CHOICE BASED CREDIT SYSTEM(CBCS)

M.Sc. in PHYSICS

Department of Physics
Cotton University
Guwahati, Assam-781 001

Post Graduate Course in Physics
(2 years, 4 Semesters)

Semester Course and Credit Distribution
(Number within brackets is the number of credits)

Semester	Core	LAB	SEC	SPL	OPE	DPW	Credit
I	C1(4) C2(4) C3(4) C4(4)	LAB 1 (4)	SEC 1 (2)				22
II	C5(4) C6(4) C7(4) C8(4)	LAB 2 (4)	SEC 2 (2)				22
III	C9(4) C10(4) C11(4)			SPL 1 (5)	OPE 1 (4)		21
IV	C12(4)			SPL 2 (5)	OPE 2 (4)	DPW (6)	19
Credit	48	8	4	10	8	6	

Details of courses under M.Sc.

I. **Compulsory Course**:

Core: 4X12=48 (12 Papers of 4 credit each)

LAB: 4X2=8 (2 Laboratory work of 4 credit each)

(1 Paper in Sem I and 1 Paper is Sem II)

DPW: 6X1=6 (1 Dissertation/Project Work in Sem IV)

II. A. **Special papers:** 5X2=10 (2 Papers of 5 credit each)

(1 Paper in Sem III and 1 Paper is Sem IV)

B. **Open Elective** (***Interdisciplinary)***: 4X2=8 (2 Papers of 4 credit each)

(1 Paper in Sem III and 1 Paper is Sem IV)

III. **Ability Enhancement Courses:**

1. **Skill Enhancement Course**: 2X2=4 (2 Papers of 2 credit each)

(1 Paper in Sem I and 1 Paper is Sem II)

Minimum total credits required for the complete programme are:

$(4X12)_{Core} + (4X2)_{LAB} + (6X1)_{DPW} + (2X2)_{SEC} + (5X2)_{SPL} + (4X2)_{OPE} = 84$

SCHEME FOR CHOICE BASED CREDIT SYSTEM IN

M.Sc. (Physics)

Semester	Paper Code	Paper Name	Credit
Semester I	PHY701C	Classical Mechanics	3+1+0
	PHY702C	Quantum mechanics-I	3+1+0
	PHY703C	Mathematical Physics-I	3+1+0
	PHY704C	Electronics	3+1+0
	PHY705C	Electronics based Experiments	0+0+4
	PHY003SEC	Workshop Practice	0+0+2
Semester II	PHY801C	Electromagnetic Theory & Electrodynamics	3+1+0=4
	PHY802C	Quantum mechanics II	3+1+0=4
	PHY803C	Mathematical Physics II	3+1+0=4
	PHY804C	Solid State Physics	3+1+0=4
	PHY805C	Solid State Physics, Nuclear Phys & Laser Experiments	0+0+4=4
	PHY004SEC	Computational Data Analysis	0+0+2=2
Semester III	PHY901C	Atomic, Molecular & Laser Physics	3+0+1
	PHY902C	Statistical Mechanics	3+1+0
	PHY903C	Nuclear & Particle Physics	3+0+1
	PHY904S	*(One paper to be selected)*	5
	PHY905E	*(One paper to be selected)*	4
Semester IV	PHY1001C	Numerical Analysis and Computer Programming	2+0+2
	PHY1002S	*(One paper to be selected)*	5
	PHY1003E	*(One paper to be selected)*	4
	PHY1004dPW	Dissertation & Project Work	6

Post Graduate Course in Physics

SEM I

M.Sc. (Physics)

Semester	Paper Code	Paper Name	Credit
SEM I	PHY701C	Classical Mechanics	3+1+0
	PHY702C	Quantum mechanics-I	3+1+0
	PHY703C	Mathematical Physics-I	3+1+0
	PHY704C	Electronics	3+1+0
	PHY003SEC	Workshop Practice	0+0+2
	PHY705C	Electronics based Experiments	0+0+4

Paper Code: PHY701C **Paper No. C1**

Paper Name: Classical Mechanics

Credit: 3+1+0

Theory: 48 Lectures

Objective: The aim of this course is to familiarize the students with the Lagrangian and Hamiltonian formalisms of simple classical systems and makes them able to learn the methods of problem solving related to central force, rigid body dynamics and canonical transformation.

Course Outcomes: At the end of the course, the students will be able to:

CO1: Understand basic formalism of constraints and Lagrangian dynamics. Application of Lagrange's equations in real physical problems.

CO2: Understand Lagrangian formalism for solving Kepler's problem.

CO3: Apply the Variational principles to real physical and engineering problems.

CO4: Enable to solve Hamilton-Jacobi equations and use it for the solution of harmonic oscillator problem.

An overview of the Lagrangian and Hamiltonian formalism

Simple applications of Lagarange's and Hamilton's equation of motion: Small oscillation, Lagrangian for dissipative system, Conservation principle. [8Lectures]

Hamilton's principle

Calculus of variations, simple applications, Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action. [6 Lectures]

Canonical transformations

Generating functions; examples of canonical transformations; group property; Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations. [6 Lectures]

Hamilton-Jacobi theory

The Hamilton Jacobi equation for Hamilton's principle function; The harmonicoscillator problem; Hamilton's characteristic function; Action angle variables.

[4 Lectures]

Rigid bodies

Independent coordinates; Rotation as orthogonal transformations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation. [8 Lectures]

Fluid Mechanics:

Elements of fluid mechanics Energy and momentum flux, Navier -Stokes Equation.

[6 Lectures]

Introduction to Chaos

Periodic motions and perturbations; Attractors; Chaotic trajectories and Liapunov exponents; The logistic equation. [4 Lectures]

Classical field theory

Lagrangian and Hamiltonian formulation for continuous systems, Symmetry andconservation principles – Noether's Theorem, Classical field theory.

[6 Lectures]

Recommended Books:

1. Classical Mechanics: H.Goldstein
2. Mechanics: Landau and Lifshitz
3. Theoretical Mechanics: Murry r. Spiegel
4. Fluid Mehanics: L.D Landau and E.M. Lifshitz
5. Classical Mechanics: John R Taylor
6. Classical Mechanics: Jeol A Shapiro
7. Classical Mechanics: Rana and Joag
8. Introduction to Mathematical Physics, Methods and Concepts: C.W. WongChaos and Nonlinear Dynamics: R.C.Hibron

Paper Code: PHY702C **Paper No. C2**

Paper Name: Quantum mechanics I

Credit: 3+1+0

Theory: 48 Lectures

Objective: Students will acquire essential understanding needed for other courses for theoretical formulation of the physical phenomena at quantum level in matter and radiation fields.

Course outcomes:

CO1: General basic foundation of quantum mechanics needed for various quantum mechanical approaches. Three quantum numbers helps to explain atomic structure, H-atom and multi-electron systems.

CO2: Matrix formulation of quantum mechanics and three different pictures with their respective importance in physics.

CO3:.Space quantization, commutator algebra, theory of orbital and spin angular momenta. C.G. coefficients for unitary transformation.

CO4: Stationary perturbation theoretical approach for finding approximate solution of quantum mechanical problems.

Wave Particle Duality and Uncertainty Principle

Wave Particle Duality and Uncertainty Principle: Particles and waves in classical physics. Quantum view of particles and waves (Double slit experiment with wave and particles), de Broglie's hypothesis of matter wave. Probabilistic interpretation of wave function. Uncertainty relation. Wave packet description of a particle: Gaussian and square wave packets. Wave packet and uncertainty principle. Group velocity and phase velocity. **(8 lectures)**

Schrodinger's Equation

Schrodinger's Equation. Eigenfunctions and eigenvalues. Time dependent and time independent Schrodinger's equation. Probability density and probability current density. Simple applications of Schrodinger Equation: particle in a box, the harmonic oscillator, tunnelling through a barrier. The hydrogen atom. **(8 lectures)**

Operators, States and Measurements:

Stern-Gerlach experiment. Kets, bras and operator. Basis and matrix representations. Eigenstates, orthogonality and completeness. Change of basis and unitary transformation. Measurements, observables and uncertainty principle. Probability of outcome of measurements. Expectation value. Postulates of quantum mechanics. Continuous spectra. Position and momentum basis. **(10 lectures)**

Quantum Dynamics:

Translation operator; momentum operator and its representations. Time evolution of states. Unitary time evolution operator. Schrodinger and Heisenberg picture. Heisenberg's equation of motion. Ehrenfest's theorem. **(6 lectures)**

Application of the Operator method:

The harmonic oscillator, ladder operators, coherent states. **(4 lectures)**

Relativistic quantum mechanics:

Relativistic quantum mechanics. Klein Gordon equation and its physical significance, Klein- Gordon equation in the presence of electromagnetic field and its non-relativistic approximation. Dirac equation and plane wave solutions. Electron spin and its relationship with magnetic moment. Non-relativistic limit of the Dirac equation. Hydrogen atom problem. **(12 lectures)**

Recommended Books:

1. Quantum Mechanics: C. Cohen-Tannoudji, B. Diu, and F. Laloe
2. The Principles of Quantum Mechanics: P. A. M. Dirac
3. Quantum Mechanics: N. Zettili
4. The Feynman Lectures on Physics: R. Feynman, R. Leighton and M. Sands
5. Quantum mechanics: A. Ghatak and S. Lokanathan
6. Quantum Mechanics: A. Arhuldass
7. Quantum Mechanics: S. N. Biswas
8. Introduction to Quantum Mechanics: D. J. Griffiths
9. Modern Quantum Mechanics: J.J.Sakurai
10. Advanced Quantum Mechanics, J.J. Sakurai

Paper Code: PHY703C **Paper No. C3**

Paper Name: Mathematical Physics I

Credit: 3+1+0

Theory: 48 Lectures

Objective: The aim and objective of the course is to familiarize the students with the mathematical techniques necessary to approach problems in advanced physics courses. The knowledge of Special functions (Bessel, Hermite, Laguerre, Legendre), concepts of Complex analysis, Fourier analysis, Laplace transforms, tensor analysis, Green's function, integral transform are helpful to approach problems in advanced physics courses and research.

Course Outcomes: At the end of the course, the students will be able to:

CO1: Understand and apply the mathematical methods to solve quantitative problems in the study of physics and engineering. Enhance their problem solving ability and critical thinking.

CO2: Demonstrate contour integrals in relevant problems in Physics.

CO3: Enable to apply integral transform to solve mathematical problems of interest in physics. Can use Fourier transforms as an aid for analyzing experimental data.

CO4: Explain basic, preliminary concepts related to Green's function method and group of elements. Formulate and express a physical law in terms of tensors, and simplify it by use of coordinate transforms.

Complex Analysis:

Complex numbers. Functions of a complex variable: single and multiple valued functions. Limit and continuity. Differentiation: Cauchy-Riemann equations andtheir applications. Analytic and harmonic functions. Complex integrals. Cauchy's theorem (elementary proof only). Cauchy's Integral Formula. Taylor and Laurent expansion. Classification of singularities. Branch point and branch cut. The residue theorem and evaluation of some typical real integrals using this theorem. Cauchy's principal value of an integral. **(20 lectures**)

Vector Spaces:

Linear vector space. Linear independence. Completeness. Basis and dimension. Norm. Inner product. Orthogonal basis. Gram-Schmidt orthogonalization. Infinite dimensional spaces. Hilbert space. Applications in physics. **(12 lectures)**

Fourier Transforms:

Fundamental properties. Fourier transfrom of derivatives of a function. Shift theorem. Change of scale. Modulation theorem. Convolution theorem. Parseval'sidentity. Fourier transform of complex conjugates of functions. **(8 lectures)**

Laplace Transforms:

Laplace transforms of elementary functions. Basic properties. Change of scale theorem. Shift theorem. Laplace transform of derivatives and integrals of functions. Derivatives and integrals of Laplace transforms. Convolution theorem. Inverse Laplace Transform (Bromwich Integral). Solution of differential equations.

(8 lectures)

Recommended Books:

1. Mathematical Methods for Physicists, George B. Arfken, Hans J. Weber and Frank
2. E. Harris, Academic, Press, 2013.
3. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover, 1995.
4. Complex Variables, Murray R. Spiegel, Schaum's Outline Series, McGraw Hill, 1981.
5. Mathematical Physics, A. K. Ghatak, I. C. Goyal and S. J. Chua, Macmillan, 1995. Introduction to Mthematical Physics, Charlie Harper, Prentice-Hall, 1976.
6. Complex Variables and Applications, R. V. Churchill and J. D. Brown, McGraw Hill 1980.

Paper Code: PHY704C **Paper No. C4**

Paper Name: Electronics

Credit: 3+1+0

Theory: 48 Lectures

Objective: The main objective of this course is to expertise the students about various electronic circuits used in practical applications. After going through this course, the students are supposed to understand fundamental physics of semiconductor materials and the construction and operation of various electronic devices like PN-diode, BJT, FET, Op-amp under different operating conditions and two-port network analysis. In addition the topics of various number systems and their arithmetic, basic logic gates, combinational and sequential circuits and simplification techniques for Boolean Expressions will enable the students to enter into the fascinating world of digital electronics. The idea of differential amplifier and operational amplifier along with their applications is also introduced.

Course Outcomes: After successful completion of the course on Fundamental of Electronics, a student will be able to:

CO1: Aware of the general characteristics of important semiconductor materials and develop a deep understanding of the basic design, operation and characteristics of a PN-junction and a BJT along with knowledge of the two port network analysis and their application in electronic circuit. Learn to devise and analyze various transistor amplifier models.

CO2: Acquaint with the field effect transistor like JFET, MOSFET MESFET, VMOS and CMOS along with frequency response of variously FET amplifiers and various FET biasing arrangements.

CO3: Implement Boolean expression with basic logic gates, design and analysis of different combinational and sequential circuits to achieve desired output. Express numbers, alphabets, special characters etc. in binary representation, perform mathematical operations. Idea of different types of memories and Boolean expression simplification technique are also introduced.

CO4: Explain the basic physics of differential amplifier, operational amplifiers, effect of feedback on opamp parameters and various applications of op-amp.

Network Analysis: **[4 lectures]**

Network properties of transfer function of linear and lumped systems; Zero input and zero state response; system stability; poles and zeros of network; Routh array and Bode plotting.

MOS and CMOS devices and applications: **[10 lectures]**

Static and dynamic characteristics; depletion and enhancement modes; use of the devices
in amplifiers and oscillators.

(a) TUNNEL diode and applications: Tunnelling effect; transfer coefficient; tunnel diode characteristics; use of tunnel diode as oscillator and amplifier.

(b) GUNN diode and applications: Transferred electron effect; TE modes; Gunn diode in oscillation circuit.

(c) IMPATT/AVALANCHE diode and applications: Drift and scattering velocity; relation between fields, current and terminal impedance; equivalent circuits of the diodes and their use in amplifiers and oscillators.

OP-AMP applications **[6 lectures]**

Oscillators: Phase shift, Wien bridge and high frequency and voltage controlled oscillators; saw-tooth generator.

Filters: active low and high pass filters; Butterworth filter (up to 2nd order).

Analog computation: solution of differential equation (up to second order), solutionof Simultaneous equations.

Digital Circuits **[8 lectures]**

Mapping of logic expression and function minimization: SOP, POS expressions and circuit configurations; combinatorial logic gates; working and configuration of TTL, DTL, RTL, CMOS, MOSFET, ECL and L2L gates

Sequential circuits: RS, JK, D and T Flip Flops

Register: serial, parallel and shift register -- their design

Counter: synchronous counter and design (up to module-10 counter)

Microprocessor: flow chart; assembly language; solution of simple problems

Signal Transmission and Devices: **[10 lectures]**

Transmission line: Basic conception of transmission of LF and HF in open wire and coaxial lines; wave equations; characteristic impedance; VSWR; short and open circuit impedance; matching and stub matching.

Waveguides: fundamental concepts of signal propagation through a waveguide; rectangular waveguides; relation between cut-off frequency and waveguide dimension.

Antenna: $\lambda/4$ dipole; antenna arrays; end fire and broadside. Horn antenna, dual mode, E/Hplane, directivity, phase error, reflector, cylindrical, doubly curved, lens antenna: single surface dielectric, stepped lenses, metal plate lens antenna, aperture and field, microstrip antenna: cavity model, impedance, radiation pattern.

Modulation and De-modulation **[10 lectures]**

Amplitude modulation: Bandwidth and frequency spectra.

Frequency modulation: Narrow band and wide band; power; bandwidth; improvement of

S/N with emphasis and de-emphasis circuits

Detection: Balanced detector; zero-crossing detector; PLL.

PAM: Basic principles; baseband binary PAM.

PCM: Sampling of signal; quantization of signal; noise and bandwidth.

Reading List:

1. Modern digital electronics: R. Jain
2. Electronic Communication System: G. Kennedy and B. David
3. Microwaves: K. Gupta

Paper Code: PHY705C **Paper No. L1**

Name: Electronics Experiments
Practical paper
Credit: 0+0+4=4

Objective: The major objective of this course is to expose the various types of mathematical operations like addition, subtraction using digital circuits. Students by this course will be trained to acquire practical knowledge about the characteristics of FET, MOSFET, and the applications of Op-Amp., diodes, resistors and capacitors.

Course outcomes: After completion of experimental, students will be able to:

CO1: perform the mathematical operations like addition, subtraction using digital circuits.

CO2: learn the characteristics and applications of semiconductor based FET, MOSFET.

CO3: understand the working of various types of digital circuits and importance in our daily life.

CO4: understand the applications of Op-Amp., diodes, resistors and capacitors.

List of laboratory Experiments

1. To design an RC-coupled class A amplifier and
    a) Draw the frequency response graph and find the half power points
    b) Measure the output impedance of the amplifier
    c) Measure the gain bandwidth product
2. Draw the characteristic curve for a FET and measure the pinch-off voltage
3. Using an IC 741
    a) Design an integrator circuit and a differentiator circuit
    b) Draw the wave form
    c) Measure the rise and fall time
    d) Compare the result with theoretical values

4. Design a Wien Bridge Oscillator and find the frequency of oscillation. Compare the result with theoretical values.
5. To design 1st and 2nd order low-pass filters using IC 741 and
    (i) Draw the frequency response and find the roll-off rate.
    (ii) Determine the gain and cut-off frequency and compare with theoretical values.
6. To design 1st and 2nd order high-pass filters using IC 741 and
    (i) Draw the frequency response and find the roll-off rate.
    (ii) Determine the gain and cut-off frequency and compare with theoretical values.
7. Simplify given Boolean equations and verify with NAND/NOR gates.
8. Construct AND, OR, NOT, NOR, XOR and half adder with the help of NAND gates and verify their truth tables
9. Design 4 to 1 multiplexer
10. Design and construct 4 bits binary Adder/Subtractor and verify the truth table
11. Design Clipping and Clamping Circuits and draw the response curves

Paper Code: PHY003SEC **Paper No. SEC1**

Paper title: Workshop Practice
Credit: 0+0+2=2

CO1: Students will learn about mechanical workshop instruments and have hands on experience of filing, sawing, lathe machine and tap & die.
CO2: Students will have learn household electrical wiring.
CO3: Students will learn fabrication of PCB of a circuit, and simple electronic devices.

1. **Mechanical workshop:**
   (i) Identification of the tools of Mechanical workshop
   (ii) Filing and Sawing: Preparation of a wooden cube and a wooden sonometer bridge
   (iii) Lathe machine job: Preparation of a wooden solid cylinder
   (iv) Use of tap and die: Preparation of a nut

2. **Electrical workshop:**
   (i) Identification of the tools of Electrical workshop
   (ii) Design and fabrication of an Extension Board with two switches, plug points, fuse and indicator
   (iii) Preparation of a Stair-case wiring with two switches and a bulb shocket

3. **Electronic workshop:**
   (i) Identification of the tools of Electronic workshop
   (ii) Preparation of a PCB from a given circuit
   (iii) Design a dual power supply circuit of ±9v.

SEMESTER-II

Paper	Paper Name	Credit
PHY801C	Electromagnetic Theory & Electrodynamics	3+1+0=4
PHY802C	Quantum mechanics II	3+1+0=4
PHY803C	Mathematical Physics II	3+1+0=4
PHY804C	Solid State Physics	3+1+0=4
PHY805C	Solid State Physics, Nuclear Phys & Laser Experiments	0+0+4=4
PHY004SEC	Computational Data Analysis	0+0+2=2

Paper Code: PHY801C **Paper No. C5**

Paper Name: Electromagnetic Theory & Electrodynamics

Credit: 3+1+0

Theory: 48 Lectures

Course Objectives:

The most important objects of this paper are to study the fundamental facts about the electrodynamics and plasma physics. The present era is digital era so the basic knowledge about the fundamentals is more essentials. The course is elaborated many facts, general properties and state-of-art of the subject.

Course Learning Outcomes:

Upon successful completion of the course, the student:

CO1: The students able to describe the fundamentals of classical electrodynamics and quantum mechanics. The details of scaler and vector potentials, Maxwell's equations and fields of charged particles in uniform motion. The Maxwell's equations are the basic tool to under stand the electrostatic and electromagnetic theory of waves.

CO2: In this unit the extended study of Maxwell's equations is able to understand the fields study, particle velocity, review of four vectors and Lorentz transformation in 4-dimension spaces. This will give the depth knowledge about the invariance of electric charge.

CO3: Students will get the knowledge about the electromagnetic field's tensors in 4-dimensional Maxwellian equations. They will also gain the deep knowledge about the Lorentz transformation, Langragian and Hamiltonian transformations which are able to explain the motion of charged particles in Electro Magnetic fields.

CO4: Students can understand the basic concept of plasma physics and theory of astrophysical plasma as well as space plasma. Present era is digital and satellite era so the deep knowledge about the transient phenomena occur in space is too much essential to know every student. This unit provide the deep understanding about the space, astrophysics and plasma physics.

CO5: Will get working knowledge of electromagnetism using the tools of magnetohydrodynamics. To improve the skill of solving mathematical problems related to magnetohydrodynamics concepts.

Electro and Magnetostatic **[8 lectures]**

Boundary valu problems of electro and magnetostatics, Green's function, Image problem. Green's reciprocity theorem. Scalar and vector potential for steady localized charge and current distributions, Multipole expansion.

Maxwell's Equations **[6 lectures]**

Maxwell's equations. Electromagnetic scalar and vector potentials and gauge transformations, Inhomogeneous wave equations and their solutions; Radiation from localised sources and multipole expansion in the radiation zone.

Conservation Laws **[4 lectures]**

Energy density of elctromagnetic field, Conservation law for energy and momentum, Poynting vector, Maxwell's Stress tensor, Energy-momentum tensor.

Electromagnetic Wave **[6 lectures]**

Propagation of em-waves in free space, non-conducting and conducting media; reflection and transmission at the boundary of two non-conducting media; reflectionfrom a metal surface; propagation of em-waves in bounded media; idea of wave guides.

Relativistic Electrodynamics **[6 lectures]**

Recap of basic concepts of STR, introduction to 4-vectors, Lorentz transformations interms of 4-vectors, Charge-Current density 4-vectors. Electromagnetic field tensor, Covariance of Maxwell's equations. Applications.

Radiation from moving charge **[6 lectures]**

Lienard Wiechert potential and fields for a point charge; total power radiated by an accelerated charge; angular distribution of radiation from charged particles inextremely relativistic motion: Cherenkov radiation, Synchrotron radiation.

Radiation reaction **[3 lectures]**

Radiation reaction from energy conservation; Problem with Abraham-Lorentzformula; Limitations of Classical Electrodynamics.

Scattering of electromagnetic waves **[3 lectures]**

Scattering of em-waves due to free electrons: Thompson scattering; scattering from bound electrons: Rayleigh scattering, resonance fluorescence; energy loss in radiation.

Plasma physics **[6Lectures]**

Definition of plasma; Its occurrence in nature; Dilute and dense plasma; Uniform buttime-dependent magnetic field: Magnetic pumping; Static non-uniform magnetic field: Magnetic bottle and loss cone; MHD equations, Magnetic Reynold’s number; Pinched plasma; Bennett’s relation; Qualitative discus- sion on sausage and kink instability.

Recommended Books:

1. Introduction to Electrodynamics: D. Griffiths
2. Classical Electrodynamics: J. Jackson
3. Classical Electricity and Magnetism: W. K. H. Panofsky and M. Phillips.
4. Classical Electrodynamics: Julian Schwinger
5. The Classical Theory of Fields: L. Landau
6. The Feynman lectures on Physics: R. Feynman, R. Leighton and M. Sands.
7. Electromagnetic Field Theory and Wave Propagation: Uma Mukherjee
8. Engineering Electromagnetics: W. H. Hyat and J. A. Buck
9. Fundamentals of Electromagnetics: M. A. Wazed Miah
10. Electromagnetic Fields and Waves: P. Lorrain and D. Corson
11. 2000 Solved Problems in Electromagnetics: S. A. Nasar
12. Electromagnetics: B. B. Laud
13. Elementary Plasma Physics: C. L. Longmire
14. Introduction to Plasma Physics and Controlled Fusion: F. F. Chen

Paper Code: PHY802C **Paper No. C6**

Paper Name: Quantum mechanics II

Credit: 3+1+0

Theory: 48 Lectures

Objective: Objective of the current course is to familiarize the students to the formal structure of the subject and to equip them with techniques in various approximation methods like time dependent perturbation, concept of scattering, idea of identical particles, relativistic quantum mechanics and their applications so that they can use such concepts in various branches of Physics as per requirement.

Course Outcomes: After successful completion of the course on Quantum Mechanics-II, the outcomes are as:

CO1: Students would be able to explain the fundamentals of quantum mechanics angular momentum, eigenfunctions, orbital angular momentum operator, spherical harmonics.

CO2: Students get enabled to understand the basics of quantum theory of addition of angular momentum, tensor and Wigner-Eckart theorem.

CO3: Students would be capable to learn about approximation methods, time independent and time dependent perturbations, non-degenerate and degenerate cases.

CO4: Students would be introduced to symmetries and conservation laws, space inversion and time reversal symmetry.

AngularMomentum: **12 lectures**

Angular momentum as the generator of rotation. Commutation relations. Spin half system and Pauli matrices. Angular momentum algebra: Raising and lowering operators. Eigenfunctions and eigenvalue of angular momentum. Orbital angular momentum operator. Commutation relations. Spherical harmonics.

Addition of Angular Momentum: **8 Lectures**

Addition of angular momenta and Clebsch-Gordan coefficients. Tensor operator and Wigner-Eckart theorem (statement and elementary application only).

Indistinguishable and identical particles in quantum mechanics: **4 lectures**

Indistinguishable and identical particles in quantum mechanics. Combination of wave functions for a system of particles. Symmetric and anti-symmetric wavefunctions. Spin statistics connection. Exchange interaction and exchange energy.

Approximation Methods: **18 lectures**

Time-independent perturbation theory: first and second order non-degenerate degenerate cases. Stark and Zeeman effects. Variational methods and examples of hydrogen atom, Harmonic oscillator. Time-dependent perturbation theory: transition probability. Transition probability for constant perturbation. Transition toa continuum of final states. Fermi's golden rule. Harmonic perturbation. Adiabatic and sudden approximations.

Symmetry in Quantum Mechanics: **6 lectures**

Symmetries and conservation laws. Parity. Space inversion and time reversalsymmetry.

Reading List:

1. Quantum Mechanics: C. Cohen-Tannoudji, B. Diu, and F. Laloe
2. The Principles of Quantum Mechanics: P. A. M. Dirac
3. Quantum Mechanics: N. Zettili
4. The Feynman Lectures on Physics: R. Feynman, R. Leighton and M. Sands
5. Quantum Mechanics: A. Ghatak and S. Lokanathan
6. Quantum Mechanics: A. Arhuldass
7. Quantum Mechanics: S N Biswas
8. Introduction to Quantum Mechanics: D. J. Griffiths
9. Modern Quantum Mechanics: J.J. Sakurai
10. Quantum Mechanics: Eugen Merzbacher

Paper Code: PHY803C **Paper No. C7**

Paper Name: Mathematical Physics II

Credit: 3+1+0

Theory: 48 Lectures

Course Outcome

CO1: Develop analytical skills in order to solve problems in different branches of Physics.
CO2: Develop understanding of special functions and polynomials.
CO3: Understand Sturm-Liouville theory. Hermitian operators.
CO4: Learn how to apply symmetry operations using group theory.

Tensor Analysis: **12 lectures**

Co-ordinate transformations. Scalars, covariant and contravariant vectors and tensors. Vector algebra: addition, subtraction, outer product, inner product and contraction. Symmetric and anti-symmetric tensors. Quotient law. The metric tensor. Associate tensor. Raising and lowering of indices. The Christoffel symbols: transformation laws. Covariant derivatives of tensors.

Special Functions and Polynomials: **16 lectures**

Rodrigues' formula, generating functions, recurrence relations and orthogonality of Legendre, Hermite and Laguerre polynomials. Series expansion of a function interms of a complete set of Legendre functions; Bessel functions: first and second kind. Generating function. Recurrence formula. Zeros of Bessel functions. Orthogonality.

Differential Equations: **8 lectures**

Sturm-Liouville theory. Hermitian operators. Completeness. Simple applications. Inhomogeneous equations. Green's functions and their applications.

Group Theory: **12 lectures**

Definition of group. Subgroups, cosets and classes. Factor group. Homomorphism. Isomorphism. Direct products, Group representation: reducible and irreducible representations. Symmetry group. Unitary group. Lie groups. SU(2) and SU(3). Simple applications.

References:

1. Mathematical Methods for Physicists, George B. Arfken, Hans J. Weber and Frank E. Harris, Academic Pres.s, 2013.
2. Mathematical Physics, A. K. Ghatak, I. C. Goyal and S. J. Chua, Macmillan, 1995.
3. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover, 1995.
4. Mathematical Physics (Advanced Topics), S. D. Joglekar, Universities Press, 2006.
5. Introduction to Mathematical Physics, Charlie Harper, Prentice-Hall, 1976.

Paper Code: PHY804C **Paper No. C8**

Paper Name: Solid State Physics

Credit: 3+1+0

Theory: 48 Lectures

Objective: This course conveys a broad knowledge of solid structure, diffraction of waves, lattice vibrations, free electron gas, Kronig-Penny model and superconductivity. The principles and techniques are basics of materials science research.

Course Outcomes:

CO1: Basic knowledge of lattice structure and diffraction of waves by crystals develop an understanding of solid state.

CO2: Formulate basic models for electrons and lattice vibrations for describing the physics of crystalline materials

CO3: Understand the electron states of solid crystals.

CO4: Knowledge of superconductivity and BCS theory will be imparted to the students.

Crystal structure and binding:

Diffraction of electromagnetic waves by crystals,Reciprocal Lattice, Powder and Rotating Crystal method, Neutron and electrondiffraction. Types of crystal binding, London's theory of Van der Waals forces, Ionicbonding and Medelung constant.

(10 Lectures)

Vibrations in solids:

Classical treatment, Normal modes; Quantum treatment,Phonons, Anharmonic effects, Thermodynamic properties related to phonons,Continuum approximation; Measurement of phonon frequencies and inelasticscattering. Scattering mechanism- impurity and phonon scattering; Normal andUmklapp processes. Mobility of charge carriers and Seebeck coefficient.

(10 Lectures)

Electronic states in solids:

Sommerfeld model, thermodynamic properties due tofree electrons. Band structure: basic concepts, Bloch theorem, density of states, nearlyfree electron approach and pseudopotentials; tight binding method (linearcombination of atomic orbital method); modern band structure method.

(10 Lectures)

Motion of electrons in solids:

Semi classical model, band velocity, effective mass;Concept of electron, hole and open orbits. Effect of open orbits on electric and high magnetic fields; magnetoresistance. Experimental determination of Fermi surface, deHaas-van Alphen effect, anomalous skin effect and cyclotron resonance.

(14 Lectures)

Defects and diffusion in solids:

Point defects and dislocations, Fick's law, diffusionconstant, self-diffusion, colour centres and exitons. **(4 lectures)**

Suggested Books:

1. Solid State Physics, Neil W Ashcroft and N Devid Mermin, McGraw-Hill Education, 1976).
2. Principles of the Theory of Solids, J M Jiman, Cambridge University Press, 2000. Condensed Matter Physics, Michael P Marder, Wiley Interscience, 2000.

Paper Code: PHY805C Paper No. L2

Paper Name: Solid State Physics, Nuclear Phys & Laser Experiments

Credit: 0+0+4

CO1: Students will learn to find crystal planes and calculate crystal parameters.
CO2: Students will learn to find majority carrier in semiconductor and Hall effect.
CO3: Students will learn to find specific charge of electron (e/m).

List of Experiments:

1. Set the c-axis of the given crystal perpendicular to the incident x-ray beam.
2. Obtain an oscillation photograph of the given single crystal about c-axis,calculate the c-dimension of the unit cell, and index of reflection.
3. Obtain the Laue photograph of the given single crystal, draw gnomonic projection, and index of reflections.
4. Determine the cell dimensions and establish the face centering of copper by Debye-Scherrer method (Powder Method)
5. Measure the energy band-gap of a given semiconductor material of a PN junction and its junction capacity by reverse-biasing the junction.
6. Determine the conductivity type and Hall constant of a given semiconductor
7. Determine the constant of a Ballistic Galvanometer (BG) and study I-H and B-H curves
8. Determine e/m for electrons by magnetron method.
9. To study the statistical distribution law the govern nuclear decay using GMcounter.
10. To study the variation of count rate with applied voltage and therebydetermine the plateau, the operating voltage and the slope of plateau.

Paper Code: PHY004SEC Paper No. SEC2

Paper title: Computational Data Analysis
Credit: 0+0+2=2

CO1: Students will learn data analysis with Microsoft Excel, Microcal Origin.
CO2: The students are expected to become skilled, both theoretically and practically, in computer programming and are expected to be able to solve numerical problems that are frequently used in physics.

using computer programs.

1. Data analysis with excel
a) Creating chart in Microsoft excel.
b) Types of chart- Column chart, line chart, Pie chart, Doughnut chart, bar chart, area chart, scatter chart, surface chart.
c) Chart elements- Chart style, Chart filter, fine tune of chart; Chart design tools.

2. Data analysis with Origin
a) Basic graph plotting with Origin Workspace.
b) Importing Data from different sources, creating and customizing graphs.
c) Basic Data Analysis, Customizing Data Import, exporting and processing of graph, creating and customizing multi-layer graphs.

3. Fitting of graphs in origin
a) Linear fitting of data using common functions and equations, Calculating fitting parameters.
b) Graph fitting and analysis using given data sources (XRD, UV-Visible, FTIR data)
c) Advanced Nonlinear Fitting, fitting of graphs by writing equations.

Semester III

Paper Code	Paper No	Paper Name	Credit
PHY901C	C9	Atomic, Molecular & Laser Physics	3+0+1
PHY902C	C10	Statistical Mechanics	3+1+0
PHY903C	C11	Nuclear & Particle Physics	3+0+1
PHY904S	SPL1		5
PHY905E	OPE1		4

Special Papers For SEM-III (SPL-1):

Paper Code	Paper No	Paper Name	Credit
PHY904S1	SPL1-1	GTR & Cosmology	4+1+0
PHY904S2	SPL1-2	High Energy Physics-I	4+1+0
PHY904S3	SPL1-3	Adv. Electronics	3+1+1
PHY904S4	SPL1-4	Adv. Solid State Physics	3+1+1

Open Elective (Interdisciplinary) For SEM-III (OPE-1):

Paper Code	Paper No	Paper Name	Credit
PHY905E1	OPE1-1	Introduction to Astronomy & Astrophysics I	3+1+0
PHY905E2	OPE1-2	Introduction to Atmospheric Science	3+1+0
PHY905E3	OPE1-3	Nano Physics	3+1+0
PHY905E4	OPE1-4	Polymer Physics	3+1+0
PHY905E5	OPE1-5	Radiation Physics	3+0+1
PHY905E6	OPE1-6	Nonlinear Physics	3+1+0

Paper Code: PHY901C **Paper No: C9**

Paper Name: Atomic, Molecular & Laser Physics

Credit: 3+0+1

Theory: 48 Lectures

Objective: The main objective is to teach students the basic atomic structures with quantum mechanical approach leading to their fundamental spectroscopies. The effect of magnetic and electric field on the atomic spectra is also highlighted. To teach the students the nature of molecular spectra (rotational, vibrational, electronic and Raman), polyatomic molecules (including diatomic) are classified on the basis of their topological symmetry. The fundamentals of electronic states will also be taught.

Course Outcomes:

CO1: Students will learn the details of atomic and diatomic molecular (diatomic) structures in terms of quantum mechanical treatment elaborately beyond the basic models. It will give the descriptions of fine and hyperfine structure of atoms and molecular.

CO2: The various coupling schemes and interactions of fields with spectra will enrich the student's knowledge about transitions. The details of these spectroscopies would serve as the fundamentals for various concerned experimental studies.

CO3: Students learn to analyze the polyatomic molecules (including diatomic) and to predict the nature of their vibrational spectra depending on their symmetry using IR Raman Spectroscopy.

CO4: The complete picture of rotational, vibrational and electronic spectra of polyatomic molecules will be comprehended. This kind of specialization is expected to provide a larger scope for research in the various related and interdisciplinary areas.

Atomic Physics:

Fine structure of hydrogen atoms – Mass correction, spin-orbit term, Darwin term, Intesity of fine structure lines. The ground state of two-electron atoms – perturbation theory and variation method. Many-electron atoms - LS and jj coupling schemes, Zeeman effect; Paschen-Bach effect; Stark effect, Lande interval rule. The idea of Hartree-Fock equation. The spectra of alkalis using quantum defect theory. Selectionrules for electric and magnetic multiple radiations. Oscillator strengths and theThomas-Reiche-Kuhn sum rule. **(14 Lectures)**

Molecular Spectra:

Born-Oppenheimer approximation, rotation, vibration and electronic structure of diatomic molecules, molecular orbital and valance bond methods for H_2^+ and H_2. Correlation diagrams for heteronuclear molecules. Heterogeneous molecules:correlation diagrams; polyatomic molecules and their structure. **(12 Lectures)**

Rotation, vibration-rotation and electronic spectra and Raman spectra selectionrules. Resonance; nuclear magnetic resonance; chemical shift. The Frank-Condonprinciple. The electroc spin and Hund's rule. Idea of symmetry elements and pointgroups for diatomic and polyatomic molecules. **(10 Lectures)**

Lasers:

Spontaneous and stimulated emission; Einstein A & B coefficients, Multilevel rate equations and saturation. Rabi frequency . Laser pumping and population inversion.Modes of resonators and coherence length, He-Ne Laser, Solid State Laser, Free- electron laser, Non-linear phenomenon. Harmonic generation. Laser accelerator,liquid and gas lasers, semiconductor lasers. **(12 Lectures)**

List of Experiment:

1. Fine structure of H or Hg using spectrometer
2. Frank & Hertz experiment
3. Raman scattering using laser
4. Band spectra
5. Zeeman Effect

(More Experiments will be added by the department)

Reference Book:

1. Physics of Atoms and Molecules by B H Bransden and C J Jochain, Pearson Education
2. Atomic Physics by C J Foot Oxford Univ. Press
3. Atoms, Molecules and Photons by W Demtroder, Springer
4. Molecular Spectra and Molecular Structure by G Herzberg, Van Nostrand
5. Basic Atomic & Molecular Spectroscopy by J M Hollas, Royal Society of Chemistry
6. Laser Spectroscopy by W Demtroder, Springer
7. Molecular Physics by W Demtroder, Wiley-VCH

Paper Code: PHY902C **Paper No: C10**

Paper Name: Statistical Mechanics

Credit: 3+1+0

Theory: 48 Lectures

Objective:

The aim of this course is to help the students to relate between statistics and thermodynamics. A student will be introduced with microcanonical, canonical and grand canonical ensembles and their partition functions and phase transitions of first and second order.

Course outcomes:

CO1: A student will be able to understand the basic concepts of thermodynamics and set a relation between thermodynamics and statistics.

CO2: A fair knowledge about the various ensembles and learn about the behavior of classical Ideal gas under various ensembles.

CO3: A student will acquire sound knowledge of M.B., B.E. and F.D. statistics and understand the phenomenon of Bose-Einstein condensation and black body radiations.

CO4: A student will have fair knowledge of Landau theory of phase transition, Ising model, Langevin theory of Brownian motion.

Classical Statistical Mechanics **[15 lectures]**

Statistical basis of thermodynamics: the macroscopic and the microscopic states;postulates of equal a-priori probability; connection between statistical mechanics andthermodynamics. Elements of ensemble theory: Phase space of a classical system;Lioville's theorem; micro canonical, canonical and grand canonical ensemble;equivalence to other ensembles.

Fluctuations **[8 lectures]**

Thermodynamic fluctuations; Gaussian distribution; random walk and Brownian motion; diffusion equation; approach to equilibrium: the Fokker-Planck equation; introduction to non-equilibrium processes.

Formulation of Quantum Statistics **[15 lectures]**

Basic principle; inadequacy of the classical theory; quantum mechanical ensembletheory; density matrix; ensembles in quantum statistical mechanics; Maxwell-Boltzmann statistics; Bose-Einstein statistics; Fermi Dirac statistics; properties of anideal Bose gas system and ideal Fermi gas system and their equations of state; someapplication: black-body radiation, white dwarf.

Phase transitions **[10 lectures]**

Formulation of the problem; the theory of Lee and Yang; first and second order phase transitions; diamagnetism, paramagnetism and ferromagnetism; Ising model; Bose-Einstein condensation (BEC). Liquid helium; two-fluid hydrodynamics: secondsound; theories of Landau and Feynman.

Reading List:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2 nd Ed., 1996,Oxford University Press.
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W.

Sears and Gerhard L. Salinger, 1986, Narosa.
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
5. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press
6. Statistical Mechanics B. K. Agarwal and M. Eisner
7. Perspectives of Modern Physics by A. Beiser
8. Statistical Mechanics: R. Feynman
9. Statistical Physics: L. Landau and E. Lifshitz

Paper Code: PHY903C **Paper No: C11**

Paper Name: Nuclear & Particle Physics

Credit: 3+0+1

Theory: 48 Lectures

Objectives: Students basic concepts building to develop ability for the understanding of nuclear structure along with advance level topics in nuclear and high energy physics.

Course outcomes:

CO1: Impart knowledge of introductory nuclear physics and deuteron as the smallest fundamental nucleus helps to understand strongest force of the nature.

CO2: Stability and properties of different nuclei explained by various nuclear models.

CO3: Radioactive α, β, γ -decay of nuclei by their respective quantum mechanical theories. Conservation laws and various nuclear reactions.

CO4: Elementary particles as the building blocks of matter and interacting fields. Conservation laws and quantum numbers for production and decay of particles.

Static properties of the nucleus

Size of the nucleus and its determination from electron scattering; form factor; angular momentum; spin and moments. **(4 Lectures**)

Two nuclear system

Bound state problem, deuteron ground state with square well potential; electric quadruple and magnetic dipole moments—experimental values. Scattering problem: low energy n-p scattering; partial wave analysis; scattering length. **(10 Lectures)**

Models of nuclear structure

Nucleon stability; mass parabolas- prediction of stability against β decay; stability limits against spontaneous fission. Shell model: evidence of shell structure; magic numbers; effective single particle potentials-square well and harmonic oscillator; Wood-Saxon with spin orbit interaction; extreme single particle models-its success and failures in predicting ground state spin; parity; Nordheim rule. **(10 Lectures)**

Nucleon Reaction

Classification; conservation principle; laboratory and centre of mass frame of reference-energy and angle relationship for non-relativistic cases; kinematics and Q- value; exoergic and endoergic reaction; threshold energy. Basic concepts of flux and cross sections; attenuation; Coulomb and Rutherford scattering; quantummechanical and relativistic effects; extended particle; the compound nucleus hypothesis; Ghosal experiment. **(8 Lectures)**

Nuclear β decay

Fermi's theory of β decay; comparative half lives and forbidden decays; Kurie plot; neutrino physics; Reins and Cowen experiment; concept of double β decay and Majorana neutrino. **(4 Lectures)**

Nuclear radiation detectors

Ionisation; proportional and GM Counters; scintillation counters; solid state nuclear track detectors (SSNTDs). **(4 Lectures)**

Elementary particles

Classifications of elementary particles and their interactions; conservation laws; symmetry principle; and quantum numbers; strangeness and isospin; Gell- Mann Nishijima scheme. **(8 Lectures)**

List of Experiments:

1. To verify inverse square law using GM counter.
2. To determine the operating voltage for a Geiger tube and to calculate the effectof dead time and recovery time of the tube on the counting rate.
3. A GM counter for measuring the beta ray activity of liquids.
4. To study energy calibration curve using gamma spectrometer.
5. To study the absorption of β particles in Aluminium using GM counter.

(More experiments will be added by the department)

Reference books

1. Introductory Nuclear Physics: K Krane and D. Halliday
2. Introductory Nuclear Physics: S. Wong
3. Atomic and Nuclear Physics: S. Ghosal
4. Concepts of Nuclear Physics: B. Cohen

Special Papers: For SEM-III (SPL-1):

Paper Code: PHY904S1 **Paper No: SPL1-1**

Paper Name: GTR & Cosmology

Credit: 4+1+0

Theory: 64 Lectures

Course outcome:

CO1: Students will have a review of special theory of relativity and tensor calculus.

CO2: Students will understand the general theory of relativity, general covariance and laws of physics in curved space-time.

CO3: Students will learn Derivation of Einstein's field equation. Weak field solution, Newtonian gravity, Gravitational radiation. Schwarzschild's exterior solution

CO4: Students will be introduced to cosmology, cosmological parameters, universe, Hubble's law.

1. Review of special theory of relativity: Poincare and Minkowski's 4-dimensional formulation, geometrical representation of Lorentz transformations in Minkowski's space and length contraction, time dilation and causality, time-like and space-like vectors, Newton second law of motion expressed in terms of 4-vectors. **(4 lectures).**

2. Review of tensor calculus: Manifold, vectors and tensors, Euclidean and non-Euclidean space, meaning of parallel transport and covariant derivatives, Geodesics and autoparallel curves, Curvature tensor and its properties, Bianchi Identities,vanishing of Riemann-Christoffel tensor as the necessary and sufficient condition of flatness, Ricci tensor, Einstein tensor. Algebric properties of curvature tensor.

(8 lectures)

3. General theory of relativity: Inconsistencies of Newtonian gravitation with STR, Principles of equivalence, Application of principle of equivalence, motion of test particles in an arbitrary gravitational field, gravitation as the propety of curved space-time. Gravitational time dialation. Principle of general covariance, Metric tensors and Newtonian Gravitational potential, laws of physics in curved space- time. **(10 lectures).**

4. Einstein's field equations and its solutions in simple cases: Derivation of Einstein's field equation. Weak field solution, Newtonian gravity, Gravitational radiation. Schwarzschild's exterior solution, Geodesic motion, bending of light, precession of perihelion of mercury, singularity and black hole. Birkhoff's theorem.

(10 lectures)

6. Cosmology: Introduction, Cosmological Principles, Weyl postulates, Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe, Expanding universe, Open and Closed universe, Cosmological red shift,Hubble's law. Olber's Paradox. **(10 lectures)**

7. **Qualitative discussions on:** Big Bang, Early Universe (thermal history and nucleosynthesis), Cosmic Microwave Background Radiation, Event Horizon, Particle Horizon. Problems of standard cosmology. **(6 lectures)**

Recommended Books:

Paper Code: PHY904S2 **Paper No: SPL1-2**

Paper Name: High Energy Physics-I

Credit: 4+1+0

Theory: 64 Lectures

Course Outcomes:

CO1: The students will be able to get some introductory and advanced knowledge of particle physics like classification of particles, fundamental interactions, quark model, parton model, weak interactions, gauge theories, statistical tools for particle physics etc.

CO2: The student would be able to get some introductory and some advance knowledge of elementary particles and their interactions, and gauge theories and some knowledge of statistical tools required for particle physics.

CO3: The students will get a basic training for research in more advanced topics of high energy physics.

Introduction to Elementary Particles and Quark Models of Hadrons: (**24 Lectures**)
Introductory survey of elementary particles, fundamental interactions and their characteristics in terms of decay lifetimes, strengths, ranges; conservation laws anddecay modes, charged leptonic weak interactions, decay of muons, neutron andcharged pions. Isospin symmetry and G-parity. Classification schemes, the Gell- Mann and Nishijima scheme, eightfold way, quark hypothesis (Gell-Mann andZweig), properties of quarks and their kinds, elementary idea of Lie groups, spinSU(2) and flavour SU(3) symmetry, colour quantum number.

Quantum Field Theory: (**28 Lectures)**

Concept of fields, classical fields as generalized coordinates, Schwinger's action principle, Euler-Lagrange equations, Noether's theorem.

Canonical quantization of one dimensional classical system. Canonical quantization of free fields: Hermitian and non-Hemitian scalar fields, Dirac spinor field and Maxwell field. Invariance principles, Lorentz invariance of free field theory, C, P, T and CPT transformation, CPT theorem.

Path Integral Formalism: **(12 Lectures)**

Path Integral method of field quantization.

Reading List:

1. Introduction to Elementary Particles: David Griffiths
2. Quarks and Leptons: An Introductory Course in Modern Particle Physics: Francis Halzen & Alan D. Martin
3. Gauge Theory of Elementary Particle Physics: Ta-Pei Cheng & Ling-Fong Li
4. Quantum Field Theory: L. H. Ryder
5. Relativistic Quantum Mechanics (Vol-I & Vol-II): James D. Bjorken & Sidney D. Drell

Paper Code: PHY904S3 **Paper No: SPL1-3**

Paper Name: Adv. Electronics

Credit: 3+1+1

Theory: 48 Lectures

Objective: The aim of this course is to train students to a host of important electronic device being used in
vital practical applications. This course familiarizes about the microprocessor programming and their applications. The overall course is designed in such a manner that the student after studying this will have strong basic knowledge to design power electronic systems and optical communication system easily.

Course Outcomes: After successful completion of the course, the students will be able to:

CO1: have a clear concept of analog filter design.

CO2: understand about signal and noise in communication systems, encoding, channels in communication.

CO3: have concepts of logic circuits with ICs, gates, MSI devices, threshold voltage, operating speed, power dissipation, noise margin, logic voltage level, fan in and fan outoperations, fault detection.

CO4: realize the role and importance of different modulation and demodulation processes in modern electronic and optical communication system.

Analog filter design: **[4Lectures]**

Group delay and phase difference, approximation of ideal filter by practical filters like Butterworth, Bessel, Chebyshev (Type I)

Information Theory: **[8 Lectures]**

Information, channel and fundamental limits on performance, random signal, noise in communication systems, uncertainty, information and entropy, average information content (entropy) of symbols in long independent and dependent sequences, source encoding theorem, Shanon's encoding theorem, communication, channel discrete with memory and memoryless, continuous channel, Shanon- Hartley theorem and channel capacity.

Combinational Logic Design: **[12 Lectures]**

Circuit design of logic circuits with ICs: Combinational logic design with SSI gates, MSI devices (RTL. TTL, CTL, ECL, MOS, CMOS, IIL), threshold voltage, operatingspeed, power dissipation, noise margin, logic voltage level, fan in and fan out operations, fault detection and location by path sensitizing and SPOOF methods

Synthesis and design of sequential circuits: Analysis and synthesis of synchronousand asynchronous circuits, hazard free asynchronous circuits, sequential machine,flow chart, reduced dimension map state, function synthesis, logic design with SMcharts with examples.

Modulation Technique for Digital Communication: **[8 Lectures]**

Description of OOK, ASK, OSK, FSK, coherent ASK, PSK and FSK, non-coherent ASK, FSK, differential PSK, bandwidth and power requirement, M-arry signalling scheme, QPSK, transmitter and receivers FSK, PSK and QPSK, multiplexing and demultiplexing: TDM, FDMA, elements of CDMA and spread spectrum techniques and applications, error control coding, methods of controlling errors, types of errorsand codes.

Elements of Optical and Microwave Communication **[8 Lectures]**

Circular waveguides, reflection and matching in waveguides, elementary discussion on propagation of optical signal through fibre, step-index fibre, graded fibre and propagation and multipath dispersion in graded fibre, attenuation in optical fibre, optical communication by laser, detector and amplifier circuits.

Microprocessor and Microcomputer **[4Lectures]**

Microprocessor architecture and microcomputer interfacing, buses, details of microprocessor programming, input/output techniques, modems, higher levellanguages and microcontrollers.

Servomechanism **[4 Lectures]**

Open loop system, first and second order system with derivative and integralcontrol, servomotor and its control circuits

Reading List:

1. Modern Digital and Analog Communication Systems: B. P. Lathi
2. Electronic Communication Systems: Kennedy and Davis
3. Network Analysis: M. E. Van Valkenburg
4. Network Theory and Filter Design: V. K. Aatre
5. Engineering Electronics: J. D. Ryder
6. Integrated Electronics: J. Milman and C.C. Halkias
7. Digital Circuits and Logic Design: S. C. Lee
8. Electronic Communication: D. Roddy and J. Coolen
9. Digital Communication: J. G. Proakisd
10. Digital System Design and Multiprocessor: J. P. Hayes
11. Microprocessor Architecture: Programming and Applications: R. S. Gaonkar
12. Microelectronics: J. Milman
13. Antenna Theory and Design: R. S. Elliot
14. Antenna: J. D. Kraus
15. Antennas and Radio wave Propagation: Robert E. Collin

Paper Name: Advance Electronics Lab
List of Experiments:

Practical: (Any five from the list)

1. Design a low pass and high pass filters (1st and 2nd order)
2. Design a Band pass and band Reject filters
3. Microprocessor Programming experiment
4. Fourier Transform experiment using DSO
5. Modulation index determination experiment
6. Analog /Digital Communication experiment
7. Loss in optical fibre with Laser kit experiment

Paper Code: PHY904S4 **Paper No: SPL1-4**

Paper Name: Adv. Solid State Physics

Credit: 3+1+1

Theory: 48 Lectures

Objectives: The course is designed to provide advanced concepts of solid state physics where topics like dielectrics and ferroelectrics, optical properties of solids, superconductivity, magnetic properties will be discussed.

Course outcome: After completion of the course, the he students will

CO1: Will get knowledge about dielectric and ferroelectric materials, their properties.

CO2: Will get knowledge about the Superconductivity of materials. They will survey of important experimental result; critical temperature, persistent current, Meissner effect; the Basic idea of BCS theory, Type I and Type II superconductor super conducting Materials, and their application. High Tc superconductivity.

CO3: Will get the knowledge about the diamagnetic, paramagnetism. Quantum theory of paramagnetism. Transition metal ions and rare-earth ions in solids. Crystal field effect and orbital quenching. Ferromagnetic and antiferromagnetic ordering. Curie-Weiss theory, Heisenberg theory, Curie and Neel temperatures.

CO4: Will understand quantum Hall effect, two dimensional electron system, Landau quantization.

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Dielectrics and Ferroelectrics: Macroscopic electric field, local electric field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, phase transition, piezoelectricity, ferroelasticity, electrostriction. **(10 Lectures)**

Optical properties of materials: Optical constants and their physical significance, Kramers-Kronig Relations, Electronic inter bond and intra bond transitions, Relations between optical properties and band structures – colour of material (Frenkel Exitons), Bond structure determination from optical spectra reflection, refraction, diffraction, scattering, dispersion, photoluminescence, Electroluminiscence. **(10 Lectures)**

Superconductivity: Phenomenological theories of superconductivity, BCS theory, two fluid and Pippard's theory, Flux quantization, BCS ground state and energygap, Determination of energy gap, Elecron tunnelling in various configurations, SQUID, High temperature superconductors. **(10 Lectures)**

Magnetism: Diamagnetism, paramagnetism, various contributions to para and dia magnetism and diamagnetic susceptibility. Quantum theory of paramagnetism: unfilled electron shells; Hund's rules, Ferromagnetism, antiferromagnetism, molecular field model, susceptibility above Curie temperature, magnetisation below Tc; domains, magnetic energy, Bloch walls, anisotropy energy, Hysteresis – soft and hard magnets;

Magnetic force microscopy. **(12 Lectures)**

Quantum Hall Effect: Integer quantum Hall effect, two-dimensional electron systems, Landau quantization and filling factor. Fractional quantum Hall effect.

(6 lectures)

Suggested Books:

1. Solid State Physics, Neil W Ashcroft and N Devid Mermin, McGraw-Hill Education, 1976).
2. Principles of the Theory of Solids, J M Jiman, Cambridge University Press, 2000.
3. Condensed Matter Physics, Michael P Marder, Wiley Interscience, 2000.
4. Solid State Physics, H Ibach and H Luth, Narosa, 1991
5. Introduction to Superconductivity, M Tinkham, Dover Publications, 2004.

LIST OF EXPERIMENTS

1. Determine the Curie temperature of a given ferroelectric material.
2. Study the thermoluminescence of F-centres in alkali halide crystals.
3. Determine the transverse Magnetoresistance coefficient and resistivity for the given sample and calculate the value of the mobility of the carriers and the carrier concentration (R_H is given).
4. Determine the value of Hall coefficient for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (transverse magnetoresistance coefficient is given)
5. Measure Hall Coefficient, dc conductivity and mobility of a semi-conductor at different temperatures.

Open Elective For SEM-III (OPE-1):

Paper Code: PHY905E1 **Paper No: OPE1-1**

Paper Name: Introduction to Astronomy & Astrophysics I

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will get introduced to basic concepts of Astronomy.
CO2: Students will learn about different types of telescopes.
CO3: Students will understand about stellar structure.
CO4: Students will learn about nuclear reactions in starts and formation of stars.

Introduction to Astronomy:

Astronomical Coordinates - Celestial Sphere, Horizon, Equatorial, Ecliptic and Galatic System of Coordinates, Conversion from one system of coordinates to another, Concept of time, Magnitude Scale - Apparent and absolute magnitudes, distance modulus, Parallax method for distance determination, Determination of mass, luminosity, radius, temperature and distance of a star, Colour Index, Stellar Classification-Henry-Draper and modern M-K Classification Schemes, H-R diagram, H-R Diagram of Clusters, Empirical mass-luminosity relation, Kepler Laws, Binary Systems and their uses.

Different Types of Optical Telescopes and Their Mountings, Telescopes of Gamma Ray, X-Ray UV and IR, mm and Radio Astronomy, Stellar Photometry - Use of Photomultiplier Tube and CCD-based Photometers, Atmospheric Extinction.

Stellar Structure:

Integral Theorems of Hydrostatic Equillibruim for Stars, Dynamical Timescale, Homologous Transformations, the Theory of Polytropic Gas Spheres - Lane Emden Equation and its Solution, Mass-Luminosity Relation, Luminosity-Temperature Relation, Mass Limits of the Main Sequence, Eddington Luminosity, Maximum Stellar Mass, Virial Theorem and Stability of Polytropes, Pressure Equation of State,Electron Degeneracy.

Stellar Radiation Theory:

Electromagnetic radiation and its interaction with matter, Stellar Atmospheres, Transport of Energy in Stellar Interior, Ionization and Mean Molecular Weight, Saha's Ionization Equation and its Applications, Stellar Opacity and Rosseland MeanOpacity Coefficient, Theory of Stellar Radiation and Equation of Transfer, Limb Darkening.

Nuclear Reactions in Stars:

Thermonuclear Reaction Rates, Nuclear Cross-Section, Non-Resonant and Resonant Reaction Rates, Hydrogen Burning in Stars; Helium Flash; Advance of Nuclear

Burning and Nucleosynthesis of Elements, The PP-Chain, The CNO-Cycle.

Star Formation and the Interstellar Medium:

The Interstellar Medium, The Interstellar Extinction, Interstellar Extinction Curves, 21-cm Radiation of Hydrogen, The formation of Protostars - The Jeans Criterion, Free-fall Collapse, Isothermal Collapse, Pre Main-Sequence Stars and Hayashi Track, Main-Sequence and Post Main-Sequence Evolution.

Reference Books:

An Introduction to Modern Astrophysics - Bradley W. Carroll and Dale A. Ostlie

1. An Introduction to the Study of Stellar Structure - S. Chandrasekhar
2. Physics of Stars - A C Phillips
3. Introduction to Stellar Astrophysics - D Prialnik
4. Telescopes and Techniques – C. R. Kitchin
5. Principles of Stellar Evolution and Nucleosynthesis - D D Clayton
6. Astronomical Photometry - A. A. Henden and R. H. Kaitchuk.

Paper Code: PHY905E2 **Paper No: OPE1-2**

Paper Name: Introduction to Atmospheric Science

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will be introduced to Atmospheric Physics, role of various components in climate.

CO2: Students will learn about Atmospheric dynamics, general circulation in atmosphere.

CO3: Students will learn about climate monitoring and prediction, global warming.

CO4: Students will understand atmospheric parameters like pressure, temperature, earth system- oceans, hydrological cycle, carbon cycle.

Introduction:

The components of the climate system- oceans, cryosphere, terrestrial biosphere, earth's crust and mantle, Role of various components in climate, Hydrological cycle, Carbon cycle, Brief history of climate and the earth system Atmospheric thermodynamics: Gas laws, Hydrostatic equation, First law, Adiabatic processes, Water vapour in air, Static stability, Second law and entropy, atmospheric dispersionRadiative transfer: EM spectrum, Radiation laws, Physics of absorption, emission and scattering, Radiative transfer in atmosphere, Planetary radiation budget, Introduction to Remote Sensing

Atmospheric Dynamics: Equations of motion, Geostrophic approximation, Atmospheric General Circulation

Atmospheric Boundary Layer: Surface energy balance and bulk aerodynamic formulae- Vertical structure

Climate dynamics: Present day climate- Climate variability -Climate sensitivity and feedback - Global warming – Climate monitoring and prediction

Unit: 1

Introduction and Earth system **(5 hours)**

- Atmosphere-A brief survey (Pressure, Temperature and Chemical composition), Vertical structure of the atmosphere,
- The Earth system – Oceans
- The Earth system - Hydrological cycle
- The Earth system - Carbon cycle
- The Earth system - Carbon in the oceans and Earth's crust

Unit-2 **(17 hours)**

Atmospheric Thermodynamics

- Atmospheric Thermodynamics- Introduction
- The hydrostatic equation
- Hypsometric equation and pressure at sea level
- Basic Thermodynamics
- Concept of air parcel and dry adiabatic lapse rate
- Potential temperature and problems
- Skew-T ln-P chart

- Lifting Condensation Level (LCL)
- Saturated adiabatic and Psedo-adiabatic processes
- Saturated adiabatic lapse rate
- Tutorial on using Skew-T ln-P chart
- Normand's rule and static stability
- Stability - Brunt-Vaisala frequency
- Conditional and convective stability
- Second law of Thermodynamics - Clausius-Clayperon equation

Unit-3 **(8 hours)**

Radiative transfer

- Atmospheric radiation- Introduction
- Quantitative description of radiation
- Concept of Black body and Stefan-Boltzmann law
- Radiative properties of non-black surfaces
- Kirchoff's law
- Physics of Absorption, Emission and Scattering in the atmosphere
- Equation of Radiative Transfer (RTE)
- Radiative cooling rates

Unit-4 **(5 hours)**

Atmospheric Dynamics

- Atmospheric Dynamics - An Introduction
- Hydrostatic and Geostrophic approximations
- Cyclostrophic approximation and Thermal winds

Unit-5 **(4 hours)**

Atmospheric boundary layer

- Surface energy balance and bulk aerodynamic formulae
- Vertical structure

Unit-6 **(8 hours)**

Climate Dynamics

- Climate Dynamics – Introduction
- Climate sensitivity and feedback
- Transient and equilibrium response
- Tutorial on climate dynamics and feedback

References:

Atmospheric science - An Introductory Survey, J.M.Wallace and P.V.Hobbs, 2nd Edition, Academic Press, London, 2006

1. The Physics of Atmospheres, John Houghton, 3rd Edition, Cambridge

University Press, Cambridge, 2002

2. An Introduction to Atmospheric Thermodynamics, A.A.Tsonis, 2nd Edition, Cambridge University Press, Cambridge, 2007
3. A Climate Modelling Primer, K.McGuffie and A.Henderson-Sellers, 3rd Edition, John-wiley, New York, 2004.
4. Climate Change 2007 - The Physical Science Basis, IPCC Fourth Assessment Report, Cambridge University Press, Cambridge, 2007.

Paper Code: PHY905E3 **Paper No: OPE1-3**

Paper Name: Nano Physics

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will understand the basic concepts of nano materials, their classification.
CO2: Students will understand the differences between bulk and nano structures and the physics behind it.
CO3: Students will learn about fabrication and characterization techniques for nano structured materials.
CO4: Students will learn about different applications of nanomaterials.

Unit 1: Quantum confinement and its consequences, quantum wells, quantum wiresand quantum dots. Electronic structure from bulk to nano crystal, Electronic structure calculations by tight binding and density functional method. Electron states in direct and indirect gap semiconductor nanocrystals, confinement in disordered and amorphous system. (8 Lectures)

Unit 2: Coulomb interaction in nanostructures, concept of dielectric constant for nanostructures. Carrier transport in nanostructure, Coulomb blockade effect,tunnelling and hopping conductivity. Defects and impurities in nanocrystals, deep level and surface defects. Excitons in direct and indirect band gap semiconductor nanocrystals, general formulation of absorption, emission and luminescence, optical properties of nanostructures. (10 Lectures)

Unit 3: Crystalline phase transitions and geometric evolution of the lattice in nano crystals, thermodynamics of very small systems. (4 Lectures)

Unit 4: Synthesis of metal, semiconductor, carbon and bio nanomaterials, thermal evaporation-PVD, E-beam sputtering, Pulsed Laser deposition. Chemical vapor deposition, mechanical milling, photolithography, MBE and MOCVD methods, Gas phase synthesis, chemical and colloidal methods, dispersion in solids, doped glasses, sol-gel methods, nanoporous media. guided self-assembly and aimed structure. Specific features of the nanoscale growth control of size and size distribution, nucleation, growth and aggregation. Processing of nano materials. Fuctionalization of nano materials. (8 Lectures)

Unit 5: Characterizations: Direct imaging, Electron microscopy, SEM & TEM, X-Ray and electron diffractions, optical methods, magnetism at nano scale and mechanical properties at nano scale. XPS, EXAFS, grains and grain boundaries, distribution of grain size, pores and strains. Chemical reactivity, mechanical super plasticity, magnetic and electron transport, GMR and linear and nonlinear optical properties.

(10 Lectures)

Unit 6: Applications of nanomaterials: Electronics, Electromagnetics, magnetic recording, nanophosphors and photonics crystals, mechanical applications, biological and environmental applications. Quantum dot heterostructure lasers, all optical switching and optical data storage, single electron devices, nanomaterials in health care. (8 Lectures)

Reference Books:

Nanostructured Materials and Nano technology by HS Nalwa, Academic Press

5. Introduction to Nanotechnology by C P Poole Jr and F J Owens, Wiley Interscience
6. Characterization of Nanophase Materials by Z L Wang, Wiley VCH
7. Nanomaterials and Nanotechnology by C Brechignac, P Houdy and M Lahmani, Springer
8. Semiconductor Nanocrystal Quantum Dots by A. L. Gogach, Springer Wien, NY

Paper Code: PHY905E4 **Paper No: OPE1-4**

Paper Name: Polymer Physics

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will learn about polymers, structure of polymers, their classification and different parameters of polymers.
CO2: Students will learn about different theories of polymers.
CO3: Students will understand about scattering in polymers, their viscosity.
CO4: Students will learn about colloidal polymers and their properties.

Nomenclature of Polymers, Skeletal structure, homopolymers, copolymers, classification of polymers, Isomerism in polymers, Molar mass distribution, molar mass average. Step-Growth Polymerization, Chain-Growth Polymerization. Average end-to-end distance for model chains (freely-joined, freely rotating and hindered rotation chains), Characteristic ratio and statistical segment length, Semiflexible chains and the persistence length, Spheres, rods and coils, Distributions for end-to- end distance and segment density. **(5 Lectures)**

Thermodynamics of Polymer Solutions and Blends , Regular solution theory (for solution mixtures) Flory, Huggins theory (for polymer solutions), Osmotic pressure of solutions, Number-average molecular weight based on osmotic pressure, Predictions by Flory-Huggins theory, Phase behaviour of polymer solutions, Findingthe binodal, spinodal, and critical point, Miscibility phase diagrams (UCST and LCST), Interpretation and prediction by the Flory-Huggins theory, Flory-Huggins interaction parameter □. **(9 Lectures)**

Light Scattering by Polymer Solutions: Basic concepts, Scattering from randomly placed objects, Scattering from a perfect crystal, Origins of incoherent and coherent scatter, Bragg's diffraction law Scattering by an isolated small molecule, Scattering from a dilute polymer solution, The Form factor, Zimm equation and Zimm plot, Scattering regimes and form factor of spheres, rods and coils. **(7 Lectures)**

Dynamics of Dilute Polymer Solutions: Friction and viscosity, Stokes' law and Einstein's law, Viscous forces on rigid spheres, Suspension of spheres, Intrinsicviscosity and Mark-Houwink equation, Measurement of viscosity, Poiseuille equation and capillary viscometers, Concentric cylinder viscometers, Diffusion coefficient and friction factor, Tracer diffusion and hydrodynamic radius, Mutual diffusion and Fick's laws, Dynamic light scattering, Hydrodynamic interactions and draining, Size Exclusion Chromatography (SEC) **(8 Lectures)**

Linear Viscoelasticity: Basic concepts, Stress and strain, Transient response: Stress relaxation and creep, Dynamic response: loss and storage moduli; complex modulusand complex viscosity, Bead-spring model, Zimm model for dilute solutions, Rouse model, Phenomenology of Entanglement, Reptation model. **(7 Lectures)**

Glass Transition: Definition of a glass, Glass and melting transitions, Thermodynamic aspects of the glass transition, First-order and second-order phase transitions, Kauzmann temperature, Locating the glass transition temperature - Dilatometry - Calorimetry - Dynamic mechanical analysis, Factors affecting the glass transition temperature, Dependence on chemical structure, Dependence on molecular weight, Dependence on composition, Mechanical properties of glassy polymers. **(8 Lectures)**

Colloids, Characterizations of colloidal particles: Size distribution, Inter-particle interactions and Aggregation phenomena, Dynamics of colloidal particles in a suspension, Jamming phenomenon, Applications of colloidal particles. **(4 Lectures)**

Reference Books:

1. M. Rubinstein and R. Colby, "Polymer Physics" (Oxford University Press,2003)
2. G. R. Strobl, "The Physics of Polymers" (Springer, 2007 or later)

Paper Code: PHY905E5 **Paper No: OPE1-5**

Paper Name: Radiation Physics

Credit: 3+0+1

Theory: 48 Lectures

Objective: To impart knowledge in depth about nuclear radiation, its detection, nuclear spectrometry and related aspects.
Course Outcome: Students will have understanding about:
CO1: nuclear radiation and its detection procedure, nuclear spectrometry.
CO2: applications of nuclear spectrometry.
CO3: nuclear radiation for diagnosis in medical field.
CO4: problems related to safety aspect of nuclear radiation.

Radioactivity

Natural radioactivity: Radioactive law, radioactive branching, radioactive decay series, law of successive disintegration and radioactive equilibrium, Units of radioactivity, Applications of radioactivity. Artificial radioactivity: The artificial radionuclides, the transuranic elements, alpha-emitters, isotope tables and nuclide charts. Interaction of radiation with matter, Nuclear cross-section. **(6 Lectures)**

The Radioacive Radon Gas

Sources of atmospheric radiation: Natural and artificial radiations, ionising radiation and its health risks. Indoor radiation: Physical and chemical properties of radon, radon progenies, thoron and its progenies, ranges of alpha particles and recoil nuclei, sources of radon in indoor environs. Geology and radon: Radon in rocks andsoil, formation and emanation of radon, transport of radon, radon concentrations at different soil depths, variations of radon and thoron with geological characteristics, radon in ground water. **(8 Lectures)**

Indoor Radon Measurements

Introduction to indoor radon surveys, Sources of indoor radon: indoor radon and bedrock, indoor radon from building materials, indoor radon from household water,distribution of indoor radon within a house, seasonal variations of indoor radon concentrations. Origin of the radioactivity of the atmosphere in underground mines,Mapping of probability of high radon concentrations in buildings. Applications of radon emission in earth sciences: Uranium exploration, oil prospecting, delineation of faults and thrusts, exploration of geothermal sources. **(10 Lectures)**

Radiation Dosimetry

Units of radiation dose, Absorbed dose, Effective dose, Equivalent dose, Committed dose. Biological effects of radiation: Interaction with the cells and somatic effects of radiation. Radiation protection standards: Radiation dose to individuals from natural radioactivity, basic concepts of radiation protection standards, Radiation accidents. Radon-induced health effects: Indoor radon exposure and its implications,epidemiological studies, radon as carcinogen: lung cancer and other cancers, dosimetry recommendations by international organisations, evaluation and control,remedial measures. **(6 Lectures)**

Radiation Detection and Measurements

Principles of radiation detection, Ionisation chambers, Geiger-Muller counter, Sparkchamber, Scintillation counters, Cherenkov counter, Nuclear emulsion technique, TLD, Solid State Nuclear Track Detectors (SSNTD): CR-39 and LR-115, Gamma RaySpectrometers. **(6 Lectures)**

Medical Instruments

X-rays, NMR, Sonography, Lithography, Endoscopy, chemotherapy. **(2 Lectures)**

Radon Measurements by Etched Track Detectors

Active and passive devices, Track formation mechanism, Etching procedures and methodology, Track visualisations, Track measurement techniques: Optical counting systems and Spark counting systems, Calibration and standardisation of etched track detectors, Radon monitoring devices based on etched track detectors. Uncertainty principles: Poisson and Normal distribution, Statistical errors. **(10 Lectures)**

List of Experiments:

1. To determine indoor radon/thoron concentrations using dosemeters.
2. To determine radionuclides in soil and rocks using gamma spectrometer.
3. To determine radon emissions in subsoil.
4. To determine radon concentrations in air, soil and water using AlphaGuard.

Reference Books:

1. H. Cember, T. Johnson: Introduction to Health Physics, 4th Edition, McGraw Hill.
2. J. E. Turner: Atoms, Radiation and Radiation Protection, 2nd Edition, Willey Interscience
3. F. H. Attix: Introduction to Radiological Physics and Radiation Dosimetry, Willey
1. Interscience.
4. M. G. Stabin: Radiation Protection and Dosimetry: Introduction to Health Physics, Springer.
5. G. F. Knoll: Radiation Detection and Measurement, John Willey & Sons.
6. Nuclear Physics: I. Kaplan, Oxford & IBH Publishing Pvt. Ltd.

Paper Code: PHY905E6 **Paper No: OPE1-6**

Paper Name: Nonlinear Physics

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will be introduced to the concepts of nonlinear waves in optical process, optical bistability, stimulated Brillouin and Rayleigh scattering, Raman scattering.
CO2: Students will understand nonlinear physics in acoustic shock waves, nonlinear Landau damping, nonlinear plasma, nonlinear Schroedinger equation.
CO3: Students will learn nonlinearities in chemistry, biology, economics, ecology and sociology.
CO4: Students will learn numerical methods involving Fourier methods, finite difference method, energy equations.

Unit 1: Nonlinear waves I
Nonlinear optical waves:

1. Introduction to nonlinear optics, Non-linear optical processes, Kramers-Kronig Relations in linear and non-linear optics, wave-equation description of nonlinearoptical interactions, Phase matching, Quasi Phase matching, sum frequency generation, second harmonic generation, difference frequency generation and parametric amplification.
   [8 lectures]
2. Intensity dependent refractive index, self-focusing of light, optical phase conjugation, optical bistability and optical switching, pulse propagation andsoliton.
   [4 lectures]
3. Stimulated Brillouin and stimulated Rayleigh scattering, stimulated Raman scattering
   [4 lectures]
4. The electro-optic effects, Photorefractive effects, Four-Wave mixing in Photorefractive materials
   [4 lectures]
5. Optical solitons: modulation instabilities, linear stability analysis, temporal soliton, soliton stability.
   [6 lectures]

Unit 2: Nonlinear waves II
Nonlinear waves in plasma:

1. Ion acoustic shock waves, Ponderomotive force, parametric instabilities, Nonlinear Landau damping, modulation instability.
   [6 lectures]
2. Equations of nonlinear plasma physics: Kortweg-de Vries equation, Nonlinear Schrödinger equation, Langmuir-wave soliton, soliton in inhomogeneous plasma
   [6 lectures]

Unit 3: Nonlinearities in other branches of science
Examples of Nonlinear phenomena in Chemistry, Biology, Economics, Ecology and Sociology.
[4 lectures]

Unit 4: Numerical methods
Split step Fourier method; Finite difference methods, Numerical solutions of energy equations.
[6 lectures]

Books:

1. Nonlinear Optics, Robert W. Boyd (Academic press)
2. Non-linearfiber optics, G. Agrawal (Academic press)
3. Introduction to Plasma Physics and Controlled Fusion, F. F. Chen, (Springer)
4. Darbaux Transformations and Solitons, V. B. Matveev and M A Salle (Springer series in Nonlinear Dynamics)

Semester IV

Paper Code	Paper No	Paper Name	Credit
PHY1001C	C12	Numerical Analysis and Computer Programming	2+0+2
PHY1002S	SPL2		5
PHY1003E	OPE2		4
PHY1004dPW	DPW	Dissertation & Project Work	6

Special Papers: (Credit 5)

For SEM-IV (SPL-2):

Paper Code	Paper No	Paper Name	Credit
PHY1002S1	SPL2-1	High Energy Physics –II	4+1+0
PHY1002S2	SPL2-2	Nuclear Physics	3+1+1
PHY1002S3	SPL2-3	Thin Film Physics	4+1+0
PHY1002S4	SPL2-4	Advanced Electronics II	3+1+1
PHY1002S5	SPL2-5	Astronomy and Astrophysics	4+1+0

Open Elective (Interdisciplinary): (Credit 4)

For SEM-IV (OPE-2):

Paper Code	Paper No	Paper Name	Credit
PHY1003E1	OPE2-1	Introduction to Astronomy & Astrophysics II	3+1+0
PHY1003E2	OPE2-2	Biophysics	3+1+0
PHY1003E3	OPE2-3	Opto Electronics	3+0+1
PHY1003E4	OPE2-4	Physics of Materials	3+1+0
PHY1003E5	OPE2-5	Plasma Physics	3+1+0

Paper Code: PHY1001C **Paper No: C12**

Paper Name: Numerical Analysis and Computer Programming

Credits: 2+0+2

Theory: 32 Lectures

Objective: The basic objective of this paper to teach computer programming for writing programes and running the same in computers.
CO1: Students will learn about representations of integers, real numbers in computers, float point arithmetic, rounding and truncation errors.
CO2: Students will learn high level programming with C++
CO3: Students learn to solve nonlinear equations using C++
CO4: The students will learn programming to write and run computer programes for interpolation, curve fitting numerical integration, solving differential equations.

Introduction: (2 Lectures)
Representation of integers and real numbers in computers; floating point arithmetic; rounding and truncation errors; introduction to simple numerical procedures suchas iterations, recursions etc .

High Level programming language with emphasis on C++: (4 Lectures)
An overview of Computers and Programming Languages, Basic Elements of C++, Input/Output, Control Structures I (Selection) and Control Structures II (Repetition),User defined functions I, User defined function II, User defined simple data types, Name-spaces and the string, Arrays and strings, Arrays and strings, Application of arrays (searching and sorting), Structures and Unions, Idea of classes and objects

Solution to non-linear equations: (4 Lectures)
Isolation of roots of simple equations; general methods for solving transcendental equations; Fixed Point Iteration method, Newton-Raphson method - advantages and disadvantages; Secant Method, Regula-Falsi method; propagation of errors in each ofthese methods.

Solution of linear systems Ax = b: (4 Lectures)
Gauss elimination, Gauss-Jordan elimination and Gauss-Seidel methods.

Interpolation and curve-fitting: (4 Lectures)
Polynomial interpolation using Lagrange's method; construction of Newton-Gregory forward difference and backward difference tables; error estimation in these methods; curve-fitting and the principle of least square.

Numerical Integration: (8 Lectures)
Integration as quadrature (or area under the curve); Newton-Cote's formulae: trapezoidal and Simpson's rule; Gaussian quadrature. Monte Carlo Integration: Uniform random number generation, Statistical Distributions and Their Properties, Rejection Method, Transformation Method, Crude Monte Carlo, Importance Sampling Monte Carlo, Metropolis Algorithm, Evaluation of Multi-dimensional Integrals, Evaluation of Surface and Volume Integrals bounded within a region.

Solution of differential equations: (6 Lectures)

Euler's method for solving first order linear differential equations (initial valueproblem): limitations and discussion on its accuracy; Runge-Kutta method and its comparison with Euler's method; 4th order R-K method. Solving second order ordinary differential equations with boundary conditions using finite differencemethod.

List of Experiments: Computer Laboratory

1. Introduction to Linux and C++ Programming
2. Introduction to Graphics (gnuplot etc)
3. Finite and Infinite Series
4. Matrices (arrays of variable sizes, addition, subtraction, multiplication, eigenvalues, eigenvectors, matrix inversion, solutions of simultaneous equations)
5. Interpolation by using difference table and divided difference table
7. Derivative by forward difference and central difference methods
8. Integration by Gauss-Legendre quadrature method
9. Solving first and second order ODEs by Euler and Runge-Kutta methods
10. Solving second order ODE using finite difference method
11. Schrodinger equation (finding eigenvalues abd eigenfunctions)
12. Solving wave equation and Laplace equation in two dimensions
13. Monte Carlo methods: (e.g. simulating the value of π and evaluation of integrals)
14. Ground state energies of quantum mechanical systems using Variational Monte Carlo techniques
15. Applications of numerical techniques using C++ to solve some problems in Physics based on Classical Mechanics, Statistical Mechanics, Quantum Mechanics, Waves and Oscillations, etc.

Reference Books:

Introductory Methods of Numerical Analysis: S. Sastry

1. Numerical Methods: E. Balagurusamy
2. Computer Oriented Numerical Methods: V. Rajaraman
3. FORTRAN 77 and Numerical Methods: C. Xavier
4. Numerical Recipes: W. Press
5. Numerical Recipes Example Book (FORTRAN): W. Vetterling and W. Press
6. Gnuplot in action: understanding data with graphs, Philip K Janert
7. Computational Physics: An Introduction, R. C. Verma et al.
8. Linux Command Line and Shell Scripting Bible - Richard Blum
9. Unix: Concepts and applications – Sumitabha Das.

<u>Special Papers For SEM-IV (SPL-2):</u>

Paper Code: PHY1002S1 **Paper No: SPL2-1**

Paper Name: High Energy Physics-II

Credit: 4+1+0

Theory: 64 Lectures

General concepts of Gauge Theories: (20Lectures)

Gauge theories of interaction, Abelian and Non-Abelian gauge theories, local and global invariance in gauge theories, Yang-Mills Theory.

Standard Model: SU(2)xU(1) electroweak theory, 2 component left handed fermions,weak and charged neutral currents, Spontaneous symmetry breaking, Goldstone theorem and Goldstone bosons, SU(2)XU(1) symmetry breaking via Higgs mechanism, masses of vector bosons.

Quantum Electro-Dynamics: (16Lectures)

Interacting fields: Interaction representation, Normal and time ordered products,Wick's theorem.

Feynman diagrams and rules in QED, Calculation of QED first and second order processes, Mott scattering, Compton scattering, renormalization of charge and mass.

Electrodynamics of quarks and hadrons: (16Lectures)

Elastic electron-muon scattering, electron positron annihilation to hadrons, elastic e -p scattering and concepts of form factors and charge radii, deep-inelastic scatteringand structure function, Parton model, Bjorken scaling and its violation, Elementary ideas of QCD evolution equations.

Beyond standard model: (12Lectures)

Introductory ideas on grand unified theories (GUTs). SU(5) model and proton decay possibilities, neutrino puzzles, neutrino oscillations and neutrino masses.

Reading List:

1. Introduction to Elementary Particles: David Griffiths
2. Quarks and Leptons: An Introductory Course in Modern Particle Physics:Francis Halzen & Alan D. Martin
3. Gauge Theory of Elementary Particle Physics: Ta-Pei Cheng & Ling-Fong Li
4. Quantum Field Theory: L. H. Ryder
5. Relativistic Quantum Mechanics (Vol-I & Vol-II): James D. Bjorken & Sidney D. Drell

Paper Code: PHY1002S2 **Paper No: SPL2-2**

Paper Name: Nuclear Physics

Credit: 3+1+1

Theory: 48 Lectures

Course Outcomes:

CO1: The students will be able to understand better of the basic properties of nuclei and nuclear structure, learn the variants of nuclear reactions and detectors.

CO2: The students will learn nuclear excitation and decay, selection rule, beta decay.

CO3: The students will develop a thorough understanding of nuclear instrumentation, accelerators, data acquisition.

CO4: The students will understand fission and fusion reactions, slowing down of neutrons, rate of energy loss, application of nuclear energy.

Nuclear Model

i. Shell model: Independent particle model, total spin J for various configurations, configuration mixing, electric dipole and quadrupole moments of various nuclei in the light of extreme single particle shell model.

ii. Collective model: Failure of shell model in understanding the excited states of even-even nuclei, dynamics of collective motion, rotational and vibrational modes, Hamiltonian for collective model of a deformed nucleus -- Nilsson model. **(6 Lectures)**

Nuclear Excitation and Decay

i. Nuclear transition matrix elements, electromagnetic interaction of nuclei, multi- pole expansion, transition probability, angular momentum and parity, selection rules, nuclear isomerism, internal conversion, internal pair-creation, angularcorrelation.

ii. Weak interaction and beta decay, transition rate for beta decay, neutrino mass measurement, polarization of electron and neutrino helicity, two component theory of neutrino, parity violation in weak interactions. **(6 Lectures)**

Nuclear Instrumentation

Linear accelerator -- tandem and pelletron, variable energy cyclotron, radioactive ionbeam, detectors -- photographic emulsion, solid state nuclear track detectors.

Data acquisition techniques: pre-amplifier, pulse shaping networks in amplifiers, time to amplitude converter (TAC), analogue to digital converter (ADC). **(12 Lectures)**

Fission and Fusion:

i. Characteristics of fission, fission cross-section, spontaneous fission, mass andenergy distribution of fission fragments, slowing down of neutrons, rate of energy loss due to successive collisions, Fermi age equation

ii. Particle and nuclear interaction in the early universe, primordial nucleosynthesis,basic fusion processes, characteristics of fusion, stellar nucleosynthesis, s-process and r-process ($A < 60$ & $A > 60$) **(16 Lectures)**

Applications of Nuclear Physics

The technique of NMR, some experiments using NMR; the Mossbauer effect, some experiments on Mossbauer effect. **(4 Lectures)**

Cosmic rays:

Source, origin, cosmic ray showers, experiments on cosmic rays. **(4 Lectures)**

List Experiments:

1. To determine efficiency of a GM counter
2. To determine the dead time of a GM counter
3. To determine radon concentrations in air, soil and water using AlphaGuard.
4. To determine radionuclides in soil and rocks using gamma spectrometer.

Reading List:

1. Nuclear Physics: Roy and Nigam
2. Introduction to Nuclear Reactions: G. R. Satchler
3. Structure of the Nucleus: M. A. Preston & R. K. Bhaduri
4. Nuclear Physics -- Principles and Applications: John Lilley
5. Nuclear Physics -- Experimental and Theoretical: H. S. Hans
6. Nuclear Physics (Vol. I, II, III): E. Segri
7. Nuclear and Particle Physics: W. E. Burcham & M. Jobes
8. Introductory Nuclear Physics--Kenneth S. Krane: Willey Publications

Paper Code: PHY1002S3 **Paper No: SPL2-3**

Paper Name: Thin Film Physics

Credit: 4+1+0

Theory: 64 Lectures

On the successful completion of the course, student will be able to

CO1: acquire the knowledge about the fundamentals of nucleation and various crystallization theories.

CO2: understant various thin film deposition techniques, evaluate the merits and demerits of different growth techniques and design a new growth approach to overcome the existing demerits.

CO3: apply the essential processing parameters for thin film deposition techniques and characterization techniques

CO4: Understand different physical properties like optical, electrical, magnetic properties of thin films

Introduction:

Thin film, importance of thin film, Nucleation and Growth, Film Formation, Growth modes and Zone models. **(8 Lectures)**

Film Deposition Methods:

o Physical methods of films deposition:

Evaporation – thermal, e-beam

Sputter Deposition - DC, MF, RF, Microwave, pulsed laser, Ion BeamArc

Deposition – Cathodic, Anodic

Molecular Beam Epitaxy **(10 Lectures)**

o Chemical methods of Film deposition: Deposition

of Inorganic Films From Solutions

Chemical Vapor Deposition - Electrolysis, Anodization, Spray pyrolysis, polymerization **(8 Lectures)**

o Other techniques:

Langmuir Blodgett, Self-Arrangement Monolayer and Spin Coating **(6 Lectures)**

Properties of Thin Films:

Optical properties, electrical properties, conductivity in thin films, magneticproperties, mechanical properties. **(10 Lectures)**

Thin Film Characterization:

Imaging Techniques, Structural Techniques, Chemical Techniques, Optical Techniques, Electrical / Magnetic Techniques, Mechanical Techniques. **(12 Lectures)**

Applications for Thin Film of Advanced Materials:

Transparent conducting coating, Optical coating, Sensors, Superconductivity, Giantand colossal magnetoresistance, Superhard coatings, Ferro-electronic effect.

(10 Lectures)

References:

1. Thin Film Phenomena - K L Chopra, McGraw-Hill.
2. Thin Film - Ashok Goswami, New Age Intl., India.
3. Thin Film Deposition: Principles and Practice, Donald L. Smith, McGrawHill, Singapore.
4. Plasma techniques for film deposition, Konuma Mitsuharu, Alpha Science, Harrow, UK.
5. Introduction to surface and thin film processes, John A. Venables, Cambridge : Cambridge University Press.
6. An introduction to physics and technology of thin films, Alfred Wagendristel, Yuming Wang, Singapore : World Scientific.
7. Thin film processes, John L Vossen, Werner Kehn editors, Academic Press, New York.
8. Thin film physics, O.S. Heavens, London : Methuen.

Paper Code: PHY1002S4 **Paper No: SPL2-4**

Paper Name: Advanced Electronics II

Credit: 3+1+1

Theory: 48 Lectures

CO1: Students will learn about digital signal processing, classification of signals,

CO2: Students will understand cellular and mobile communication, GSM, performance of cellular phones, operation system of cellular phone.

CO3: Students will have hands on experience of signal processing, Fourier analysis of waveforms, fabrication of low pass, high pass and band pass filters.

1. Digital Signal Processing (DPS): [16 Lectures]

Discrete-Time signal and systems: Discreet-Time signals and classification, Operation on signals, discrete-Time systems, Classification of Discrete-Time systems, Impulse resource and convolution sum, difference equation, FIR and IIR systems, stable and unstable systems.

Z-transform: Z-Transform, ROC of finite duration sequences, ROC of Infinite duration sequences, ROC of two sided sequences, properties of Z-transforms, relation between Fourier transform and Z-transform, inverse Z-transform.

Digital filters: Design of IIR filters from analog filter- approximation of derivatives, impulse invariance, bilinear transformation, matched Z transformation.

2. Spread-Spectrum techniques in Communication: [12 Lectures]

Principle of spread spectrum, Time Hop spreading, spread spectrum Modulationsystem, Generation of Pseudo Random Sequences, Spread spectrum modulation,Reception of Spread spectrum signal, Code Division Multiple Access (CDMA).

3. Cellular and Mobile Communication: [20 Lectures]

Main methods of Radio Transmission, GSM standard for Cellular Telephony,Architecture of GSM, Cellular Mobile Radio systems, structure of Cellophane,working, other Services of GSM, performance criterion for Cellular phones,Operation of Cellular systems, Concept of frequency reuse channels, consideration of components in a Cellular systems, power control for Cellular systems, function of MTSO, Cellular analog switching equipment, Cellular digital switching equipment,Digital Mobile telephony, MTSO interconnection, Radio paging systems.

List of Experiments:

1. Designing of a 4 to 1 MUX and 1 to 4 DEMUX
2. Fourier analysis of different waveforms using Digital Storage Oscilloscope
3. Designing of Low pass, High pass and Band pass filters using DSP.
4. Simulation: System identification: Signal processing using Matlab tool box.

Reference Books:

1. Digital Signal Processing: Alvan V. Oppenheim & Ronald W. Schafer
2. Signals and Linear Systems: Rabert A. Gabel & Richard A. Roberts
3. Digital Signal Processing: P. Ramesh Babu
4. Communication Systems: Sanjay Sharma

Paper Code: PHY1002S5 **Paper No: SPL2-5**

Paper Name: Astronomy and Astrophysics

Credit: 4+1+0

Theory: 64 Lectures

CO1: The students would be able to get adequate idea on the Astronomy & Astrophysics specialization: about the astronomical observation, stellar structure, stellar evolution, the solar system, galaxies and also about the statistical tools to be used for astrophysical analysis.
CO2: The students, opting a career in teaching and research in astronomy and astrophysics, will get adequate training.
CO3: The students will also get adequate training for a career in Astroparticle physics.

Introduction to Astronomy [6 lectures]

The celestial sphere; coordinate systems; concept of time; magnitude scales and colour index; astronomical telescopes; Stellar parallax and other methods to measure stellar distances; binary systems and derivation of stellar parameters. Solar interior, solar atmosphere and the solar cycle.

Stellar Structure [10 lectures]

Integral Theorems of Hydrostatic Equillibruim for Stars, Dynamical Timescale, Homologous Transformations, the Theory of Polytropic Gas Spheres - Lane Emden Equation and its Solution, Mass-Luminosity Relation, Luminosity-Temperature Relation, Mass Limits of the Main Sequence, Eddington Luminosity, Maximum Stellar Mass, Virial Theorem and Stability of Polytropes, Pressure Equation of State, Electron Degeneracy.

Stellar Radiation Theory [6 lectures]

Transport of energy in stellar interior; ionization and mean molecular weight; Saha's ionization equation; stellar opacity and Rosseland mean opacity coecient; theory of stellar radiation and equation of transfer; limb darkening; stellar classication and the Hertzsprung-Russel (H-R) diagram.

Nuclear Reactions in Stars [6 lectures]

Thermonuclear reaction rates; nuclear cross section; non-resonant reaction and resonant reaction rates; hydrogen burning in stars; helium flash; advance stages of nuclear burning and nucleosynthesis of elements.

Star Formation and the Interstellar Medium [10 Lectures]

The Interstellar Medium, The Interstellar Extinction, Interstellar Extinction Curves, 21-cm Radiation of Hydrogen, The formation of Protostars - The Jeans Criterion, Free-fall Collapse, Isothermal Collapse, Pre Main-Sequence Stars and Hayashi Track, Main-Sequence and Post Main-Sequence Evolution.

Physics of Compact Objects [6 lectures]

The end point in stellar evolution; degenerate stars; white dwarf mass and Chandrasekhar's limit; mass-radius relation; collapse of stellar core; electron capture and formation of a neutron star; gravitational binding energy of neutron stars; rotating neutron stars and pulsars; the maximum mass of a neutron star.

Galaxies [10 lectures]

Classification of Galaxies and Their Properties, Active Galatic Nuclei and Their Classification, The Milky Way Galaxy: Structure, Content, Rotation, Kinematics, Stellar Populations, Surface Brightness - Isophotes and the de Vaucouleurs Profile, The Rotation Curves of Galaxies, Dark Matter, The Tully-Fisher Relation, Mass-to-Light Ratios.

Large-Scale Structure of the Universe [10 lectures]

Cosmic Microwave Background Radiation, Expansion of the Universe: The Cosmological Context, The Proper Distance, The Luminosity Distance, The Redshift-Magnitude Relation, Cosmological Distance Ladder, Standard Candles, Measurement of Distances: Cepheid Distance Scale and the Underlying Physics, Main Sequence Fitting, Tully-Fisher Relation, Type Ia Supernova, The Hubble Constant and Age of the Universe, Cosmological Models.

Reference Books:

1) An Introduction to Modern Astrophysics - Bradley W. Carroll and Dale A. Ostlie
2) An Introduction to the Study of Stellar Structure - S. Chandrasekhar
3) Physics of Stars - A C Phillips
4) Introduction to Stellar Astrophysics - D Prialnik
5) Telescopes and Techniques – C. R. Kitchin
6) Principles of Stellar Evolution and Nucleosynthesis - D D Clayton
7) Astronomical Photometry - A. A. Henden and R. H. Kaitchuk

8) Astrophysics for Physicists - A.R. Choudhuri
9) An Introduction to Astronomy and Astrophysics - P. Jain
10|) Galaxy Formation and Evolution. Galaxy Formation and Evolution - H. Mo, F. van den Bosch, and S. White.
11) Galaxies in the Universe: An Introduction - Linda S. Sparke and III Gallagher, John S.

Open Elective For SEM-IV (OPE-1):

Paper Code: PHY1003E1 **Paper No: OPE1-1**

Paper Name: Introduction to Astronomy & Astrophysics II

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will learn about the sun, physical characteristics of Sun, solar magnetic field, solar atmosphere.

CO2: Students will learn about different stars, stellar pulsation, period-luminosity relations, the physics of stellar pulsation.

CO3: Students will understand evolution and end point of stars, supernova, types of supernova, Chandrasekhar's limit, white dwarf, neutron stars, black holes.

CO4: Students will learn about galaxies, classification of galaxies, their properties; structure, content and rotation of milky way galaxy.

Sun:

Physical Characteristics of Sun - Basic Data, Solar Rotation, Solar Magnetic Fields, Photosphere - Granulation, Sunspots, Babcock Model of Sunspot Formation, Solar Atmosphere - Chromosphere and Corona, Solar Activity – Flares, Prominences, Solar Wind, Activity Cycle, Helioseismology.

Stellar Pulsation:

Observations of Pulsating Stars, The Period-Luminsoty Relation, The Instability Strip, The Physics of Stellar Pulsation - The Period-Density Relation, Radial Modes of Pulsation, Eddingtin's Thermodynamic Heat Engine, Opacity Effects and the Kappa and Gamma Mechanisms, The Hydrogen and Helium Partial Ionization Zones.

Physics of Compact Objects:

The End Point in Stellar Evolution, Supernova - Type I and Typen II Supernova, The Physics of Degenerate Stars - The Pauli Exclusion Principle and Electron Degeneracy, White Dwarfs, Classes of White Dwarfs, Chandrasekhar's Mass limit and Mass-Radius Relations for White Dwarfs, Neutron Stars - Neutron Degeneracy, Pulsars, The Maximum Mass of Neutron star, Tolman-Oppenheimer-Volkof Equation, Black Holes and Gamma Ray Bursts.

Galaxies:

Classification of Galaxies and Their Properties, Active Galatic Nuclei and Their Classification, The Milky Way Galaxy: Structure, Content, Rotation, Kinematics, Stellar Populations, Surface Brightness - Isophotes abd the de Vaucouleurs Profile, The Rotation Curves of Galaxies, Dark Matter, The Tully-Fisher Relation, Mass-to- Light Ratios.

Large-Scale Structure of the Universe:

Cosmic Microwave Background Radiation, Expansion of the Universe: The

Cosmological Context, The Proper Distance, The Luminosity Distance, The Redshift-Magnitude Relation, Cosmological Distance Ladder, Standard Candles, Measurement of Distances: Cepheid Distance Scale and the Underlying Physics, Main Sequence Fitting, Tully-Fisher Relation, Type Ia Supernova, The Hubble Constant and Age of the Universe, Cosmological Models.

Reference Books:

An Introduction to Modern Astrophysics - Bradley W. Carroll and Dale A. Ostlie

1. An Introduction to the Study of Stellar Structure - S. Chandrasekhar
2. The Physical Universe: An Introduction to Astronomy - Frank H. Shu
3. Physics of Stars - A C Phillips
4. Introduction to Stellar Astrophysics (Vol I, II and III) - Erika Bohm-Vitense
5. An Introduction to Astronomy and Astrophysics - Pankaj Jain
6. Astrophysics for Physicists - Arnab Rai Choudhuri
7. Fundamental Astronomy - H. Karttunen et al.
8. Introduction to Stellar Astrophysics - D Prialnik
9. Galactic Astronomy - J. Binney and M. Merrifield
10. Solar Astrophysics – P. V. Foukal

Paper Code: PHY1003E2 **Paper No: OPE2-2**

Paper Name: Biophysics

Credit: 3+1+0

Theory: 48 Lectures

Aim and Objective

This course aims to bridge the gap between basic physics and '*Physics of life*'. It provides a basic knowledge on the application of physical principles of Thermodynamics and Statistical Mechanics in biological systems. The contents of thecourse will aid students to understand molecular structure, their behavior and different biological processes.

Pre-requisite: A basic knowledge in biology is desirable, though not mandatory, to credit this course.

CO1: Students will get introduced to proteins, DNA, RNA, lipids and carbohydrates.
CO2: Students will learn about application of statistical thermodynamics in biology.
CO3: Students will understand chemical kinetics, transport phenomenon in Biology.
CO4: CO1: Students will learn molecular dynamics, free energy calculations, issues in protein structure prediction.

Syllabus

Introduction to bio-macromolecules **[4 Lectures]**

Proteins, DNA, RNA, lipids and carbohydrates.

Applications of equilibrium and non-equilibrium Statistical Thermodynamics in Biology **[8 lectures]**

Definition of equilibrium, steady state, out of equilibrium systems, enthalpy, entropy, free energy and their applications in biology, protein folding, protein aggregation.

Chemical kinetics in Biology **[8 lectures]**

Law of mass action, catalysis and enzymes, Michaelis–Menten (M.M.) kinetics, Inhibition, Allostery

Transport phenomena in Biology **[8 lectures]**

Diffusion, anomalous diffusion, phase transition, polymer translocation, ion channels, molecular motors

Life at low Reynolds number **[7 lectures]**

Scallop theorem, Reciprocal deformation, swimming of microorganisms, mechanismof propulsion

Pattern formation in Biology **[8 lectures]**

Order in space & time, instabilities, Turing patterns

Molecular dynamics of macromolecules **[5 lectures]**

Molecular mechanics; free energy calculations; conformational sampling; Issues in protein structure prediction

Recommended Texts:

1. Molecules of life – Physical and Chemical principles by J. Kuriyan, B. Konforti and D. Wemmer, Taylor and Francis (2013)
2. Molecular driving forces: Statistical Thermodynamics in Chemistry and Biology by K. Dill and S. Bromberg, Garland Science (2010)
3. Biological Physics: Energy, Information, Life by P. Nelson, W.H. Freeman & Co. (2007)
4. Physical biology of the cell by Rob Phillips, Jane Kondev, Julie Theriot,Hernan G.Garcia, Garland Science (2013)

Reference(s):

- **Principles of Physical Biochemistry** by K. E. van Holde, W. C. Johnson and P. S. Ho, , Prentice Hall, 1998.
- **Biophysics: Searching for Principles** by W. Bialek
- **Life at Low Reynolds Number**, E.M. Purcell, *Am. J.Phys*, **45,** 3-11,1977.

Paper Code: PHY1003E3 **Paper No: OPE2-3**

Paper Name: Opto Electronics

Credit: 3+0+1

Theory: 48 Lectures

CO1: Students will learn about light sources and their characterization, efficiency of light sources, use of optical filters, total internal reflection.
CO2: Students will understand about simple and hetero-junction light sources, simple and double hetero structure light sources, LEDs, types of LEDs.
CO3: Students will learn about light detectors, different types of light detectors, and use of light detectors.
CO4: Students will learn about optical fiber, theories involving optical fiber, transmission through optical fiber, losses in optical fiber, splicing and fiber connections, optical fiber devices.

Basic Optics: **[3 lectures]**

Natural, artificial and specialized light sources, characterization of light sources based on intensity spectrum, emission, spatial distribution, conversion efficiency. Experimental methods for studying these characteristics; Use of optical filters, their disadvantages and necessity and use of monochromatic source, Snell's law, Total Internal Reflection.

Light Sources: **[6 lectures]**

Study of LEDs: variable band-gap semi material idea of hetero-junction, simple and double hetero structure light sources, quantum efficiency, internal and external quantum efficiency, expression for total and internal quantum efficiency, reasons for external quantum efficiency to be less than internal quantum efficiency, intensity distribution of LED, Lambertial sources, encapsulation of LEDs, types of LED surfaces and edge emitting, Burus LED.

Light Detectors: **[7 lectures]**

Idea of light detectors and their basic types, natural and specialised light detectors, type of specialised light detectors, thermal, quantum light detectors, types of quantum photodetectors, photo-resistive, photo-voltaic, photo-emissive detectors. Study of quantum detectors - photo-electric cell, photo-multiplier tube, photo- diode, Important characteristics of light detectors - spectral response, viewing angle, efficiency and material used for photo-detectors.

Optical Fibre: Theory and Applications: **[16 lectures]**

Advantages of optical fibre communication over normal medium. Step index and graded-index fibres, expression for angle of acceptance and cone of acceptance, Numerical aperture, time dispersion, splicing and fibre connections, requirements of splicing, practical methods of splicing; Types of optical fibre connectors, losses in optical fibre communication. Losses due to fibres: intrinsic and extrinsic losses, intrinsic losses due to atomic scattering and molecularabsorption, expression for loss factor. Extrinsic losses due to mechanical effects, micro bends, cracks etc. Losses due to connectors, core longitudinal, angular misalignment, mismatch of rate indices of fibre material etc.

Action of optical fibre as wave guide, necessary conditions for wave-guiding mechanisms of optical fibres, Expression for electromagnetic wave guided by fibre, modes of transmission, dispersion in optical fibres, wavelength and time dispersion, internodes dispersion

Optical Fibre Systems and Devices: [9 lectures]
Optical transmitter/receiver circuits, driver circuits for LED, detector circuit design using photo- diode, photo transistors and fibre choice. Communication over special fibres, DS fibres, NZDS fibre, integrated optics, slab and strip waveguides and electro-optic devices - phase shifters, interferometer modulators.

Opto-electronic modulation and switching devices: analog and digital modulation, electrooptic modulators, optical switching and logic. Opto-electronic integrated circuits.

Measurement on Optical Fibre: [7 lectures]
Optical fibre experimental set-up, launching light into fibre, detection etc. Fibre attenuation measurement, dispersion measurement, profile measurement, numerical aperture measurement, diameter measurement.

Paper Name: **Optoelectronics Lab**
Practical [Any 5 experiments to be performed]
1. Study of characteristics of:
i. Photo-diode
ii. Photo-transistor
2. Study of characteristics of
i. LDR
ii. LED
3. Study of characteristics of a solar cell
4. Studies of
i. Analog signal transmission through fibre
ii. Digital signal transmission through fibre
5. Study of fibre optics voice communication through fibre with different bending losses
6. Study of Splice loss in fibre optics
7. PC-to-PC communication using RS232 port over fibre
8. Transmission of modulated signal through optical fibre and its demodulation

9. Time division multiplexing and demultiplexing through optical fibre
10. Study of Gaussian nature of LASER beam and evaluation of beam spot-size

Reading List:

1. Optical Electronics: A. K. Ghatak & K. Thyagarajan
2. An Introduction to Fibre Optics: A. K. Ghatak & K. Thyagarajan
3. Semiconductor Optoelectronic Devices: P. Bhattacharya
4. Optoelectronics and Fibre Optics Communication: C. K. Sarkar & D. C. Sarkar
5. Fibre Optics Essentials: A. K. Ghatak & K. Thyagarajan

Paper Code: PHY1003E4 **Paper No: OPE2-4**

Paper Name: Physics of Materials

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will learn about a wide range of characterization techniques used to study materials.
CO2: Students will understand different properties of materials like mechanical properties, dielectric properties, magnetic properties, optical properties,
CO3: Students will understand the basic methods to characterize materials and study the properties and hence find their applicability in different areas.
CO4: Students will learn about advanced materials like metallic glasses, piezoelectric, magnetostrictive, electrostrictivematerials, shape memory alloys, rheological fluids, CCD device materials and applications, solar cell materials.

CHARACTERISATON OF MATERIALS: Thermo-gravimetric analysis (TGA), differential thermal analysis (DTA), cooling curves, differential scanning calorimetry (DSC), determination of thermo-mechanical parameters. Bright field and Dark field optical microscopy, phase contrast microscopy, confocal microscopy, scanning probe microscopy (SPM), STM, AFM. SEM, EDAX, EPMA, TEM, UV-Vis-IR absorption, Photoluminescence, electroluminescence, thermoluminescence. Two probe and fourprobe methods, van der Pauw method, C-V characteristics, Schottky barrier capacitance, electrochemical C-V profiling. FTIR spectroscopy, Raman spectroscopy, ESR, NMR, Nuclear quadrupole resonance (NQR) spectroscopy, XPS, AES and SIMS, Proton induced X-ray Emission spectroscopy (PIXE), Rutherford BackScattering (RBS). **(14 Lectures)**

MECHANICAL PROPERTIES: Factors affecting mechanical properties - mechanical tests - tensile, hardness, impact, creep and fatigue - Plastic deformation by slip, shear strength, work hardening and recovery, fracture, creep resistant materials, Fick's law. **(6 Lectures)**

DIELECTRIC PROPERTIES: Dielectric constant and polarizability, different kinds of polarization, Internal electric field in a dielectric, Clausius-Mossotti equation,dielectric in dc & ac field, dielectric loss, ferroelectric - types and models of ferro electric transition, piezoelectric and pyroelectric materials. **(7 Lectures)**

MAGNETIC PROPERTIES: Dia, para, ferro, antiferro and ferrimagnetism, Langevin and Weiss theories, exchange interaction, magnetic aniostrophy, magnetic domains, molecular theory, hysteresis, hard and soft magnetic materials, ferrite structure and uses, magnetic bubbles, magnetoresistance - GMR materials, dilute magnetic semiconductor (DMS) materials. **(7 Lectures)**

OPTICAL PROPERTIES: Optical absorption in insulators, semiconductors and metals – band to band absorption, luminescence, photoconductivity. Injection luminescence and LEDs - LED materials, super luminescent LED materials, liquid crystals - properties and structure, liquid crystal displays, comparison between LEDand LC displays. **(6 Lectures)**

TECHNOLOGICAL MATERIALS: Metallic glasses - preparation, properties and applications, SMART materials, piezoelectric, magnetostrictive, electrostrictivematerials, shape memory alloys, rheological fluids, CCD device materials and applications, solar cell materials (single crystalline, amorphous and thin films), surface acoustic wave and sonar transducer materials and applications, introduction to nanophase materials and their properties. **(8 Lectures)**

REFERENCE BOOKs:

1. Growth and Characterization of semiconductors, Stradling, R.A; Klipstain, P.C; Adam Hilger, Bristol,1990.
2. Electron microscopy and microanalysis of crystalline materials, Belk, J.A; Applied Science Publishers, London, 1979.
3. Electron and Ion microscopy and Microanalysis principles and Applications,Lawrence E.Murr, Marcel Dekker Inc., New York, 1991
4. Analytical Chemistry, D.Kealey & P.J.Haines, Viva Books Private Limited, New Delhi 2002.
5. Materials Science and Engineering, V.Raghavan, Prentice Hall,2003.
6. Superfludity and superconductivity, D.R.Tilley and J.Tilley, 3rd Edition, Hilger,1990.
7. Introduction to solid state physics, Charles Kittel, Wiley 7th edition, 1996.
8. Principles of solid state physics, K.V.Keer, Wiley - Eastern, 1993.
9. Microelectronic Materials - C.R.M.Grovenor, Adam Hilger, Bristol and Philadelphia,1989.

Paper Code: PHY1003E5 **Paper No: OPE2-5**

Paper Name: Plasma Physics

Credit: 3+1+0

Theory: 48 Lectures

CO1: Students will be introduced to the fourth state of matter, the plasma and the Physics involved.
CO2: Students will learn about magneto-hydrodynamics, fundamental equations of MHD, diffusion and mobility of plasma.
CO3: Students will understand un-magnetized plasma, energy transport, MHD waves, plasma stability, interactions between plasma particles.
CO4: Students will learn about kinetic theory of plasma, phase space for many particle motion, velocity and space distribution function, electron-ion plasma oscillation, Landau damping and Vlasov equation.

Introduction: **[10 lectures]**

Recap of non-relativistic dynamics of charged particles in electro-magnetic field; plasma as the 4th state of matter; electron and ion temperature; Debey length;cyclotron frequency; Larmour radius; drift velocity of guiding center; magnetic moment; magnetic mirror systems and their relation to plasma contentment devices.

Magneto-Hydrodynamics (MHD): **[10 lectures]**

Introduction to ideal MHD system; fundamental equations of magneto-hydrodynamic systems; diffusion and mobility of charged particles in plasma; plasma as afluid and MHD equations; approximations and linearization of MHD fromdimensional considerations; single fluid MHD equation.

Waves and Instabilities in Plasma: **[16 lectures]**

Waves in un-magnetized plasma; energy transport; ion-acoustic waves and MHDwaves; plasma stability and the use of normal modes to analyzed stability; interactionbetween plasma particles; perturbation at two fluid interface; Raleigh Taylorinstability; Kelvin Helmholtz instability; Jeans instability.

Kinetic Theory: **[12 lectures]**

Need for kinetic theory and MHD as approximation of kinetic theory; phase space for many particle motion; velocity and space distribution function; electron-ion plasma oscillation frequency; derivation of Landau damping and Vlasov equations for fluid dynamics.

Reading List

1. Introduction to Plasma Physics and Controlled Fusion: F. Chen and F. Chen.
2. Introduction to Plasma Physics: R. Goldston and P. Rutherford.