KAZI NAZRUL UNIVERSITY

DEPARTMENT OF PHYSICS

Program: Two Years M.Sc in Physics

Program Objectives:

- Rendering the fundamental knowledge of Physics and problem solving skills for achieving scientific and research excellence with embedded human values.
- From third semester onward, elective papers in the field of cutting edge research are introduced, which have potential applications in basic research as well as industry.
- Confidence level building of the students to be ready for various competitive examinations in different level
- To provide a glimpse of research experience.
- To promote the critical thinking, openness to social, scientific, technological and educational changes.

Program Outcomes:

- Bring up students as educated individuals imbued with Indian values and to prepare them to serve as good educators or scientists.
- Exposure to proper laboratory infrastructures will create opportunity to enhance their technological skill. Exposure to sophisticated instruments will also widen their knowledge.
- Seminars will give an opportunity to the students to develop their scientific temper, to improve their communication skills.
- Computational skills acquired would be of immense use in future while working with theoretical and as well as experimental physics.
- *Will motivate students to pursue research careers especially in the field of Applied Optics ,Photonics, Spintronics, Quantum computing and information processing.*
- Will equip students to appear different competitive examinations like NET/GATE/SET/JEST/WBCS/UPSC etc for future research or professional career.

CBCS Syllabus for two years M. Sc. Physics

SEMESTER-I

MSCPHYSC101**: CLASSICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY**
(50 marks) **(Class 42 Hrs)**

Objective:

- The laws of physics in the Macroscopic and Microscopic world are significantly different. It is extremely important and absolute necessary to have a clear concept of classical mechanics before or simultaneous introduction of quantum mechanics.
- Alternate and generalized formulation of classical mechanics will help in to create a bridge with quantum mechanics.
- Non linear aspects of classical motions will help in understanding complex dynamical systems.

Review of the Lagrangian formalism; Some specific applications of Lagarange's equation; small oscillations, normal modes and frequencies. (5L)

Hamilton's principle ; Calculus of variations; 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. (6L)

Canonical transformations ; Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations. (6L)

Hamilton-Jacobi theory ; The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables. (4L)

Rigid bodies; Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation. (7L)

Non-linear Dynamics and Chaos; Nonlinear Differential Equations; Phase trajectories (Singular points and linear systems) ; Damped harmonic oscillator and overdamped motion; Poincare theorem; Bifurcations in various forms; Attractors; Chaotic trajectories; Lyaponov exponents; Logistic equations. (6L)

Special theory of relativity ; Lorentz transformations; 4-vectors, Tensors, Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; 4-momentum and 4-force;

Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle. (8L)

Books Recommended:

1. Classical mechanics-Goldstein
2. Mechanics- Landau and Liftshitz.
3. Classical Mechanics- Rana and Jog
4. Strogatz, Nonlinear Dynamics and Chaos
5. R. Resnick – Introduction to Special Theory of Relativity.
6. S. Banerji and A. Banerjee – The Special Theory of Relativity (Prentice Hall of India, 2002)
7. Stephen Wiggins, "Introduction to Applied Nonlinear Dynamical Systems and Chaos", Springer-Verlag, Second Edition.
8. Dominic Jordan, Peter Smith, "Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers" (Oxford Texts in Applied and Engineering Mathematics)

Course Outcome:

- The Lagrangian and Hamiltonian approach will be usefull in microscopic systems and field theoretic description of continuos systems.
- The concept of Hamilton-Jacobi theory will raise the idea of transition of a system from classical to quantum mechanics.
- The description of rigid body dynamics in terms of Euler angles will have direct implication in rotation in quantum mechanics.
- Relativistic formulation will be useful in understanding relativistic electrodynamics and relativistic quantum mechnics.
- Non linear aspects will be helpful in understanding chaotic behaviour of dynamical systems e.g. turbulence in fluid mechanics, weather systems etc.

MSCPHYSC102**: QUANTUM MECHANICS-I**

(50 marks) **(Class 42 Hrs)**

Objective:

- Classical mechanics fails to explain certain physical processes like photoelectric effect, black body radiation and many more. Quantu mechanics serves as a theory for the satisfactorily understanding these processes where classical mechanics fails.
- Course is dedicated to give a self-contained, yet concise presentation of most issues of non relativistic Quantum Mechanics; which helps us in understanding the dynamics and structure in atomic and sub atomic scale.
- It serves as a tool to better understand various atomic and nuclear phenomenon with proper justification.

Review of Basic Quantum Mechanics (4 lectures)
Particle in one-dimensional potential well (finite and infinite depth) and its energy states; Linear harmonic oscillator; Solutions of different one-dimensional barriers (finite and infinite width) and penetration problems. Motion of a charged particle in a spherically symmetric potential; Solution of Hydrogen atom problem. Spin and Angular Momentum. (9 lectures)

Linear vector space – State space, Dirac notation and Representation of State Spaces, Concept of Kets, Bras and Operators, Expectation Values, Superposition Principle, Orthogonality, Completeness, Expansion of State Vector, Non commutating Observables, Uncertainty Relations, Commutation and Compatibility, Change of basis, Unitary operators. State function and its interpretation, Expectation Values, Expansion of a State Function and superposition of states. Matrix Representation of State Vectors and operators, Continuous Basis. Relation between a State Vector and its Wave function. Solution of the Linear Harmonic Oscillator using Operator Method, Coherent States. (13 lecturers)

Equation of Motion: Heisenberg, Schrodinger and Interaction pictures. (2 lectures)

Approximation methods - Time-independent perturbation theory for non-degenerate and degenerate states. Applications: Anharmonic oscillator, Helium atom, Stark effect in hydrogen atom, Variational methods. WKB method; Connection formulae. Time-dependent perturbation theory; Harmonic perturbation; Fermi's golden rule. Sudden approximation. Examples and problems. (14 lectures)

Books Recommended:
1) 'Quantum Physics' by Robert Eisberg and Robert Resnick (John Wiley and sons).

2) 'Introduction to Quantum Mechanics', D, J. Griffiths.

3) 'Quantum Mechanics: Concepts and Applications", N. Zettili.

4) Quantum Mechanics, B. H. Bransden and C. J. Joachain

5) 'Quantum Mechanics' by L. I. Schiff (McGraw-Hill Book, New York).

6) 'Quantum Mechanics' by C. Cohen-Tannoudji.

Course Outcome:

- Students will learn to solve Schrodinger's equation for different potentials.
- Familarisation with mathematical tool of quantum mechanics such as linear spaces, operator algebra, matrix mechanics and eigen value problems.
- A good understanding of the mathematical tools used in the subject will help the students in solving problems in nuclear physics, electrodynamics, high energy physics etc.

- The advanced topics will help the students in understanding several atomic and nuclear phenomenon.

MSCPHYSC103: MATHEMATICAL METHODS OF PHYSICS

(50 marks) **42 Hrs**

Objective:

- *Students in all branches of physics need to be familiar with several mathematical techniques to understand content of their studies.*
- *The main motivation of this course is to develop a mathematical basis such that it can strengthen the ability of students to understand the mathematical treatment of physical problems which are encountered in the entire course.*

Syllabus

Functions of a complex variable. Brief review of the topics included in the honours syllabus: analytic functions, Cauchy-Riemann equations, integration in the Complex plane, Cauichy's theorem, Cauchy's integral formula. Liouville's theorem. Moretra's theorem.
Proof of Taylor and Laurent expansions. Singular Points and their classification. Branch Point and branch Cut. Riemann sheets. Residue theorem. Application of residue theorem to the evaluation of definite integrals and the summation of infinite series. (11 lectures)
Linear vector spaces, subspaces, Bases and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalisation procedure. Linear operators. Matrix representation. The algebra of matrices. Special matrices. Rank of a matrix. Elementary transformations. Elementary matrices. Equivalent matrices. Solution of linear equations. Linear transformations. Change of Basis. Eigenvalues and eigenvectors of matrices. The Cayley-Hamilton theorem. Diagonalisation of matrices. Bilinear and Quadratic forms. Principal axis transformation. (9 Lectures)

Fourier and Laplace transforms. Inverse transforms. Convolution theorem. Solution of ordinary and partial differential equations by transform methods. (7 lectures)

Green's functions for ordinary and partial differential equations of mathematical physics. (3 lectures)
Group theory: Definition. Group postulates. Finite and infinite groups, order of a group, subgroup; rearrangement theorem, multiplication table. Cosets, Lagrange's theorem. Order of an element.. Conjugate elements and classes. Invariant subgroups, factor groups. Generators. Isomorphism and homomorphism. Cyclic and other distinct groups. Permutation and alternating groups. Cayley's theorem. (5 lectures)
Representation theory: Definition of representation. Faithful and unfaithful representations. Invariant subspaces and reducible representations. Reducible and irreducible representations. Schur's lemmas, great orthogonality theorem and its geometrical interpretation. Character.

First and second orthogonality theorems of characters and its geometrical interpretation. Regular representation, celebrated theorem and its implication. Projection operators; determination of basis functions. Construction of character tables of simple groups.

(5 lectures)

Application in Physics: Group of Schrodinger equation. Reduction due to symmetry. Perturbation and level splitting. Selection rules. (2 lectures)

Course outcome:

- *Students are expected to be well acquainted with technique to solve different problems related to complex analysis, differential equations, integral transform, linear algebra.*
- *Students would be capable to apply their knowledge to read/understand other branches of physics, especially in Quantum Mechanics, Electrodynamics, Solid State Physics, Quantum Optics.*
- *The understanding of Group Theory will be useful in studying various symmetry properties in high energy physics, quantum mechanics as well as condensed matter physics.*

Books Recommended:

1. M. R. Spiegel (Schaum's outline series) – Theory and Problems of Complex Variables.
2. G. Arfken (Academic Press) – Mathematical Methods for Physicists.
3. P. Dennery and A. Krzywicki (Harper and Row) – Mathematics for Physicists.
4. Mary L. Boas; *Mathematical* Methods in the Physical Sciences.
5. W. Joshi (Wiley Esstern) – Matrices and Tensors
6. M. Hammermesh. 'Group Theory'. Addison-Wesley
7. M. Tinkham. 'Group Theory and Quantum Mechanics;. McGraw-Hill.
8. A. W. Joshi. 'Group Theory'. Wiley Eastern Ltd..
9. F. A. Cotton. 'Chemical Application to Group Theory'. Wiley Eastern Limited.
10. N. Deo : Group Theory (Tata McGraw Hill)
11. Advanced mathematical methods for scientists and engineers; Carl M. *Bender*., Steven A.*Orszag*.

MSCPHYSC104: **Computer Programming and Computational Physics**

(50 marks) **(Class 42 Hrs)**

Objective:

- Theoretical as well as experimental physicists require advanced knowledge in computers and programming languages to process and analyze vast and increasingly complex data sets. Also, advent of fast and economical computational resurces has enabled us in understanding physical systems through numerical simulations. Therefore it is absolutely essential to train and familiarize post graduate students to computers and computer programming in general.
- Learning computer programming increases a students employability in industry and imparts essential skills required to carry out research and development.

Syllabus

Elements of Programming Language:

Algorithms and flowchart; Structure of a high level language program; Features of C language; constants and variables; expressions; Input and output statements; conditional statements and loop statements; arrays; functions; character strings; structures; pointer data type; list and trees. Ideas of Symbolic manipulations. Basic introduction to MATLAB and MATHEMATICA (14 lectures)

Representation of integers and real numbers; Accuracy, range, overflow and underflow of number representation; error propagation and instability. Solution of polynomial equations- bisection, Newton-Raphson algorithm. Zeroes and extremes of multivariate functions. Solution of system of simultaneous equations- Gauss elimination, Gauss-Seidel, LU decomposition algorithms. Interpolation- Newton interpolation formula. Numerical integration – trapezoidal formula, Simpson's formula, Romberg formula. Numerical solution of differential equations- Euler, Runge-Kutta formula. Numerical solution of differential equations. Monte Carlo technique of numerical integration. (14 lectures)

Solution to Physical Problems: examples of ODE and PDE, damped harmonic oscillator. Eigenvalue problems, Application to 1D Quantum mechanical problems, Shooting methods to solve time-independent Schrodinger wave equation for particle in a box., Maxwell's Equation (boundary value problems), logistic map. (14 lectures)

Course outcome :

- The student will lern to implement numerical methods in solving physical problems using computer programmes.
- Knowledge in C programming language will be the stepping stone to learn object oriented programming languages like C++, Java, Python, Ruby, Perl etc.
- Skill and knowledge will increase student's employability in industry significantly.
- Student will be ready to participate in R&D programmes.

Books Recommended:

1. Tanenbaum, Operating system. Prentice Hall.
2. Gottfried, Programming with C. Schaum series.
3. Balaguruswamy, ANSI C. TMH.
4. Sastry, Introductory Methods of Numerical Analysis. PHI
5. Kyayszig, Advance Engineering Mathematics. John Willey, 9th
6. Programming in C
7. An Introduction to Computational Physics, Tao Pang

MSCPHYSC105: Physics Lab-I & Seminar

Objective:

- Experiments are an integral part of physics. Experiments demonstrate an extensive range of physical processes. It gives a better understanding and a more realistic picture of the physical processes. It sharpens the capability of observation, stimulate questions and help in developing new understanding and terminology.

- Apart from just understanding theory and performing experiments to check the validation of theory students must also learn to communicate their perception and understanding of scientific study, hence seminars also become an integral part of the subject.

List of Experiments:

1. Determination of Hall coefficient
2. Measurement of resistivity and band-gap of a semiconductor using four probe method
3. Determination of Planck's constant
4. Characteristics of light dependent resistor (LDR)
5. Determination of Lande g factor of an electron using electron spin resonance
6. Measurement of ultrasonic velocity using Ultrasonic Interferometer

Course Outcome:

- Experiments will enhance knowledge, and assist in learning and clarification and consolidation of theory.
- Students will learn to operate and handle various instruments.
- Seminars will give an opportunity to the students to develop their scientific temper, to improve their communication skills and scientific documentation skills.

Semester-II

MSCPHYSC201: Thermal and Statistical Physics

Marks 50 **(Class 42 Hrs)**

Objective:

- *This course deals with basis the aspect of Statistical Mechanics in thermal equilibrium.*
- *Introduces various statistical techniques to solve physical system involving a large number of particles.*

Syllabus

Scope and aim of Statistical Mechanics: Phase Space, Phase Points, Ensemble. Density of Phase Point and Liouville's Equation, Stationary ensembles: Micro - Canonical, Canonical and Grand Canonical. Partition functions. Equilibrium Properties of Ideal System: Ideal gas, Harmonic Oscillators, Rigid rotators. Bose – Einstein and Fermi – Direct distribution functions, general equations of states for ideal quantum systems, Properties of ideal Bose - gas, Bose – Einstein condensation.

Density Matrix: Statistical and Quantum mechanics approaches, Properties of mixed and Pure states, density matrix for stationary ensembles, Application of a free particle in a box, an electron in a magnetic field, Density matrix for a beam of spin ½ Particles, construction of density matrix for different spin states and calculation of the polarization vector.

Statistical mechanics of interacting systems: Cluster expansion for a classical gas, Virial expansion of equation of state, Evaluation of the Virial coefficients.

Spin-systems and exchange interaction:
Basic idea of spin-exchange between two electrons (Heitler-London), Ferro- and Antiferro-magnetic exchange, Ising model, solution in one dimension - absence of phase transition at finite temperature.

Phase transitions: General remarks, Examples of phase transition, critical opalescence. Basic ideas of critical phenomena, critical indices, introduction to the order parameter and Ginzburg-Landau theory.

Course Outcome:

- *The knowledge of statistical mechanics acquired from the course can be applied to understand properties of different systems ranging from condensed matter physics to Astrophysics*
- *It helps reader to realize distinguishable features of quantum and classical systems of particles*

Suggested Readings:

1. R. K. Pathria, *Statistical Mechanics*
2. *K. Huang,* Statistical Mechanics, John Wiley.
3. L. D. Landau, and E. M. Lifshitz, *Statistical Physics (Pt.-I)*
4. R. P. Feynaman, *Statistical Mechanics, A set of lectures*
5. S. K. Ma, *Statistical Physics*
6. A. Ishihara, *Statistical Physics*
7. Reif – *Fundamentals of Statistical and Thermal Physics : McGraw Hill*
8. Stephen J. Blundell and Katherine M. Blundell - *Concepts in Thermal Physics*

MSCPHYSC202**: Electrodynamics and Plasma Physics**

Marks 50 **(Class 42 Hrs)**

Objective:

- Newtonian mechanics describing the motion of neutral particles and electrodynamics describing the motion of charged particles are essentially the backbone of classical physics. Therefore a physics student must have sound understanding of classical elctrodynamics in order to understand fundamental properties of the visible universe.

- Students will be introduced to a new state of matter in plasma physics. The knowledge and concepts are extremely relevant in active area of reaerch in fusion and astrophysics.

Non Stationary Systems: Maxwell’s equations in moving medium, Lorentz force, conservation of momentum and energy, Pointing’s theorem, Maxwell’s stress tensor, scalar and vector potentials, gauge transformations-Lorentz gauge and Coulomb gauge, the inhomogeneous wave equations; solution of inhomogeneous wave equations by Green’s function; retarded and advanced solutions.

Fields and Radiations: Fields and radiation of a localized oscillating source; multipole expansion of the scalar and vector potentials; radiation fields; electric and magnetic dipole and electric quadrupole fields; Hertz potential and corresponding field equations.

Moving Charge: Lienard-Wiechert potentials, the field of a uniformly moving point charge; convection potential and virtual photons.

Radiation from an Accelerated Charge: Fields of an accelerated charge; angular and frequency distributions of the emitted radiation; special cases of acceleration-parallel and perpendicular (circular orbit) to velocity; Larmors formula and its relativistic generalisation; Bremsstrahlung; Cerenkov radiation; radiation reaction; electromagnetic mass.

Multipole Radiations: Multipole expansion of the electromagnetic field; magnetic dipole radiation; electric dipole radiation; Electric quadrupole radiations; Sources of multipole radiation-multipole moments.

Scattering: Radiation damping; scattering by a free electron; scattering and absorption of radiation by a harmonically bound electron; scattering of electromagnetic waves from a system of charges, coherent and incoherent Bragg diffraction.

Magneto-hydrodynamics and Plasma Physics: Conducting fluid in a magnetic field; freezing in of lines of force; MHD equations; magnetic pressure; magnetic viscosity; pinch effect; Alfven waves; plasma oscillations; screened potential and Debye length.

Antenna theory: Oscillating dipole antenna, Linear antenna (half wave and full wave) , antenna array.

Course outcome:

- The students will understand origin of electric and magnetic field and their unification.
- Students will gain solid knowledge on generation and propagation of electromagnetic radiation.
- The mathematical formulation in multipole expansion will be helpful in understanding nuclear models.

- Understanding of scattering of electromagnetic waves will be helpful in understanding scattering in quantum mechanics.
- Basic concepts in plasma physics will be stepping stone to research in the new and active area of research.
- Introduction to antenna will be helpful in Communication Electronics.

Books Recommended:

1. Marion- Classical Electrodynamics
2. Jackson- Classical Electrodynamics
3. Panofsky & Phillips- Classical Electrodynamics
4. Chen- Plasma Physics
5. Griffith-Electrodynamics
6. Electromagnetics – Sadiku
7. Modern Electrodynamics : Andrew Zangwill

MSCPHYSC203**: Condensed Matter Physics**

Marks 50 **(Class 42 Hrs)**

Objective:

- In the last century there is a significant advancement of technology through explotations of various materials. Therefore it is extremely important to understand structure and properties of various materials. A basic course in condensed matter physics is essential to introduce the students to fundamental concepts of ordered solids. This will be a stepping stone to advanced topics in condensed matter physics, photonics, spin tronics and semi conductor devices.

Syllabus

Structure of solids, lattice translation vectors, unit cell, fundamental types of lattices (2 & 3 dimensions), simple crystal structures, diffraction, Bragg's law, Fourier analysis, reciprocal lattice vectors, structure factor, methods for structure determination, Brillouin zone. **(8L)**

Crystal binding-ionic, covalent, metallic and weak-bonding, cohesive energy. **(5L)**

Vibration of lattice, normal modes, spring-mass coupled system, mono and di-atomic chains, periodic lattices, phonons, force constant from experiments, quantization of elastic waves. **(6L)**

Free electron theory of metals, Fermi-Dirac distribution, Free electrons, boundary conditions, Density of levels in 1, 2 & 3 dimensions, Fermi momentum and Fermi energy, Connection between electron density and Fermi energy. Specific heat of metals, semiclassical theory of transport, Drude theory and Hall effect. **(8L)**

From atoms to molecules, molecular orbitals, LCAO, band theory, periodic potential, Bloch's theorem, tight binding approximation, Brillouin zones (first and second) for square, triangular, cubic lattices, Energy bands in reduced zone scheme, energy bands and Fermi surfaces in a few metals as example. **(10L)**

Properties of Superconductor, Occurrence of Superconductivity, Superconducting Elements, Zero Resistance, Meissner Effect, AC Resistance, Entropy, Specific Heat. Type-I and Type-II Superconductors, London's Theory, Thermodynamics of Superconductor, BCS Theory, Cooper pair. **(5L)**

Course outcome :

- A thorough knowledge of basic condensed matter physics will be helpful in understanding magnetic, electronic and transport properties of materials and their response to externally applied fields.
- This will be stepping stone in developing concepts of new technology and materials.
- This vibrant branch of physics will open up new arenas of professional and academic career of the students.

Books Recommended:

1. Ashcroft &Mermin, Solid State Physics;
2. C. Kittel, Introduction to Solid State Physics;
3. Marder, Condensed Matter Physics.
4. Quantum Transport : From atoms to Transistors, SupriyoDatta.
5. Elementary Solid State Physics, M. Ali Omar, Pearson

MSCPHYSC204**: Nuclear and Introduction to Particle Physics**

Marks 50 **(Class 42 Hrs)**

Objective:

- *Deals with different nuclear models to understand properties of nucleus through analysis of the structure and behaviour of nuclei within atoms.*
- *Introduces theoretical discussion on nuclear spectrum and radioactive properties of nuclear*
- *Improves knowledge of elementary particle and different fundamental forces constituting the Universe.*

Syllabus

1. Two-nucleon system : (a) Bound-state problem – relative stability of neutron (n)-neutron, neutron-proton (p) and proton-proton systems, properties of the deuteron, rms radius, ground and excited states in the central field approximation, electric quadrupole and magnetic dipole moments, non-central and tensor forces

(b) Scattering problem: n-p scattering at low energies, partial-wave analysis, effective-range approximation, scattering length and effective range, shape-independent approximation,

modification of effective range for deuteron bound state, scattering by hard sphere and finite square well , p-p scattering at low energies, Coulomb – modified nuclear scattering
(c) Charge independence of nuclear forces: SU (2) symmetry, isotopic spin and isobaric analog, mirror nuclei, exchange forces and saturation, repulsive core

2. Structure of complex nuclei and nuclear models: Qualitative discussion about ground state and stability of nuclei of small mass numbers, nuclear many-body theory and need for nuclear models, liquid drop model, Bethe-Weizacker mass formula; shell model – shell structure and magic numbers, effective single-particle potentials with spin-orbit interaction , success and failure of shell model in predicting ground state, spin, parity and electro-magnetic moments,, anomalous magnetic moments of nucleons, γ decay, collective model– evidence of collective motion, vibrational and rotational spectra, phonons

3. Nuclear reaction and fission: Types of reaction, quantum mechanical theory, Q values, scattering reaction and resonance, Breit-Wigner formula, compound nucleus formation and break up, optical model, nuclear fission and liquid drop model

4. β **decay :** Energetics and theory for allowed β decay, selection rules for Fermi and Gamow-Teller transitions, weak interaction and parity non-conservation, experimental verification of parity violation

5. (*i*) **Elementary particles**: Historical introduction-electron, photon, mesons, antiparticles, neutrinos, strange particles, eightfold way. quark model
(ii) Particle dynamics : The four forces- Strong, electromagnetic, weak and gravitational-(a) strong interaction, symmetries and conservation laws, Hadrons, isospin and hyper charge, SU(3) algebra, quarks and gluon, Gellman - Okubo mass formula (b) quantum electrodynamics, Compton scattering, (c) electroweak theory - elementary ideas of electroweak unification, introduction to the standard model or Weinberg –Salam theory

Outcome of the Course

- *This course helps develop a physical feeling on the complexity of nuclear potential and spectrum.*
- *It extends the idea about nuclear reactions, reactors and radioactive properties of material and grows interest in the studies of Radio Therapy.*
- *It may motivate to learn about the mystery of mass generation and to study astro-particle physics.*

Books Recommended :

1. Nuclei and Particles: An Introduction to Nuclear and Subnuclear Physics by E. G. Segre
2. Nuclear Physics: Theory and Experiment by Roy and Nigam
3. The structure of Nuclear Physics by Preston and Bhaduri
4. Nuclear Physics by S N Ghoshal
5. Theory of Nuclear Structure by M.K. Pal

6. Introduction to Elementary Particle Physics by D. Griffith
7. Introductory nuclear Physics by K.S. Krane
8. An Introduction to Nuclear Physics, W L Cottingham and D A Greenwood
9. Nuclear and Particle Physics: An Introduction, Brian R Martin
10. Introductory Nuclear Physics, Samuel S. M. Wong
11. Introduction To High Energy Physics, Donald H Perkins.
12. Modern Elementary Particle Physics, Gordon L Kane

MSCPHYSC205: Physics Lab – II & Seminar

Objective:

- Experiments are an integral part of physics. Experiments demonstrate an extensive range of physical processes. It gives a better understanding and a more realistic picture of the physical processes. It sharpens the capability of observation, stimulate questions and help in developing new understanding and terminology.
- Apart from just understanding theory and performing experiments to check the validation of theory students must also learn to communicate their perception and understanding of scientific study, hence seminars also become an integral part of the subject.

List of experiments:

1. Study of the working of 741 op-amp
2. Astable and monostable multivibrator using 555 timer
3. Amplitude modulation and demodulation
4. Integrator and Differentiator using op-amp
5. Observation of Transmission grating
6. Characteristic study of diode laser using Michelson interferometer
7. LED characteristics

Course Outcome:

- Experiments will enhance knowledge, and assist in learning and clarification and consolidation of theory.
- Students will learn to operate and handle various instruments in electronics and photonics laboratory.
- Seminars will give an opportunity to the students to develop their scientific temper, to improve their communication skills and scientific documentation skills.

Minor Elective

MSCPHYSMIE201: HISTORY AND PHILOSOPHY OF SCIENCE

Science and scientific method: meaning of science. Types of science and scientific method (including observation and measurement); Scientific explanations Scientific law, Hampel's covering law model,, revolution in science: formal definition of history of science, emergence of science with periods between 600 BC upto Dark ages (500 AD to 1000 AD.)

Endeavour of Modern Science from 1000 AD; Renaissance termed as Golden age of Science; era of Newton and others. Industrial revolution; remaining part of 19^{th}. Century. Modern Science post 1900 A. D. to the recent past.

Definition of Philosophy of Science; theory of falsibility, Bayesianism. Origin of the Universe, Anaximane, Anaximander, Heraclitus, Aristotle, Plato, Pythagoras, Big Bang theory, Quantum Cosmological theory. Stages in the history of Physics, Chemistry, Biology.

Impact of Science and technology. Medicine, Transport, Pollution, Classification of natural resources, toxicity and its impact. Life and works of great scientists.

Project work: free to chose any topic on science / technology.

Recommended Books :

1. Philosophy of Science (Routledge, 2000) by Rosenberg Alexander.
2. Scientific Method (Routledge, 1997) by Gower Barry.
3. A Historical Introduction to the Philosophy of Science, (Oxford 20001) by Losse John.

Semester – III

MSCPHYSC301: **Quantum Mechanics II**

Marks 50 **(Class 42 Hrs)**

Objective:

- The aim of the course is to introduce to the students advanced topics and concepts in quantum mechanics relevant to new age physics.
- Topics covered in this course will be necessary in advanced research area of condensed matter physics and high energy particle physics.
- Knowledge in advanced topics will be helpful in desiging new materials with interesting topological properties.

Syllabus

WKB Approximation (4 Lectures)

WKB method; Connection formulae; quantization rule; tunnelling through a barrier; α-decay and field emission devices.

Symmetries in quantum mechanics (4 Lectures)

Conservation laws and degeneracy; continuous symmetries – space and time translation and rotation; discrete symmetries –parity; double well potential; symmetry breaking and instantons; time reversal, Kramer's degeneracy.

Identical Particles (3 Lectures)

Identity and indistinguishable; symmetric and anti symmetric wave function; Slater determinant; spin statistics theorem; permutation symmetry; spin singlet and triplet state.

Electrons in Magnetic field (5 Lectures)

Hamiltonian in magnetic field; gauge invariance and Aharanov-Bohm effect; solution in Landau and symmetric gauge; degeneracy; Quantum Hall Effect; Laughlin wave function

Applications of Quantum Mechanics (7 Lectures)

Quantum wells (square, triangular, arbitrary); confined levels in semiconductor transistors; multiple barriers and resonant tunnelling diode; quasi-bound states and transmission resonance widths; excitons in semiconductors and quantum wells; quasi bound states in spherically symmetric potentials and radioactivity; transition probability for continuous spectra; electron-photon interaction.

Scattering theory (7 Lectures)

Lippmann-Schwinger equation; scattering amplitude and cross sections; Optical theorem;Born approximation; phase shift and partial wave analysis; S-matrix theory; scattering length; zero energy scattering and bound states; resonant scattering.

Relativistic quantum mechanics (12 lectures)

Klein-Gordon equation – negative probability; Dirac equation; Covariant form; Free particle solution; Dirac matrices – physical interpretation; spin operator; non-relativistic limit – fine structure, spin-orbit coupling; products of Dirac matrices; Negative energy states and Feynman –Stückelberg interpretation; anti particles, Helicity, chirality and charge conjugation; Klein paradox; Majorana and Weyl representations – application to graphene, topological superconductor and Weyl semi metals.

Course outcome :

- Students will learn about discrete symmetries, scattering theory, quantum Hall effect and their applications.

- Relativistic cases, Dirac equation, concept of particles and anti-particles etc. would motivate post graduate students to further study in field theory and particle physics.
- Students will get introduction to active research topics like topological superconductor, Weyl semi-metals etc. and this can lead to further career in academics and research.

Suggested Books:

1. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson (2011).
2. E. Merzbacher, *Quantum Mechanics*, Wiley.
3. D. J. Griffiths, *Introduction to Quantum Mechanics*, Pearson.
4. Jasprit Singh, *Quantum Mechanics : fundamentals and applications in technology*, Wiley.
5. R. Levi, *Applied Quantum Mechanics*, Cambridge University Press.
6. W. A. Harrision, *Applied Quantum Mechanics*, World Scientific .
7. Band, Yehuda B, Avishai, Yshai, *Quantum Mechanics with Application to Nanotechnology and Information Science*, Academic Press (2012).
8. J. J. Sakurai, *Advanced Quantum Mechanics*, Pearson (2002).
9. H. A. Bethe and R. Jackiw, *Intermediate Quantum Mechanics*, Levant (2005).
10. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics*,Tata McGraw-Hill (2013).

MSCPHYSC302**: Atomic and Molecular Spectroscopy**

Marks 50 **(Class 42 Hrs)**

Objective:

- *This course is designed for the fundamental studies on atomic and molecular spectrum.*
- *It includes rigorous discussion on Interactions atomic system with externally field*

Syllabus

1. One Electron Atom (3L)

Introduction: Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

2. Interaction of radiation with matter (7L)

Time dependent perturbation: Sinusoidal or constant perturbation; Application of the general equations; Sinusoidal perturbation which couples two discrete states — the resonance phenomenon. Interaction of an atom with electromagnetic wave: The interaction Hamiltonian — Selection rules; Nonresonant excitation — Comparison with the elastically bound electron model; Resonant excitation — Induced absorption and emission.

3. Fine and Hyperfine structure (8L)

Fine structure of spectral lines; Selection rules; Lamb shift. Effect of external magnetic field - Strong, moderate and weak field.

4. Rotation and Vibration of Molecules (5L)

Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.

5. Molecular Electronic States (5L)

Concept of molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions

6. Spectra of Diatomic Molecules (5L)

Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules.

Course outcome:

Basic concept of atomic and molecular spectrum is indispensible to do any kind advance studies in pure and applied physical science

- *This course can motivate students to pursue research careers especially in material sciences and associated fields.*

Suggested Books:

1. Physics of Atoms and Molecules by Bransden and Joachain
2. Atomic and Molecular Spectroscopy by S. Svanberg
3. Atomic Physics by Max Born
4. Introduction to Atomic Spectra by H.E. White

MSCPHYSC303: **Electronics (Analog and Digital)**

Marks 50 **(Class 42 Hrs)**

Objective: To give overview of electronics (both analog and digital) to the students and to strengthen their basic concepts that can be applied in problem solving mechanism. Electronics comprises the physics, engineering, technology and applications that deal with the emission, flow and control of electrons in vacuum and matter. Electronics is widely used in information processing, telecommunication, and signal processing.

Syllabus

1. Semiconductor Device:
   Bipolar Device- Junction diode, Junction capacitance, Bipolar junction transistor, Hetero junction devices, Unipolar devices-Metal-Semiconductor contacts, JFET, MOSFET. (12L)
2. Active Circuits:

Amplifiers- Discrete component Transistor, Amplifier design technique, Video amplifiers, RF amplifiers, Power amplifier design consideration. Oscillators-Feed back principle, OP-Amp based R-C phase shift, Wien bridge oscillators, OP-Amp circuits – Active filters, Butter worth filter. (10L)

3. <u>Passive Networks and Transmission line:</u>

   Prototype LC frequency selective networks, HF transmission lines, Primary and secondary line constants, input impedance, VSWR, Distortion of e.m. wave in practical lines, Fault location in practical line. (5L)

4. <u>Digital Electronic Circuits:</u>

   Logic Circuits- Classification, Logic simplification, SOP and POS design of Combinational circuits. Sequential circuit-Flip-Flap, counters and Registers. Arithmetic circuit-RCA, CLA, BCD adders multipliers. (7L)

5. **<u>Modulation:</u>** Review of AM, FM&PM, DSBSC, SSBSC, VSB *Pulse Modulation*: PAM, PWM,PCM, DIgital Modulation: ASK,FSK,PSK(ideas Only) (8 L)

Text Books:

1. S.M Sze,Physics of Semiconducter Device.
2. J. Millman & Grable, Microelectronics
3. J.D. Ryder, Network lines & Fields.
4. Malvino and Leach, Digital Pronciples & Applications
5. R. P. Jain, Digital Electronoics
6. Fraser, Telecommunications
7. R. Roody & J. Coolen, Electronic lominilation
8. Jain, Linear Integral Circuit

Recommended Books:

1. J. D. Ryder, Electronic fundamental and applications
2. S. Soclof, Applications of analog integral circuit
3. Streetman, Banerjee - Solid state electronic devices.

Course outcome

- Students will develop in-depth knowledge both in analog and digital electronics.
- Course will give a thorough knowledge about semiconductor and its properties and will help the students to design several electronic devices
- Will help the students to get knowledge in Electronics circuits that are widely being used in industrial applications.

MSCPHYSC304: Advanced Optics

Marks 50 **(Class 42 Hrs)**

Objective:

- The aim of the course is to introduce to the students with the topics of advanced optics namely Light Emitting Diode, Laser, optical fiber, Holography etc . Laser and optical fiber are recognized as revolutionary technological achievements of 20th century and there are few areas in technology that are not influenced by it. It plays an important role in, medicine, industry, entertainment, in fiber-optic communication, CDs, CD-ROMs, and DVDs. Without lasers there would be no supermarket bar code readers, certain life-saving cancer treatments, or precise navigation techniques for commercial aircraft.

- This course could also play pivotal role in the understanding basics of source, wave guide and detectors.

Syllabus

1. Basic principles of Laser :

Properties of Laser Radiation, Basic components of Laser. Classification of lasers. Spontaneous and simulated emission.

Einstein's coefficient and their relations, conditions of population inversion

Absorption and amplifications of light in a medium, population inversion and threshold condition for a laser, gain coefficient.

Laser Rate Equation, 2- level laser, 3-level and 4-level lasers.

Line broadening mechanism- (Spontaneous transition, collision broadening and Doppler broadening). (12**L)**

2. Modulation Techniques :

Propagation of EM waves in anisotropic dielectric medium, dielectric Tensor, Index ellipsoid. (**2L)**

Electro-optic effect, Pockel and Kerr effect, electro-optic phase retardation, electro-optic amplitude modulation, phase-modulation of light. (**6L)**

3. Photonic devices : Light Emitting Diode (LED), quantum efficiencies (internal and external), responsivities, Characteristics and applications of various kinds of LEDs, dome type LED , homojunction LED, heterojunction LED,Semiconductor junction Laser. (6**L)**

Photo diode, quantum efficiencies (internal and external), responsivities, Characteristics and applications of various kinds of photodetectors, P-I-N photodiode, Avalanche photodiode, solar cell. (**6L)**

4. Fiber Optics: Rectangular and cylindrical wave guides, propagation of radiation in dielectric waveguide. Step index and graded index fiber, modes in fiber, dispersion in multimode & single mode fiber, attenuation mechanisms in fibers, signal distortion, mode coupling, power launching and coupling, fiber parameter specifications. **(6L)**

Holography: Importance of Coherence, Principles of holography and characteristics, classification of hologram and application, non-destruction texting. **(4L)**

Text Books:

1. S.M. Sze, Physics of semiconductor devices.
2. O. Svelto, Principles of lasers..
3. Franz and Jain, Optical communication system

Recommended Books:

1. P. Bhattacharya, Semiconductor opto-electronic devices.
2. W. Koechner Solid State Laser Engineering.
3. J.M Senior, Optical fiber communications principles and practice
4. S.O. Kasap, Optoelectronics and photonics principles and practices
5. Martin A Green Solar Cells: Operating Principles, Technology, and System Applications.

Course Outcome:

- Students will be familiar with different types of light source and detector needed in present day optical communication.
- Students will gather knowledge about propagation of light through optical fiber. Different types of losses incurred during propagation.
- *This course can motivate students to pursue research careers especially in the field of applied optics and photonics*

MSCPHYSC305: Physics Lab - III & Seminar

Objective:

- Experiments are an integral part of physics. Experiments demonstrate an extensive range of physical processes. It gives a better understanding and a more realistic picture of the physical processes. It sharpens the capability of observation, stimulate questions and help in developing new understanding and terminology.
- Apart from just understanding theory and performing experiments to check the validation of theory students must also learn to communicate their perception and understanding of scientific study, hence seminars also become an integral part of the subject.

List of experiments:

1. High pass, Low pass and Band pass filter using op-amp 741C.
2. 723 voltage regulator.
3. Characteristics study of solar cell.
4. Characteristics study of photo diode.
5. Characteristics study of photo transistor.
6. Characteristics study of opto-coupler.
7. Characteristics study of optical fiber.
8. Experiments of single slit and Double slit.

Course Outcome:

- Experiments will enhance knowledge, and assist in learning and clarification and consolidation of theory.
- Students will learn to operate and handle various instruments in electronics and photonics laboratory.

- Seminars will give an opportunity to the students to develop their scientific temper, to improve their communication skills and scientific documentation skills.

EMESTER-IV (Elective Papers)

MSCPHYSMJE401: Optoelectronics and Laser Physics

Marks 50 **(Class 42 Hrs)**

Objective:

Optoelectronics, which combines the properties of light with capabilities of micro-electronics, is an essential enabling technology for the information age. In fact it is said that optoelectronics may be the most significant new technology since semiconductors. The main objective of the course is to formally introduce students to optoelectronics, thereby helping them to guide their studies and career development.

1. Resonators: [4L]

Stability of resonators-'g' parameter, various types of resonators, evaluation of beam waist of such combination, design aspect of resonator for various types of lasers, unstable resonator and their application.

2. Different laser systems: [10L]

Gas Laser: CO_2 laser, Solid State Laser: Host material and its characteristics, doped ions, Nd:YAG laser Solid State Laser: (i) Nd:YAG laser, (ii) Nd:Glass laser, comparison of performances , Liquid laser: Dye laser, Semiconductor laser. Excimer laser; Color centre laser; Free electron laser; semiconductor diode laser.

3. Q-switching and Mode Locking: [8L]

Different Q-switching techniques: mechanical Q-switching, electrooptic Q-switching, acoustooptic Q-switching, dye Q-switching, Principle of generation of ultrafast pulses (mode locking), basic concepts for measurement of fast processes.

4. **Nonlinear interactions of light and matter** [10L]

Nonlinear polarization of the medium, Optical susceptibility tensor, Generation of second harmonic, Sum frequency and difference frequency generation, Basic idea of phase matching, quasi-phase matching method, various methods of phase matching (angle, temperature, birefringence etc.) critical and noncritical phase matching, collinear and non-collinear phase matching, Optical rectification, Parametric amplifier and oscillation, Generation of third harmonic, Intensity dependent refractive index, Self-focussing, Wave equation for nonlinear optical media.

Soliton Optics:[4L]

Optical Soliton, Non-linear Schrodinger equation, self-phase modulation and cross phase modulation.

Optoelectronics [6]: guidedwave LED, edge-emitting LED, quantum casecaded LED, quantum dot LED, operational circuit and modulation of LEDs. Different type of coupling procedure of LED with optical fiber. Coupling coefficient and coupling loss.

Recommended Books:

1. O. Svelto, *Principles of Lasers*
2. A Ghatak and K. Thyagarajan, *Optical Electronics, Cambridge University Press (2003)*
3. A Yariv, Quantum Electronics
4. Y. R. Shen, The principles of Nonlinear Optics, Wiley, New York, 1984.
5. R. W. Boyd, Nonlinear Optics Academic Press Inc.

Course Outcome:

- *Students will be familiar with different types of advanced light sources and their modulating mechanism widely used in present day information processing.*
- *Students will also learn about Nonlinear optics (NLO) which is the branch of optics that describes the behaviour of light in nonlinear media,.*
- *This course can motivate students to pursue research careers especially in the field of applied optics and photonics*

MSCPHYSMJE402 : Magnetic Materials and Spintronics

Marks 50 **(Class 42 Hrs)**

Objective:

- Spintronics, a portmanteau meaning "spin transport electronics", where both charge and spin degrees of freedom of electrons are employed simultaneously to produce device with new functionality, is a fascinating and promising field of research. It has potential to revolutionize the field of electronics. Two physical basis of Spintronics, i.e., GMR and TMR have already been commercialized in read heads of hard disk drive. It is extremely important and absolutely necessary to have a clear concept of spintronics so that students get exposure of such modern day cutting edge technology.
- This course could also play crucial role in the development of understanding of the new research initiative like Opto-Spintronics.

Syllabus

Magnetic properties of Solids

Origin of magnetism; A charged particle in a magnetic field, Diamagnetism: Quantum theory of atomic diamagnetism; Paramagnetism: Quantum theory of paramagnetism; Quenching of orbital angular momentum; Curie-Weiss law; Temperature dependence of magnetization; Pauli Paramagnetism; The Exchange Interaction: between free electrons; Heisenberg's exchange interaction; Spontaneous Magnetization and Ferromagnetism : The Band Model of Ferromagnetism; Ferromagnetic domains - wall thickness and energy; Ferrimagnetism and Antiferromagnetism. **(10 L)**

Introduction to Magnetic Materials

Types of magnetic materials; Magnetic structure of materials - collinear and non-collinear structures; Types of magnetic anisotropy; Micro-magnetism and domain structures; Magnetic properties of nanoparticles and super-paramagnetism. **(4 L)**

An Overview of Spintronics

Quantum Mechanics with Spin; Spin-Dependent Band Gap in Ferromagnetic Materials.
Basic elements of Spintronics : Spin Polarization; Spin Injection; Spin Relaxation; Spin-orbit interaction; Spin Filter Effect; Spin Valve. **(8 L)**

Giant Magnetoresistance (GMR)

Definition of Magnetoresistance; Magnetoresistance of ferromagnetic Transition Metals; Introduction on Giant Magnetoresistance (GMR): Resistor Network Theory. **(6 L)**

Tunneling Magnetoresistance (TMR)

Introduction on Tunneling Magnetoresistance: Magnetic Junctions; Magnetic properties of the electrodes; Theory of Tunneling Magnetoresistance; Measurement of spin relaxation length and time in the spacer layer. **(4 L)**

Spin Transfer Torque (STT)

Introduction on Spin Transfer Torque: Spin Transfer Torque in Layer Structures; Spin-Transfer-Torque driven Magnetization Dynamics; Experimental Results; Possible applications of spin transfer torques. **(4 L)**

Magnetic Domain Wall (DW) Motion

Introduction on Magnetic Domain Wall Motion: Magnetic Domain Wall Motion in Spintronics; Ratchet Effect in magnetic DW motion; Domain wall motion velocity measurements; Current-driven DW motion. **(4 L)**

Spintronics Applications

Read Head in Magnetic Data Storage; Spin-tunnel junctions. **(2 L)**

Course outcome :

- Students will develop indepth knowledge in magnetism and spintronics.

- Students will understand spin dependent transport processes in spintronics devices.
- Students will get introduction to Spin transfer Torque and Magnetic Domain Wall motion Memory systems.
- This course will help students in cutting edge research technology like hard disk drive read head and Magnetic Random Access Memories.

Books Recommended :

1. Stephen Blundell, *Magnetism in Condensed Matter,* Oxford Master Series in Condensed Matter Physics, (2001).
2. B.D. Cullity and C.D. Graham, *Introduction to Magnetic Materials,* 2nd Ed., Wiley, 2009.
3. D. Jiles, *Introduction to Magnetism and Magnetic Materials*, 2^{nd} Ed., CRC Press, 1998.
4. S. Bandyopadhyay, M. Cahay, Introduction to Spintronics, CRC Press, 2008.
5. D. J. Sellmyer, R. Skomski, Advanced Magnetic Nanostructures, Springer, 2006.
6. D.D. Awschalom, R.A. Buhrman, J.M. Daughton, S.V. Molnar, and M.L. Roukes, Spin Electronics, Kluwer Academic Publishers, 2004.
7. M. Johnson, Magnetoelectronics, Academic Press 2004.
8. S. Maekawa, Concepts in Spin Electronics, Oxford University Press, 2006
9. Y.B. Xu and S.M.Thompson, Spintronic Materials and Technology, Taylor & Francis, 2006.

MSCPHYSMJE403: Communication Electronics

Marks : 50 **Lectures 42**

Objective:
- To teach students about communication systems, different techniques of modulation and demodulation both digital and analog.
- To give an introduction about information theory.
- To make familiar with working of Radar,
- To give an introduction about satellite and mobile communication and working of TV and TV broadcasting system.

Syllabus

1. Review of CW Modulation Technique: Types of Signals: Analog and digital, Telecommunication Service; Linear modulation; DSB, SSB, VSB, QAM techniques, Exponential modulation FM and PM; AM and FM modulators and demodulators. (4 lectures)
2. Pulse Modulation and Demodulation Techniques: Sampling Theorem, PAM, PWM, PPM, Pulse code modulation – coding technique modulation and demodulation, DPCM (Elementary Idea). (5 lectures)
3. Digital Modulation Techniques: ASK, FSK, PSK, DEPSK, QPSK, QASK, MSK, Principle, modulators and demodulators. (5 lectures)

4. Noise in Communication System: Types of noise, Sources of Noise, Noise Figure, Performance of AM, FM and PCM receivers in the face of noise;

(5 lectures)

5. Elements of Information Theory: Concept of amount of Information, average information, Entropy, information rate, Effect of coding and coding efficiency; Shanon Fano Algorithm; Shanon's theorem; Channel capacity, Continuous channel, Capacity of a Gaussian channel, Shannon Hartley Theorem, BW-S/N tradeoff, orthogonal signals and Shannon limit.

(6 lectures)

6. TV Systems: Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal; Transmitter and receiver systems of TV broadcasting. 2L

7. RADAR System: Basic Radar system, Radar Range, pulsed radar system – modulators, duplexer indicators, CW radar; MTI radar, Doppler effect, MTI principle, FM radar;. (3 lectures)

8. Satellite Communication: Orbits, basic components of satellite communication system, Constructional features, Station keeping; Path loss calculation; Link calculation; Multiple access techniques; Transponders; Effects of nonlinearity of transponders. (3 lectures)

9. Advanced Communication Systems: Mobile Communication – Concepts of cell and frequency reuse description of cellular communication standards; FAX, Important features of FAX machine, Application of FAX, VSAT, Radio paging system. Computer communication – Types of networks; Circuit message and packet switched networks; Features of network, design and examples of ARPANET, LAN, ISDN, Medium access techniques – TDMA, FDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol. (9 lectures)

Books Recommended

1. A B Carlson – Communication Systems.
2. D Roddy and J Coolen – Electronic Communications.
3. Franz and Jain – Optical Communication Systems.
4. A M Dhake – Television and Video Engineering
5. Gulati – Monochrome and Color TV
6. Kennedy and Davis – Electronic Communication Systems
7. Taub and Schilling – Principle of Communication Systems
8. Communication Systems, Singh & Sapre
9. Modern digital and analog Communication System, B P Lathi
10. Principles of Communication Engineering, Singh & Chhabra
11. Advanced Electronics, T Chattopadhyay.

Course Outcome:

After taking the course the students will be familiar with different types of communication systems used in electronics. They also be familiar with information theory and coding techniques. They will get knowledge about principle of Radar, satellite and mobile communication system. The students will also acquire knowledge about Television.

MSCPHYSMJE404 : Non-linear Optics & Optical Switching

Marks 50 **(Class 42 Hrs)**

Objective: The aim of the course is to introduce to the students with the topics of Nonlinear optics and optical switching. Nonlinear optics led to countless optical devices that have become indispensable in our daily lives. Nonlinear optics played a major role in many of the optical applications such as optical signal processing, optical computers, ultrafast switches, ultra-short pulsed lasers, sensors, laser amplifiers, and many others. They play a pivotal role in the future evolution and its impact in technology and industrial applications.

1. **Wave nature of light:**
   Light waves in Homogeneous medium. Group velocity and group index. Fresnels equation.
   Multiple interference and optical resonators. Goos-Hanchen shift and Optical tunnelling. Temporal and Spatial Coherence.
2. **Dielectric wave guide and optical fibers :**
   Symmetric plane dielectric slab waveguide: Waveguide condition, Single and multimode waveguides, TE and TM modes, V-numbers, Mode field distance. Modal and waveguide dispersion in planar waveguides. Step index fiber, Numerical aperture, Dispersion in single mode fiber. Bit rate, dispersion, electrical and optical bandwidth. Graded index fibers. Attenuation in optical fibers.
3. **Laser and Nonlinear Optics:**
   Basic principle, Gas Lasers: He-Ne Laser. Laser oscillation conditions: Optical gain coefficient, threshold gain coefficient, phase condition and laser modes.
   Nonlinear optics: Induced polarization, phase matching, nonlinear frequency mixing, Third order nonlinear optical process, pulse propagation through 3rd order nonlinear optical medium, Soliton, long distance soliton transmission.
4. **Semiconductor devices:**
   Semiconductor lasers: Principle of laser diode, Homojunction and Heterojunction, Steady State rate equation, Single Frequency Solid State Lasers, DFB Laser, Quantum well laser, VCSEL.
   Light Emitting Diode: LED principle and device structure, materials, characteristics (output spectrum, wavelength variations).
   PN junction: Photodiode principle, Quantum efficiency, Responsivity, PIN, APD, Noise in photodetectors, Avalanche noise in APD.
5. **Polarization and Modulation of light:**
   Light propagation in an anisotropic medium: Uniaxial crystals, optical indicatrix, dichorism, retarding plates, electro optic effect, phase and polarization modulation, MZI, Acousto-optic modulator, Modulation directional coupler, Magneto-optic effect.
6. **Optical Switching :**
   Nonlinear material based switching: Kerr effect, Frequency mixing, Photorefractive effect, FWM Semiconductor Optical Amplifier based switching: XGM, XPM, FWM, TOAD. MZI, Polarization Rotation, Quantum Dot SOA Add Drop Multiplexer: Basic

principle and methodology, Fiber Bragg Grating Principle Different types of encoding system for states of information. Advantages & Disadvantages.

Recommended Books:

1. O. Svelto, *Principles of Lasers*
2. A Ghatak and K. Thyagarajan, *Optical Electronics, Cambridge University Press (2003)*
3. A Yariv, Quantum Electronics
4. Y. R. Shen, The principles of Nonlinear Optics, Wiley, New York, 1984.
5. R. W. Boyd, Nonlinear Optics Academic Press Inc.

Course outcome:

- *Students will also learn about Nonlinear Optics (NLO) which is the branch of optics that describes the behaviour of light in nonlinear media.*
- *Students will be familiar with different types nonlinear phenomena(different frequency mixing, parametric oscillation, self focusing etc. and their applications in present day industry.*
- *Students will be acquainted with working and application of optical* ***switch*** *which is a device for opening or closing an* ***optical*** *circuit in a communication application that selectively* ***switches*** *the signal in an* ***optical fiber*** *or integrated* ***optical*** *circuit (IOC) from one circuit to another.*
- *This course can motivate students to pursue research careers especially in the field of Optical computing and information processing.*

MSCPHYSMJE405 : Advanced Condensed Matter Physics

Marks 50 **(Class 42 Hrs)**

Objective:

- Advanced concepts in condensed matter physics will enhance students knowledge in the field of strongly correlated electron systems.
- Detailed treatment of magnetism will help students in grasping concepts in Spintronics
- Introduction to formal transport theory will help students in developing microscopic understanding of transport processes in quantum systems.
- This course will be the stepping stone of cutting edge research in theoretical and experimental condensed matter physics.

Syllabus

Magnetic properties of solids (13 Lectures)

Origin of magnetism – Bohr-van Leeuwen theorem; Diamagnetism : quantum theory of atomic diamagnetism ; Landau diamagnetism; Paramagnetism: classical an quantum theory of para-magnetism; case of rare earth and iron-group ions; quenching of orbital angular momentum; Van-Vleck para-magnetism and Pauli para-magnetism; Ferromagnetism : Curie-Weiss law, temperature dependence of of saturated magnetisation, Band model of ferromagnetism, Heisenberg's exchange interactions, Ferromagnetic domain walls – calculation of wall thickness and energy; Ferrimagnetism and anti-ferromagnetism. Models of magnetism – Heisenberg, XY and Ising model; spin waves and magnons.

Magnetic resonance (5 Lectures)

Nuclear magnetic resonances, paramagnetic resonance, Bloch equation, longitudinal and transverse relaxation time; spin echo; Hyperfine field; Electron-spin resonance.

Imperfections in solids (6 Lectures)

Frenkel and Schottky defects, defects by non stoichiometry; electrical conductivity of ionic crystals; classifications of dislocations; role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys, Hume-Rothery rules.

Basic ideas of electron localisation, disorder-induced MIT

Superconductivity (11 Lectures)

Experimental overview; quasi-particles and Bogoliubov-de Gennes equations; Order parameter – singlet and triplet superconductors. Ginzburg-Landau theory, London equation; type-I and type-II superconductors; vortex state; high temperature superconductors (experimental overview only), pnictidesand topological superconductors; applications of superconductors.

Quantum transport (7 Lectures)

Boltzman transport equation; relaxation time approximation; transport coefficients – electrical and thermal conductivity, Widemann-Franz law; Mott-Ioffe-Regel limit; Onsagar relations; thermo-power –figure of merit.

Course outcome :

- Students will develop indepth knowledge in magnetism and superconductivity.

- Students will understand microscopic transport processes in quantum systems and learn calculation of transport coefficients.
- Students will get introduction to Anderson localization and topological superconductors.
- This course will help students in cutting edge research in condensed matter physics.

References :

1. Stephen Blundell, *Magnetism in Condensed Matter*, Oxford Master Series in Condensed Matter Physics, Oxford University Press (2001).
2. M. Tinkham, *Introduction to Superconductivity*, Medtech (2017).
3. R. D. Parks, *Superconductivity(Vol I & II)*, CRC Press (1969).
4. P. G. de Gennes, *Superconductivity of Metals and Alloys,* Advanced Books Classics, CRC press, Taylor & Francis Group (2003)
5. James F. Annett, *Superconductivity, superfluids and condensates,* Oxford master series in condensed matter physics, Oxford University Press (2004).
6. J. M. Ziman, *Electrons and Phonons : The theory of transport phenomena in solids,* Oxford University Press.
7. Ashcroft &Mermin, *Solid State Physics*, Cengage (2003).
8. Philip Phillips, *Advanced Solid State Physics*, Cambridge University Press (2012).
9. Review articles and journals.

MSCPHYSMJE407: MICROWAVE AND QUANTUM DEVICES

Marks : 50 **Lectures 42**

Objective:

- To give details working of different microwave sources and waveguides. Both tube and solid state devices are made familiar in this course.
- To teach students about measurement techniques of microwave power, frequency, and impedance. Introduction to few quantum devices are also included.

Syllabus

1. Microwave frequencies, characteristic features of microwaves, Applications of Microwaves.

Waveguides: Rectangular waveguide and circular waveguides; Maxwell’s equations, TE and TM modes; Resonators: Rectangular waveguide and circular waveguide resonators.

(8 lectures)

2. Limitations of conventional tubes for microwave generation; Reentrant cavities, Two cavity Klystron, velocity modulation, bunching process, Efficiency of Klystron; Reflex Klystron, Velocity modulation, condition of maximum energy transfer; Slow wave structure,

Helix Travelling wave tube, Amplification process, convection current in the electron beam; Magnetron, Cylindrical Magnetron, Hull cut off magnetic field, Hull cut off voltage, Cyclotron angular frequency, π mode of oscillation, equivalent circuit, power output and efficiency. **(13 lectures)**

3. Solid state microwave devices; Gunn Diode: Differential negative resistance, RWH theory, Domain formation, Different modes of operation, LSA diodes; Physical description and principle of operations of Read diodes, IMPATT diodes, TRAPATT diodes; Microwave Tunnel diodes: Principle of operation and microwave characteristics; Heterojunction Bipolar Transistor: Physical structure and operation; High Electron Mobility Transistor(HEMT): Physical Structure and operation.

(12 lectures)

4. Microwave Measurements: Detection of microwaves; Diode detectors, Travelling wave detector; Measurement of VSWR, Impedance, Frequency measurement (electronic technique); Microwave power measurements: Bolometer, Bridge type meters.

(07 lectures)

5. Quantum effect devices: Resonant tunnelling Diode: Band diagram, working principle, I-V characteristics; Unipolar Resonant tunnelling transistor: working principle. Simple applications.

(02 lectures)

List of Books:

1. Microwave devices and Circuits, Samuel Y. Liao
2. Microwaves, K C Gupta
3. Microwaves, Sisodia and Gupta
4. Microwave devices and applications, Dinesh C Dube
5. Semiconductor Devices, S. M. Sze

Course outcome:

After taking this course, students will be familiar with different techniques of microwave sources and waveguides. They also get knowledge about measuring power, frequency, and impedance in microwave region. They will learn about the working of quantum devices also.

MSCPHYSMJE408: QUANTUM COMPUTING AND CRYPTOGRAPHY

Full Marks: 50 **Contact Hours : 42**

Objective:

- *Introduces basic concepts of quantum information and its theoretical formulation*

- *Makes students familiar with quantum algorithm, quantum communication and cryptography*

Syllabus

1. Brief history and overview of information theory; Quantitative measure of information; Shannon's first coding theorem;Turing machine;
2. Mathematical tools for quantum computing;The C^n vector space; Inner product space and Hilbert space; C^2 space: The space spanned by a single qubit;
3. Basic ideas of quantum mechanics; Density operator and density matrix; Density operator of pure states; Density operator of mixed states; The meaning of entanglement; Bell's inequality and nonlocality;
4. Bell measurement and entanglement; Quantum bit commitment and quantum cointossing; Schmidt decomposition; Partial transpose and test of entanglement; entanglement measures;Trace distance and fidelity; Schmidt measure; Bloch sphere; Noncoloning theorem;
5. Quantum gates; Single qubit gates; Two qubit gates; quantum circuits; Circuit optimization rules. Quantum algorithm: Quantum parallelism; Deutsch's algorithm; The Deutsch–Jozsa algorithm;Simon's algorithm; Shor algorithm; Grover algorithm;
6. Quantum error correction; Decoherence and decoherence free subspace; DiVincenzo criteria;
7. Quantum communication; Quantum teleportation; Probabilistic teleportation; Quantum cryptography; Quantum key distribution; Different aspects of quantum cryptography;

Outcome of the Course

- *This course builds up basic understanding on the quantum information and computation.*

- *The field quantum computation is an active research area because of the possibility to disrupt modern computation and communication.*

Suggested Books:

1. Quantum computation and quantum Information by Nielsen and Chuang
2. Elements of quantum computation and quantum communication by A. Pathak
3. Quantum Computation Explained by David McMahon
4. The temple of Quantum Computing by R.T. Perry
5. An introduction to Quantum Computing by Kaye, Laflamme and Mosca.

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