DEPARTMENT OF PHYSICS

SCHEME OF STUDIES FOR BS PHYSICS.

Year	Semester	Course Code	Course Title	Cr.Hours
1st year	1st	PHY-311	Mechanics	4
		PHY-312	Lab-1	2
		PHY-313	English-I	2
		PHY-314	Calculus-1	3
		PHY-315	Introduction to Computing	3
		PHY-316	Chemistry-1	2+1
		PHY-317	(Islamic Studies)Islamiyat	2
			Total Credit Hours	19
	2nd	PHY-321	Electricity & Magnetism	4
		PHY-322	Lab-II	2
		PHY-323	English –II	2
		PHY-324	Calculus-II	3
		PHY-325	Pakistan Studies	2
		PHY-326	Chemistry-II	3
			Total Credit Hours	16
2nd year	3rd	PHY-431	Waves & Oscillations	3
		PHY-432	Heat & Thermodynamics	4
		PHY-433	Lab-III	2
		PHY-434	English-III	2
		PHY-435	Differential Equations	3
		PHY-436	Complex Variable, Infinite & Fourier series	3
			Total Credit Hours	17
	4th	PHY-441	Optics	3
		PHY-442	Modern Physics	4
		PHY-443	Lab-IV	2
		PHY-444	Linear Algebra	3
		PHY-445	Probability and Statistics	3
		PHY-446	Introduction to Computer Programming	2
			Total Credit Hours	17
3rd year	5th	PHY-551	Mathematical Methods of Physics-I	3
		PHY-552	Electromagnetic Theory-I	3

Year	Semester	Code	Course	Credit Hours
		PHY-553	**Classical Mechanics**	**3**
		PHY-554	**Basic Electronics**	**3**
		PHY-555	**Lab-V**	**2**
		PHY-556	**Social Psychology**	**3**
		Total Credit Hours		**17**
	6th	**PHY-561**	**Mathematical Methods of Physics-II**	**3**
		PHY-562	**Quantum Mechanics-I**	**3**
		PHY-563	**Electromagnetic Theory-II**	**3**
		PHY-564	**Statistical Physics**	**3**
		PHY-565	**Lab-VI**	**2**
		PHY-566	**Ethics**	**3**
		Total Credit Hours		**17**
4th year	**7th**	**PHY-671**	**Quantum Mechanics-II**	**3**
		PHY-672	**Atomic & Molecular Physics**	**3**
		PHY-673	**Solid State Physics-I**	**3**
		PHY-674	**Lab-VII**	**2**
		PHY-675	**Elective-I**	**3**
		PHY-676	**Project/thesis**	**3**
		Total Credit Hours		**17**
	8th	**PHY-681**	**Elective-II**	**3**
		PHY-682	**Elective-III**	**3**
		PHY-683	**Project/thesis**	**3**
		PHY-684	**Solid State Physics-II**	**3**
		PHY-685	**Nuclear Physics**	**3**
		Total Credit Hours		**15**
Total Credit Hours				**135**

RECOMMENDED COURSES FOR BS PHYSICS

Semester-I

PHY- 311 MECHANICS

Credit Hours: Four (4)

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

Basic Concepts: Units and Dimensions, SI Units, Inter-conversion of Units; Scalars and Vectors, Adding Vectors: Graphical as well as Component Method, Multiplying Vectors: Dot and Cross Products.

Motion in One, Two and Three Dimensions: Position & Displacement; Velocity and Acceleration; Motion under Constant Acceleration; Projectile Motion; Uniform Circular Motion; Relative Velocity and Acceleration in One and Two Dimensions; Inertial and Non-Inertial Reference Frames

Newton's Laws: Newton's Laws of Motion and their Applications Involving some Particular Forces including Weight; Normal Force; Tension; Friction; and Centripetal Force; Newton's Law of Gravitation; Gravitational Potential Energy; Escape Velocity; Kepler's Laws; Satellite Orbits & Energy

Work and Kinetic Energy: Work done by Constant and Variable Forces; Gravitational and Spring Forces; Power; Conservative and Non-conservative Forces; Work and Potential Energy; Isolated Systems and Conservation of Mechanical Energy; Work done by External Forces including Friction, Conservation of Energy

System of Particles: Motion of a System of Particles and Extended Rigid Bodies; Center of Mass and Newton's Laws for a System of Particles; Linear Momentum; Impulse; Momentum & Kinetic Energy in One and Two Dimensional Elastic and Inelastic Collisions

Rotational Motion: Rotation about a Fixed Axis; Angular Position; Angular Displacement; Angular Velocity and Angular Acceleration; Rotation under Constant Angular Acceleration; relationship between Linear and Angular Variables; Rotational Inertia; Parallel-axis Theorem; Torque and Newton's Law for Rotation; Work and Rotational Kinetic Energy; Power; Rolling Motion; Angular Momentum for a single Particle and a System of Particles; Conservation of Angular Momentum; Precession of a Gyroscope; Static Equilibrium involving Forces and Torques; Rotational inertia of various shapes i.e. for a disc, bar and solid sphere; Elasticity; Stress; Strain and Properties of Materials

Angular Momentum: Angular Velocity; Conservation of angular momentum; effect of Torque and its relation with angular momentum

Simple Harmonic Motion (SHM): Amplitude; Phase; Angular Frequency; Velocity and Acceleration in SHM; Linear and Angular Simple Harmonic Oscillators; Energy in SHM; Simple Pendulum; Physical Pendulum; SHM and Uniform Circular Motion.

Fluid Mechanics: Static Fluids and Pressure; Archimedes' Principle; Fluid Dynamics; Equation of Continuity and Bernoulli's Principle

Recommended Books:

1. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley & Sons, 9th ed. (2010).
2. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. (2010).
3. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed. (2010).
4. F. J Keller, W. E. Gettys and M. J. Skove, "Physics: Classical and Modern, McGraw Hill, 2nd ed. (1992).
5. D. C. Giancoli, "Physics for Scientists and Engineers, with Modern Physics", Addison-Wesley, 4th ed., (2008).

PHY- 312 Lab-I

Credit Hours: Two (2)

Mechanics and Fluids: 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 (over-damped, under-damped and critically damped), pressure in fluids, experiments demonstrating continuity, Bernoulli's principle, buoyancy and Archimedes's principle, Atwood machine, fluid viscosity, surface tension.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, “Experiments in Modern Physics”, Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-313 English I (Functional English)

Credit Hours: Two (2)

Objectives: Enhance language skills and develop critical thinking.

Course Contents

Basics of Grammar
Parts of speech and use of articles
Sentence structure, active and passive voice
Practice in unified sentence
Analysis of phrase, clause and sentence structure
Transitive and intransitive verbs
Punctuation and spelling

Comprehension

Answers to questions on a given text

Discussion

General topics and every-day conversation (topics for discussion to be at the discretion of the teacher keeping in view the level of students)

Listening

To be improved by showing documentaries/films carefully selected by subject teachers

Translation skills

Urdu to English

Paragraph writing

Topics to be chosen at the discretion of the teacher

Presentation skills

Introduction

Note: Extensive reading is required for vocabulary building

Recommended books:

1. **Functional English**

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 1. Third edition. Oxford University Press. 1997. ISBN 0194313492

2. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2. Third edition. Oxford University Press. 1997. ISBN 0194313506

b) Writing

1. Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 0 19 435405 7 Pages 20-27 and 35-41.

c) Reading/Comprehension

1. Reading. Upper Intermediate. Brain Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 453402 2.

d) Speaking

PHY-314 CALCULUS-I (Calculus for Functions of one variable)

Credit Hours: Three (3)

Functions and graphs (shifting and stretching), limits and continuity, differentiation (rates of change, slope of the tangent to a curve, rules for differentiation, chain rule, implicit differentiation, extrema of functions, mean value theorem, simple problems in optimization, use of derivatives in sketching, asymptotic behavior of functions, L'H'opital's rule), integration (indefinite integrals, introduction to the idea of differential equations and their solution – the initial value problem, techniques of integration, Riemann sums and definite integrals, physical interpretation as areas, mean value theorem, areas between curves, finding volumes by slicing, volumes of solids of revolution, arc lengths, areas of surfaces of revolution, centres of mass and higher moments, work), differentiation and integration of transcendental functions (exponential and logarithmic functions and applications to growth and decay problems, trigonometric and inverse trigonometric functions, hyperbolic functions), infinite series (limits of sequences of numbers, series, tests of convergence, power series, Taylor and Maclaurin series).

Recommended Books:

1. G. B. Thomas, R. L. Finney, "Calculus and Analytic Geometry", National Book Foundation, 9th ed. (1995)
2. G. Strang, "Calculus", Wellesley-Cambridge, 2nd ed., (2010).
3. E. W. Swokowski, M. Olinick, D. Pence, and J. A. Cole, "Calculus"; Pws Pub Co; 6th ed. (1994).

PHY- 315 INTRODUCTION TO COMPUTING
Credit Hours: Three (3)

Introduction and Evolution of Computing, Computer Systems and its Components, Computer Hardware and Software, Binary Numbers and Logic Operations, Developing a Web Page using HTML, Operating Systems, JavaScript Interactive forms and Event Handling, Word Processing and Desktop Publishing, Spreadsheets, Developing Presentations, Introduction to Algorithms, Software Development Methodologies, Design Heuristics, Web Design for Usability, Arrays, Computer Networks, Internet Services, Graphics, Images and Animations, Intelligence Systems in computing, Data Management, Database Software, Cyber Crime, Social Implications of Computing, The Future of Computing

Recommended Books

1. Charles S. Parker, Understanding Computers: Today and Tomorrow, Boston, Massachusetts 02210, USA (2009)
2. Jerry Lee Ford, Jr. Prima Tech, Learn JavaScript in a Weekend, 2nd Edition, Priemer Press, Boston (2004)

PHY-316 CHEMISTRY-I
Credit Hours: Three (3)

Introduction of Chemistry
The study of chemistry, matter, Mass and Weight, Atoms and Molecules, ions, Relative atomic mass and relative molecular mass, Empirical and molecular formula, Mole, Stoichiometric calculations, Limiting reactants and percentage yield of reactions.
Atomic Structure
Fundamental particles, Discovery of electron, Discovery of proton, Discovery of neutron, Model of atom, X-rays and atomic number, Dual nature of electron, Heisenberg's uncertainty principle, Quantum numbers, Shapes of orbital's, Electronic configuration.
States of Matter
Gases: Ideal gas laws, kinetic theory of gases, Collusion properties, real gases, Vander waals equation, The principle of corresponding state.
Liquid: Vapour pressure, measurements of vapour pressure, factors effecting the vapour pressure, Surface tension, measurements of Surface tension, factors effecting the surface tension, applications of surface tension, Viscosity, measurements of, Refractive index, Dipole moment.
Solids: Types of solid, Properties of crystalline solids, Crystal Lattice, Crystals and their classification, Investigation of structure (X-ray Diffraction, Bragg's law), Classification of solids.
Basic Concepts of Organic chemistry

Delocalized chemical bonding, Resonance, Hyper conjugation, Hydrogen bonding, Tautomerism, Inductive effect, Aromaticity.

PHY-317 ISLAMIC STUDIES

Credit Hours: Two (2)

Objectives:

This course is aimed at:

1. To provide Basic information about Islamic Studies
2. To enhance understanding of the students regarding Islamic Civilization
3. To improve Students skill to perform prayers and other worships
4. To enhance the skill of the students for understanding of issues related to faith and religious life.

Detail of Courses

Introduction to Quranic Studies

1) Basic Concepts of Quran
2) History of Quran
3) Uloom-ul -Quran

Study of Selected Text of Holly Quran

1) Verses of Surah Al-Baqra Related to Faith (Verse No-284-286)
2) Verses of Surah Al-Hujrat Related to Adab Al-Nabi (Verse No-1-18)
3) Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11)
4) Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77)
5) Verses of Surah Al-Inam Related to Ihram (Verse No-152-154)

Study of Sellected Text of Holly Quran

1) Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6, 21, 40, 56, 57, 58.)
2) Verses of Surah Al-Hashar (18, 19, 20) Related to thinking, Day of Judgment
3) Verses of Surah Al-Saf Related to Tafakar,Tadabar (Verse No-1,14)

Seerat of Holy Prophet (S.A.W) I

1) Life of Muhammad Bin Abdullah (Before Prophet Hood)
2) Life of Holy Prophet (S.A.W) in Makkah
3) Important Lessons derived from the life of Holy Prophet in Makkah

Seerat of Holy Prophet (S.A.W) II

1) Life of Holy Prophet (S.A.W) in Madina
2) Important Events of Life Holy Prophet in Madina
3) Important Lessons derived from the life of Holy Prophet in Madina

Introduction to Sunnah

1) Basic Concepts of Hadith
2) History of Hadith
3) Kinds of Hadith
4) Uloom –ul-Hadith
5) Sunnah & Hadith
6) Legal Position of Sunnah

Selected Study from Text of Hadith

Introduction to Islamic Law & Jurisprudence

1) Basic Concepts of Islamic Law & Jurisprudence
2) History & Importance of Islamic Law & Jurisprudence
3) Sources of Islamic Law & Jurisprudence
4) Nature of Differences in Islamic Law

5) Islam and Sectarianism

Islamic Culture & Civilization
1) Basic Concepts of Islamic Culture & Civilization
2) Historical Development of Islamic Culture & Civilization
3) Characteristics of Islamic Culture & Civilization
4) Islamic Culture & Civilization and Contemporary Issues

Islam & Science
1) Basic Concepts of Islam & Science
2) Contributions of Muslims in the Development of Science
3) Quranic & Science

Islamic Economic System
1) Basic Concepts of Islamic Economic System
2) Means of Distribution of wealth in Islamic Economics
3) Islamic Concept of Riba
4) Islamic Ways of Trade & Commerce

Political System of Islam
1) Basic Concepts of Islamic Political System
2) Islamic Concept of Sovereignty
3) Basic Institutions of Govt. in Islam

Islamic History
1) Period of Khlaft-E-Rashida
2) Period of Ummayyads
3) Period of Abbasids

Social System of Islam
1) Basic Concepts of Social System of Islam
2) Elements of Family
3) Ethical Values of Islam

Reference Books:

1. Hameed ullah Muhammad, "Emergence of Islam" , IRI, Islamabad
2. Hameed ullah Muhammad, "Muslim Conduct of State"
3. Hameed ullah Muhammad, 'Introduction to Islam
4. Mulana Muhammad Yousaf Islahi,"
5. Hussain Hamid Hassan, "An Introduction to the Study of Islamic Law" leaf Publication Islamabad, Pakistan.
6. Ahmad Hasan, "Principles of Islamic Jurisprudence" Islamic Research Institute, International Islamic University, Islamabad (1993)
7. Mir Waliullah, "Muslim Jrisprudence and the Quranic Law of Crimes" Islamic Book Service (1982)
8. H.S. Bhatia, "Studies in Islamic Law, Religion and Society" Deep & Deep Publications New Delhi (1989)
9. Dr. Muhammad Zia-ul-Haq, "Introduction to Al Sharia Al Islamia" Allama Iqbal Open University, Islamabad (2001)

Semester-II

PHY- 321 ELECTRICITY AND MAGNETISM

Pre-requisite: Mechanics
Credit Hours: Four (4)

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

Electrostatics: Electric Charge; Conductors and Insulators; Coulomb's Law; Electric Fields due to a Point Charge and an Electric Dipole; Electric Field due to Charge Distribution; Electric Dipole in an Electric Field; Electric Flux; Gauss' Law and its Applications in Planar; Spherical and Cylindrical Symmetry
Electric Potential: Equipotential Surfaces; Potential due to a Point Charge and a Group of Point Charges; Potential due to an Electric Dipole; Potential due to Charge Distribution; Relation between Electric Field and Electric Potential Energy
Capacitors and Capacitance: Parallel Plate; Cylindrical and Spherical capacitors; Capacitors in Series and Parallel; Energy Stored in an Electric Field; Dielectrics and Gauss' Law
DC Circuits: Electric Current and Current Density; Resistance and Resistivity; Ohm's Law; Power in Electric Circuits; Semiconductors and Superconductors; Work; Energy and EMF; Resistances in Series and Parallel; Single and Multi-loop Circuits; Kirchhoff's Rules; RC Circuits; Charging and Discharging of a Capacitor
Magnetic Field and Magnetic Force: Sources of Magnetic Field; Magnetic Force on a Moving Charge; Crossed Electric and Magnetic Fields and their Applications; Hall Effect; Magnetic Force on a Current Carrying Wire; Torque on a Current Loop; Magnetic Dipole Moment; Magnetic Field Due to a Current; Force between two Parallel Currents; Biot-Savart Law: Magnetic Field due to a Current, Long Straight Wire, Solenoids and Toroids, Ampere's Law; A Current-carrying Coil as a Magnetic Dipole; Inductance; Faraday's Law of Induction; Lenz's Law; Induction and Energy Transfer; Induced Electric Fields; Inductors and Inductance; Self Inductance; RL Circuits; Energy Stored in a Magnetic Field; Energy Density; Mutual Induction
Alternating Fields and Currents: LC Oscillations; Damped Oscillations in an RLC circuit; Alternating Currents; Forced Oscillations; Resistive, Capacitive, and Inductive Loads; RLC series Circuit; Power in AC Circuits; Transformers; Gauss' Law for Magnetism; Induced Magnetic Fields; Displacement Current; Spin & Orbital Magnetic Dipole Moment; Diamagnetism; Paramagnetism; Ferromagnetism and Hysteresis.

Recommended Text Books:

1. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley & Sons, 9th ed. (2010).
2. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed., (2010).
3. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed., (2010).
4. F. J Keller, W. E. Gettys and M. J. Skove, "Physics: Classical and Modern", McGraw Hill, 2nd ed., (1992).
5. D. C. Giancoli, "Physics for Scientists and Engineers, with Modern Physics", Addison-Wesley, 4th ed., (2008).

PHY- 322 Lab-II
Credit Hours: Two (2)

Electricity and Magnetism: 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.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, "Experiments in Modern Physics", Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, "An Introduction to Uncertainty in Measurement", Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).

6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-323 English II (Communication Skills)
Credit Hours: Two (2)

Objectives: Enable the students to meet their real life communication needs.

Course Contents

Paragraph writing
Practice in writing a good, unified and coherent paragraph
Essay writing
Introduction
CV and job application
Translation skills
Urdu to English
Study skills
Skimming and scanning, intensive and extensive, and speed reading, summary and précis writing and comprehension
Academic skills
Letter/memo writing, minutes of meetings, use of library and internet
Presentation skills
Personality development (emphasis on content, style and pronunciation)

Note: documentaries to be shown for discussion and review

Recommended books:

Communication Skills

a) Grammar

1. Practical English Grammar by A.J. Thomson and A.V. Martinet. Exercises 2. Third edition. Oxford University Press 1986. ISBN 0 19 431350 6.

b) Writing

2. Writing. Intermediate by Marie-Chrisitine Boutin, Suzanne Brinand and Francoise Grellet. Oxford Supplementary Skills. Fourth Impression 1993. ISBN 019 435405 7 Pages 45-53 (note taking).
3. Writing. Upper-Intermediate by Rob Nolasco. Oxford Supplementary Skills. Fourth Impression 1992. ISBN 0 19 435406 5 (particularly good for writing memos, introduction to presentations, descriptive and argumentative writing).

c) Reading

4. Reading. Advanced. Brian Tomlinson and Rod Ellis. Oxford Supplementary Skills. Third Impression 1991. ISBN 0 19 453403 0.
5. Reading and Study Skills by John Langan
6. Study Skills by Riachard Yorky.

PHY-324 CALCULUS-II (Calculus for Functions of Several Variables)
Credit Hours: Three (3)

Motivation and geometric background (conic sections, parametrized curves, polar coordinates, vectors and analytic geometry in space, examples of vector fields in space relevant to physics), partial derivatives (limits and continuity, partial derivatives, chain rule, role of constraints, directional derivatives – gradient vectors and tangent planes, extrema and saddle points, Lagrange multipliers, Taylor's expansion of a multi-variable function), multiple integrals (double and triple integrals, centres of mass and higher moments, areas and volumes, integration in spherical and cylindrical coordinate systems), calculus of vector fields with emphasis on physical interpretation (line integrals and work, circulation and curl, conservative fields and gradients, surface and volume integrals, divergence of a vector field, Green's theorem in a plane, Stoke's theorem, divergence theorem).

Recommended Books:

4. G. B. Thomas, R. L. Finney, "Calculus and Analytic Geometry", National Book Foundation, 9th ed. (1995)
5. G. Strang, "Calculus", Wellesley-Cambridge, 2nd ed., (2010).

6. E. W. Swokowski, M. Olinick, D. Pence, and J. A. Cole, “Calculus”; Pws Pub Co; 6th ed. (1994).

PHY-325 Pakistan Studies
Credit Hours: Two (2)

Introduction/Objectives

- Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan.
- Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Outline

1. **Historical Perspective**

    a. Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-i-Azam Muhammad Ali Jinnah.

    b. Factors leading to Muslim separatism

    c. People and Land

    i. Indus Civilization

    ii. Muslim advent

    iii. Location and geo-physical features.

2. **Government and Politics in Pakistan**

    Political and constitutional phases:

    a. 1947-58

    b. 1958-71

    c. 1971-77

    d. 1977-88

    e. 1988-99

    f. 1999 onward

3. **Contemporary Pakistan**

    a. Economic institutions and issues
    b. Society and social structure
    c. Ethnicity
    d. Foreign policy of Pakistan and challenges
    e. Futuristic outlook of Pakistan

Recommended Books:

1. Burki, Shahid Javed. *State & Society in Pakistan,* The Macmillan Press Ltd 1980.
2. Akbar, S. Zaidi. *Issue in Pakistan’s Economy.* Karachi: Oxford University Press, 2000.
3. S.M. Burke and Lawrence Ziring. Pakistan’s Foreign policy: An Historical analysis. Karachi: Oxford University Press, 1993.
4. Mehmood, Safdar. *Pakistan Political Roots & Development.* Lahore, 1994.
5. Wilcox, Wayne.*The Emergence of Banglades.,* Washington: American Enterprise, Institute of Public Policy Research, 1972.

6. Mehmood, Safdar. *Pakistan Kayyun Toota,* Lahore: Idara-e-Saqafat-e-Islamia, Club Road, nd.
7. Amin, Tahir. *Ethno - National Movement in Pakistan,* Islamabad: Institute of Policy Studies, Islamabad.
8. Ziring, Lawrence. *Enigma of Political Development.* Kent England: WmDawson & sons Ltd, 1980.
9. Zahid, Ansar. *History & Culture of Sindh.* Karachi: Royal Book Company, 1980.
10. Afzal, M. Rafique. *Political Parties in Pakistan,* Vol. I, II & III. Islamabad: National Institute of Historical and cultural Research, 1998.
11. Sayeed, Khalid Bin. *The Political System of Pakistan.* Boston: Houghton Mifflin, 1967.
12. Aziz, K.K. *Party, Politics in Pakistan*, Islamabad: National Commission on Historical and Cultural Research, 1976.
13. Muhammad Waseem, Pakistan Under Martial Law, Lahore: Vanguard, 1987.
14. Haq, Noor ul. *Making of Pakistan: The Military Perspective.* Islamabad: National Commission on Historical and Cultural Research, 1993.

PHY-326 CHEMISTRY-II
Credit Hours: Three (3)

Periodic Table
Development of periodic table, Classification of elements based on s,p,d and f orbitals, general group trends.
Solution
Introduction of solution, concentration units of solution, Molarity, Normality, molality, Mole fraction, Types of solution, Azeotropic mixture, solubility, Colligative properties, Hydration and hydrolysis, Solutions of gases in liquids, Solutions of liquidsin liquids.
Introduction of Hydrocarbons
Isomerism, nomenclature and properties of

i. Alkanes
ii. Alkenes and Alkynes
iii. Arenes

Kinetics
Rate of a reaction, rate constant, molecularity of a reaction, order of reaction, Zero order of reaction, First order of reaction, Second order of reaction, Third order of reaction, Methods for the determination of order of reaction, Effect of temperature on reaction rates, Energy of activation.

Semester-III

PHY- 431 WAVES AND OSCILLATIONS

Pre-requisites: Mechanics, Calculus II
Credit Hours: Three (3)
Objective(s): To develop a unified mathematical theory of oscillations and waves in physical systems

Simple and Damped Harmonic Oscillation: Mass-Spring System; Simple Harmonic Oscillator Equation; Complex Number Notation; LC Circuit; Simple Pendulum; Quality Factor; LCR Circuit
Forced Damped Harmonic Oscillation: Steady-State Behavior; Driven LCR Circuit; Transient Oscillator Response; Resonance
Coupled Oscillations: Two Spring-Coupled Masses; Two Coupled LC Circuits; Three Spring Coupled Masses; Normal Modes; Atomic and Lattice Vibrations
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
Travelling Waves: Standing Waves in a Finite Continuous Medium; Traveling Waves in an Infinite Continuous Medium; Energy Conservation; Transmission Lines; Reflection and Transmission at Boundaries
Wave Pulses: Fourier Series and Fourier Transforms; Wave-Packets and Bandwidth

Multi-Dimensional Waves: Plane Waves; Three-Dimensional Wave Equation; Electromagnetic waves; Laws of Geometric Optics; Waveguides; Cylindrical Waves
Interference and Diffraction of Waves: Double-Slit Interference; Single-Slit and Double-slit Diffraction.

Recommended Books:

1. J. Pain, "The Physics of Vibrations and Waves", John Wiley, 6^{th} ed., (2005).
2. A. P. French, "Vibrations and Waves", CBS Publishers, 2003.
3. F. S. Crawford, Jr., "Waves and Oscillations", Berkeley Physics Course, Vol. 3, McGraw-Hill, (1968).
4. A. Hirose, and K .E. Lonngren, "Introduction to Wave Phenomena", Krieger Publications, (2003).

PHY- 432 HEAT AND THERMODYNAMICS

Pre-requisites: Mechanics
Credit Hours: Four (4)
Objective(s): To understand the fundamentals of heat and thermodynamics

Heat and Temperature: Heat and Work; Unit of work; Work Done at the Moving Boundary of a Simple Compressible System; Heat Transfer Mechanisms; Thermometers; Temperature and the Statistical definition of Temperature; Kinetic theory of Ideal gas; Work done on an Ideal gas; Internal energy of an Ideal gas; Equipartition of Energy; Intermolecular forces; The Virial expansion; The Van der Waals equation of state.
Basic Concepts of Thermodynamics: Thermodynamic Systems; Surrounding and Boundaries; Type of Systems; Macroscopic and Microscopic description of System; Properties and State of the substance; Extensive and Intensive variables; Equilibrium, Mechanical and Thermal Equilibrium; Processes and Cycles (Isothermal, Isobaric Isochoric and adiabatic); Zeroth Law of Thermodynamics; Consequence of Zeroth law of Thermodynamics; Criteria of thermo-dynamical equilibrium.
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 potentials; Maxwell's relations; TdS equations, Energy equations and their applications; Intrinsic and mutual stabilities of single component system; Conditions of stabilities; The Lech-atelier Braun Principle; First order Phase transition; Discontinuities of Volume and Entropy; Second Order Phase Transition; Low Temperature Physics; Joule-Thomson effect and its equations; Thermoelectricity; Thermocouple, Seebeck'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 Langevin equation,

Recommended Books:

1. M. W. Zemansky, "Heat and Thermodynamics", Mc Graw Hill, 7^{th} ed. (1997).
2. M. Sprackling, "Thermal Physics" McMillan (1991).
3. B. N. Roy, "Principle of Modern Thermodynamics", Institute of Physics, London (1995).
4. D. Halliday, R. Resnick and K. Krane, "Physics", John Wiley, 5^{th} ed. (2002).
5. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley, 9^{th} ed. (2010).

PHY-433 Lab-III
Credit Hours: Two (2)

Heat: Calorimetry, heat transfer, Newton's cooling under ambient and forced convection and radiation, measurement of temperature using Si diodes, thermistors, thermocouples and RTD's, black bodies, 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 proportional-integral-derivative (PID) schemes, thermal expansion and its measurement using strain gauges.

Waves and Oscillations, Sound: Resonance in a stretched string, normal modes of oscillation, dispersion relations for mono- and di-atomic lattices, 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 of harmonic motion (Lissajous patterns), sonometer.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, "Experiments in Modern Physics", Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, "An Introduction to Uncertainty in Measurement", Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-434 English III (Technical Writing and Presentation Skills)
Credit Hours: Two (2)

Objectives: Enhance language skills and develop critical thinking
Course Contents

Presentation skills
Essay writing
Descriptive, narrative, discursive, argumentative
Academic writing
How to write a proposal for research paper/term paper
How to write a research paper/term paper (emphasis on style, content, language, form, clarity, consistency)
Technical Report writing
Progress report writing

Note: Extensive reading is required for vocabulary building

Recommended books:

Technical Writing and Presentation Skills
a) Essay Writing and Academic Writing

1. Writing. Advanced by Ron White. Oxford Supplementary Skills. Third Impression 1992. ISBN 0 19 435407 3 (particularly suitable for discursive, descriptive, argumentative and report writing).
2. College Writing Skills by John Langan. Mc=Graw-Hill Higher Education. 2004.
3. Patterns of College Writing (4th edition) by Laurie G. Kirszner and Stephen R. Mandell. St. Martin's Press.

b) Presentation Skills
c) Reading

The Mercury Reader. A Custom Publication. Compiled by norther Illinois University. General Editiors: Janice Neulib; Kathleen Shine Cain; Stephen Ruffus and Maurice Scharton. (A reader which will give students exposure to the best of twentieth century literature, without taxing the taste of engineering students).

PHY-435 DIFFERENTIAL EQUATIONS
Credit Hours: Three (3)

Introduction to ODEs (physical motivation), First order ODEs (separable variables, homogeneous equations, exact equations, linear equations, Bernoulli equation and other examples), applications of first order ODEs – linear and non-linear, linear differential equations of higher order (initial value and boundary value problems, linear dependence and independence, solutions of linear equations, constructing a second solution from a known solution, homogeneous linear equations with constant coefficients, undetermined coefficients, variation of parameters), applications of second order ODEs (simple harmonic motion, damped and forced oscillators, electrical circuits and springs), differential equations with variable coefficients (Cauchy-Euler equation, power series solution of differential equations – solutions about ordinary and singular points-Legendre's and Bessel's equations as examples), Laplace transform (Laplace transform and its inverse and properties, use in solving differential equations, Dirac delta function).

Recommended Books:

1. D. G. Zill and M. R. Cullen, "Differential Equations with Boundary Value Problems", 3rd ed. National Book Foundation. (2008)
2. E. Kreyszig, "Advanced Engineering Mathematics", John Wiley, 8th ed. (1999).
3. K. F. Riley, M. P. Hobson and S. J. Bence, "Mathematical Methods for Physicists", Cambridge University Press (2006).

PHY- 436 COMPLEX VARIABLE, INFINITE & FOURIER SERIES
Credit Hours: Three (3)

Complex Variables: Complex numbers, De Moivre's theorem and its applications. Exponential, logarithmic, trigonometric, and hyperbolic functions of a complex variable. Separation of complex valued functions into real and imaginary parts of complex expressions.

Infinite Series: Sequences, infinite series and their convergence. Comparison, quotient, ratio and integral tests of convergence (without proof). Absolute and conditional convergence.

Fourier series: Fourier series. Fourier Sine and Cosine Series.

Recommended Books:

1. Ervin Kreyszig, Advanced Engineering Mathematics (latest edition), John Wiley and Sons.
2. S.M.Yusuf Mathematical Methods 1996, Ilmi Kitab Khana Kabir Street, Urdu Bazar, Lahore.
3. Karamat H. Dar,Irfan ul Haq and M. Ashraf Jagga, Mathematical Techniques. 3rd edition 1998, The Caravan Book House, Lahore.

Semester-IV

PHY- 441 OPTICS

Pre-Requisites: Waves and Oscillations
Credit Hours: Three (3)
Objective(s): To understand optical phenomena and their uses in physical systems

Propagation of Light & Image Formation: Huygens' Principle; Fermat's Principle; Laws of Reflection and Refraction; Refraction at a Spherical Surface, Thin Lenses; Newtonian Equation for a Thin Lens
Matrix Methods in Paraxial Optics: 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-Pérot Interferometers; Resolving Power; Free-Spectral Range
Polarization: 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; Multilayered 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).

PHY- 442 MODERN PHYSICS

Pre-requisites: Mechanics, Electricity and Magnetism
Credit Hours: Four (4)
Objective(s): To understand the non-classical aspects of Physics, applications of Quantum Physics in micro-scale, atomic and molecular structure and processes

Contents: Introduction to Relativity; Particle properties of waves; Wave properties of particles; Wave-Particle duality; Atomic Structure; Introduction to Quantum mechanics; Quantum Theory of Hydrogen Atom; Many Electron Atoms; Molecules

Recommended Books:
1. A. Beiser, “Concepts of Modern Physics”, McGraw-Hill, 6th ed. (2002).
2. P. A. Tipler and Ralph A. Llewellyn, “Modern Physics”, W H Freeman and Company 6th ed. (2012).
3. R. A. Serway, C.J. Moses and C.A. Moyer, “Modern Physics”, Brooks Cole, 3rd ed. (2004).
4. R. M. Eisberg and R. Resnick, “Quantum Physics of Atoms, molecules, Solids, Nuclei and Particles”, John Wiley, 2nd ed. (2002).

PHY-443 Lab-IV
Credit Hours: Two (2)

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.
Recommended Books:
1. A. C. Melissinos and J. Napolitano, “Experiments in Modern Physics”, Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-444 LINEAR ALGEBRA
Credit Hours: Three (3)

Review of vectors in 3 dimensions [(arrows) with a view of abstraction into properties of vector spaces in N dimensions (closure, associativity and commutativity of addition, existence of identity and inverse, distributivity of scalar multiplication), idea of vector norm in 3 dimensions, orthogonality, expansion in a basis, multiplication of vectors in 3 dimensions, applications of vector algebra to geometry and physics], vector spaces in N dimensions (definition, basis, inner product), linear operators, matrices (matrix algebra, functions of matrices, transpose, complex and Hermitian conjugates, trace, determinant, inverse, rank, special types of matrices – diagonal, triangular, symmetric and antisymmetric, orthogonal, Hermitian and anti-Hermitian, unitary, normal, eigenvalue problem, similarity transformations and change of basis, diagonalisation, simultaneous linear equations), normal modes (oscillatory systems, elementary use of symmetries to guess normal modes, Rayleigh-Ritz method), Fourier series as an application of the ideas of linear algebra to the space of periodic functions (identification of the space of periodic functions of a certain period as a linear vector space, identification of sinusoidal functions as basis vectors in this infinite dimensional vector space, properties of Fourier series, Parseval's theorem, handling of non-Periodic functions via extending the domain of definition of function), sets of functions, eigenvalue problem in the context of differential operators, adjoint and Hermitian operators, properties of Hermitian operators (reality of eigenvalues, orthogonality of eigenfunctions, completeness of eigenfunctions - eigenbasis), Sturm-Lioville equations (Hermitian nature of Sturm-Lioville operator, transforming an equation into Sturm-Lioville form, Fourier-Legendre and Fourier-Bessel series).

Recommended Books:

1. K. F. Riley, M. P. Hobson and S. J. Bence, "Mathematical Methods for Physicists", Cambridge University Press (2006).
2. P. V. O'Neil, "Advanced Engineering Mathematics", 7th ed. CL Engineering, (2011).

PHY-445 PROBABILITY AND STATISTICS
Credit Hours: Three (3)

Course Outline:
Set theory, basic concepts of probability, conditional probability, independent events, Baye's formula, discrete and continuous random variables, distributions and density functions, probability distributions (binomial, Poisson, hyper geometric, normal, uniform and exponential), mean, variance, standard deviations, moments and moment generating functions, linear regression and curve fitting, limits theorems, stochastic processes, first and second order characteristics, applications.

Recommended Books:

- Susan Milton and Jesse C Arnold, "Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences," Fourth Edition, 2003, McGraw-Hill, ISBN: 007246836.
- William Mendenhall and Terry Sincich, "Statistics for Engineers and the Sciences," Fifth Edition, 2007, Prentice Hall, ISBN10: 0131877062.

PHY-446 INTRODUCTION TO COMPUTER PROGRAMMING

Pre-requisite: Introduction to computing
Credit Hours: Three (3)
Objectives: the main objective of this course are to introduce the students with basic programming skills related to their own computing problems, processing of data and calculation of various parameters. This intern will enable students to save their time by using ad developing computer software instead of manual calculations.

Course Outlines:
Programming and problem analysis. Development of basic algorithms. Translation of algorithms into programs. Standard Data Types. Basic control structures. Functions. Structured data types; Arrays, Structures, Pointers and Files. Debugging and testing programs.

Recommended Books:

1. Robert Lafore, C Programming Using Turbo C++, Sams, 1997.
2. Deitel & Deitel, C How to Program, 3rd Edition, Prentice Hall, 2000.
3. Aho, AV, Ulman JD, Foundation of Computer Science, 1995, Computer Science Press, WH Freeman, New York
4. Hein JL, Theory of Computation: An Introduction (1st edition), Jones & Bartlett, Boston

Semester-V

PHY- 551 MATHEMATICAL METHODS OF PHYSICS-I

Pre-requisite: Differential Equations
Credit Hours: Three (3)
Objectives: To give an understanding of the Partial Differential equations and their uses in Physics; Introduction to Special Functions; Complex Functions and their Applications.

Special Functions: Bessel Functions; Neumann Functions; Henkel Functions; Spherical Bessel Functions; Legendre Functions; Associated Legendre Functions; Spherical Harmonics; Hermite Polynomials.
Partial Differential Equations (PDEs): Introduction to Important PDEs in Physics (Wave Equation; Diffusion Equation; Poisson's Equation; Schrodinger's Equation); General form of Solution; General and Particular Solutions (First Order; Inhomogeneous; Second Order); Characteristics and Existence of Solutions; Uniqueness of Solutions; Separation of Variables in Cartesian Coordinates; Superposition of Separated Solutions; Separation of Variables in Curvilinear Coordinates; Special Functions; Integral Transform Methods; Green's Functions.
Complex Analysis: Review (Polar form of Complex Numbers and De Moivre's Theorem; Complex Logarithms and Powers); Functions of a Complex Variable; Cauchy-Riemann Conditions; Power Series in a Complex Variable and Analytic Continuation with Examples; Multi-valued Functions and Branch Cuts; Singularities and Zeroes of Complex Functions; Complex Integration; Cauchy's Theorem; Cauchy's Integral Formula; Laurent Series and Residues; Residue Integration Theorem; Definite Integrals using Contour Integration.

Recommended Books:

1. G. Arfken, H. J. Weber, and F. E. Harris, "Mathematical Methods for Physicists", Academic Press, 7th ed. (2012).
2. K. F. Riley, M. P. Hobson, S. J. Bence, "Mathematical Methods for Physicists", Cambridge University Press, (2006).
3. E. Kreyszig, "Advanced Engineering Mathematics", John Wiley, 8th ed. (1999).

PHY-552 ELECTROMAGNETIC THEORY-I

Pre-requisites: Electricity and Magnetism, Calculus-II
Credit Hours: Three (3)
Objectives: To give an understanding of the basic electromagnetic theory

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

Magnetostatics: The Lorentz Force law: magnetic fields, magnetic forces, currents. The Biot-Savart Law: steady currents, the magnetic field of a steady current. The divergence and curl of B: straight-line currents, applications of Ampere's law, comparison of magnetostatics and electrostatics. Magnetic Vector Potential: the vector potential, summary, magnetic boundary conditions, multipole expansion of the vector potential

Magnetic Fields in Matter: Magnetization, diamagnets, paramagnets, ferromagnets, torques and forces on magnetic dipoles, effect of a magnetic field on atomic orbits. The Field of a Magnetized Object: bound currents, physical interpretation of bound currents, and the magnetic field inside matter. The auxiliary field H: Ampere's law in magnetized materials, a deceptive parallel, boundary conditions. Linear and nonlinear media: magnetic susceptibility and permeability, ferromagnetism.

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).

PHY-553 CLASSICAL MECHANICS

Credit Hours: Three (3)

Objectives: To give a basic understanding of the classical mechanics concepts

Introduction: Space and Time, Newton's Laws, The Concepts of Mass and Force, External Forces

Linear Motion: Conservative Forces; Conservation of Energy, Motion near Equilibrium; the Harmonic Oscillator, Complex Representation, The Law of Conservation of Energy, The Damped Oscillator, Oscillator under Simple Periodic Force, General Periodic Force, Impulsive Forces; the Green's Function Method, Collision Problems

Energy and Angular Momentum: Energy; Conservative Forces, Projectiles, Moments; Angular Momentum, Central Forces; Conservation of Angular Momentum, Polar Co-ordinates, The Calculus of Variations, Hamilton's Principle; Lagrange's Equations

Central Conservative Forces: The Isotropic Harmonic Oscillator, The Conservation Laws, The Inverse Square Law, Orbits, Scattering Cross-sections, Mean Free Path, Rutherford Scattering

Rotating Frames: Angular Velocity; Rate of Change of a Vector, Particle in a Uniform Magnetic Field, Acceleration; Apparent Gravity, Coriolis Force, Larmor Effect, Angular Momentum and the Larmor Effect

Potential Theory: Gravitational and Electrostatic Potentials, The Dipole and Quadrupole, Spherical Charge Distributions, Expansion of Potential at Large Distances, The Shape of the Earth, The Tides, The Field Equations.

The Two-Body Problem: Centre-of-mass and Relative Co-ordinates, The Centre-of-mass Frame, Elastic Collisions, CM and Lab Cross-sections

Many-Body Systems: Momentum; Centre-of-mass Motion, Angular Momentum; Central Internal Forces, The Earth–Moon System, Energy; Conservative Forces, Lagrange's Equations

Rigid Bodies: Basic Principles, Rotation about an Axis, Perpendicular Components of Angular Momentum, Principal Axes of Inertia, Calculation of Moment of Inertia, Effect of a Small Force on the Axis, Instantaneous Angular Velocity, Rotation about a Principal Axis, Euler's Angles

Lagrangian Mechanics: Generalized Co-ordinates; Holonomic Systems, Lagrange's Equations, Precession of a Symmetric Top, Pendulum Constrained to Rotate about an Axis, Charged Particle in an Electromagnetic Field, The Stretched String, Small Oscillations and Normal Modes, Orthogonal Co-ordinates, Equations of Motion for Small Oscillations, Normal Modes, Coupled Oscillators, Oscillations of Particles on a String, Normal Modes of a Stretched String

Hamiltonian Mechanics: Hamilton's Equations, Conservation of Energy, Ignorable Co-ordinates, General Motion of the Symmetric Top, Liouville's Theorem, Symmetries and Conservation Laws, Galilean Transformations

Recommended Books:

1. T. Kibble and F. Berkshire, "Classical Mechanics", World Scientific, 5th ed. (2004).
2. T. L. Chow, "Classical Mechanics", John Wiley, (1995).
3. S.T. Thornton, J.B. Marion, "Classical Dynamics of Particles and Systems", Brooks Cole; 5th ed. (2003).

PHY- 554 BASIC ELECTRONICS

Pre-requisite: Modern Physics

Credit Hours: Three (3)
Objectives: To give an understanding of the basic electronics

The semiconductor Diode: Conductors, Insulators, and semiconductors; Silicon Crystal and Energy Band; 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 and real diode models; The half wave rectifier; The Transformer; 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; Diode wave clippers; Diode clampers.
Circuit Theory and Analysis: Basic circuit concepts; Superposition theorem; Thevenin’s Theorem; Norton’s Theorem; Model for circuit; one-port and two-port networks; 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: 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. J.D. Ryder, “Electronic Circuits and Systems”, Prentice Hall (1976).
2. Thomas L. Floyd, “Electronics Fundamentals: Circuits, Devices and Applications”, Prentice Hall, 8th ed. (2009).
3. Theodore F. Bogart, “Electric Circuits”, McGraw Hill, (1992)
4. B. Grob, “Basic Electronics”, MacGraw Hill, Tch ed. (1997).
5. A. P. Malvino, “Electronic Principles”, McGraw Hill, 7th ed. (2006).
6. R. T. Paynter, “Introductory Electric Circuits”, Prentice Hall, (1998)

PHY-555 Lab-V
Credit Hours: Two (2)

Electronics: DC voltages and current measurement, simple DC circuits, generating and analyzing time-varying signals, op-amps 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.
Recommended Books:

1. A. C. Melissinos and J. Napolitano, “Experiments in Modern Physics”, Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-556 SOCIAL PSYCHOLOGY
Credit Hours: Three (3)
Objective(s): To develop a basic understanding of the field of social psychology and develop an understanding of major theories of social interaction.
Course contents

Concepts of Self, Judging Ourselves and Others, The Relationship Between Attitudes and Behavior, Influences of Nature and Nurture, Conformity and Obedience, Persuasion, The Effects of Being with Others, Prejudice, Aggression, Liking and Loving, Helping Others, Getting Along With Others, Psychology and the Law

Recommended Books

1. Alcock, J. E., Carment, D. W., & Sadava, S. W. (2005). *A Textbook of Social Psychology* (6th ed). Scarborough, Ontario: Prentice-Hall Canada
2. Aronson, E., Wilson, T. D., & Akert, R. M. (2010). *Social Psychology* (7th ed.). Upper Saddle River, NJ: Prentice Hall.
3. Baron, R. A., Branscombe, N. R., & Byrne, D. (2009). *Social Psychology* (12th ed.). Boston, MA: Pearson/Allyn and Bacon.
4. Baumeister, R. F., & Bushman, B. J. (2010). *Social Psychology and Human Nature* (2nd ed.). Belmont, CA: Thomson/Wadsworth.

Semester-VI

PHY-561 MATHEMATICAL METHODS OF PHYSICS-II

Pre-requisite: Mathematical Methods of Physics-I
Credit Hours: Three (3)
Objective(s): To give the understanding of Differential equations and their uses in Physics, Introduction to special functions, Fourier Series, Fourier Transforms, Solution of Boundary value problems and their uses.

Fourier Series and Integral Transforms: Definition and general properties, Fourier Series of Various Physical Functions, Uses and Applications of Fourier Series, Fourier Transforms, Convolution Theorems, Laplace transforms and applications.

Tensor Analysis: Vector calculus (differentiation, integration, space curves, multi-variable vectors, surfaces, scalar and vector fields, gradient, divergence and curl, cylindrical and spherical coordinates, general curvilinear coordinates), change of basis, Cartesian tensor as a geometrical object, order/rank of a tensor, tensor algebra, quotient law, pseudo-tensors, Kronecker delta and Levi-cevita, dual tensors, physical applications, integral theorems for tensors, non-Cartesian tensors, general coordinate transformations and tensors.

Group Theory and Representations for finite groups: Transformations, groups– definitions and examples, subgroups and Cayley’s theorem, cosets and Lagrange’s theorem, conjugate classes, invariant subgroups, factor groups, homomorphism, direct products, mappings, linear operators, matrix representations, similarity transformation and equivalent matrix representations, group representations, equivalent representations and characters, construction of representations and addition of representations, invariance of functions and operators, unitary spaces and Hermitian matrices, operators: adjoint, self-adjoint, unitary, Hilbert space, reducibility of representations, Schur’s lemmas, orthogonality relations, group algebra, expansion of functions in basis of irreducible representations, Kronecker product, symmetrized and anti-symmetrized representations, adjoint and complex-conjugate representations, real representations.

Recommended Books:

1. G. Arfken, H. J. Weber, and F. E. Harris, “Mathematical Methods for Physicists”, Academic Press, 7^{th} ed. (2012).
2. E. Kreyszig, “Advanced Engineering Mathematics”, John Wiley, 8^{th} ed. (1999).
3. M. b and its Applications to Physical Problems”, Dover Publications (1989).

PHY- 562 QUANTUM MECHANICS-I

Pre-requisites: Modern Physics
Credit Hours: Three (4)
Objectives: To give a basic understanding of the quantum mechanics

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 observables, *Q* and *P*, whose commutator is equal to $i\hbar$, 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, Gauge 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 of quantum mechanics 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, Eigen values and Eigen states 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 Eigen values 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, 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).

PHY- 563 ELECTROMAGNETIC THEORY-II

Pre-requisites: Electromagnetic Theory-I
Credit Hours: Three (3)
Objective(s): This course is the second part of the core level undergraduate course on Electromagnetic Theory and a previous knowledge of Electromagnetic Theory I is expected.

Electrodynamics: Electromotive force (emf): Ohm's law, electromotive force, motional emf, electromagnetic induction: Faraday's law, the induced electric field, inductance, energy in magnetic fields, Maxwell's equations: electrodynamics before Maxwell, how Maxwell fixed Ampere's law, Maxwell's equations, magnetic charges, Maxwell's equations in matter, boundary conditions

Conservation Laws: Charge and energy: the continuity equation, Poynting's theorem, momentum: Newton's third law in electrodynamics, Maxwell's stress tensor, conservation of momentum, angular momentum
Electromagnetic Waves: Waves in one dimension: the wave equation, sinusoidal waves, boundary conditions, reflection and transmission, polarization, electromagnetic waves in vacuum: the wave equation for E and B, monochromatic plane waves, energy and momentum in electromagnetic waves, electromagnetic waves in matter: propagation in linear media, reflection and transmission at normal incidence, reflection and transmission at oblique incidence, absorption and dispersion: electromagnetic waves in conductors, reflection at a conducting surface, the frequency dependence of permittivity, guided waves: wave guides, the waves in a rectangular wave guide, the coaxial transmission line
Potentials and Fields: The potential formulation: scalar and vector potentials, gauge transformations, Coulomb gauge and Lorentz gauge, continuous distributions: retarded potentials, Jefimenko's equations, point charges: Lienard-Wiechert potentials, the field of a moving point charge
Radiation, Dipole Radiation: Introduction to radiations, electric dipole radiation, magnetic dipole radiation, radiation from an arbitrary source, point charges: power radiated by a point charge, radiation reaction, the physical basis of the radiation reaction
Electrodynamics and Relativity: The special theory of relativity: Einstein's postulates, the geometry of relativity, the Lorentz transformations, the structure of space-time, relativistic mechanics: proper time and proper velocity, relativistic energy and momentum, relativistic kinematics, relativistic dynamics, relativistic electrodynamics: magnetism as a relativistic phenomenon, the field transformation mechanism, the field tensor, electrodynamics in tensor notation, relativistic potentials.

Recommended Books:

1. D. J. Griffiths, "Introduction to Electrodynamics", ed. Prentice Hall, 3rd ed. (1999).
2. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Press, 5th ed. ed. (2009).
3. F. Melia, "Electrodynamics", University of Chicago Press, 1st ed. (2001).
4. J. Hearld and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed. (2011).

PHY- 564 STATISTICAL MECHANICS

Pre-requisites: Heat and Thermodynamics
Credit Hours: Three (3)
Objective: The main objective is to develop an understanding of the physical properties of the matter "in Bulk", on the basis of the Dynamic behaviour of its microscopic constituents.

Review of Classical Thermodynamics: Review of Thermodynamic Potentials; Chemical Potential; Phase Equilibria; Maxwell Relations
Foundations of Statistical Mechanics: Phase Space; Trajectories in Phase Space; Conserved Quantities and Accessible Phase Space; Macroscopic Measurements and Time Averages; Ensembles and Averages over Phase Space; Liouville's Theorem; The Ergodic Hypothesis; Equal a priori Probabilities; Specification of the state of a system; concept of ensembles; elementary probability calculations; distribution functions; statistical interpretation of entropy (Boltzmann theorem)
Statistical Ensembles: Phase Space; Specification of the State of a System; Statistical Ensembles; Probability Calculations and Density of States;
Micro-canonical ensemble; canonical ensemble and examples (e.g., paramagnet); calculation of mean values; calculation of partition function and its relation with thermodynamic quantities; the grand canonical ensemble and examples (e.g. adsorption); calculation of partition function and thermodynamic quantities
Simple Applications of Ensemble Theory: Monoatomic ideal gas in classical and quantum limit; Gibb's paradox and quantum mechanical enumeration of states; equipartition theorem and examples (ideal gas, harmonic oscillator); specific heat of solids; quantum mechanical calculation of paramagnetism
Quantum Statistics: Indistinguishability and symmetry requirements; Maxwell-Boltzmann statistics; Bose-Einstein and photon statistics; Fermi-Dirac statistics (distribution functions, partition functions); Examples: polyatomic ideal gas (MB), black body radiation (photon statistics), conduction electrons in metals (FD), Bose condensation (BE)
Systems of Interacting Particles: Lattice vibrations in solids; van der Waals gas; mean field calculation; ferromagnets in mean field approximation

Recommended Books:

1. F. Reif, “Fundamentals of Statistical and Thermal Physics”, Waveland Pr Inc, (2008).
2. W. Brewer, F. Schwabl, “Statistical Mechanics”, Springer, 2nd ed. (2006).
3. T. L. Hill, “Statistical Mechanics”, World Scientific Publishing Company, (2004).
4. K. Huang, “Statistical Mechanics”, John Wiley, 2nd ed. (1987).
5. A. J. Pointon, “Introduction to Statistical Physics”, Longman (1967).

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PHY-565 Lab-VI
Credit Hours: Two (2)

Modern Physics: photoelectric effect, Frank-Hertz's quantization of energy levels, determination of Planck's constant (e.g. using a light bulb), verification of Moseley's law using X-ray fluorescence, Compton effect, Millikan's experiment for determination of charge of electron, properties of nuclear radiation (absorption in different media and response to external magnetic fields), statistical nature of radioactivity, determination of the half-life of radio-isotopes, Geiger-Muller tubes, cloud chambers, gamma rays spectroscopy, experiments on medical physics.

Electronic Materials: 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.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, “Experiments in Modern Physics”, Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).
4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-566 ETHICS
Credit Hours: Three (3)

Course Objectives: • This course will serve as an introduction to ethics, learn about arguments and their critical assessment, your own and your fellow beings duties and rights, the significance of trust and honesty in your day to activities, reporting and discrimination

Course Outlines:

Definition of ethics, Different principles and theories of making an action right or wrong, character traits, the status of ethical theories and claims, objective truths, ethics as a matter of subjective opinions and desires, practical ethical issues such as global poverty and animal welfare, responsibilities and rights as a student, teacher and friend, responsibilities and rights as a resident of a village, city and global village, moral strength and mutual trust, academic and research ethics, a society without ethics

Recommended Books:

1. John D'Angelo, Ethics in Science: Ethical Misconduct in Scientific Research 1st Edition, CRC Press, 2012
2. Judith A Boss, Ethics For Life, 5th Edition, McGraw-Hill Publishing Company, 2010
3. Francis L. Macrina, Scientific Integrity: Text and Cases in Responsible Conduct of Research 4th Edition, ASM Press Washington D C.

Semester-VII

PHY- 671 QUANTUM MECHANICS-II

Pre-requisites: Quantum Mechanics-I
Credit Hours: Three (3)
Objective(s): This course is aimed at bridging the classical concepts with quantum mechanical concepts and will lead to the second part of the core level undergraduate course on quantum mechanics

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 spherical harmonics, 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 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_2^+ 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 1*s*, 2*s* and 2*p* 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, Oscillations 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, 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 para-hydrogen)
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).

PHY- 672 ATOMIC AND MOLECULAR PHYSICS

Pre-requisites: Quantum Mechanics I
Credit Hours: Three (3)
Objective(s): To provide an introduction to the structure and spectra of atoms and molecules and to prepare students for more advanced courses on Physics of Atoms, Molecules and Photons

Structure of Atoms: Review of Bohr's theory, Sommerfeld Model, Frank Hertz experiment and approximation methods.
One Electron System: Review of Schrodinger equation for hydrogen atom, Fermi Golden rule, Quantum numbers, Atoms in radiation field, Radiative transitions, Einstein coefficients, Selection rules, normal Zeeman effect, Stark effect, Hyperfine structure.
Many body Systems: Pauli exclusion principle, Periodic system of the elements, Stern-Gerlach experiment, Spin orbit coupling, Central field approximation, Hartree Fock methods and self consistent field, Thomas Fermi potential, LS coupling, jj coupling and other types of coupling, X-ray spectra.
Interaction with field: Many electron atoms in an electromagnetic field, Anomalous Zeeman effect, Paschen back effect, Stark effect.
Molecules: Ionic and covalent bonding, Diatomic molecules, rotational, vibrational and electronic spectra; Born Oppenheimer approximation, Transition probabilities of diatomic molecules, electron spin and Hund's cases, Polyatomic molecules (brief introduction), Raman effect, Hydrogen Molecular ion (LCAO approximation), Hydrogen molecule (Heitler London and molecular orbital theories)

Recommended Books:

1. B. H. Bransden and C. J. Joachain, "Physics of Atoms and Molecules", Pearson Education, 2nd ed. (2008).
2. C. J. Foot, "Atomic Physics", Oxford University Press, (2005).
3. Anne P. Thorne, Spectrophysics, Chapman and Hall, 2nd ed. (1988).
4. W. Demtroder, "Atoms, Molecules and Photons", y, Springer, 2nd ed. (2010).
5. C. N. Banwell and E. M. McCash, "Fundamentals of Molecular Spectroscopy", McGraw-Hill, 4th ed. (1994).
6. J. M. Hollas, "Basic Atomic & Molecular Spectroscopy", John Wiley, 2002.

PHY- 673 SOLID STATE PHYSICS- I

Pre-requisites: Quantum Mechanics I, Statistical Mechanics
Credit Hours: Three (3)
Objective: This course will focus on collective quantum phenomena in solids, such as the emergence of physical phenomena from the interaction of a large number of atoms. It is designed to apply the previous knowledge of Physics to understand the crystal structure, thermal and electrical properties of solids and the Physics of these phenomena.

Crystal Structure: Lattices and basis; Symmetry operators; Fundamental Types of Lattice; Position and Orientation of Planes in Crystals; Simple crystal structures.
Crystal Diffraction and Reciprocal Lattice: Diffraction of X-rays, Neutron and electron diffraction from crystals; Bragg's law; Reciprocal lattice; Ewald Construction and Brillouin zone; Fourier Analysis of the Basis.
Phonons and Lattice: Quantization of Lattice Vibrations; Phonon momentum; Inelastic scattering by phonons; Lattice Vibrations for Mono-atomic and diatomic basis; Optical Properties in the Infrared Region.
Thermal Properties of Solids: Lattice heat Capacity; Classical model; Enumeration of normal modes, Density of state in one, two or three dimensions, Einstein Model and Debye model of heat capacity; Comparison with experimental results; Thermal conductivity and resistivity; Normal & Umklapp processes.
Electrical Properties of Metals: Classical free electron theory of metals; Energy levels and density of orbital's in one dimension; Effect of temperature on the Fermi–Dirac distribution function; Properties of the free electron gas; Electrical conductivity and Ohm's Law; Thermal and electrical conductivities of metals and their ratio; Motion of free electrons in magnetic fields; Cyclotron frequency; Static magneto conductivity and Hall Effect along with applications.

Recommended Books:

1. C. Kittle, "Introduction to Solid State Physics", John Wiley, 8th ed. (2005).
2. M. A Omar, "Elementary and Solid State Physics", Pearson Education, (2000).
3. H. M. Rosenberg, "The Solid State", Oxford Science Publication, 3rd ed. (1988).
4. M. A. Wahab, "Solid State Physics", Narosa Publishing House, (1999).
5. N. W. Ashcroft and N. D. Mermin, "Solid State Physics", Rinehart & Winston (1976).
6. J.S. Blakemore, "Solid State Physics", Cambridge University Press, 2nd Ed. (1985).
7. S. R. Elliott, "The Physics and Chemistry of Solids", John Wiley (1998).

PHY- 674 Lab-VII
Credit Hours: Two (2)

Advanced Experiments: nuclear magnetic resonance, electron spin resonance, Zeeman effect, optical pumping, lifetime of Muons, surface Plasmon resonance, Brownian motion, experiments with vacuum, low temperature physics, superconductivity, synthesis of nano-materials and their characterization, electromagnetically induced transparency, Mossbauer spectroscopy.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, "Experiments in Modern Physics", Academic Press, 2nd ed. (2003).
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. (2009).
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. (1996).

4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, (2006).
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. (2001).
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley (2001).

PHY-675 ELECTIVE-I
Credit Hours: Three (3)

Note: Any subject from the list for elective subjects below can be taken as Elective-I

PHY-676 PROJECT/THESIS
Credit Hours: Three (3)

Note: Student has to do a project in the last two semesters

Semester-VIII

PHY-681 ELECTIVE-II
Credit Hours: Three (3)

Note: Any subject from the list for elective subjects below can be taken as Elective-II

PHY-682 ELECTIVE-III
Credit Hours: Three (3)

Note: Any subject from the list for elective subjects below can be taken as Elective-III

PHY-683 PROJECT/THESIS
Credit Hours: Three (3)

Note: Student has to do a project in the last two semesters

PHY- 684 SOLID STATE PHYSICS - II

Pre-requisites: Quantum Mechanics, Statistical Physics and Solid State Physics I
Credit Hours: Three (3)
Objective(s): This course will focus on collective quantum phenomena in solids and has been designed to apply the previous knowledge of Physics to understand the electrical, optical and magnetic properties of solids. The knowledge obtained so for will be applied to understand the Physics of Semiconductors and Superconductivity.

Dielectric Properties of Solids: Polarization; Depolarization; Local and Maxwell field; Lorentz field; Clausius-Mossotti relation; Dielectric Constant and Polarizability; Measurement of dielectric constant; Ferro-electricity and ferroelectric crystals; Phase Transitions; First and 2nd order phase transitions; Applications.
Semiconductors: General properties of semiconductors; Intrinsic and extrinsic semiconductors; Band structure; Carrier statistics in thermal equilibrium; Band level treatment of conduction in semiconductors and junction diodes; Diffusion and drift currents; Collisions and recombination times.
Optical Properties: Interaction of light with solids; Optical Properties of Metals and Non-Metals; Kramers-Kronnig Relation; Excitons; Raman Effect in crystals; Optical spectroscopy of solids.
Magnetic Properties of Materials: Magnetic dipole moment and susceptibility; Different kinds of magnetic materials; Langevin diamagnetism equation; Paramagnetic equation and Curie law; Classical and quantum approaches to paramagnetic materials; Ferro-magnetic and anti–ferromagnetic order; Curie point and exchange integral; Effect of temperature on different kinds of magnetic materials and applications.
Superconductivity: Introduction to superconductivity; Zero-Resistance and Meissner Effect; Type I and Type II superconductors; Thermodynamic fields; Two fluid model; London equations; BCS and Ginzburg–Landau Theory; Vortex Behaviour; Critical Current Density; Josephson effect and 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).

PHY- 685 NUCLEAR PHYSICS

Pre-Requisites: Modern Physics
Credit Hours: Three (3)
Objective(s): To understand the nuclear structure using different nuclear models, the nature of nuclear forces, radioactivity and nuclear reactions

Basic Properties of Nucleus: Nuclear size; mass; binding energy; nuclear spin; magnetic dipole and electric quadrupole moment; parity and statistics
Nuclear Forces: Yukawa's theory of nuclear forces; Nucleon scattering; charge independence and spin dependence of nuclear force; isotopic spin
Nuclear Models: Liquid drop model; Fermi gas model; Shell model; Collective model
Theories of Radioactive Decay: Theory of Alpha decay and explanation of observed phenomena; measurement of Beta ray energies; the magnetic lens spectrometer; Fermi theory of Beta decay; Neutrino hypothesis; theory of Gamma decay; multipolarity of Gamma rays; Nuclear isomerism
Accelerators and detectors: Van de Graph generator; linear accelerator; cyclotron; magnetron; Geiger-Muller counter; bubble chamber; cloud chamber; scintillator.
Nuclear Reactions: Conservation laws in nuclear reactions; Q-value and threshold energy of nuclear reaction; energy level and level width; cross sections for nuclear reactions; compound nucleolus theory of nuclear reaction and its limitations; direct reaction; resonance reactions; Breit-Wigner one level formula including the effect of angular momentum.

Recommended Books:

1. E. Segre, “Nuclei and Particles”, Bejamin-Cummings, 2^{nd} ed. (1977).
2. I. Kaplan, “Nuclear Physics”, Addison-Wisely, (1980).
3. Green, “Nuclear Physics”, McGraw Hill, 1954.
4. K. S. Krane, “Introducing Nuclear Physics”, John Wiley, 3^{rd} ed. (1988).
5. B. Povh, K. Rith, C. Scholtz, F. Zetsche, “Particle and Nuclei”, (1999).

ELECTIVE COURSES IN BS PHYSICS

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. The host institution may also tailor these courses according to their needs and available facilities.

1. FLUID MECHANICS

Pre-requisites: Classical Mechanics
Credit Hours: Three (3)
Objectives: The main objective of this course is to make students familiar with the concepts of fluid flows. This course provides a theoretical foundation for ideal and real fluid flows. This fundamental course will provide sufficient knowledge to enable students to understand, model and solve basic practical flow problems

Basic Concepts: Fluid properties-viscosity, the microscopic and macroscopic view of fluid, incompressible and compressible fluids; circulation; elementary fluid kinematics; velocity field; substantial derivative; streamlines and path-lines; pressure distribution in stationary and accelerated systems; fluid forces; hydrostatics; manometry; buoyancy; Reynolds transport theorem
Constitutive Equations and Related Concepts: Continuity equation; momentum equation and angular momentum equation for control volumes; energy equation and Bernoulli equation; Euler's equation for inviscid flow and Navier-Stokes equation for viscous flow; boundary conditions for the basic equations of fluid mechanics; boundary layer; stream function; vorticity and rotation; viscous stresses and strain rates
Turbulent Flows: Introduction to turbulent flows; qualitative issues on turbulence; laminar and turbulent pipe flow; Reynolds number
Potential Theory: Two-dimensional potential theory, velocity potential

Recommended Books:

1. Y. A. Çengel and J. M. Cimbala, Fluid Mechanics: Fundamentals and Applications, Publisher: McGraw-Hill, 2nd ed., (2010).
2. P. K. Kundu, I. M. Cohen and D. R. Dowling, Fluid Mechanics, Publisher: Elsevier : Academic Press, 5th ed. (2012).
3. Y. Nakayama and R. F. Boucher, Introduction to Fluid Mechanics, Publisher: Butterworth-Heinemann, (2000).
4. G. Falkovich, Fluid Mechanics, Publisher: Cambridge University Press, (2011).

2. INTRODUCTION TO PLASMA PHYSICS

Pre-requisite: Electromagnetic Theory-II
Credit Hours: Three (3)
Objective(s): To introduce the basic concepts of the physics of plasmas and its major applications

Introduction: Plasmas in Nature; Basic Properties of Equilibrium Plasmas; Quasi-neutrality; Debye Shielding; Transmission of Electromagnetic waves through Plasmas; Degree of Ionization and Saha Equation; Applications of Plasmas.
Single Particle Motions: Single Particle Motion in Uniform, Non-uniform and time-varying Electric and Magnetic fields; Guiding Center Drifts; Adiabatic Invariants.
Plasma as a Fluid: Plasma Physics and Electromagnetics; The Fluid Equations of Motion; Fluid Drifts Parallel and Perpendicular to Magnetic Field; The Plasma Approximation.
Waves in Plasmas: Dispersion Relations; Plasma Oscillations; Electron Plasma Waves; Sound Waves; Ion Waves; Validity of the Plasma Approximation; Comparison of Electron and Ion Waves; Electron Oscillations and Ion Waves Perpendicular to Magnetic Field; The Lower Hybrid Frequency; Electromagnetic Waves with B_0=0 and Applications; Electromagnetic Waves Parallel and Perpendicular to Magnetic Field; Cutoff and Resonances; Hydro-magnetic Waves; Magneto-sonic Waves.

Plasma Sources: An Overview of Laboratory Plasmas and their Applications
Introduction to Controlled Fusion: Basic Nuclear Fusion Reactions; Reaction rates and Power Density; Radiation losses from Plasma; Operational Conditions; Lawson Criteria; Magnetic Confinement Fusion; Inertial Confinement Fusion.

Books Recommended:

1. F. F. Chen, "Introduction to Plasma Physics", 2nd ed., Plenum (1984).
2. N. A. Krall and A. W. trivelpiece, 'Principle of Plasma Physics', McGraw Hill (1973).
3. S. Glasstone and R. H. Lovberg, "Controlled Thermonuclear Reactions", D. Van Nestrand (1960).
4. D. A. Gurnett and A. Bhattacharjee, "Introduction to Plasma Physics: with space and laboratory application", Cambridge University Press, 2005.
5. T. J. M. Boyd and J. J. Sanderson, "The Physics of Plasmas", Cambridge University Press, 2003.

3. METHODS OF EXPERIMENTAL PHYSICS

Pre-requisites: Labs. I to VI.
Credit Hours: Three (3)
Objective(s): The objective of this course is to learn about the vacuum techniques and sensor technologies, the use of computer to acquire data from instruments and analysis of collected data.

Vacuum Techniques: Gas Transport; Throughput; Pumping Speed; Rotary pumps; Diffusion pumps; Sorption pumps; 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; Pirani gauges; The McLeod 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 & Electrical feed through; Leak detection; Basic consideration; Leak detection equipment; Special Techniques and problems; Repair Techniques;
Sensor Technology: Sensors for Temperature; Heat; Pressure; Displacement; Rotation; Flow; Level; Speed; Position; Phase; Current; Voltage; Power; Magnetic field; Tilt; Metal; Explosive materials.
Introduction to Computer Interfacing: GPIB Interface; RS 232; 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).

4. ENVIRONMENTAL PHYSICS

Credit Hours: Three (3)
Objective(s): To become familiar with the essentials of environment and global climate and to learn the use of spectroscopy for environmental study

Introduction: The human environment, Laws of thermodynamics, energy transfer, the green house effect and climate change.
Basic Environmental Spectroscopy: Electromagnetic spectrum, radiation from a black body, Lambert -Beer's Law, Radiative flux in the atmosphere, scattering and absorption of light by small particles, Rayleigh scattering, Mie scattering, Geometric scattering.

Greenhouse gases and Global Climate change on Earth: Energy balance, Anthropogenic CO_2 and other greenhouse gases, evidence for increase in the atmosphere. Aerosols and their properties, dynamics of aerosol population, climate change due to aerosols.

Transport of Pollutants: Diffusion and diffusion equation, dispersion of pollutant in rivers, ground water flow, Gaussian plumes in air, continental transport of pollutant.

Sound and Noise: Basic acoustics, measuring sound, propagation of sound over distance, human perceptions of sound and noise, noise level, controlling noise, active control of sound.

Atmosphere and Radiation: General laws of radiation, natural Radiation, solar and terrestrial radiation, energy balance for Earth and Atmosphere, solar variability, absorption of radiation by atmospheric gases.

Atmosphere and Climate: Structure of the atmospheres, vertical profiles in the lower layers of the atmospheres, lateral movements in the atmosphere, atmospheric circulation, cloud and fog formation, cloud types.

Climatology and Measurements of Climate Factor: Data collection and organization, statistical analysis of climatic data, general characteristics of measuring equipments, measurement of temperature, air humidity, surface wind velocity, radiation balance, precipitation, atmospheric pressure, automatic weather stations

Books Recommended:

1. B. Egbert and V. G. B. Rienk, Environmental Physics 2^{nd} *ed. John Wiley and Sons* (1999)
2. Guyot Praxis Publication, Physics of Environmental and Climate (1998)
3. J. H. Seinfeld and S. N. Pandis, Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. *John Wiley and Sons* (1998)
4. C. Smith, Environmental Physics. *Environment and Politics, 2^{nd} ed.* (2001)

5. INTRODUCTION TO QUANTUM COMPUTING

Prerequisites: Quantum Mechanics I

Credits: Three (3)

Objectives: The main objective of this course is to provide an introduction to theory and practice of quantum computation. This course explores how properties of quantum mechanical systems can be exploited to design quantum algorithms which are efficient than classical ones.

Basic concepts: Hilbert spaces; tensor products; notion of Qubits.

Introduction to computer science: Turing machine; universal Turing machine; circuits; Quantifying computational resources; computational complexity; P and NP problems.

Quantum circuits: Quantum algorithms; single qubit operations; controlled operations; universal quantum gates; simulation of quantum systems.

Quantum algorithms: Quantum Fourier transform and its application to period finding; order finding and factoring; Grover's search algorithm and its applications

Quantum error correction codes: The three qubit phase flip code; the three qubit bit flip code; The Shor code

Physical realization of quantum computers: Harmonic oscillator quantum computer; Ion trap.

Recommended Books:

1. M. A. Nielson and I. L. Chuang, "Quantum Computation and Quantum Information", Cambridge University Press (2000).
2. A. Steane, "Quantum Computing", Rep. Prog. Phys. 61 117–173 (1998).
3. M. A. Nielson and I. L. Chuang, "Quantum Computation and Quantum Information", Foundation Books (2007).
4. C. P. Williams and S. H. Clearwater, "Exploration in Quantum Computation" Springer, 2^{nd} ed. (2011).
5. P. Bouwmester, A. Ekert, and A. Zeilinger, "The Physics of Quantum Information: Quantum Cryptography, Quantum Teleportation, Quantum Computation", Springer (2010).
6. R. K. Brylinsky and G. Chen, "Mathematics of Quantum Computation" by Chapman & Hall/CRC (2002).

6. QUANTUM INFORMATION

Prerequisites: Quantum Mechanics I
Credits: Three (3)
Objectives: The main objective of this course is to provide broad overview of quantum information to students thus enabling them to keep up with recent developments in this rapidly growing field. The main emphasis is to understand basic quantum phenomena contributing to quantum information and then their application to important quantum information processes.

Mathematical Formalism: Hilbert spaces; Density matrix formalism; Tensor product for many body systems; Pauli matrices
Qubits: Introduction to qubits; familiarizing with single qubit algebra; concept of Bloch vector and pure and mixed state; Introduction to entangled states and Bell states
Bell Inequalities: EPR paradox leading to Bell inequality to be satisfied by local hidden variable theory; Violation of Bell inequality by entangled states; CHSH inequality and maximum violation.
Measurement theory: Projective measurements; POVM and Neumark theorem; Application of POVM to unambiguous state discrimination and minimum error state estimation
Entanglement as a physical resource: No cloning theorem; trivial cloning and optimal cloning; Application of entanglement to quantum teleportation; quantum dense coding; quantum cryptography and quantum state discrimination
Entropy and Information: Shannon entropy; basic properties of entropy; Von Neumann entropy

Recommended Books:

1. M. A. Nielson and I. L. Chuang, "Quantum Computation and Quantum Information", Cambridge University Press (2000).
2. V. Vedral, "Introduction to Quantum Information Science", Oxford University Press, 2007.
3. Cambridge University Press, 10^{th} *ed*. (2010).
4. W. Steeb and Y. Hardy, "Problems and Solutions in Quantum Computing and Quantum Information", World Scientific Publishing, 3^{rd} *ed*. (2011).
5. Book on general quantum mechanics: A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers (2002).
6. Seth Lloyd's notes on quantum information available online at: *web.mit.edu/2.111/www/notes09/spring.pdf*
7. J. Preskill, "Lecture notes on Quantum Information and Computation", http://www.theory.caltech.edu/~preskill/ph219/index.html#lecture

7. QUANTUM OPTICS

Pre-requisites: Electromagnetic Theory-I
Credit Hours: Three (3)
Objectives: The main objective of this course is to understand the quantization of electromagnetic radiations and its interaction with matter. 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)

8. QUANTUM FIELD THEORY

Pre-requisites: Quantum Mechanics-II
Credit Hours: Three (3)
Objectives: The main objective of this course is to further enhance the understanding of classical and quantum field theories.

Lagrangian Field Theory: Classical Field Theory. Canonical Quantization. Noether's theorem.
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. M. Maggiore, "A Modern Introduction to Quantum Field Theory (Oxford Master Series in Statistical, Computational, and Theoretical Physics)", Oxford University Press (2005)

9. DIGITAL ELECTRONICS

Pre-requisites: Basic Electronics
Credit Hours: Three (3)
Objective(s): To learn the basics of digital electronics such a as Boolean Algebra, to develop logic circuit using the Boolean Algebra and understand the computer interface and micro-controller along with the embedded systems

Review of Number Systems: Digital Systems; Characteristics of digital systems and analog Vs digital system; Binary Numbers (Decimal, Binary, Octal and Hexadecimal number systems); their inter-conversion; concepts of logic; truth table; basic logic gates.
Boolean Algebra: Basic Definitions; De Morgan’s theorem; Simplification of Boolean expression by Boolean Postulates and theorem; Standard Representations for Logical/Boolean Functions(sum of product & product of sum Forms); K-maps(one, two, three and four-variables Maps) and their uses; Don’t Care Conditions; Different Codes (BCD, EBCDIC, ASCII, Gray etc.); Parity in Codes.
IC Logic Families: Basic characteristics of a logic family (Fan in/out, Propagation delay time, power dissipation, noise margins, speed power product, current Sinking and current Sourcing); Different logic based IC families (DTL, RTL, ECL, TTL, and CMOS).
Combinational Logic Circuits: Introduction; Logic circuits based on AND–OR, OR-AND, NAND, NOR Logic; gate design; addition; subtraction (One’s and Two’s Complements); Half and Full Adders; Half and Full Subtractors; Encoder; Decoder; PLA; Exclusive OR and NOR gates.
Sequential Logic Circuits: Introduction; Flip-flops; Clocked (RS-FF, D-FF, T-FF, JK-FF); Shift Registers; Counters (Ring, Ripple, up-down, Synchronous); A/D and D/A Converters.
Memory Devices: Memory terminology; Classification of Memories; ROM; PROM; EAPROM; EEPROM; RAM (Static and dynamic); Memory mapping techniques.
Micro-controller/ Embedded System: Introduction to Embedded and microcontroller based systems; The Microprocessor & 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:

1. M. M. Mano, “Digital Logic and Computer Design”, Prentice Hall, (1995).
2. R. Tokheim, “Digital Electronics”, McGraw Hill, 7th ed. (2007).
3. B. B. Brey, “The Intel Microprocessors: Architecture, Programming and Interfacing”, Merril, 2nd ed. (1991).
4. Thomas L. Floyd, “Electronics Fundamentals: Circuits, Devices and Applications”, Prentice Hall, 8th ed. (2009).
5. T. Wilmshurst, “The Design of Small-Scale Embedded Systems”, Palgrave, (2001).

10. ELECTRONICS

Pre-requisites: Basic Electronics
Credit Hours: Three (3)
Objective(s): To enhance the understanding of electronic circuits and key electronic components such as amplifiers, oscillators etc. for applications in telecommunication systems

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; Simplification of Boolean expression using POS and SOP.

Recommended Books:

1. T. 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.
5. D. H. Navon and B. Hilbert, “Semiconductor Microdevices and Materials”, CBS College Publishing, (1986).
6. A. P. Malvino, “Electronic Principles”, McGraw Hill, 7th ed. (2006).
7. R. T. Paynter, “Introductory Electric Circuits”, Prentice Hall, (1998).

11. INTRODUCTION TO LASER PHYSICS

Pre-requisite: Quantum Mechanics-I
Credit Hours: Three (3)

Objective(s): The main objective of the course is to introduce students to basic principles, characteristics, and some applications of lasers. This course provides the foundation for further studies at graduate level in the field of lasers and applied photonics.

Introductory Concepts: Spontaneous Emission; Absorption; Stimulated Emission; Unique Properties of Laser Light: Monochromaticity, Coherence, Directionality, and Brightness
Energy Levels of Atoms, Molecules and Semiconductors: Energy Levels for One-electron and Multi-electron atoms; Radiative and Non-radiative Transitions; Selection Rules; Line Broadening Mechanisms and Line-widths; Energy Levels in Molecules; liquids; solids and Semiconductors
Radiation and Thermal Equilibrium: Boltzman's Distribution; Absorption and Stimulated Emission; Principle of Detailed Balance; Einstein's A & B Coefficients
Population Inversion and Gain: Population Inversion as a Necessary Condition; Gain Coefficient and Stimulated Emission Cross-section; Small Signal Gain; Gain Saturation; Gain Threshold for Lasers with and without Resonators
Laser Resonators: Plane Parallel (Fabry-Perot) Resonator; Longitudinal and Transverse Cavity Modes; Concentric Resonator; Confocal; Resonator; Generalized Spherical Resonator; Ring Resonator; Stable Resonators; Unstable Resonators; Matrix Formulation of Geometrical Optics; Stability Condition; Standing and Traveling Waves in a two Mirror Resonator
Laser Pumping Requirements and Techniques: Three- and Four-Level Laser Systems; Optical pumping; Flash lamp and Laser; Electrical Discharge and Collision Pumping; Indirect Pumping; Chemical Pumping; Electrical Pumping of Semiconductors; Threshold Pump Power; Pumping Efficiency; Pumping Geometries
Continuous Wave (CW) and Pulsed Lasers: Steady State and Transient Population Inversions; Rate Equations; Relaxation Oscillation; Q-Switching and Mode-Locking Methods; Phase Velocity; Group Velocity and Group-Delay Dispersion; Laser Tuning
Lasers Systems: Solid State Lasers: Ruby Laser, Nd: YAG Laser; Semiconductor Lasers: Homojunction Lasers; Heterostructure Lasers; Gas Lasers**:** He-Ne Laser, CO_2 Laser, Ar Laser; Excimer Lasers, Free-Electron Lasers; X-Ray Lasers; Metal Vapor Lasers; Dye Lasers
Laser Applications: Material Processing: Surface Hardening, Cutting, Drilling, Welding Holography, Optical Communication; Medical Applications; Remote Sensing; Defense and Industrial Applications

Recommended Books:

1. W. T. Silfvast, “Laser Fundamentals”, Cambridge University Press, 2nd ed. (2008).
2. O. Svelto, “Principles of Lasers”, Springer, 5th ed. (2009).
3. J. Hecht Understanding lasers: an entry-level guide, New York: IEEE Press (1994).
4. J. T. Verdeyen "Laser electronics" Englewood Cliffs, New Jersey Prentice Hall (1995).
5. K. Thyagarajan, A.K. Ghatak."Lasers, theory and applications" New York Plenum Press (1981).

12. LASER APPLICATIONS

Pre-requisites: Introduction to Laser Physics
Credit Hours: Three (3)
Objective(s): This course is designed to introduce the major applications of lasers in different fields of science and technology

Fundamentals of Lasers: Review of the working principles of a laser; Laser Resonators and Modes; Q-switching; Mode-locking; Ultrafast pulse generation; Fixed Frequency and Tunable Lasers
Characteristics of Laser Light: Laser wavelength**;** CW and pulsed modes**;** Laser power; energy per pulse; pulse duration; repetition rate; frequency width; beam divergence
A Survey of Laser Sources: Brief descriptions of solid state lasers; gas lasers; semiconductor lasers; dye lasers; excimer lasers; metal vapor lasers; fiber lasers
Applications of Low-Power Lasers: Scanning; Alignment; Surface Monitoring; Position and Velocity Measurements; Laser Interferometry; Laser Radar**;** Environmental Applications
Applications of High-Power Lasers: Laser Material Processing including Cutting; Drilling; Trimming; Welding; Marking and Surface Treatment; Surface Cleaning and Decontamination; Laser Ultrasonics, Laser Produced Plasmas and Laser Fusion
Laser Applications based on Frequency Resolution: Photo-physical and Photo-chemical Processes; Laser Isotope Separation; Laser Enhanced Chemical Reactions

Laser Applications based on Time Resolution: Laser Radar; Ultrafast Processes
Optical Communications, Data Storage and Processing: Fiber Optics; High Speed Communication; Optical Holography; Optical Computers
Medical Applications: Ophthalmology; Dermatology; Photodynamic Therapy; Dentistry; Microsurgery
Military Applications: Ranging and Tracking; Target Designation; Guidance System; Directed Energy Weapons
Lasers in Scientific Research: Laser Spectroscopy
Laser Safety: Eye and Skin Hazards, Electrical and Chemical Hazards

Recommended Books:

1. K. R. Nambiar, "LASERS: Principles, Types and Applications", New Age, (2009).
2. K. Thyagarajan, "Lasers: Fundamentals and Applications", Springer, 2^{nd} ed. (2010).
3. J. F. Ready, "Industrial Applications of Lasers", Academic Press, 2^{nd} ed. (1997).
4. W. M. Steen, J. Mazumder and K. G. Watkins, "Laser Material Processing", Springer, 4^{th} ed. (2010).
5. W. T. Silfvast, "Laser Fundamentals", Cambridge, 2^{nd} ed. (2008).

13. EXPERIMENTAL TECHNIQUES IN PARTICLE AND NUCLEAR PHYSICS

Credit Hours: Three (3)
Objective(s): To give students an idea of the experimental techniques used to understand nuclear and sub-nuclear phenomena

Review of Basic Concepts: Units used in particle physics; Types of particles to be detected; Cross section and Decay width; Lab Frame and CM frame; Pseudo rapidity; History of Accelerators; 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:

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, 4^{th} ed. (2000).

14. ELECTRONIC MATERIALS AND DEVICES

Pre-requisite: Electronics-I, Optics

Credit Hours: Three (3)
Objective(s): To understand the relation between electrical, optical and magnetic devices

Semiconductor Fundamentals: Composition, purity and structure of semiconductors, energy band model, band gap and materials classification, charge, effective mass and carrier numbers, density of states, the Fermi function and equilibrium distribution of carriers, doping, *n* and *p*-type semiconductors and calculations involving carrier concentrations, E_F etc., temperature dependence of carrier concentrations, drift current, mobility, resistivity and band bending, diffusion and total currents, diffusion coefficients, recombination-generation, minority carrier life times and continuity equations with problem solving examples
Device Fabrication Processes: Oxidation, diffusion, ion implantation, lithography, thin-film deposition techniques like evaporation, sputtering, chemical vapour deposition (CVD), epitaxy etc.
***PN* Junction and Bipolar Junction Transistor:** Junction terminology, Poisson's equation, qualitative solution, the depletion approximation, quantitative electrostatic relationships, ideal diode equation, non-idealities, BJT fundamentals, Junction field effect transistor, MOS fundamentals, the essentials of MOSFETs
Dielectric Materials: Polarization mechanisms, dielectric constant and dielectric loss, capacitor dielectric materials, piezoelectricity, ferroelectricity and pyroelectricity
Optoelectronic Devices: Photoconductors, photovoltaics and photodetectors, photodiodes and photovoltaics, solar cell basics, LEDs, Lasers, displays, LCDs
Magnetism and Magnetic Materials: Basics of magnetism, hysteresis loops, magnetic domains and anisotropy, hard and soft magnetic materials, transformers, DC motors and data storage.

Recommended Books:

1. R. F. Pierret, "Semiconductor Device Fundamentals", Addison Wesley, 2nd ed. (1996).
2. N. Braithwaite, and G. Weaver, "Electronic Materials", MA: Butterworth, 2nd ed. (1990).
3. S. O. Kasap, "Electronic Materials and Devices", McGraw Hill, 3rd ed. (2005).
4. R. C. O'Handley, "Modern Magnetic Materials: Principles and Applications", Wiley Inter-Science, (1999).
5. D. Jiles, "Introduction to Magnetism and Magnetic Materials", Chapman & Hall, 2nd ed. (1998).

15. INTRODUCTION TO PHOTONICS

Pre-requisites: Optics
Credit Hours: Three (3)
Objective(s): To study the application of light and photonic devices including detectors

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; phase and amplitude 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).

16. INTRODUCTION TO MATERIALS SCIENCE

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

Objective(s): This course will explore important aspects of materials incorporating elements of applied physics and chemistry, relationship between the structure of materials at atomic or molecular scales and their macroscopic properties, defects and thermodynamics. The microstructure-mechanical properties relationship will be also addressed.

Introduction: Classification of Materials; Metals; Ceramics; Polymers; Composites; Semiconductors; Biomaterials; Smart and Nano-materials; Properties and Uses of these Materials.
Atomic Structure of Materials: The packing of atoms in 2-D and 3-D; Lattices and crystal systems in 3-D; Symmetry; Unit cells of the SC, BCC, FCC and HCP Crystal structure; Interstitial structures; Density computation; Indexing lattice directions and lattice planes; Interplanar spacing; Bragg's law and the intensities of Bragg reflections.
Imperfections in Solids: Vacancies; Impurities; Dislocations; Interfacial defects; Bulk or volume defects; Atomic vibrations.
Thermodynamics and Phase Diagrams: Microstructure and microscopy; One component phase diagrams; Pressure vs. temperature; Temperature vs. composition; Equilibrium; Thermodynamic functions; Gibbs free energy; Development of microstructure; Binary phase diagrams; Solidification; Diffusion mechanisms; Nucleation and growth of a new phase; Materials fabrication.
Mechanical Behavior of Materials: Normal stress and normal strain; Shear stress and shear strain; Elastic and plastic deformation; Young's modulus; Shear modulus; Poisson's ratio; Elastic strain energy; Yield stress, Dislocations and plastic deformation; Slip systems; Dislocations and strengthening mechanisms; Fracture mechanics; Ductile and brittle fracture; Griffith criterion; Ductile-brittle transition temperature; Cyclic stresses and fatigue; Creep.
Polymers: Polymer basics; Polymer molecules; Molecular weight and shape; Step growth polymerization; Thermosetting polymers and gels; Rubbers and rubber elasticity; Configuration and conformation of polymers; The glassy state and glass transition; Determination of Tg; Effect of temperature and time; Mechanical properties of polymers;

Recommended Books:

1. W. D. Callister, "Materials Science and Engineering: An Introduction", Wiley, 7th ed. (2006).
2. W. D. Callister and D. G. Rethwisch "Fundamentals of Materials Science and Engineering: An Integrated Approach", Wiley, 4th ed. (2012).
3. J. F. Shackelford, "Introduction to Materials Science for Engineers", Prentice Hall, 7th ed. (2008).
4. http://www.msm.cam.ac.uk/teaching/index.php,
5. http://www.doitpoms.ac.uk/

17. INTRODUCTION TO NANO SCIENCE AND NANOTECHNOLOGIES

Pre-requisite: Solid State Physics, Quantum Mechanics
Credit Hours: Three (3)
Objective(s): In this course, one will learn the importance of this interdisciplinary field, how such materials are developed atom by atom by incorporating the concepts and applications of nano-materials into nanotechnologies and how nanotechnology would be helpful to change our society in future.

Introduction: Feynman talks on small structures; Nano-scale; Nanotechnology in nature.
Nano Materials: Nanoparticles; Quantum dots; Nano-wires; Nano-tubes; Magnetic nano-structures; Nano thermal devices; Nano fluidic devices; Biomimetic materials;
Quantum Effects: Wave particle duality; Energy quanta; Uncertainty principle; De Broglie relation; Moore's law; Tunneling;
Fabricating Nano-structures: Solid state Reaction technique; Vapor deposition Method; Sol gel; Lithography (photo and electron beam); MBE; Self-assembly; Nano junctions; Thin Films; Sputtering; Self-assembled films
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; Single electron transistor; Resonant tunneling;
Nano Biotechnology: DNA micro-arrays; Protein and DNA Assembly; Digital cells; Genetic circuits; DNA computing;
Characterization Techniques: XRD; Electron Microscopy (STM, AFM, SEM and TEM); Fluorescence methods; Synchrotron Radiation;
Nanotechnology the Road Ahead: Nanostructure innovation, Quantum Informatics, Energy solutions.

Recommended Books:

1. B. Bhushan, "Springer Hand Book of Nanotechnology", 3rd Edition, Springer Berlin Heidelberg, (2010).
2. C. Binns, "Introduction to Nanoscience and Nanotechnology (Wiley Survival Guides in Engineering and Science)", Wiley, (2010).
3. S. Lindsay, "Introduction to Nanoscience", Oxford University Press, (2009).
4. S.C. Tjong, Nano-crystalline Materials: Their synthesis-Structure-property Relationship and Applications, Elsevier, 2006.
5. Y.Gogotsi (Editor), Nano-Materials Hand Book, CRC Press, Taylor & Francis Group, (2006).
6. M.J. Schulz, A.D. Kelkar and M.J. Sundaresan (Editors), Nano-engineering of structural, Functional and Smart Materials, CRC Press, Taylor & Francis Group, (2006).

18. PARTICLE PHYSICS

Pre-requisites: Quantum Mechanics-I
Credit Hours: Three (3)
Objective(s): In this course, one will learn about the concepts of Quantum Electrodynamics, Quantum Chromo-dynamics and related special topics to build up a strong base in theoretical physics.

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

Recommended Books:

1. D. J. 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).

19. COMPUTER SIMULATIONS IN PHYSICS

Pre-requisites: Calculus-II, Linear Algebra, Probability and Statistics, Differential Equations, Introduction to Computing and Mechanics
Credit Hours: Three (3)
Objective(s): The aim is to develop one's ability to turn theoretical ideas of mathematics and physics into models speculated outcomes via computer simulations.

Programming for Scientific Computation: unix/linux basics, the editing-coding-compiling-debugging-optimizing-visualizing-documenting production chain, FORTRAN 95
Numerical Programming: Functions: approximation and fitting, Numerical calculus.
Ordinary differential equations, Matrices, Spectral analysis, Partial differential equations
Modeling and Simulation: Molecular dynamics simulations, Modeling continuous media
Monte Carlo simulations
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 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:

1. T. Pang, "An Introduction to Computational Physics", Cambridge University Press, (2008).
2. R. Landau, M. Paez, C. Bordeianu, "A Survey of Computational Physics", Princeton University Press, (2008).

20. SURFACE PHYSICS

Pre-requisite: Solid State Physics-I
Credit Hours: Three (3)
Objective(s): To understand the basics of surface physics, strengthen the previous knowledge of Solid State Physics and Quantum Mechanics

An Introduction to Surfaces: What is a surface? The energetics and thermodynmics of creating a surface. An introduction to surface Physics. Surface energies and the Wulff Theorem.
Studying Surfaces: What is UHV? Do we need UHV to study surfaces? The kinetic theory of gases, concept of vacuum and standard vacuum hardware components. Comparison of different types of pumps with measurement of vacuum pressure. Preparing a clean surface.
Surface Structures and Reconstructions: Lattice concept. 3-D crystal structures, 2D surface structures. Specific types of surface, fcc, hcp, bcc and stepped surfaces and a discussion of their relative energies. More complex ceconstruction, stability, growth mechanisms, adsorption. Desorption and experimental probes of surface structure such a LEED and RHEED. The structure of semi-conductor surfaces. The surface structures of very small metal particles.
Adsorption, Desorption Bonding , Catalysis and Growth Processes: Adsorption mechanisms and kinetics chemisorption vs. physiorption, the kinetics of adsorption, potential energy curves and adsorption energetics. Adsorption mechanisms and kinetics for low coverages Langmuir Isotherms, derivation, adsorbate phase diagrams and phase transitions.
The Structure of Adsorbate Layers: Experimental probes of surface structure such as LEED and RHEED. Growth processes, vibrational spectroscopy, catalysis, Desorption.
The Electronics and Magnetic Structure of Surfaces: Band theory, Free electron theories and the work function. The electronic structure of semiconductor surfaces, Electron emission processes. Magnetic processes at surfaces.
Electron-Surface Interactions: Electron diffraction and quasi–elastic scattering, comparison of particle scattering techniques. Electron spectroscopes, Discussion of the merits of different types of electron energy analysers and electron deterctors. Signal processing and spectral analysis. Theory and practice of Auger electron spectroscopy, Quantification of Auger spectra, Auger depth. Profiling.
Atom/ion surface interactions: Comparison of particle scattering techniques, An Introduction to the theory and practice of SIMS, SIMS imaging and depth profiling, Auger depth profiling, theory and practice of Rutherford. Back scattering.
Surface Microscopy: Classification of microscopy techniques, Basic concepts in surface imaging and localized spectroscopy, Imaging XPS, Optical microscopy, STEM. SEM. SPM. An introduction to the theory and practice of scanning Tunneling Microscopy, Scanning probe microscopy techniques, Atomic Force Microscopy.

Recommended Books:

1. John A. Venables, "Introduction to Surface and Thin Film Processes", Cambridge University Press (2000).
2. A. Zangwill, "Physics at Surfaces", Cambridge University Press, (1988).
3. D. P. Woodruff and T. A. Delchar, "Modern Techniques of Surface Science", Cambridge University Press, 2^{nd} ed. (1994).
4. D. Briggs and M. P. Seah, "Practical Surface Analysis", Vol-I, John Wiley, 2^{nd} ed. (1990).
5. J. B. Hudson, "Surface Science, an Introduction", Wiley-Interscience, (1998).
6. H. Luth, "Surfaces and Interfaces of Solids", Springer-Verlag, 2^{nd} ed. (1993).
7. M. Prutton, "Introduction to Surface Physics", Oxford University Press, (1994).
8. R. I. Masel, "Principles of Adsorption and Reaction on Solid Surfaces", Wiley-Interscience, (1996).

21. COMPUTATIONAL PHYSICS

Credit Hours: Three (3)
Objective(s): Introduction of computer languages to know the use of computer in numerical analysis, Computer simulation and modeling

Computer Languages: A brief introduction of the computer languages like Basic, C. Pascal etc and known software packages of computation

Numerical Methods: Numerical Solutions of equations, Regression and interpolation, Numerical integration and differentiation. Error analysis and technique for elimination of systematic and random errors

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.

Recommended Books:

1. M. L. De Jong,"Introduction to Computational Physics", Addison Wesley, (1991).
2. S. T. Koonini, "Computational Physics", the Benjamin-Cummings, (1985).
3. H. Gould, J. Tobochnik and W. Christian, "An Introduction to Computer Simulation Methods", Addison Wesley, 3rd ed. (2006).
4. S. C. Chapra and R. P. Chanle,"Numerical Methods for Engineers with Personal Computer Applications", McGraw Hill, (1990).
5. S. C. Chapra, "Applied Numerical Methods with MATLAB for Engineers and Scientists", McGraw Hill, 2nd ed. (2006).

22. RENEWABLE SOURCES OF ENERGY

Credit Hours: Three (3)
Objectives: To give students an understanding of the renewable energy resources

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.

Photovoltaics: 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, electrical, fuel cells etc.

Recommended Books

1. J. W. Twidell and A. D. Weir; Renewable Energy Resources; E & F.N. Spon. Ltd. London. (1986).
2. M. Iqbal; An Introduction to Solar Radiation: Academic Press, Canada. (1983).
4. S. Roberts, A Practical Guide to Solar Electricity, Prentice Hall Inc. USA, (1991).
5. M. A. Green; Solar Cells, Operating Principles, Technology, and system Application: Prentice Hall, Inc. USA, (1982).
6. T. J. Jansen, Solar Engineering Technology; Prentice Hall Inc. USA, (1985).
7. V. D. Hunt, Wind Power, A Book on Wind Energy Conversion System; Litton Educational Publishing Inc. (1981).
8. E. C. Price, P. N. Cheremisinoff; Biogas, Production and Utilization; Ann Arbor Science, USA, (1981).
9. I. Campbell, Biomass, Catalysts and liquid fuels; Technonic Publishing Co. Inc. USA, (1983).

LIST OF SUGGESTED EXPERIMENTS

MECHANICS & PROPERTIES OF MATTER

1. Modulus of Rigidity by Static & Dynamic methods (Maxwell's needle, Barton's Apparatus).
2. Measurement of viscosity of liquid by Stoke's / Poisseulli's method.
3. Surface tension of water by capillary tube method.
4. To determine the value of "g" by compound pendulum / Kater's Pendulum.
5. To study the dependence of Centripetal force on mass, radius, and angular velocity of a body in circular motion.
6. Determination of moment of inertia of a solid/hollow cylinder and a sphere etc.
7. To study the conservation of energy (Hook's law)
8. To determine the Young's Modulus by bending beam method.

HEAT, WAVES & OSCILLATIONS

9. To determine thermal emf and plot temperature diagram.
10. Determination of temperature coefficient of resistance of a given wire.
11. Determination of "J" by Callender – Barnis method.
12. To determine the Thermal conductivity of good and bad conductors using Lee's and Searl's apparatus.
13. The determination of Stefan's constant.
14. Calibration of thermocouple by potentiometer.
15. To determine frequency of AC supply by CRO.
16. To study the damping features of an oscillating system using simple pendulum of variable mass.
17. To determine Horizontal/Vertical distance by Sextant.
18. The determination of wavelength of Sodium –D lines by Newton's Ring.
19. The determination of wavelength of light/laser by Diffraction grating.
20. Determination of wavelength of sodium light by Fresnel's biprism.
21. The determination of resolving power of a diffraction grating.
22. The measurement of specific rotation of sugar by Polarimeter and determination of sugar concentration in a given solution.
23. Investigation of phase change with position in traveling wave and measurement of the velocity of sound by C.R.O.
24. To study the combinations of harmonic motion (Lissajous figures).
25. To study the parameters of waves (Beats phenomenon).
26. To study the laws of vibration of stretched string using sonometer.

ELECTRICITY & MAGNETISM

27. Measurement of resistance using a Neon flash bulb and condenser
28. Conversion of a galvanometer into Voltmeter & an Ammeter
29. To study the characteristics of Photo emission and determination of Plank's constant using a Photo cell.
30. Calibration of an Ammeter and a Voltmeter by potentiometer
31. Charge sensitivity of a ballistic galvanometer
32. Comparison of capacities by ballistic galvanometer.
33. To study the B.H. curve & measure the magnetic parameters.
34. Measurement of low resistance coil by a Carey Foster Bridge.
35. Resonance frequency of an acceptor circuit
36. Resonance frequency of a Rejecter Circuit.
37. Study of the parameter of wave i.e. amplitude, phase and time period of a complex signal by CRO.
38. Measurement of self/mutual inductance.
39. Study of electric circuits by black box.
40. To study the network theorems (Superposition, Thevinin, Norton).

MODERN PHYSICS

41. To study the application of Lorentz force by CRO.
42. To determine the stopping potential by photo cell.
43. To study the spectral characteristics of Photovoltaic cell.
44. To develop understanding and uses of electronic devises including GATS, Transistors.
45. To understand the behaviour of nuclear radiation including beta and gamma radiation.
46. Determination of e/m of an electron.
47. Determination of ionization potential of mercury.
48. To study the characteristic curves of a G. M. counter and use it to determine the absorption co-efficient of β-particle in Aluminum.
49. Determination of range of α particles.
50. Mass absorption coefficient of lead for γ-rays using G.M counter.
51. To study the characteristics of a Geiger-Muller counter and to examine the attenuations of beta particles in Al- and Pb foils.
52. Measurement of the half life of a radio nuclide. To study the pulse height as a function of the H.H.T. in a scintillation counter.
53. Measurement of the spectrum of gamma rays from a radioisotope. Shielding and attenuation of gamma rays.
54. To study the characteristics of a solid-state detector and use it to measure the spectra of alpha and beta particles.
55. Determination of Planck's constant (h) by using the photoelectric effect.
56. Determination of the charge on an electron (e) by Millikan's method.
57. The Frank-hertz experiment (Measurement of excitation potential of Hg)

ELECTRONICS

58. Characteristics of a semiconductor diode (Compare Si with Ge diode)
59. Setting up of half & full wave rectifier & study of following factors.
    i. Smoothing effect of a capacitor.
    ii. Ripple factor & its variation with load.
    iii. Study of regulation of output voltage with load.
60. To set up a single stage amplifier & measure its voltage gain and bandwidth.
61. To set up transistor oscillator circuit and measure its frequency by an oscilloscope.
62. To set up and study various logic gates (AND, OR, NAND etc) using diode and to develop their truth table.
63. To set up an electronic switching circuit using transistor LDR and demonstrate its use as a NOT Gate.
64. Characteristics of a transistor.
65. Use of computer in the learning of knowledge of GATE and other experiments.
66. AC circuits and dielectric constants of water and ice.
67. Radio frequency measurement. Skin effect, etc.
68. Experiments with transmission lines.
69. Measurement of characteristic impedance. Velocity. Standing wave ratio, etc.

ADVANCED EXPERIMENTS

70. To study the generation and measurement of low and high vacuum.
71. Study of random processes and fluctuations in random processes (Poission distribution, etc.)
72. Measurement of transistor hybrid parameters.
73. To build and investigate the properties of hard value multivibrators.
74. Transistor pulse-circuitry (three types of flip flop and the Schmidt trigger circuit).
75. Design of high or medium voltage dc power supply and measurement of the voltage regulation. Ripple factor etc.
76. Design of an L.F.R.C. coupled amplifier and a study of its characteristics.
77. Design of high or medium voltage dc power supply and measurement of the voltage regulation. Ripple factor, etc.
78. Design of a medium wave T.R.F. or superheterdyne receiver and measurement of its sensitivity. Power out-put selectivity, etc. the operational amplifier.

79. To design and build a linear integrator to enable digitization of photo-multiplier pulses, or to design and build a height-to-width converter.
80. To design and build a lotic circuit (using AND/OR/NOR gates) for performing a given function.
81. Study of leaser parameters. Gain characteristics and spectral response of a photo-multiplier tube.
82. Measurement of the total neutron cross-section.
83. To prove the Rutherford law of scattering of charged particles.
84. Measurement of the spectrum of gamma rays from a radioisotope (e.g.Cs) and study of their photoelectric and Compton absorption.
85. Source strength of Co60 by gamma coincidence methods.
86. Determination of the constituents of substance by activation analysis.
87. To examine the characteristics of a Solid-State detector and to use it for alpha and beta Spectroscopy and compare the results with those obtained by a scintillation counter.
88. Use of an analogue computer for solving differential equations.
89. To examine the stopping-power of various substances for thermal neutrons.
90. Determination of the Rydberg constant from the spectrum of hydrogen.
91. Fabry-Perot interferometer used as a gas refractometer.
92. To study the Zeeman Effect for a line in the spectrum of helium.
93. Experiments with microwaves. Study of their optical properties.
94. Electron spin resonance (E.S.R.) by microwave absorption. Nuclear magnetic resonance (N.M.R.) of protons in water.
95. The study of the Mossbauer Effect.
96. The measurement of the Hall Effect in germanium and silicon.
97. To build a medium or short-wave transmitter.
98. Measurement of the conductivity of Si and Ge as a functions of temperature.
99. To determine the energy gap in silicon and Germanium.
100. Drift mobility. (Shockley-Haynes experiments for Germanium, demonstrating transistor action).
101. Simple diode manufacture and point-contact transistor.