representation, Hermite polynomials, solving the Eigenvalues of the harmonic oscillators by the polynomial method, study of the stationary states in the $\{|p\rangle\}$ representation, isotropic three-dimensional harmonic oscillator, charged harmonic oscillator placed in a uniform electric field, coherent states, Normal vibrational modes of coupled harmonic oscillators, vibrational modes of an infinite linear chain of coupled harmonic oscillators, phonons, one-dimensional harmonic oscillator in thermodynamics equilibrium at a temperature T. General Properties of Angular Momentum in Quantum Mechanics: concept of angular momentum in quantum mechanics, commutation relations, application to orbital angular momentum, spherical harmonics, rotation operators, rotation of diatomic molecules, angular momentum of stationary states of a two-dimensional harmonic oscillator, charged particle in a magnetic field and Landau levels. Particle in a Central Potential:

The Hydrogen atom, Stationary states of a particle in a central potential, motion of the center of mass and relative motion for a system of two interacting particles, Hydrogen atom, Hydrogen-like systems, A solvable example of a central potential: the isotropic three-dimensional harmonic oscillator, probability currents associated with the stationary states of the hydrogen atom, The hydrogen atom placed in a uniform magnetic field, paramagnetism and diamagnetism, Zeeman effect, study of some atomic orbitals, vibrational-rotational levels of diatomic molecules.

Recommended Books:

1. D.J. Griffiths, "Introduction to Quantum Mechanics", Addison-Wesley, 2^{nd} ed. 2004.R. Liboff, "Introductory Quantum Mechanics", Addison-Wesley, 4 ed. 2002.
2. N. Zettili, "Quantum Mechanics: Concepts and Applications", John Wiley, 2^{nd} ed. 2009.

Phys-365 **NUCLEAR PHYSICS** **Credit Hours: 03**

Pre-Requisites: Modern Physics

Objective(s): To understand the nuclear structure using different nuclear models, nature of nuclear forces, radioactivity and nuclear reactions

Contents: Nuclear Decay and Radioactivity: The basis of theory of radioactive disintegration, the disintegration constant, the half-life and the mean life, successive radioactive transformation, radioactive equilibrium, the natural radioactive series, units of radioactivity.

Alpha Decay: Why alpha decay occurs, Basic alpha decay process, the velocity and energy of alpha particle, Abortion of alpha particles: Range, ionization, and stopping power, Alpha decay systematic, Theory of alpha decay emission, Angular momentum and parity in alpha decay, Alpha decay spectroscopy

Beta Decay: Energy release in beta decay, Fermi theory of beta decay, The experimental test of Fermi theory, Angular momentum and parity selection rules, Neutrino Physics, Double beta decay, Beta-delayed nucleon emission, Gamma decay: Energetic of gamma decay, Classical electromagnetic radiation, Transition to quantum mechanics.

Nuclear Fission: Why Nuclear Fission, Characteristics of nuclear fission, Energy in fission, Fission and nuclear structure, Controlled fission reaction, Fission reactors, Radioactive fission products.

Nuclear Fusion: Basic nuclear fusion process, Characteristic of fusion, Solar fusion, Controlled fusion reactor.

Recommended Books:

1. E. Segre, “Nuclei and Particles”, Bejamin-Cummings, 2^{nd} 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.

Phys-366L **LAB-VI (Optics)** **Credit Hrs: 01**

Pre-requisites: Optics.

Objective(s): To understand different aspect of light.

Course outline:

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.

Phys-471 **QUANTUM MECHANICS-II** **Credit Hours: 03**

Pre-requisites: Quantum Mechanics-I

Contents: Addition of Angular Momenta: Total angular momentum in classical mechanics, total angular momentum in quantum mechanics, addition of two spin ½ angular momenta, addition of two arbitrary angular momenta, Clebsch-Gordon coefficients, addition of sphericalharmonics, vector operators, Wigner-Eckart theorem, electric Multipole moments, Evolution of two angular momenta J_1 and J_2 coupled by an interaction $aJ_1 . J_2$. Stationary Perturbation Theory: Description of the method, perturbation of a non-degenerate level, perturbation of a degenerate level, one-dimensional harmonic oscillator subjected to a perturbing potential, interaction between the magnetic dipoles of two spin ½ particles, Van der waals forces, volume effect and The influence of the spatial extension of the nucleus on the atomic levels, variational method, energy bands of electrons in solids, a simple example of the chemical bond: The H^+ ion. Applications of Perturbation Theory to Atomic Systems: fine and hyperfine structure of atomic levels in hydrogen, Calculation of the mean values of the spin-orbit coupling in the 1s,2s and 2p levels, hyperfine structure And the Zeeman effect for muonium and positronium, Stark effect. Approximation Methods for Time-Dependent

Problems: Statement of the problem, approximate solution of the Schrodinger equation, An important special case: Sinusoidal or constant perturbation, Interaction of an atom with electromagnetic waves, linear and non-linear response of a two-level system subjected to a sinusoidal perturbation, Ooscillations of a system between two discrete states under the effect of a resonant perturbation, Rabi flopping, decay of discrete state resonantly coupled to a continuum of final states, Fermi's golden rule. 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). Scattering by a Potential: Importance of collision phenomena, Stationary scattering states, scattering cross section, scattering by a central potential, method of partial waves, phenomenological description of collisions with absorption.

Recommended Books:

1. D.J. Griffiths, "Introduction to Quantum Mechanics", Addison-Wesley, 2nd ed. 2004
2. R. Liboff, "Introductory Quantum Mechanics", Addison-Wesley, 4th ed. 2002.
3. N. Zettili, "Quantum Mechanics: Concepts and Applications", John Wiley, 2nd ed. 2009.

Phys-472 **SOLID STATE PHYSICS-I** **Credit Hours: 03**

Pre-requisites: Quantum Mechanics I, Statistical Mechanics

Contents: Crystal structure in 2D and 3D, fundamental types of lattices, index system for crystal planes, simple crystal structures, X-ray diffraction, Braggs law, reciprocal lattice, Diffraction of waves by crystals, scattered wave amplitude, Brillouin zones, crystal binding and elastic constants, Classification of Solids, ionic crystals, covalent crystals, Ionic Radii, II-VI and III-V compounds, Molecular crystals, metals, Cohesive energy, The Lenard Jones Potential, Density, Cohesive energy and Bulk Modulus of crystalline solids, The Madelung constant, Cohesion in Covalent crystals, elastic waves in cubic crystals. Vibration of crystals with monatomic basis, two atoms per primitive basis, quantization of elastic waves, normal vibration modes and phonon, phonon momentum, inelastic scattering by phonons, Phonon heat capacity, lattice heat capacity, Einstein and Debye models, Somerfield model of free electron theory, Energy levels in one dimension, free electron gas in three dimensions, DC and AC electrical conductivity of metals.

Recommended Books:

1. C. Kittle, “Introduction to Solid State Physics”, John Wiley, 8th ed. 2005.
2. N. W. Ashcroft and N. D. Mermin, “Solid State Physics”, Rinehart & Winston, 1976.
3. S. R. Elliott, “The Physics and Chemistry of Solids”, John Wiley, 1998
4. M. A. Omar, “Elementary and Solid State Physics”, Pearson Education, 2000.
5. H. M. Rosenberg, “The Solid State”, Oxford Science Publication, 3rd ed. 1988.
6. M. A. Wahab, “Solid State Physics”, Narosa Publishing House, 1999.

Phys-473 ATOMIC AND MOLECULAR PHYSICS Credit Hours: 03

Pre-requisites: Quantum Mechanics I

Co-requisite: Quantum Mechanics II

Objective(s): Introduction to the structure and spectra of atoms and molecules,

Contents: Nuclear Atom, Rutherford’s Scattering formula, Electron Orbits, Atomic spectra, The Bohr’s atom, Energy levels and spectra, Origin of line spectra, Correspondence Principle, Nuclear motion, Atomic excitation, Laser, Wave function, Wave equation, Time dependent and Time independent Schrödinger equation, Harmonic oscillator, Schrödinger equation for Hydrogen Atom, Separation of variables, Quantum Numbers, Electron Probability Density, Radiative transitions, Selection rules, Zeeman effect, Electron spin, Strern-Gerlach experiment, Pauli Exclusion Principle, Symmetric and anti-symmetric wave functions, Periodic table, atomic structure, Explanation of Periodic table, Spin orbit coupling, Total angular momentum, LS coupling, JJ coupling, Term symbols, X-ray spectra, Discrete X-ray spectra, Continuous X-ray Spectra, Auger effect.

Molecular bond, Electron sharing, H2+ molecular ion, Hydrogen molecule, complex molecules, Rotational energy levels, Rotational spectra, Vibrational energy levels, Vibrational spectra, Vibration – Rotation spectra, Electron spectra of molecules.

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”, y, 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.

Phys-474 COMPUTATIONAL PHYSICS Credit Hours: 03

Objective(s): Introduction of computer languages, Computer in numerical analysis Computer simulation and modeling

Contents: Programming for Scientific Computation: unix/linux basics, the editing-codingcompiling-debugging-optimizing-visualizing-documenting production chain, fortran 95 and known software packages of computation. Numerical Programming: Functions: approximation and fitting, Numerical calculus. Ordinary differential equations, Matrices, Spectral analysis, Partial differential equations.

Modeling & Simulations: Conceptual models, The mathematical models, Random numbers and random walk, Doing Physics with random numbers, Computer simulation, Relationship of modeling and simulation. Some systems of interest for physicists such as Motion of Falling objects, Kepler's problems, Oscillatory motion, Many particle systems, Dynamic systems, Wave phenomena, Field of static charges and current, Diffusion, Populations genetics etc. Project: A project will be chosen by the student in consultation with the instructor. Selection of the project should be done soon after the module on modelling and simulation starts and continue over the course of the rest of the semester. The final part of the course is reserved for presentation of preliminary and final results.

Recommended Books:

a. T. Pang, "An Introduction to Computational Physics", Cambridge University Press, 2008.
b. R. Landau, M. Paez, C. Bordeianu, "A Survey of Computational Physics", Princeton University Press, 2008.
c. M. L. De Jong, "Introduction to Computational Physics", Addison Wesley, 1991.
d. S. T. Koonini, "Computational Physics", The Benjamin-Cummings, 1985.
e. H. Gould, J. Tobochnik and W. Christian, "An Introduction to Computer Simulation Methods", Addison Wesley, 3rd ed. 2006.
f. S. C. Chapra and R. P. Chanle, "Numerical Methods for Engineers with Personal Computer Applications", McGraw Hill,1990.
g. S. C. Chapra, "Applied Numerical Methods with MATLAB for Engineers and Scientists", McGraw Hill, 2nd ed. 2006.

Phys-477L **LAB-VII (Electronics)** **Credit Hours: 01**

Course outline:

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.

Phys-481 **SOLID STATE PHYSICS-II** **Credit Hours: 03**

Pre-requisites: Solid State Physics-I

Contents: Transport Properties of Solids: Motion of electron in bands, Effective mass, Electrical conductivity of metals, electrical Conductivity of localized electrons, Boltzmann equation.

Defects in Crystals: Crystal imperfections, Thermodynamics of Point defects, Schottky and Frenkel defects, color centers, Dislocations in Solids, Burgers vectors, edge dislocation, Screw dislocation Slip and plastic deformation, Stacking faults and grain Boundaries, Strength of Crystals, Diffusion and Fick's law Dielectrics and Ferroelectrics: Maxwell Equations, Polariza

tion, Dielectric Constant and Dielectric Polarizability, Susceptibility, Electronic Polarizablity, Clausius-Mossotti Relation, Structural Phase Transitions, Langevin theory of Dia and Paramagnetism, Ferro-magnetism, Domain theory, Weiss theory of Ferromagnetism, Magnetic relaxation and resonance phenomena.

Semiconductors and Superconductivity: Intrinsic Semiconductors, Extrinsic semiconductors, Band structure, Energy Gap, Donor and acceptor Level, Hall Effect, Superconductivity-an introduction, zero resistivity and Meissner effect, Diamagnetism, susceptibility, Critical field, temperature and current, Type-I and type-II superconductors, BCS theory, electron-phonon-electron interaction via lattice deformation, ground state of superconductors, Cooper pairs, Coherence length, the origin of energy gap, London equations (electrodynamics), London penetration depth, thermodynamics of superconductors, entropy and the Gibbs free energy, Josephson effect, superconductors applications.

Recommended Books:

1. C. Kittle, "Introduction to Solid State Physics", John Wiley, 8^{th} ed. 2005.
2. N. W. Ashcroft and N. D. Mermin, "Solid State Physics", Rinehart & Winston, 1976.
3. G. Burns, "High Temperature Superconductivity - An Introduction", Academic Press, 1992.
4. M. Fox, "Optical Properties of Solids", Oxford University Press, 2^{nd} ed. 2010.
5. N. A. Spaldin, "Magnetic Materials: Fundamentals and Device Applications", Cambridge University Press, 2^{nd} ed. 2010.

BS PHYSICS ELECTIVE COURSES

These elective courses can be chosen from the list or new elective course may be offered according to the availability of staff and necessary infrastructure.

University may also tailor these courses according to their facilities.

Phys-401 **PLASMA PHYSICS** **Credit Hours: 3**

Pre-requisite: Electrodynamics II, Waves and Oscillations

Objective(s): To learn about the importance of the plasma along with the basic concept of plasma, fluid description of the plasma

Contents: Basics of Surface Science: Surface reactions, Heterogeneous catalysis, Semiconductor technology, Corrosion, Nanotechnology, Surface Structure and Reconstruction: Electronic Structure of Surfaces: Band structure of metals, insulators and semiconductors, Fermi level, Screening, Work Function, Surface States, Electron Affinity, Ionization Potential, Surface Chirality, Thermodynamics of Surfaces, Equilibrium Crystal Shape, Quantum confinement of Electrons at Surfaces: Interference of Electron Waves, Quantum size effects, Quantum wells, Mechanical Quantum Wells, Quantum Wires, Chemist's Approach, Bonds to Bands, Surface Dynamics: Nucleation and growth of nanostructures and films Surface Magnetism and magnetic imaging, Diamagnetism, Paramagnetism, Anti-Ferromagnetism, Magnetism in thin films, , Magnetic Force Microscopy (MFM).Surface Study Techniques: Surface Sensitivity and specificity Auger Electron Spectroscopy (AES), X-Ray Photo-electron Spectroscopy, Scanning Tunneling Microscopy (STM), Photovoltaic and Organic Electronics: Different types of semiconductors(organic, inorganic, conjugated polymers), intra-molecular bonding, Van der Waals, electronic properties, polarization effects, Field effect Transistors, basics of excitonic solar cells.

Recommended Books:

1. F. F. Chen, "Introduction to Plasma Physics", 2nd ed. Plenum, 1995.
2. D. A. Gurnett and A. Bhattacharjee, "Introduction to Plasma Physics: with space and laboratory application", Cambridge University Press, 2005.
3. T. J. M. Boyd and J. J. Sanderson, "The Physics of Plasmas", Cambridge University Press, 2003.

Phys-402 **SURFACE SCIENCES** **Credit Hours: 03**

Co-requisite: Solid State Physics-II

Objective(s): To understand the basics of surface physics, Strengthen the previous knowledge of Solid State Physics and Quantum Mechanics

Contents: Basics of Surface Science: Surface reactions, Heterogeneous catalysis, Semiconductor technology, Corrosion, Nanotechnology, Surface Structure and Reconstruction: Classification of solids, Crystal structure, Unit cell, Bravais lattices, Electronic Structure of Surfaces: Band structure of metals, insulators and semiconductors, Fermi level, Screening, Work Function, Surface States, Electron Affinity, Ionization Potential, Surface Chirality, Thermodynamics of Surfaces, Equilibrium Crystal Shape, Quantum confinement of Electrons at Surfaces: Interference of Electron Waves, Quantum size effects, Quantum wells, Mechanical Quantum Wells, Quantum Wires, Chemist's Approach, Bonds to Bands, Surface Dynamics: Nucleation and growth of nanostructures and films, Surface Magnetism and magnetic imaging, Diamagnetism, Paramagnetism, Anti-Ferromagnetism, Magnetism in thin films, Kerr microscopy (MOKE), Spin Polarized Photoemission (SP-PEEM), Magnetic Force Microscopy (MFM), Surface Study Techniques: Surface Sensitivity and specificity, Explanation and comparison of Low-Energy Electron Diffraction (LEED) and Reflection High-Energy Electron Diffraction (RHEED), Explanation of Near-Edge X-ray Absorption Fine Structure (NEXAFS), High-Resolution Electron Energy Loss Spectroscopy (HREELS), Introduction to Desorption Techniques, Thermal Desorption Spectroscopy (TDS), Electron Stimulated Desorption (ESD), Electron Stimulated Desorption Ion Angular Distribution (ESDIAD), Photon Stimulated Desorption (PSD), Electron Spectroscopy, Theory: Mean free path, Koopman's Theorem, Spin orbit coupling effects, chemical shifts, binding energy, AugerElectron Spectroscopy (AES), X-Ray Photo-electron Spectroscopy, Electron Analyzer, Electron optics, Scanning Tunneling Microscopy (STM), History, Theory, Electronics and applications, Case Studies: Silicon Surfaces: Geometric and Electronic Structure, Molecular Adsorption on Semiconductor Surfaces, Adsorption Properties of CO on Metal Single-Crystal Surfaces, Molecular or dissociative adsorption, Chemical bonding and Orientation, AdsorptionSite as a function of coverage, Over layer long-range order, Ammonia Synthesis, Oxide Surfaces, Photovoltaic and Organic Electronics: Different types of semiconductors (organic, inorganic, conjugated polymers), Prototypes (OLEDs etc), intra-molecular bonding, Van der Waals, electronic properties, polarization effects, Field effect Transistors, basics of excitonic solar cells.

Recommended Books:

1. A. Zangwill, "Physics at Surfaces", Cambridge University Press, 1988.
2. D. P. Woodruff and T. A. Delchar, "Modern Techniques of Surface Science", Cambridge University Press, 2nd ed. 1994.
3. D. Briggs and M. P. Seah, "Practical Surface Analysis", Vol-I, John Wiley, 2nd ed. 1990.
4. J. B. Hudson, "Surface Science, an Introduction", Wiley-Interscience, 1998.

Phys-403 **FLUID DYNAMICS** **Credit Hours: 3**

Pre-requisites: Mechanics, Calculus-I, Ordinary Differential Equations

Objective(s): Physical understanding of fluid dynamics

Contents: Phenomenological introduction to fluid dynamics, Kinematics and conservation laws, Ideal fluids, the Euler equations, ir-rotational flow, The Navier-Stokes equations, Viscous flow: Stokes flow, drag, lubrication theory, thin film flow, Waves: surface waves, internal gravity waves, nonlinear waves. solitons, shocks, Instabilities: linear stability analysis, Kelvin-Helmholts instability, Rayleigh-Bénard convection, other instabilities, Other topics depending on interest and as time permits possibly: airfoil theory, granular flows, biophysical flows.

Recommended Books:

1. D. J. Acheson, “Elementary Fluid Dynamics”, Oxford University Press, 1990.
2. P. K. Kundu and I.M. Cohen, “Fluid Mechanics”, Academic Press, 4^{th} ed. 2010.
3. D. J. Tritton, “Physical Fluid Dynamics”, Clarendon, 2^{nd} ed. 1988.
4. L. D. Landau and E. M. Lifschitz, “Fluid Mechanics”, Butterworth-Heinemann, 2^{nd} ed. 1987.

Phys-404 **METHODS OF EXPERIMENTAL PHYSICS** **Credit Hours: 3**

Objective(s): To learn about the vacuum techniques, To learn the detection techniques about radiation, temperature. To learn about the measuring techniques along with data analysis.

Contents: Vacuum Techniques: Gas Transport: Throughout, Pumping Speed, Pump down Time Ultimate pressure. Fore-Vacuum Pumps: Rotary Oil pumps, sorption pumps. Diffusion pumps, sorption pumps (High Vacuum). Production of ultrahigh vacuum, Fundamental concepts, guttering pumps, Ion pumps, Cryogenic pumps, Turbo molecular pumps. Measurement of total pressure in Vacuums Systems, Units pressure ranges, Manometers, Perini gauges, The McLoad gauges, Mass spectrometer for partial measurement of pressure. Design of high Vacuum system, Surface to Volume ratio, Pump Choice, pumping system design. Vacuum Components, Vacuum valves, vacuum Flanges, Liquid Nitrogen trap, Mechanical feed throughs & Electrical feed throughs Leak detection: Basic consideration, leak detection equipment, Special Techniques and problems, Repair Techniques, Radiation Detection and Measurement: GM tubes, scintillation detector, channeltron, photo multipliers, neutron detectors, alpha/beta detectors, x-rays/gamma detectors, cosmic ray’s detectors, Spectrographs and Interferometers, Sensor Technology: Sensors for temperature, pressure displacement, rotation, flow, level, speed, rotation position, phase, current voltage, power magnetic field, tilt, metal, explosive and heat, Electronics and Electronic Instruments: Operational amplifiers, summing amplifiers, difference amplifiers, Differentiators, Integrators, Logarithmic amplifiers, current to voltage converter, Spectroscopy amplifiers, charge sensitive pre-amplifiers, Coincidence circuits, Isolators, Ramp Generators, and single channel analyzer. Power supplies, Signal Generators, Counters, Multichannel analyzer, Lock in Amplifiers, Boxcar averages Computer Introduction: Introduction to computers, GPIB Interface, RS 232. Interfacing, DA/AD conversion, Visual c/visual Basic Data Analysis: Evaluation of measurement: Systematic Errors, Accuracy, Accidental Errors, Precision, Statistical Methods, Mean Value and Variance, Statistical Control of Measurements, Errors of Direct measurements, Rejection of data, Significance of results, Propagation of errors, preliminary Estimation, Errors of Computation. Least squares fit to a polynomial. Nonlinear functions. Data manipulation, smoothing, interpolation and extrapolation, linear and parabolic interpolation.

Recommended Books:

1. F. James, "Statistical Methods in Experimental Physics", World Scientific Company, 2nd ed. 2006.
2. M. H. Hablanian, "High-Vacuum Technology", Marcel Dekker, 2nd ed. 1997.
3. P. Bevington and D. K. Robinson, "Data Reduction and Error Analysis for Physical Science", McGraw Hill, 3rd ed. 2002.
4. S. Tavernier, "Experimental Techniques in Nuclear and Particle Physics", Springer, 2010.
5. J. B. Topping, "Errors of Observations and Their Treatment", Springer, 4th ed. 1972.

Phys-405 ENVIRONMENTAL PHYSICS Credit Hours: 3

Objective(s): To become familiar with the essentials of environment and Global climate,

To learn to use spectroscopy for environments

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 undulling 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 equipments. 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.

Phys-406 **QUANTUM INFORMATION THEORY** **Credit Hours: 3**

Pre-requisites: Quantum Mechanics I

Objective(s): To understand the fundamental concepts of quantum information, communication, computation, and physical protocols for quantum computation

Contents: Review of Quantum Mechanics and overview of Quantum information: Postulates of quantum mechanics, quantum states and observables, Dirac notation, projective measurements, density operator, pure and mixed states, entanglement, tensor products, no-cloning theorem, mixed states from pure states in a larger Hilbert space, Schmidt decomposition, generalized measurements, (CP maps, POVMs), qualitative overview of Quantum Information Quantum Communication: Dense coding, teleportation, entanglement swapping, instantaneous transfer of information, quantum key distribution. Entanglement and its Quantification: Inseparability of EPR pairs, Bell inequality for pure and mixed states, entanglement witnesses, Peres-Horodecki criterion, properties of entanglement measures, pure and mixed state entanglement, relative entropy as entanglement measure, entanglement and thermodynamics, measuring entanglement Quantum Information: Classical information theory (data compression, Shannon entropy, von Neumann entropy), fidelity, Helstrom's measurement and discrimination, quantum data compression, entropy and information, relative entropy and its statistical interpretation, conditional entropy, Holevo bound, capacity of a quantum channel, relative entropy and thermodynamics, entropy and erasure, Landauer's erasure Quantum Computation: Classical computation (Turing machines, circuits, complexity theory), quantum algorithms (Deutsch's algorithm, Oracles, Grover's algorithm, factorization and quantum Fourier transform), role of entanglement in algorithms (search algorithm), modeling quantum measurements, Bekenstein bound, quantum error correction (general conditions, stabilizer codes, 3-qubit codes, relationship with Maxwell's demon), fault tolerant quantum computation (overview) Physical Protocols for Quantum Information and Computation: Ion trap, optical lattices, NMR, quantum optics, cavity QED.

Recommended Books:

1. V. Vedral, "Introduction to Quantum Information Science", Oxford University Press, 2007.
2. M. Nielsen and I. Chuang, "Quantum Computation and Quantum Information", Cambridge University Press, 10th Anv. ed. 2010.
3. W. Steeb and Y. Hardy, "Problems and Solutions in Quantum Computing and Quantum Information", World Scientific Publishing, 3rd ed. 2011.
4. Book on general quantum mechanics: A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers (2002).
5. Seth Lloyd's notes on quantum information available online at: web.mit.edu/2.111/www/notes09/spring.pdf

Phys-407 INTRODUCTION TO QUANTUM COMPUTING Credit Hours: 3

Pre-requisite: Quantum Mechanics-I, Computational Physics

Objective(s): To be familiar with the quantum computing, To learn about the Quantum circuits, and cryptography

Contents: Computer technology and historical background, Basic principles and postulates of quantum mechanics: Quantum states, evolution, quantum measurement, superposition, quantization from bits to qubits, operator function, density matrix, Schrodinger equation, Schmidt decomposition, EPR and Bell's inequality, Quantum Computation: Quantum Circuits, Single qubit operation, Controlled operations, Measurement, Universal quantum gates, Single qubit and CNOT gates, Breaking unbreakable codes: Code making, Trapdoor function, One time pad, RSA cryptography, Code breaking on classical and quantum computers, Schor's algorithm, Quantum Cryptography: Uncertainty principle, Polarization and Spin basis, BB84, BB90, and Ekert protocols, Quantum cryptography with and without eavesdropping, Experimental realization, Quantum Search Algorithm.

Recommended Books:

1. M. A. Nielson and I. L. Chuang, "Quantum Computation and Quantum Information",

Foundation Books, 2007.
2. C. P. Williams and S. H. Clearwater, “Exploration in Quantum Computation” Springer, 2nd ed. 2011. .
3. P. Bouwmester, A. Ekert, and A. Zeilinger, “The Physics of Quantum Information: Quantum Cryptography, Quantum Teleportation, Quantum Computation”, Springer, 2010.
4. R. K. Brylinsky and G. Chen, “Mathematics of Quantum Computation” by Chapman & Hall/CRC, 2002.

Phys-408 **QUANTUM FIELD THEORY** **Credit Hours: 3**

Pre-requisites: Quantum Mechanics-II

Contents: Lagrangian Field Theory: Classical Field Theory. Canonical Quantization. Noether's theorem. (3 week) Klein-Gordon Field: Real Klein-Gordon field. Complex Klein-Gordon field. Covariant commutation relations. Meson propagator, Dirac Field: Number representation for fermions. Quantization of Dirac field. Spin-statistics theorem. Fermion propagator, Electromagnetic Field: Classical electromagnetic field. Covariant quantization. Photon propagator, Interacting Fields: Interaction Lagrangian and gauge invariance. Interaction picture. S-matrix expansion. Wick’s theorem. Feynman Diagrams. Feynman rules for QED. Cross sections and decay rates.

Recommended Books:

1. F. Mandl and G. Shaw, “Quantum Field Theory”, Wiley, 2nd ed. 2010.
2. M. E. Peskin and D. V. Schroeder, “An Introduction to Quantum Field Theory”, Addison Wesley, 1995.
3. S. Weinberg, “The Quantum Theory of Fields”, Vol. 1, Cambridge University Press, 1999.
4. N. N. Bogoliubov and D. V. Shirkov, “Introduction to the Theory of Quantized Fields”, John Wiley, 1980.

Phys-409 **PARTICLE PHYSICS** **Credit Hours: 3**

Pre-requisites: Quantum Mechanics-II, Nuclear Physics

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 covariant. 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 term. 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.

Phys-410 ANALOGUE ELECTRONICS Credit Hours: 3

Objective(s): To learn the basics of digital electronics such 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: Amplifiers and their Frequency Response: Cascade amplifier, The Amplifier pass band, The frequency plot, Low frequency plot, Low frequency limit, The un-bypassed emitter resistor, high frequency equivalent circuit, The Miller Effect, high frequency limit of transistor, bandwidth of a cascade amplifier, Feedback: Positive and Negative feedback, Principle of feedback amplifier, stabilization of gain by negative feedback, Bandwidth improvement with negative feedback, Reduction of nonlinear distortion, control of amplifier output and input resistance, current series feedback circuit, voltage shunt feedback circuit Oscillators: Introduction, Classification of oscillators, Damped and undamped oscillators, the oscillatory circuit, frequency stability of an oscillator, essentials of a feedback LC oscillator, tuned base oscillator, Hartley oscillator, Colpitis oscillator, crystal oscillator Power Amplifiers: Introduction, Power relation in class-A amplifiers, effect of thermal environment, determination of the output distortion, class-B amplifier, efficiency of class-A and class-B amplifiers Modulation and Demodulation: Introduction, carrier wave modulation, Need for modulation, radio Broadcasting, Methods of modulation, amplitude modulation, Forms of amplitude modulation, single side band system of modulation, Diode for linear detector for amplitude modulation, High power level amplitude modulation, automatic volume control, Frequency modulation Multivibrators: Multivibrators, Basic types of Multivibrators, uses of Multivibrators, Astable Multivibrators, Mono-stable Multivibrators, Bi-stable Multivibrators, Schmitt Trigger Circuit Integrated Circuits: Introduction, Integrated circuit advantages and drawbacks, scale of integration, classification of integrated circuit by structure, Classification of integrated circuit by function, comparison between different integrated circuit. Integrated circuit terminology, Integrated circuit fabrication, Basic processing steps. Silicon device processes Silicon wafer preparation, diffusion, Oxidation photolithography, Chemical vapour deposition, Metallization, Circuit probing, Scribing and separating into chips, Mounting and packing applications of integrated circuit Digital Circuits: Decimal, Binary, Octal, hexadecimal number systems, conversion of decimal numbers to any other number system and vice-versa, Binary codes, OR, AND, NOT, NAND, NOR logic gates, Boolean Algebra. Boolean expressions, simplification of Boolean expression using Boolean algebra.

Recommended Books:

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

Phys-411 EXPERIMENTAL TECHNIQUES IN PARTICLE AND NUCLEAR PHYSICS Credit Hours: 3

Pre-requisites: Particle Physics, Nuclear Physics

Objective(s): To give students with the practical hand on the experimental techniques, Physically understand the nuclear phenomena

Contents: Review of Basic Concepts: Units used in particle physics, Definition used in particle physics, Types of particles to be detected, Cross section, Decay width, Lab Frame and CM frame, Pseudo rapidity, History of Accelerator, Linear accelerators, Circular accelerators, Introduction to RHIC, Tevatron, LEP, LHC Introduction to Accelerators: Lattice and geometry, The arcs, Periodicity, Aperture, Beam crossing angle, Luminosity, RF cavities, Power requirements, Longitudinal feedback system, Injection, Injection scheme, PS, SPS, Magnets, Cryogenics, Vacuum system Introduction to Detectors: Introduction to detectors, Need of detectors, Passage of radiation through matter, Cross-section, Interaction probability in a distance x, Mean free path, Energy loss of heavy charged particles by atomic collisions, Bohr's, calculation – classical case - The Bethe Bloch formula, Cherenkov radiation, Energy loss of electron and photon, Multiple coulomb scattering, Energy straggling, The interaction of photons, The interaction of neutrons General Characteristics of Detectors and Gas Detectors: Sensitivity, Detector response, Energy resolution – The Fano-factor, The response function, Response time, Detector efficiency, Dead time- Ionization detectors, Gaseous ionization detectors, Ionization & transport phenomenon in gases, Transport of electrons and ions in gases, Avalanche multiplication, The cylindrical proportional counter, The multi-wire proportional counter, The drift chambers, Time projection chambers, Liquid ionization detector Scintillators, Photomultipliers, Semi-conductor Detectors: Scintillation detectors, Organic scintillation, Inorganic crystals, Gaseous scintillators Glasses, Intrinsic detector efficiency for various radiations, Photomultipliers, Basic construction and operation, The photocathode, The electron-optical input system, Semiconductor detectors, Silicon diode detectors, Introduction to CMS and its detectors Detector Software and Physics Objects: Introduction to Linux operating system, Introduction to CMS software (CMSSW), Basic infra structure of software, Introduction to PYTHIA, Introduction to GEN, SIM, DIGI, RECO, reconstruction of final state objects.

Recommended Books:

1. The Large Hadron Collider Conceptual Design CERN/AC/95-05 (LHC)
2. Detector performance and software, Physics Technical Design Report, Volume1
3. Techniques for Nuclear and Particle Physics Experiments by W.R. Leo
4. R. Fernow, "Introduction to experimental particle physics", Cambridge University Press, 1989.
5. D. H. Perkins, "Introduction to High Energy Physics", Cambridge University Press, 4th ed. 2000.
6. MIT website http://mit.edu

Phys-4012 **LASERS** **Credit Hours: 3**

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

Objective(s): Develop fundamental concepts about lasers, Learn the principles of spectroscopy of molecules and semi-conductors, Understand the optical resonators and laser system. Applications of lasers

Contents: Introductory Concepts: Spontaneous Emission, Absorption, Stimulated Emission, Pumping Schemes, Absorption and Stimulated Emission Rates, Absorption and Gain

Coefficients, Resonance Energy Transfers. Properties of Laser Beam: Monochromaticity, Coherence, Directionality, Brightness.

Spectroscopy of Molecule and Semiconductors: Electronic Energy Levels, Molecular Energy Levels, Level Occupation at Thermal Equilibrium, Stimulated Transition, Selection Rules, Radiative and Nonradiative Decay, Semiconductor Optical Resonators: Plane Parallel (Fabry-Perot) Resonator, Concentric (Spherical) Resonator, Confocal, Resonator, Generalized Spherical Resonator, Ring Resonator, Stable Resonators, Unstable Resonators. , Matrix Formulation of Geometrical Optics, 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 and Semiconductor Lasers: Homojunction Lasers Double-Heterostructure lasers, Gas lasers: Helium Neon laser, CO_2 laser, Nitrogen Laser and Excimer Lasers, Free-Electron and X-Ray Lasers Laser Applications: Material Processing: Surface Hardening, Cutting, Drilling, Welding etc. Holography, Laser Communication, Medicine, Defense Industry, Atmospheric Physics.

Recommended Books:

1. O. Svelto, “Principles of Lasers”, Springer, 5th ed. 2009.
2. J. Eberly and P. Milonni, “Lasers Physics”, John Wiley, 2nd ed. 2010.
3. M. O. Scully and M. S. Zubairy, “Quantum Optics”, Cambridge University Press, 1997.
4. W. T. Silfvast, “Laser Fundamentals”, Cambridge University Press, 2nd ed. 2008.
5. W. M. Steen, J. Mazumder and K. G. Watkins, “Laser Material Processing”, Springer, 4th ed. 2010.

Phys-413 RENEWABLE SOURCES OF ENERGY Credit Hours: 3

Objective(s): To give students an understanding of the renewable energy resources

Contents: Energy Scenarios: Importance of energy, world primary energy sources, energy demand, supplies, reserves, growth in demand, life estimates, and consumption pattern of conventional energy sources: oil, gas, coal, hydro, nuclear etc.

Energy & Environment: Emission of pollutants from fossil fuels and their damaging effects, and economics impact; Renewable energy and its sustainability. Renewable Scenarios: Defining renewable, promising renewable energy sources, their potential, availability, present status, existing technologies and availability. Solar Energy: Sun-Earth relationship, geometry, sun path and solar irradiance, solar spectrum, solar constant, atmospheric effects, global distribution, daily and seasonal variations, effects of till angle, resource estimation, extraterrestrial, global, direct, diffused radiation, sun shine hours, air mass, hourly, monthly and annual mean, radiation on tilt surface, measuring instruments. Solar Thermal: Flat plate collectors, their designs, heat transfer, transmission through glass, absorption transmission of sun energy, selective surfaces, performance, and efficiency; low temperature applications: water heating, cooking, drying, desalination, their designs and performance; concentrators, their designs, power generation, performance and problems. Photovoltaic: PV effect, materials, solar cell working, efficiencies, different types of solar cells, characteristics, (dark, under illumination), efficiency limiting factors, power, spectral response, fill-factor, temperature effect; PV systems, components, packing fraction, modules, arrays, controllers, inverters, storage, PV system sizing, designing, performance and applications.

Wind: Global distribution, resource assessment, wind speed, height and topographic effects, power extraction for wind energy conversion, wind mills, their types, capacity, properties, wind mills for water lifting and power generation, environmental effect. Hydropower: Global resources, and their assessment, classification, micro, mini, small and large resources, principles of energy conversion; turbines, types, their working and efficiency for micro to small power systems; environmental impact. Biogas: Biomass sources; residue, farms, forest. Solid wastes: agricultural, industrial and municipal wastes etc; applications, traditional and non-traditional uses: utilization process, gasification, digester, types, energy forming, Environment issues. Resources availability; digester, their types, sizes, and working, gas production, efficiency; environmental effects; Geothermal: Temperature variation in the earth, sites, potentials, availability, extraction techniques, applications; water and space heating, power generations, problems, environmental effects. Waves and Tides: Wave motion, energy, potentials, sites, power extraction, and transmission, generation of tides, their power, global sites, power generation, resource assessment, problems, current status and future prospects. Hydrogen Fuel: Importance of H_2 as energy carrier, Properties of H_2, production, hydrolysis, fuel cells, types, applications, current status and future prospects. Nuclear: Global generations of reserves through reprocessing and breeder reactors, growth rate, prospects of nuclear fusion, safety and hazards issue.

Energy Storage: Importance of energy storage, storage systems, mechanical, chemical, biological, heat, electrical, fuel cells etc.

Recommended Books

1. World Energy Supply: Resources, Technologies, Prospective: Manfred Grathwohl; Walter deGruyter – Berlin, 1982.
2. Renewable Energy Resources; John W. Twidell and Anthony D. Weir; E & F.N. Spon Ltd. London. 1986.
3. An Introduction to Solar Radiation: Muhammad Iqbal; Academic Press, Canada. 1983.
4. A Practical Guide to Solar Electricity, Simon Roberts: Prentice Hall Inc. USA, 1991.
5. Solar Cells, Operating Principles, Technology, and system Application: Martin A. Green; Printice Hall, Inc. USA, 1982.

Phys-414 FUNDAMENTALS OF OPTOELECTRONICS Credit Hours: 3

Prerequisites: Waves and optics, Modern physics, Quantum Physics

Objective(s): To study the application of light, studying the photonic devices including detectors.

Contents: Guided Wave Optics: Planar slab waveguides, Rectangular channel waveguides, Single and multimode optical fibers, waveguide modes and field distributions, waveguide dispersion, pulse propagation Gaussian Beam Propagation: ABCD matrices for transformation of Gaussian beams, applications to simple resonators Electromagnetic Propagation in Anisotropic Media: Reflection and transmission at anisotropic interfaces, Jones Calculus, retardation plates, polarizers Electro-optics and Acousto-optics: Linear electro-optic effect, Longitudinal and transverse modulators, amplitude and phase modulation, Mach-Zehnder modulators, Coupled mode theory, Optical coupling between waveguides, Directional couplers, Photoelastic effect, Acousto-optic interaction and Bragg diffraction, Acousto-optic modulators, deflectors and scanners Optoelectronics: p-n junctions, semiconductor devices: laser amplifiers, injection lasers, photoconductors, photodiodes, photodetector, noise.

Recommended Books:

1. Fundamentals of Photonics by B. E. A. Saleh and M. C. Teich (2nd Edition), John Wiley (2007).
2. Photonic Devices by J-M. Liu, Cambridge (2009).
3. Photonics: Optical Electronics in Modern Communications by A. Yariv and P. Yeh, Oxford (2006).
4. Optics by E. Hecht (4thEdition), Addison-Wesley (2001)

Phys-415 LASER ENGINEERING Credit Hours: 3

Pre-requisites: Modern Physics, Optics, Waves and Oscillations, Electricity and Magnetism

Objective(s): Deep understanding of Laser and its components, Designing of Laser

Contents: Introduction: What is laser, brief history of laser development, principle components of laser, types of lasers, properties of laser beam, an overview of laser technology, energy states in atom, transition between energy states (absorption, spontaneous and stimulated emission), principles of laser, power and energy, special features of laser beam (directionality, diffraction, intensity, monochromaticity, coherency, line-width), General Principles of Laser Operation: Thermal equilibrium, Einstein coefficients, condition for large stimulated emissions, condition for light amplification, population inversion, energy state, metastable state, three level laser, four level laser, line broadening, laser rate equations (two, three, and four level systems), generic laser, gain medium, pumping source, resonant cavity

Generic Laser: Amplification and gain, optical resonator, laser action, gain of active medium (mathematical treatment), threshold condition, gain calculation, conditions for steady state oscillation, cavity resonance frequencies, laser modes (longitudinal and transverse), single mode operation examples.

Optical Resonators: Resonator (cavity) configuration, fabry-perot resonator or plane parallel cavity, confocal resonator, hemispherical cavity or combination of plane and spherical resonator, long radius cavity, stability criterion, examples (stable and unstable resonator) Pumping Source and Active Medium: What is pumping, pumping methods, optical pumping, electric pumping (direct discharge), electric pumping for semiconductor laser, chemical pumping, flash lamps, optical pumping configuration, optical pumping assembly, active mediums (atoms, molecules, liquids, dielectric solids, semiconductor material) Gas Lasers (theory, working, design and construction), Metal Vapor Lasers: Gas lasers, atomic lasers, ionic lasers, molecular lasers, basic concepts of discharge tube, Brewster angle cut discharge tube, electrical circuits for gas lasers, high voltage power supplies for gas lasers, He-Ne laser, design problems related to He-Ne laser, Argon Ion laser, Krypton Ion laser, CO2 (carbon dioxide) laser, N2 (nitrogen) laser, Excimer laser, He-Cd laser, Copper vapor laser, Gold vapor laser Chemical and Dye Lasers: Introduction to chemical laser, HF (hydrogen and fluoride) laser, Chemical Oxygen-Iodine laser (COIL), military applications of COIL, dye lasers, Rhoda mine dye laser

Solid State Lasers (concepts, working, design and construction): Introduction to solid state laser, Ruby laser, Nd:YAG laser, Nd:Glass laser, electronics for solid state laser, cooling system for solid state laser, cavity design and pumping concepts for solid state laser, brief overview to commercial Nd:YAG lasers, Ti:Sapphire laser, tunable solid state laser (Alexandrite laser) Semiconductor Laser, and Free-Electron Laser: Introduction to semiconductor laser, homojunction laser, heterojunction laser, semiconductor laser array, quantum well laser, vertical cavity surface emitting laser (VCSEL), brief introduction to free-electron laser Control of Laser Output (Q-switching and mode locking): Introduction to control of laser output beam, frequency selection, generation of high power pulses, Q-factor, Q-switching and giant pulses, methods of Q-switching, active Q-switching (mechanical Q-switching, acousto-optic Q-switching, electro-optic Q-switching), passive Q-switching (saturable absorber, cavity dumping), introduction to mode-locking,mode-locking techniques (active mode-locking, passive mode-locking), Q-switched Nd:YAG laser system Ultrafast Lasers: What is ultrafast laser, Ti:Sapphire laser, chirped pulse amplification (CPA) laser system, ultrafast laser systems, ultrafast diagnostics, mode-locked Ti:Sapphire laser system, basic concepts to Ti:Sapphire CPA laser system, ultrafast phenomenon, applications of ultrafast lasers Laser Applications: Industrial applications, material processing (laser drilling, laser cutting, laser welding), LIDAR (laser imaging detection and ranging), photolithography, medical applications (LASIK surgery, laser seizer), isotope separation using laser, Nuclear fusion, brief overview of major laser facility (NIF facility), laser holography, military applications.

Recommended Books:

1. K. J. Kuhn, "Laser Engineering", Prentice Hall, 1997.
2. O. Svelto, "Principles of Lasers", Springer, 5th ed. 2009.
3. W.. T. Silfvast, "Laser Fundamentals", Cambridge, 2nd ed. 2008.
4. K. R. Nambiar, "LASERS: Principles, Types and Applications", New Age, 2009.
5. W. Koecher, "Solid-State Laser Engineering", Springer, 2009.
6. R. F. Walter, "Gas Lasers (Optical Science and Engineering)", CRC Press, 2006.

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Phys-416 **INTRODUCTION TO PHOTONICS** **Credit Hours: 3**

Pre-requisites: Waves and Oscillations, Optics, Linear Algebra, Electronics-I

Objective(s): To study the application of light,

Studying the photonic devices including detectors

Contents: Guided Wave Optics: Planar slab waveguides, Rectangular channel waveguides, Single and multi-mode optical fibers, waveguide modes and field distributions, waveguide dispersion, pulse propagation

Gaussian Beam Propagation: ABCD matrices for transformation of Gaussian beams, applications to simple resonators Electromagnetic Propagation in Anisotropic Media: Reflection and transmission at anisotropic interfaces, Jones Calculus, retardation plates, polarizers Electro-optics and Acousto-optics: Linear electro-optic effect, Longitudinal and transverse modulators, amplitude and phase modulation, Mach-Zehnder modulators, Coupled mode theory, Optical coupling between waveguides, Directional couplers, Photoelastic effect, Acousto-optic interaction and Bragg diffraction, Acousto-optic modulators, deflectors and scanners Optoelectronics: p-n junctions, semiconductor devices: laser amplifiers, injection lasers, photoconductors, photodiodes, photodetector noise.

Recommended Books:

1. B. E. A. Saleh and M. C. Teich, "Fundamentals of Photonics", John Wiley, 2nd ed. 2007.
2. J-M. Liu, "Photonic Devices", Cambridge University Press, 2009.
3. A. Yariv and P. Yeh, "Photonics: Optical Electronics in Modern Communications", Oxford University Press, 2006.
4. E. Hecht, "Optics", Addison-Wesley, 4th ed. 2001.

Phys-417 INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGIE Credit Hours: 3

Pre-requisite: Solid State Physics-II, Quantum Mechanics-II

Objective(s): Introduce the concept and applications of nano sciences and nanotechnologies

Nano structures and nano technologies

Contents: Introduction: Feynman talks on small structures, Nano scale dimension, Course goals and objectives.

Quantum Effects: Wave particle duality, Energy quanta, Uncertainty principle, De Broglie relation, Quantum Dots, Moore's law, tunneling Surfaces and Interfaces: Interfaces, Surface chemistry and physics, Surface modification and characterization, Thin Films, Sputtering, Self-assembled films Material Properties: Subatomic physics to chemical systems, types of chemical bonds, solid state physics / Material properties Tools and Instrumentation: STM, AFM, Electron Microscopy, Fluorescence methods, Synchrotron Radiation Fabricating Nano Structures: Lithography (photo and electron beam), MBE, Self-assembled masked, FIB, Stamp technology, Nano junctions Electrons in Nano Structures: Variation in electronic properties, free electron model, Bloch's theorem, Band structure, Single electron transistor, Resonant tunneling Molecular Electronics: Lewis structures, Approach to calculate Molecular orbitals, Donor Acceptor properties, Electron transfer between molecules, Charge transport in weakly interacting molecular solids, Single molecule electronics Nano Materials: Quantum dots, nano wires, nano photonics, magnetic nano structures, nano thermal devices, Nano fluidic devices, biomimetic materials Nano Biotechnology: DNA micro-arrays, Protein and DNA Assembly, Digital cells, genetic circuits, DNA computing Nanotechnology the Road Ahead: Nanostructure innovation, Quantum Informatics, Energy solutions.

Recommended Books:

1. S. Lindsay, "Introduction to Nanoscience", Oxford University Press, 2009.
2. C. Binns, "Introduction to Nanoscience and Nanotechnology (Wiley Survival Guides in Engineering and Science)", Wiley, 2010.

Phys-418 **QUANTUM OPTICS** **Credit Hours: 3**

Pre-requisites: Electromagnetic Theory-I

Objectives: The main objective of this course is to understand the quantization of electromagnetic radiations and its interaction with matter.

Contents: Establishment of the quantum theory of electromagnetic radiation that includes the number state and coherent state representations, which is used to analyze the light-matter interactions. The light-matter interaction is essential to study ultra-cold matter, quantum sensing and quantum control. Basic Concepts: Introduction to electromagnetic (e.m.) radiation; energy contained by e.m. field; historical development of ideas of optics and photons Quantization of Electromagnetic field: Quantization of single mode; multimode and thermal fields; number states; field fluctuations; vacuum fluctuations and zero-point energy; coherent states; minimum uncertainty states Atom-Field Interaction: Absorption and emission of radiation by atoms; semi-classical and quantum mechanical treatment of atom-field interaction; beam splitters and interferometers Non-classical Properties of light: Non classical light with quadrature squeezing; amplitude squeezing; Photon anti-bunching; Schrodinger cat state; optical test of quantum mechanics viz. parametric down conversion of photons; Hong-Ou-Mandel interferometer; quantum erasers; superluminal tunneling of photons and local realistic theories Applications and Advanced topics: Bell's theorem; experiments in cavity QED and with trapped ions; optical control of atoms: quantum control.

Recommended Books:

1. C. Gerry and P. Knight, "Introductory Quantum Optics", Cambridge University Press (2005).
2. M. Fox, "Quantum Optics: an Introduction", Oxford University Press, (2005)

Phys-419 **RESEARCH METHODOLOGY** **Credit Hours: 3**

Course Objectives: To familiarize students with various methods used for conducting research and latest trends in the field of physics through reading and understanding scientific literature, preparing scientific manuscripts, designing research projects and presenting them.

Course Contents: Introduction; unethical academic practices (plagiarism); need of research and research types; extraction and review of literature; identifying a research problem and formulating a hypothesis; designing a study; data collection, interpretation and analysis; writing a research report, project, thesis and/or research article or review; preparing posters; making scientific presentations; intellectual property.

Recommended Books:

1. Bryman A, 2001. Social research methods. 2nd Edition; Oxford University Press.
2. Kumar R, Kindersley D, 2010. Research Methodology: A step by step guide for beginners. Third Edition; SAGE Publications.
3. Kothari CR, 2004. Research Methodology: Methods and Techniques. Second Revised Edition; New Age International Publishers, New Delhi.

Phys-420 ADVANCED EXPERIMENTAL TECHNIQUES Credit Hours: 3

Course Objectives: This course provides a detailed account of advanced experimental techniques in physics research. It introduces the working principles, operational knowledge, and the strength and limitations of the techniques and data analysis.

Contents: Fabrication processes, basic principle and working of lithography, types of lithography with detailed description, mechanism and process, Device fabrication process, characterization and limitations, Techniques for the electrical transport , types of electrical transport, Fabrication and characterization techniques for optoelectronic devices, Electrical transport through various structures and calculation of various parameters, Techniques for magnetic transport, types of magnetic transport, Magnetic transport through various structures and calculation of various parameters, Deposition techniques, Cryogenics and vacuum technology, Various spectroscopy techniques and their advantages, Raman spectroscopy, Scanning electron microscopy, Scanning probe microscopy, Impedance spectroscopy

Recommended Books:

1. Sulabha K. Kulkarni, Nanotechnology: Principles and Practices, 3rd Edition, 2014. (Springer).
2. Hong Xiao, Introduction to Semiconductor Technology, 2nd Edition, 2012. (SPIE).
3. Joseph I. Goldstein, Scanning Electron Microscopy and X-Ray Microanalysis, 4th Edition,2018. (Springer)
4. Raghu Murali, Graphene Nanoelectronics, from Materials to Circuits, 2012.

5. Michel Houssa, 2D Materials for Nanoelectronics, 2016. (CRC Press, Taylor & Francis)

Phys-421 INTRODUCTION DENSITY FUNCTIONAL THEORY Credit Hours: 03

Learning Outcomes: Account for the fundamental background of DFT. explain how electron correlation is defined and how it is approximated within DFT and compare these approximations to other correlated methods. explain the Hohenberg-Kohn theorems and their application.

Course Contents: Many-body problem, Hartree-Fock equations, Thomas Fermi Model, Density functional, Kohn-Sham Theorems, Kohn-Sham equations, Exchange and Correlation, Electron correlation, the Perdew-Burke-Ernzerhof functional (PBE),Local Density Approximation (LDA), Generalized Gradient approximation (GGA), Self-Interaction Correction (SIC), hybrid functionals (such as B3LYP), LAPW and FP-LAPW methods, Applications with Wien2K code.

Recommended Books:

1. HandBook.pdf: Density Functional Theory: Basics, New Trends, and Applications by J. Kohanoff and N.I. Gidopoulos (2003)
2. A Chemist Guide to Density Functional Theory by Wolfram Koch, Max C. Holthausen, Wiley-VCH, Second Edi (Pbk) (2001)
3. Lectures on Density Functional Theory by Andrei Postnikov; Free Science pdf.
4. ABC of DFT by Kieron Burke and friends; Free Science pdf (2007)

Phys-422 BIOPHYSICS Credit Hours: 3

Nature and scope of biophysics; Molecular Structure of Biological Systems; Chemical binding, energies and bonds; Energy transfer and transformation in photosynthesis and biological membranes; Dynamics of biological systems; Fundamental concepts of thermodynamics, aqueous and ionic equilibrium of living cells; Other biotransport processes; Long and short distance transports; Viscoelestic properties of biomaterials.

Books Recommended:

1. Radiation Biophysics by L.Alpen Edward, Academic Press, (1988).
2. Biophysics, An Introduction. John Wiley and Son, (2002).
3. Molecular Biophysics: Structures in Motion, Oxford University Press UK, (1999).
4. Biophysics by Glaser Rowland (2001). Springer Verlag, Berlin.
5. Biophysical Thermodynamics by T. Haynie Donald, Cambridge, University Press UK, (2001).

Phys-423 MATERIALS FOR GREEN ENERGY Credit Hours: 3

Contents: Energy resources, greenhouse gases and materials, Fossil energy and materials, Nuclear energy conversion and materials, Solar energy and materials, Bioenergy conversion and materials, Wind energy conversion and materials, Hydro, geothermal, ocean energy and materials, Fuel cells and materials, Mechanoelectric energy harvesting and materials, Thermoelectric energy conversion and materials, Energy storage and materials, Hydrogen storage and materials.

Recommended Books:

1. Lu, Kathy. Materials in Energy Conversion, Harvesting, and Storage. Hoboken, New Jersey: Wiley, 2014.

Annexure-B

Associate Degree Program in Physics

An Associate Degree program is structured to be comprised of four regular semesters over a period of two years and consists of 60-72 credit hours. After completion of the Associate Degree, the qualification holder will have the option of seeking admission in the fifth semester of a relevant undergraduate/equivalent degree program through exemption of courses already studied in the Associate Degree. The courses to be exempted in this case shall be decided by the admitting university on case to case basis. The breakup of credit hours is as under:

i. General Education: 30 credit hours
ii. Major: 30-42 credit hours
iii. Field experience/internship: (Only applicable where prescribed by the respective Accreditation Council, National Curriculum Review Committee or the concerned university.)

Field Experience/Internship: The field experience of six to eight weeks (preferably undertaken during semester or summer break) must be graded by a faculty member in collaboration with the supervisor in the field. This requirement of 03 credit hours is applicable only in cases where the same is prescribed by the respective Accreditation Council, National Curriculum Review Committee or the concerned university. Where this requirement is prescribed, the courses within the major will comprise of 30-39 credit hours.

Main Structure

S. No.	Categories	Requirement of HEC 2023 Policy (Credit Hours)	Number of Courses	Credit Hours
1	General Education Cluster	30	12	30
2	Major Courses + Laboratories	26+4	09+4	30

General Education Cluster	
Title	**Cr Hrs.**
1. Ideology and constitution of Pakistan *	**2**
2. Functional English*	**3**
3. Quantities Reasoning-I*	**3**
4. Quantities Reasoning-II*	**3**
5. Islamic Studies OR Ethics in lieu of Islamic studies for Non-Muslim only*	**2**
6. Expository Writing*	**3**
7. Natural Science*	**3**
8. Social Sciences	**2**
9. Arts and Humanities	**2**
10. Civic and Community Engagement	**2**
11. Applications of Information and Communication Technologies (ICT)*	**2+1**
12. Entrepreneurship*	**2**
Total	**30**

*HEC designed model courses may be used by the university

Major Courses		**Laboratories**	
Title	**Cr Hrs.**	**Title**	**Cr Hrs.**
1. Mechanics	**3**	**1.** Laboratory I	**1**
2. Rotational Dynamics	**3**	**2.** Laboratory III	**1**
3. Electricity and Magnetism	**3**	**3.** Laboratory III	**1**
4. Waves and Oscillations	**3**	**4.** Laboratory IV	**1**
5. Heat & Thermodynamics	**3**		
6. Modern Physics	**3**		
7. Optics	**3**		
8. Introduction to Astronomy	**3**		
9. Fluid Dynamics	**2**		
Total	**26**		**04**

Scheme of Study for Associate Degree in Physics

Semester-I				
Codes	**Title of the Courses**	**Cr. Hrs.**	**Marks**	**Remarks**
	Functional English	3	100	Gen Ed-I (English-I)
	Every day Science	3	100	Gen Ed-II
	Islamic Studies / Ethics	2	100	Gen Ed-III
	Calculus-I	3	100	Interdisciplinary / Allied Requirement
Phys 111	Mechanics	3	100	Major Course
Phys 112	Rotational Dynamics	3	100	Major Course
Phys 111L	Lab-I	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	
Semester-II				
Codes	**Title of the Courses**	**Cr Hrs.**	**Marks**	**Remarks**
	Expository Writing	3	100	Gen Ed-IV (English-II)
	Exploring Quantitative Skills	3	100	Gen Ed-V
	Introduction to Law	2	100	Gen Ed-VI
	Calculus-II	3	100	Interdisciplinary / Allied Requirement
Phys 121	Electricity and Magnetism	3	100	Major Course
Phys 122	Waves and Oscillations	3	100	Major Course
Phys 122L	Lab-II	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	
Semester-III				
	Title	**Cr Hrs**	**Marks**	**Remarks**
	Introduction to Economics/Political Science	2	100	Gen Ed-VII
	Ideology and Constitution of Pakistan	2	100	Gen Ed-VIII
	Civics and Community Engagement	2	100	Gen Ed-IX
	Entrepreneurship	2	100	Gen Ed-X
	Linear Algebra	3	100	Interdisciplinary / Allied Requirement
Phys 231	Heat and Thermodynamics	3	100	Major Course
Phys 232	Modern Physics	3	100	Major Course
Phys 233L	Lab-III	1	100	Major Course
	Semester's Credit Hours	**18**	**800**	
Semester-IV				
Codes	**Title of the Courses**	**Cr Hrs**	**Marks**	**Remarks**
	Tools for Quantitative Reasoning	3	100	Gen Ed-XI
	Introduction to Information and Communication Technology (ICT)	3	100	Gen Ed-XII
	Ordinary Differential Equations	3	100	Interdisciplinary / Allied Requirement
Phys 241	Optics	3	100	Major Course
Phys 242	Introduction to Astronomy	3	100	Major Course
Phys 243	Fluid Dynamics	2	100	Major Course
Phys 244L	Lab-IV	1	100	Major Course
	Semester's Credit Hours	**18**	**700**	

Pathway for Associate Degrees Holders in Physics

a) Students having completed Associate Degrees shall be allowed admission in the fifth semester of the undergraduate/equivalent degree program offered in the same discipline without any deficiency course.

b) Where the disciplines of the Associate Degree and the undergraduate/equivalent degree program are different, students shall be required to complete deficiency courses through a bridging semester before the fifth semester as determined by the admitting university.

c) The minimum eligibility for admission in the fifth semester in above cases is 2.00/4.00 CGPA in the prior qualification i.e., Associate Degree. The admitting university may, however, set higher eligibility criteria for admission in the fifth semester of the four-year undergraduate/equivalent degree program.

Pathway for Conventional Two-Year BSc/Equivalent Degree Holders to Physics

a) Students having completed conventional two-year BA/BSc/equivalent degree programs shall be allowed admission in the fifth semester of the undergraduate/equivalent degree program, in which case students shall be required to complete deficiency courses through a bridging semester before commencement of the fifth semester as determined by the admitting university.

b) The minimum eligibility for admission in the fifth semester in this case is 45% cumulative score in the prior qualification i.e., conventional two-year BA/BSc/equivalent degree programs. The admitting university may however set higher eligibility criteria for admission in the fifth semester of the undergraduate/equivalent degree program.

<u>Exiting from Undergraduate/Equivalent Degree Program with an Associate Degree Physics</u>

Students enrolled in the undergraduate/equivalent degree program shall be allowed to exit from the program with an Associate Degree provided that the following requirements are met:

a) The student must have completed minimum of 60 credit hours in at least four (04) semesters of the undergraduate/equivalent degree program including general education courses comprised of 30 credit hours;

b) The minimum CGPA is maintained at 2.00/4.00;

c) The name of the subject field on the degree shall remain the same in which a student was initially enrolled for the undergraduate/equivalent degree program;

d) The case of exit from the undergraduate/equivalent degree program with an Associate Degree is approved by the concerned statutory body of the university.

e) The option of exit in from the undergraduate/equivalent degree program with an Associate Degree is not allowed in disciplines accredited under the councils i.e. PM&DC, PNC, PVMC, PEC, PCP, PCATP, PBC, NTC, NCT, NAEAC and NCH.

f) The option of exit from the undergraduate/equivalent degree program with an Associate Degree is allowed in disciplines accredited under the councils i.e. NCEAC, NBEAC and NACTE.