SIDHO-KANHO-BIRSHA UNIVERSITY

DEPARTMENT OF PHYSICS

CBCS Syllabus for two years MSc Course in Physics

2016

M.Sc (Physics) Course Structure

Semester	Course	Course Title	Lecture Hrs / Week	Tutorial Hrs / Week	Practical Hrs / Week	Credit	Total Marks
I	MPHYCCT 101	Mathematical Physics	3	1	0	4	50
	MPHYCCT 102	Classical & Relativistic Mechanics	3	1	0	4	50
	MPHYCCT 103	Quantum Mechanics I	3	1	0	4	50
	MPHYCCT 104	Electronics & Instrumentation	3	1	0	4	50
	MPHYCCS 105	Physics Practical I	0	0	8	4	50
	MPHYCCS 106	Physics Practical II	0	0	8	4	50
II	MPHYCCT 201	Classical Electrodynamics	3	1	0	4	50
	MPHYCCT 202	Quantum Mechanics II	3	1	0	4	50
	MPHYCCT203	Atomic, Molecular & Optical Physics	3	1	0	4	50
	MPHYCCT 204	Solid State Physics	3	1	0	4	50
	MPHYCCS 205	Physics Practical III	0	0	8	4	50
	MPHYCCS 206	Physics Practical IV	0	0	8	4	50
III	MPHYCCT 301	Nuclear & Particle Physics	3	1	0	4	50
	MPHYCCT 302	Statistical Mechanics	3	1	0	4	50
	MPHYMET 303	Elective I	3	1	0	4	50
	MPHYMES 304	Advanced Experiments	0	0	8	4	50
	MPHYOET 305	Open Elective Course	0	3	0	4	50
	MPHYOPT 306	Outreach Program	4	0	0	4	50
IV	MPHYCCT 401	Numerical Methods & Computational Physics	4	0	0	4	50
	MPHYCCT 402	Relativity, Cosmology, and Astrophysics	3	1	0	4	50
	MPHYMET 403	Elective II	3	1	0	4	50
	MPHYMEP 404	Project/Term Paper and Grand Viva	2/4	0	4/0	4	50
	MPHYCCS 405	Computer Practical	0	0	0	4	50
	MPHYACT 406	Communicative English / Computer Applications	4	0	0	4	50
	Grand Total					**96**	**1200**

Elective – I: Advanced Electronics I / Photonics I / Condensed Matter Physics/ Nuclear Structure

Elective – II: Advanced Electronics II / Photonics II / Nano Science and Technology/ Nuclear Reaction

Open Elective Course: Nature of the Universe / Concepts of Physics: Inventions and Applications

FIRST SEMESTER

MPHYCCT 101 - Mathematical Methods

Complex analysis

Cauchy-Riemann equations, Analytic and harmonic function. Cauchy's theorem and its converse, Cauchy's Integral Formula and its corollaries; Taylor and Laurent series expansion; Classification of singularities; Branch point and branch cut; Residue theorem and its applications.

Differential Equations

Ordinary second order linear homogeneous differential equation: Singular points; Frobenius method; Fuch's theorem; Linear independence of solutions - Wronskian, Second solution. Basic properties of Legendre, Bessel, Laguerre and Hermite functions.

Inhomogeneous Differential Equations: Green's function and its applications.

Integral Transform

Fourier and Laplace transforms and their inverse transforms, Bromwich integral; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.

Linear Algebra

Linear independence, Gram Schmidt orthogonalisation. Matrices and their types: representation of linear transformations and change of base, Eigenvalues and eigenvectors; Functions of a matrix, Cayley-Hamilton theorem.

Tensor Analysis

Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.

Group Theory

Concept of a group, Definition and examples, Multiplication table and rearrangement theorem, Isomorphism and homomorphism, Direct product of groups, Distinct groups of a given order, Representations of a group – faithful, unfaithful, equivalent, reducible and irreducible representations. Lie groups and Lie algebra with SU(2) and O(3) as example.

Books Recommended**:**

(1) K.F. Riley, M.P. Hobson, S.J. Bence: Mathematical Methods for Physics and Engineering (Cambridge)
(2) Tulsi Dass and S.K. Sharma: Mathematical Methods In Classical & Quantum Physics (University Press)
(3) G.B. Arfken, H.J. Weber and F.E. Harris: Mathematical Methods for Physicists (Elsevier)
(4) M. R. Spiegel: Complex Variables (Tata McGraw-Hill)
(5) S.L. Ross: Differential Equations (Wiley)
(6) A.W. Joshi: Matrices and Tensors in Physics (New Age)
(7) A.W. Joshi: Elements of Group Theory for Physicists (New Age)

MPHYCCT 102 - Classical & Relativistic Mechanics

Review of Lagrangian and Hamiltonian formalisms

Systems with constraints and Lagrange's undetermined multiplier. Small oscillations and Normal modes. Hamilton's function and Hamilton's equations of motion. Lagrangian and Hamiltonian of relativistic particles. Principle of least action. Hamilton's principle.

Canonical transformations

Conditions for transformation to be canonical. Lagrange and Poisson brackets as canonical invariants. Equations of motion in Poisson bracket notation. Infinitesimal contact transformation. Constants of the motion. Symmetry properties. Poisson bracket relations. Liouville's theorem.

Hamilton-Jacobi theory

The Hamilton Jacobi equation for Hamilton's principle function. The harmonic oscillator problem.

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.

Review of special theory of relativity

Poincare and Minkowski's 4-dimensional formulation; Geometrical representation of Lorentz transformations in Minkowski's space; Length contraction; Time dilation; Causality; Time-like and space-like vectors; 4-vectors; Relativistic Energy and Momentum; Lorentz transformations of four vectors; Relativistic dynamics and kinematics; Lagrangian and Hamiltonian of a relativistic particle.

Relativistic electrodynamics

Relativistic Formulation of Maxwell's Equations; Electromagnetic field tensor, covariance of Maxwell's equations; Maxwell's equations as equations of motion; Lorentz transformation law for the electromagnetic fields; Lorentz Force Equation and Its Generalization; Lagrangian and Equation of Motion

Books Recommended:

(1) H. Goldstein: Classical mechanics (Narosa)
(2) N.C. Rana and P.S. Joag: Classical Mechanics (Mcgraw Hill Education)
(3) S.N. Biswas: Classical Mechanics (Books & Allied)
(4) R. G. Takwale and P. S. Puranik: Introduction to Classical Mechanics (Mcgraw Hill Education)
(5) D. Morin: Introductory Classical Mechanics with Problems and Solutions (Cambridge)
(6) S. Banerji and A. Banerjee: The Special Theory of Relativity (PHI)
(7) R. Hagedorn: Relativistic Kinematics (W.A. Benjamin, Inc.)
(8) L. Meirovitch: Methods of Analytical Dynamics (Dover)

MPHYCCT 103 - Quantum Mechanics I

Vector spaces in quantum mechanics

Hilbert space. Kets, bras and operators, Base bras, kets and matrix representation. Hermitian operator (definition and properties). Eigenkets as base kets. Orthogonality. Completeness. Postulates of quantum mechanics. Observable and results of its measurement. The generalized uncertainty relation. Non-commutating observables. Complete set of commuting observables. Change of basis. Unitary operators Discrete and continuous bases. Coordinate and momentum representations. Linear harmonic oscillator by operator method. Coherent states.

Quantum dynamics

Schrödinger, Heisenberg - interaction pictures and equations of motion. Schrödinger equation – coordinate and momentum representation. Evolution operator.

Schroedinger equation and its applications

The interpretation of the wavefunction. Stationary states.

(a) One dimentional problems: The delta-function potential and the Kronig Penney model.

(b) Three dimensional problems: The rigid rotator. The spherical well with impenetrable walls. Spherical square well potential. The harmonic oscillator with Heisenberg's equation of motion.

Approximation methods

Time-independent perturbation theory for non-degenerate and degenerate states. Applications to anharmonic oscillator, Stark effect in hydrogen atom, Landau levels. Variational methods for ground and excited states. Application to the ground state of helium atom. WKB approximation, tunnelling, qualitative discussion of alpha decay.

Identical particles

Symmetry under interchange. Wave functions for bosons and fermions. Slater determinant.

Generalised angular momentum

Infinitesimal rotation. Generator of rotation. Commutation rules. Matrix representation of angular momentum operators. Spin. Pauli spin matrices. Eigenspinors. Electron in static magnetic field. Larmor precession. Electron in an oscillating magnetic field. Addition of two angular momenta. Simple examples. Clebsch-Gordan co-efficients. Recursion relations.

Books Recommended:

(1) R. Shankar: Principles of Quantum Mechanics (Springer)
(2) N. Zettili: Quantum Mechanics (Wiley)
(3) R.L. Liboff: Introductory Quantum Mechanics (Pearson)
(4) B.H. Bransden and C.J. Joachain: Quantum Mechanics (Pearson)
(5) J.J. Sakurai: Modern Quantum Mechanics (Pearson)
(6) L.I. Schiff: Quantum Mechanics (Mcgraw-Hill)
(7) C. Cohen-Tannoudji, B. Diu, F. Laloe: Quantum Mechanics Vol I and II (Wiley)
(8) A.K. Saxena: Textbook of Quantum Mechanics (CBS Publishers)

MPHYCCT 104 – Electronics & Instrumentation

Semiconductor Physics and Devices

Intrinsic and extrinsic semiconductor, energy band diagram, carrier concentration in both cases. p-n junction physics, Thermal equilibrium condition, Depletion capacitance, Current-voltage characteristics, Charge storage and transient behaviour; Metal semiconductor junction (Schottky barriers). Characteristics of some semiconductor devices: MOS devices, Photodiode, LED, Solar cell, Tunnel diode, Gunn diode.

L-C Filters

LPF, HPF, BPF and BRF type constant-k prototype filters. m-derived filters (principle only). Attenuators. T-type, Pi-type, Bridged-T type lattice attenuators.

High Frequency Transmission Line

Distributed parameters. Primary and secondary line constants; Telegraphers' equation. Reflection co-efficient and VSWR. Input impedance of loss-less line. Distortionless line.

Communications

Comparison among different modulation techniques. Generation of transmitted carrier and suppressed carrier type AM signals. Principles of FM and PM signal generation. Principles of detection of different types of modulated signals (TC and SC types). Modulation techniques in some practical communication systems. VSB modulation. Pulse modulation, Pulse code modulation and quantization error.

Op-Amp Circuits

Characteristics of ideal and practical op-amp. Nonlinear amplifiers using op-amps. Log amplifier, anti-log amplifier, regenerative comparators. Active filters. ADC and DAC circuits. Op-amp based self-oscillator circuits. RC phase shift, Wien bridge, Non-sinusoidal oscillators.

Digital Circuits

Logic functions. Logic simplification using Karnaugh maps. SOP and POS design of logic circuits. MUX - DEMUX as universal building block. RS, JK and MS-JK flip-flops. Registers and counters.

Multivibrators

Timer (IC-555): Internal Structure (Block Diagram), Operation, Astable, Monostable, and Applications.

Data Analysis

Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting

Books Recommended:

1. S.M. Zee and K.K. Ng: Physics of Semiconductor Devices (Wiley)
2. T.L. Floyd: Electronic Devices (Prentice Hall)
3. R.L. Boylestad and L. Nashelski: Electronic Devices and Circuit Theory (Pearson)
4. M.E. Van Valkenburg: Network Analysis (Pearson)
5. J. Kennedy: Electronic Communication Systems.
6. D. Roddy and J. Coolen: Electronic Communications.
7. R. Gaykwad: Operational Amplifier.
8. H. Taub and D. Schilling: Digital Integrated Electronics (McGraw Hill Education)
9. R.P. Jain: Modern Digital Electronics (Tata McGraw Hill)

MPHYCCS 105 – Physics Practical I

1. Verification of Bohr’s atomic theory (discreteness of the atomic orbital) of Ar atom by Franck Hertz Experiment.
2. Determination of the Lande g factor for the DPPH sample using the Electron Spin Resonance (ESR) setup.
3. Study of temperature dependence of resistivity for a given semiconductor using Four Probe setup and determine its energy band gap.
4. Determination of Hall Coefficient of a given semiconductor sample using variable DC magnetic field.
5. Study the I-V characteristics of light emitting diodes (LEDs) and hence determine the Planck’s constant along with finding the ac resistances of the LEDs (using at least four different LEDs).
6. Determination of Planck’s constant by Photoelectric effect.
7. Using a radioactive source and a Geiger-Müller (GM) counter (i) determine the relative efficiency of the GM counter as a function of source-to-detector distance, and (ii) perform analysis of statistical fluctuations at low count rates.
8. Determination of (i) wavelength of *He-Ne* laser light, (ii) the refractive index of a given transparent thin film, and (iii) refractive index of air at different pressures using Michelson’s Interferometer.
9. Experiments using Jamin's interferometer.

MPHYCCS 106 – Physics Practical II

1. Study the characteristics of a light dependent resistance (LDR)
2. Design and study of CC amplifier.
3. Study of OPAMP (IC 741) characteristics and its use as an inverting amplifier, non-inverting amplifier, adder and differential amplifier.
4. Study of the different gate characteristics using IC and discrete components.
5. Design and study of logarithmic and antilogarithmic amplifier.
6. Transistor based monostable, astable multivibrator circuits.
7. Half and full wave rectifier cicuit.
8. Clippers and clampers circuits.
9. Design and study of current mirror biasing.

SECOND SEMESTER

MPHYCCT 201 – Classical Electrodynamics

1. Electromagnetic theory:
Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge invariance, Lorentz invariance of Maxwell's equation. Electromagnetic waves in free space. Poynting's theorem. Dynamics of charged particles in static and uniform electromagnetic fields, Transmission Lines, Waveguides, TE and TM modes.

2. Solution of Inhomogenous wave equation (vector and scalar potential), Green's function, retarded solution.

3. Radiation from moving point charges:
Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Dipole antenna; Fields due to an accelerated charge; Radiation at low & high velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation; angular distribution of radiated power. Radiation from an oscillating dipole, radiation from a linear antenna.

4. Radiation in material media:
Cherenkov effect (qualitative treatment only), Scattering from a free electron, Thomson and Rayleigh Scattering, dispersion and absorption, Kramer Kronig dispersion relation.

5. Plasma Physics:
Quasineutrality of a Plasma. Plasma production, Debye screening length, Charged particles in homogeneous and inhomogeneous magnetic fields. Adiabatic invariance of flux through an orbit. Magnetic mirror. Plasma as a conducting fluid. Short wavelength limit. Plasma oscillations.

Books Recommended:
(1) D.J. Griffiths: Introduction to Electrodynamics.
(2) W.K.H. Panofsky and M. Phillips: Classical Electricity and Magnetism,
(3) J.D. Jackson: Classical Electrodynamics.
(4) M.A. Heald and J.B. Marion: Classical Electromagnetic radiation.
(5) Satya Prakash: Electromagnetic Theory and Electrodynamics.
(6) Y.K. Lim: Problems and Solutions on Electromagnetism.
(7) F.F. Chen: Introduction to Plasma Physics and Controlled Fusion.
(8) J.A. Bittencourt: Fundamentals of Plasma Physics.

MPHYCCT 202 – Quantum Mechanics II

1. Discrete and continuous space-time symmetries:
Invariance principles and conservation laws. Space translation. Time translation. Space rotation. Irreducible spherical tensor operators. Wigner-Eckert theorem (no proof) and applications. Space inversion. Time reversal. Kramers degeneracy.

2. Time-dependent perturbation theory:
Constant and harmonic perturbations. Perturbation coupling two discrete states. Fermi's golden rule. Sudden and adiabatic approximations. Interaction of an atom with electromagnetic wave. Electric dipole radiation.

3. Scattering theory:
Scattering amplitude. Differential and total cross sections. Integral equation for potential scattering. Green's function. Born approximation, its validity and some applications (square well potential, Yukawa potential). Method of partial waves. Phase shifts. Optical theorem. Scattering by hard sphere. Coulomb Scattering - Rutherford formula, Scattering with WKB.

4. Relativistic quantum mechanics
The Klein-Gordon equation. Covariant notation. Probability density. Negative energy solution. The Dirac equation. Properties of the Dirac matrices. A spin zero particle in EM field, The Dirac particle in an electromagnetic field. The magnetic moment of the electron.

5. Covariant form of the Dirac equation
Lorentz covariance. Rotation, parity and time reversal operations on the Dirac wave function. Conjugate Dirac spinor and its Lorentz transformation. The $\Gamma 5$ matrix and its properties. Bilinear covariants and their transformation under parity and infinitesimal Lorentz transformation.

6. Plane wave solutions of the Dirac equation and their properties Energy and projection operators. Dirac's hole theory. Charge conjugation. Feynman-Stuckelberg interpretation of negative energy states and the concept of antiparticles.

7. Non-relativistic limit of the Dirac equation
Large and small components. Spin-orbit interaction from Dirac equation. Electon in a central electrostatic potential. Hyperfine structure of hydrogenic atoms.

Books Recommended (including books from Quantum Mechanics I course)**:**
(1) E. Merzbacher: Quantum Mechanics.
(2) F. Schwabl: Advanced Quantum Mechanics.
(3) Y.V. Nazarov: Advanced Quantum Mechanics.
(4) R. Dick: Advanced Quantum Mechanics – Materials and Photons.
(5) J.J. Sakurai: Advanced Quantum Mechanics.
(6) A.K. Ghatak and S. Lokenathan: Quantum Mechanics.
(7) Satya Prakash: Advanced Quantum Mechanics.

MPHYCCT 203 - Atomic, Molecular and Optical Physics

Atomic Spectra

Quantum states of one electron atoms. Spin-orbit interaction and fine structure. Relativistic correction to spectra of hydrogen atom. Lamb shift. Lande *g* factor. Normal and anomalous Zeeman effect, Paschen-Back & Stark effects.

Two electron systems. Singlet and triplet states. Alkali spectra. Interaction energy in L-S and j-j coupling. Hyperfine structure and Isotopic Shift of monovalent atoms. Line broadening mechanisms. Electron spin resonance. Nuclear magnetic resonance. Chemical shift.

Molecular Spectra

Concept of molecular potential. Born-Oppenheimer approximation. Types of molecules - Diatomic linear symmetric top, asymmetric top and spherical top molecules. Rotational spectra of diatomic molecules as a rigid rotor. Energy levels and spectra of non-rigid rotor. Intensity of rotational lines.

Vibrational energy of diatomic molecules. Diatomic molecule as a simple harmonic oscillator. Energy levels and spectra. Morse potential energy curve. Molecules as vibrating rotator. Vibrating spectrum of diatomic molecule. P-, Q- and R- branches.

Transition matrix elements, Vibration-rotation spectra. Electronic transitions, Franck-Condon principle, Fortrat diagram, Band head, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra of diatomic molecules.

Lasers

Emission broadening, Absorption and Gain. Homogeneous broadening, Doppler broadening, Threshold requirements, Population rate equations. Population inversion. Creation of population inversion in 3 level and 4 level lasers. Pumping requirements. Laser cavity modes, Febry Perot resonator, Laser cavity modes and its properties, Q switching, Mode-Locking, Ruby Laser, He-Ne Laser, Gas Laser. CO_2 laser. Solid State Laser. Nd:YAG laser. Liquid laser. Dye laser. Semiconductor junction laser, Fiber Laser.

Nonlinear Optics

Origin of nonlinearity. Nonlinear optical materials. Nonlinear polarization. Nonlinear susceptibilities. Self-focussing. Self-phase modulation. Cross-phase modulation. Second harmonic generation. Phase matching. Three-wave mixing. Parametric amplification and oscillation.

Books Recommended:

(1) B.H Bransden and C.J. Joachain: Physics of Atoms and Molecules (Pearson)
(2) R. Kakkar: Atomic and Molecular Spectroscopy (Cambridge University Press)
(3) S.N. Thakur and D.K. Roy: Atom, Laser and Spectroscopy (PHI)
(4) G. Aruldhas: Molecular Structure and Spectroscopy (PHI)
(5) O. Svelto: Principles of Lasers (Springer)
(6) K. Thyagarajan and A.K. Ghatak: Lasers - Fundamentals and Applications (Springer)
(7) B.B. Laud: Lasers and Non-linear Optics.
(8) D. Mills: Nonlinear Optics.

MPHYCCT 204 – Solid State Physics

1. Crystal Structure and Diffraction from Periodic Structure

Reviews of fundamental ideas, Crystal class, Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; Point group and Space group (information only); Common crystal structures; Reciprocal lattice and Brillouin zone; Bragg-Laue formulation of X-ray diffraction by a crystal; Ewald construction; Atomic and crystal structure factors; Experimental methods of X-ray diffraction: Laue, Rotating Crystal, and Powder diffraction methods; Electron and Neutron diffraction by crystals (qualitative discussion only).

2. Lattice Dynamics and Specific Heat

Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limits; Optical properties of ionic crystals in infrared region (one-dimensional model); Adiabatic approximation (qualitative discussion); Normal modes and phonon lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals - thermal expansion and thermal conductivity.

3. Band Theory of Solids

Energy bands in solids; Periodic potential and Bloch's theorem; Kronig-Penney model; Brillouin zones; Number of states in the band; Band gap in the nearly free electron model; Tight binding method; Electron dynamics in an electric field; Effective mass of an electron in a band; Concept of holes; Energy band in one dimension - reduced zone scheme; Classification of metal, semiconductor and insulator; Limitations of band theory: metal- insulator transitions.

4. Magnetic Properties of Solids

Fundamental concepts; Quantum theory of paramagnetisn, Spin paramagnetism – Pauli theory; Ferromagnetism: Curie-Weiss law, Temperature dependence of saturated magnetization, Heisenberg's exchange interaction, Ferromagnetic domains; Ferrimagnetism and antiferromagnetism; Spin Waves; Magnetic resonance phenomena.

5. Superconductivity

Phenomenological description of superconductivity – occurrence of superconductivity, critical temperature, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; London equations, London penetration depth; Outlines of the BCS theory; Josephson effect (qualitative), High temperature superconductors (qualitative).

6. Defects in Solids and Optical Properties

Frenkel and Schottky defects; Defects in growth in crystals, Colour centers and luminescence; Alloys – order-disorder phenomena, Bragg- Williams theory.

Books Recommended:

(1) F.C.Phillips: An Introduction to Crystallography
(2) N. Ashcroft and N. Mermin: Solid State Physics
(3) M. Ali Omar: Elementary Solid State Physics
(4) C. Kittel: Introduction to Solid State Physics
(5) J. Christmaan: Fundamental of Solid State Physics
(6) A.J. Dekker: Solid State Physics
(7) J.P. Srivastava: Elements of Solid State Physics
(8) S.P. Kuila: Essentials of Solid State Physics
(9) Rajnikant: Applied Solid State Physics

MPHYCCS 205 – Physics Practical III

1. Using a radioactive source and a Geiger-Müller (GM) counter (i) determine the plateau and optimal operating voltage of the GM counter, and (ii) perform analysis of statistical fluctuations at high count rates.
2. Study of alpha scattering from metal targets and verification of the Rutherford scattering formula and identification of the target element.
3. Experiment with Laser.
4. Experiment with Optical Fibre.
5. Experiments using Fabry-Perot Interferometer.
6. Determination of refractive index of solid.
7. Characteristic study of Diode laser.
8. Determination of the particle size of a material (supplied).
9. Determination of diameter of a wire.

MPHYCCS 206 – Physics Practical IV

1. Square wave generation using 555 timer.
2. Design and study of Active low pass filter
3. Design and study of Active band pass filter
4. Design and study of digital to analog converter.
5. Study of photovoltaic cell.
6. Study of FET and MOSFET.
7. Design and study of current controlled oscillator.
8. Studies on LED and LED based circuits.

THIRD SEMESTER

MPHYCCT 301 - Nuclear and Particle Physics

1. General properties and Structure of nuclei:

Nuclear size, shape and charge distribution, spin and parity: Electron scattering and Form factors, Charge and Matter radius, Magnetic dipole moment, Electric quadrupole moment and nuclear shape, Anomalous magnetic moments of nucleons and qualitative discussions about their origin.

Binding energy, Semi-empirical mass formula and its applications, Liquid drop model, Bohr-Wheeler theory of fission. Evidence of shell structure, Single-particle shell model, its validity and limitations. Collective model: Vibrational and Rotational spectra (qualitative discussion).

2. Nuclear Interactions and Nuclear Reactions:

Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron. Spin, isospin dependence and the necessity of tensor forces. Two nucleon scattering, Partial wave analysis, Effective range theory. Nature of nuclear forces: charge symmetry, charge independence, exchange properties, velocity dependence. Isospin formalism. Meson theory of nuclear forces.

Direct and compound nuclear reaction mechanisms. Cross-sections in terms of partial wave amplitudes – Scattering and reaction cross-sections. Compound nucleus, Scattering matrix, Reciprocity theorem. Resonance scattering and reactions, Breit-Wigner dispersion relation.

3. Nuclear decay:

Gamow's theory of alpha decay and Geiger-Nuttal law. Qualitative discussion about Nuclear Transition Matrix Element and Estimates of Transition rates. Fermi's theory of beta decay, Selection rules, Parity violation, Neutrino detection. Gamma-decay, Multipole transitions, Selection rules.

4. Elementary particle physics:

Classification of fundamental forces - typical strengths and timescales. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Symmetry, Conservation laws and their applications to particle reactions. Relativistic kinematics. C, P, and T invariance. Quark model: Color charge and strong interactions, confinement. Gell-Mann-Okubo mass formula for octet and decuplet hadrons.

Books Recommended:

(1) K.S. Krane: Introductory Nuclear Physics (Wiley)
(2) S.S.M. Wong: Introductory Nuclear Physics (PHI)
(3) B.R. Martin: Nuclear and Particle Physics – An Introduction (Wiley)
(4) M. Thompson: Modern Particle Physics (Cambridge University Press)
(5) R. Prasad: Nuclear Physics (Pearson)
(6) J. Varma, R.C. Bhandari, D.R.S. Somayajulu: Fundamentals of Nuclear Physics (CBS Publishers)
(7) S.N. Ghosal: Nuclear Physics (S. Chand)
(8) D.J. Griffiths: Introduction to Elementary Particles (Wiley)

MPHYCCT 302 – Statistical Mechanics

1. Introduction

Objective of statistical mechanics. Transition from thermodynamics to statistical mechanics. Reviews of the ideas of macrostates, microstates, phase space and ensembles. Ergodic hypothesis, postulate of equal a priori probability and equality of ensemble average and time average. Boltzmann's postulate of entropy. Entropy of ideal gas: Sackur-Tetrode equation and Gibbs' paradox. Liouville's Theorem, Stationary ensembles.

2. Micro-canonical and canonical ensembles

Micro-canonical ensembles; System in contact with heat reservoir in canonical ensemble, canonical partition function, Helmholtz free energy, Equilibrium properties of ideal systems: Ideal gas, Harmonic Oscillators; Concept of negative temperature, Fluctuation of internal energy.

3. Grand Canonical Ensemble

System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number; Chemical potential of ideal gas.

4. Quantum statistical mechanics

Density Matrix; Quantum Liouville theorem; Statistical and quantum mechanical approach, pure and mixed states, Density matrix for stationary ensembles. Simple examples of density matrices - one electron in a magnetic field, a free particle in a box, density matrix for a beam of spin 1/2 particles.

5. Systems of indistinguishable particles

B-E and F-D distributions; Ideal Bose and Fermi gas; Statistics of occupation number, general equation of state; Bose-Einstein condensation, Fermi gas at finite temperature, theory of white dwarf stars , Saha ionization.

6. Strongly interacting systems

Ising model; Idea of exchange interaction and Heisenberg Hamiltonian; Ising Hamiltonian as a truncated Heisenberg Hamiltonian.;Exact solution of one-dimensional Ising system (Matrix method); Bragg-William's approximation (Mean field theory) and the Bethe-Peierls approximation.

7. Phase transition

General remarks; Critical relations and scaling relations; Landau's order parameter theory of phase transition; Calculation of exponents from mean field theory and Landau's theory.

8. Irreversible Thermodynamics

Thermodynamic fluctuations, Flux and affinity, Spatial correlations in a fluid, Brownian motion.

Books Recommended:

(1) F. Reif: Fundamental of Statistical and Thermal Physics.
(2) R. Pathria and P. Beal: Statistical Mechanics.
(3) R. Kubo: Statistical Mechanics.
(4) K. Huang: Introduction to Statistical Mechanics
(5) S. Bowley: Introductory Statistical Mechanics.
(6) S. Salinas: Introduction to Statistical Mechanics.
(7) F. Mandl: Statistical Physics.
(8) H.E. Stanley: Introduction to Phase Transitions and Critical Phenomena
(9) J.M. Yeomans: Statistical Mechanics of Phase Transitions
(10) L.D. Landau and E. M. Lifshitz: Statistical Physics.

MPHYMET 303 – Elective I (Any one of the following)
Advanced Electronics I / Photonics I / Condensed Matter Physics / Nuclear Structure

Advanced Electronics I

1. IC Technology
Hybrid and monolithic IC. Semiconductor processing: Diffusion, implantation, Oxidation, Epitaxy, lithography. Si IC technology: MOS and Bipolar. Packaging and testing.

2. Analog Integrated Circuits
Differential amplifier, OP-AMP comparator. Continuous time filters. Switched capacitance implementation of sample data filters. Analog multiplexers. PLL and frequency synthesizer.

3. Digital Integrated Circuits
Logic families – TTL, ECL, MOS, MESFET. Design of combinational and sequential circuits – MUX, decoder/ encoder, registers, counters, gate arrays. Programmable logic devices – PAL, GAL, PLA. Programmable gate arrays.

4. Special purpose ICs
ICs for analog communication. Digital signal processing ICs. Basic concepts of MIC, MMIC and OELC. GaAs technology.

5. Linear modulation, Exponential modulation
FM and PM; AM and FM modulators and demodulators.

6. Pulse Modulation and Demodulation Techniques
Sampling the rein PAM, PWM, PPM, Pulse code modulation – coding technique. Modulation and demodulation.

7. Digital Modulation Techniques
Principles of ASK, FSK, PSK, DPSK, QPSK, MSK. Modulators and demodulators.

8. Effect of Noise on Communication System
Characteristics of additive noise; Performance of AM, FM and PCM receivers in the face of noise. Multi-path effect.

9. Optical Communication
Types of optical fibres, numerical aperture and pulse broadening, propagation of EM waves in planar optical wave guide, V-parameter, power associated with modes, Multiplier and demultiplexer, Fibre optic communications, direct and coherent detections, signal-to-noise ratio. LIDAR and submarine communication (idea only).

Books Recommended:
(1) Geiger, Allen and Strader: VLI – Design Techniques for Analog and Digital Circuits.
(2) Gray and Meyer: Analysis and Design of Analog Integrated Circuits.
(3) A. Carlson: Communication Systems.
(4) S. Haykin: Communication Systems.
(5) D. Roddy and J. Coolen: Electronic Communications.

Photonics I

1. Coherence of light

Mutual coherence function. Complex degree of coherence. Quasi-monochromatic fields and visibility. Spatial coherence of ordinary and laser light. Photon statistics. Poissonian photon statistics. Classification of light by photon statistics. Photon statistics of thermal and laser sources. Brown-Twiss correlations. Photon bunching and antibunching. (9L)

2. Interferometry & Holography

Fabry-Perot interferometer, Mach-Zehnder interferometer, Basic holography equations; Use of coherent light in holography recording ; Advantages of holographic recording over photo graphic recording; Recording and reconstruction processes. (7L)

3. Polarization

Zones Calculus, Mueller Calculus, Poincare sphere. (4L)

4. Optical / Optoelectronic Sources

Direct band gap semiconductors for optical/ optoelectronic sources ; Principle of operation of LED and Semiconductor junction Laser diode ; Internal and External quantum efficiencies of LED, DHLED; Different types of quantum and other efficiencies of Semiconductor junction Laser diode, Equations relating the light intensity of LED and Semiconductor Laser with applied current ; Quantum well laser , Principle of operation of quantum well Laser; Quantum dot. (10L)

5. Optical/optoelectronic detectors

Vacuum photodiodes and photomultipliers; PN junction detectors and its disadvantages ; PiN detectors and its principle of operation ; Quantum efficiency of PiN detectors ; Avalanche photo detector(APD) ; Equations relating the applied light intensity with received photo current of a PiN detector and also that of a Avalanche photo detector ; Dark current of a photo detector ; Shot noise of PiN detector ; Signal to noise ratio of a photo detector; Photo conductor and its function ; Photo transistor and its principle of operation. (10L)

6. Optical modulators

Optical Q- Switching , Different processes of Q- Switching, Optical Mode locking ; Pockels effect and Kerr effect ; Electro-optic modulation by pockels materials ; Phase modulation and Amplitude modulations in Electro-optic modulators ; Modulation of light using optical Kerr effect ; Self focusing, self defocussing ; All- optical switches using Kerr effect , Optical Faraday effect. (10L)

Books Recommended:

(1) John Gower: Optical communication systems
(2) Franz and Jain: Optical Communication Systems.
(3) Gerd Keiser: Optical Fiber Communication
(4) John M. Senior: Optical Fiber Communications
(5) Selvarajan and Kar: Optical Fiber Communications
(6) Ghatak and Thyagrajan: Introduction to Fiber Optics
(7) Wilson and Hawkes: Optoelectronics
(8) Keneth E Jones: Introduction to Optical Electronics
(9) Djafer K Mynbaev and Lowell L Scheiner: Fiber Optic Communication Technology
(10)Ralf Menzel: Photonics Linear And Nonlinear Interactions Of Laser Light And Matter
(11) B. E. A. Saleh M. C. Teich: Fundamentals of Photonics

Condensed Matter Physics

Many Body Techniques

The basic Hamiltonian; Jelium Mode; Hatree and Hatree-Fock equation; Interacting electron gas; Hatree-Fock approximations for the electron gas; Excahnge hole and exchange energy; Static screening; Thomas Fermi approximation; Plasma Oscillations; Bohm Pines theory – Random Phase Approximation, plasma oscillations, dielectric function of an electron gas; Linhard dielectric function.

Transport Properties of Solids

Boltzmann transport equation and its linearization; The relaxation time approximation; Variational method for the solution of the linearized Boltzmann equation; Ideal resistance in metals - Mattheissen's rule; Transport coefficients of metals and semiconductors in presence of magnetic field; Limitations of the Boltzmann transport equation; Kubo formula for electrical conductivity.

Optical Properties of Solids

The dielectric function – the dielectric function for a harmonic oscillator, dielectric losses of electrons, Kramers-Kronig relations; Interaction of phonons and electrons with photons; Interband transition – direct and indirect transition; Polaritons; One-phonon absorption; Optical properties of metals, skin effect and anomalous skin effect.

Energy Bands

Different methods of calculation of energy bands in solids – Nearly free electron model, Tight binding approximation, Orthogonalised plane wave (OPW) method and Pseudo-potential methods; Phillops-Kleiman's cancellation: Qualitative discussions of band structures of semiconductor, semi-metal and insulator, Dynamics of an electron in a crystal, Effective mass tensor.

Electron-Phonons Interactions and Superconductivity

Interaction of electrons with Acoustical and Optical Phonons, Long wavelength limit of optical phonons and crystal polarization – Polarons; Cooper pairing due to Phonon; BCS theory of superconductivity; Ginzburg-Landau theory; Abrikosov vortex lattice.

Density Functional Theory

Basics of DFT, Comparison with conventional wave function approach, Hohenberg-Kohn Theorem; Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many body calculation and its reliability.

References:

1. N.W. Ashcroft and N.D. Mermin – Solid State Physics.
2. C. Kittel – Introduction to Solid State Physics.
3. J.M. Ziman – Principles of the Theory of Solids.
4. O. Madelung – Introduction of Solid State Theory.
5. M. Sachs – Solid State Theory.
6. A. L. Fetter and J.D. Walecka – Quantum Theory of Many Particle Systems.
7. S. Raimes – Many Electron Theory.
8. N.H. March and M. Parrinello – Collective Effects in Solids and Liquids.
9. C. Kittel – Quantum Theory of Solids.
10. D. Pines – Elementary excitations in solids.
11. M. Tinkham – Introduction to Superconductivity.

Nuclear Structure

1. Nuclear Models

Single Particle Shell Model:
Determinantal wave functions of the nucleus, Single particle operator and their expectation values.

Extended Single Particle Model:
Classification of shells, Seniority and reduced i-spin, Configuration mixing, Pairing force theory, Gap equation and ground state properties, Idea of quasiparticles. Simple description of two-particle Shell model spectroscopy.

Collective Model of Nucleus:
Deformable liquid drop and nuclear fission, Shell effects on liquid drop energy, Collective vibrations and Excited states. Permanent deformation and collective rotations, Energy levels, Electromagnetic properties of even-even, odd-A deformed nuclei. Nilsson model and equilibrium deformation. Behaviour of nuclei at high spin, Back bending.

2. Microscopic Theory

Occupation number representation, One and two-body operators, Matrix elements, Wick's theorem. Hartree-Fock approximation and HF equations. BCS model.

3. Experimental techniques

Energy loss of charged particles and gamma rays. Ionization formula, Stopping power and range. Experimental observables - Cross section, Angular distributions, Excitation functions. Radiation detectors and their comparisons for different types of radiation detection. Basic ideas for energy, timing and position sensitive spectroscopy. Charged particle detection and identification using particle telescope and time of flight measurement, neutron detection using pulse shape discrimination technique.

Books Recommended**:**

(1) K. Heyde: Basic Ideas and Concepts in Nuclear Physics (Institute of Physics Publishing)
(2) D.J. Rowe and J.L. Wood: Fundamentals of Nuclear Models – Foundational Models (World Scientific)
(3) W. Greiner and J.A. Maruhn: Nuclear Models (Springer)
(4) M.K. Pal: Theory of Nuclear Structure (Affiliated East-West Press)
(5) S.N. Mukherjee: Elements of Nuclear Theory (CBS Publishers)
(6) Y. Jana: Nuclear Physics (Narosa Publishing House)
(7) W.R. Leo: Techniques of Nuclear and Particle Physics Experiments (Springer)

MPHYMET 304 – Advanced Experiments

1. Design and study of ECL OR/NOR circuit.
2. Design of analog computer to solve differential equation using OP-AMP.
3. Design and study of shift register
4. Design and study of 4-bit ripple counter.
5. Microwave characteristic study using klystron tube
6. Design and study of Wien bridge oscillator.
7. Design and study of RC phase shift oscillator.
8. Design and study of active phase shifter.
9. Experiments on microprocessor interfacing.
10. Problems on assembly language programming using 8085 microprocessor.
11. Optical fiber: mode field diameter and numerical aperture, bend loss measurement;
12. Atomic spectra by constant deviation spectrometer
13. To verify the Malus law
14. Measurement of Brewster angle of a substance and hence determine the refractive index.
15. Experiments using Mach-Zehnder interferometer
16. Holography: construction of the hologram and reconstruction of the object beam
17. To determine the distance between the grooves of a compact disk.
18. To find the wavelength of an unknown light source using compact disk.
19. Determination of spot size and angle of divergence of a given laser source.
20. Determination of the spectroscopic splitting factor of a given sample using electron spin resonance (ESR) spectrometer.
21. Use nuclear magnetic resonance (NMR) for the study of solids.
22. Determination of saturation magnetization, retentivity and coercivity of given ferromagnetic samples using hysteresis loop tracer.
23. Determination of magnetic susceptibility of paramagnetic salts by Guoy Balance method.
24. Study of colour centers and thermoluminiscence of alkali halides.
25. Determination of Miller indices and lattice parameter of a polycrystalline material using X-ray diffractometer.
26. Determination of grain size and lattice strain of polycrystalline material applying MARQ2 software and Scherrer equation.
27. Determination of phase transition temperatures of a binary liquid crystal mixture at different concentrations.
28. Alpha particle absorption using surface barrier detectors and multichannel analyser.
29. Alpha particle spectroscopy with ^{241}Am source and calculation of branching ratio.
30. Measurement of half life of ^{40}K using beta counting.
31. Study of conversion electron spectrum of ^{57}Co.
32. Gamma spectroscopy: (a) study of energy resolution at different amplifier gains, (b) energy calibration for a fixed gain, (c) study of ^{22}Na source spectrum and determination of the activity from sum peak analysis.
33. Beta-gamma coincidence measurements: study of decay schemes and lifetime of nuclear levels

MPHYOET 305 – Open Elective Course (Anyone of the following)
Nature of the Universe **OR** Concepts of Physics: Inventions and Applications

Nature of the Universe

1. The solar family
Our motion in the Universe. The night sky, basic concepts in astronomy such as distances, constellations and the celestial sphere, Asteroids & Comets, Formation of our solar system, Sun-Moon-Earth configurations that result in Moon phases and Solar and Lunar eclipses.

2. Instruments in astronomy
Light as a tool to probe the Universe. Properties of light. The wave particle nature of light. Atoms and spectroscopy. The thermal spectrum. Stellar classification: Hertzsprung-Russell diagram. Composition of a star's outer layers and its surface temperature, The Inverse square law. Telescopes, detectors to learn about astrophysical phenomena.

3. The Sun
Origin of solar energy, Nuclear fusion, Solar cycle, Solar activity, Solar wind. Solar missions. Main-Sequence lifetime.

4. Stellar Evolution
Post-main-sequence evolution of a Sun-like star. Planetary nebulae. White dwarfs. Neutron Stars, Difference between stars, brown dwarfs and giant planets. Supernova explosions. Neutron stars and black holes. Color-magnitude diagrams, Binary star systems, stellar nuclesynthesis.

5. Galaxy and Cosmos
Populations of stars and star clusters. Galaxy types and the formation and interaction of galaxies. The Milky Way, Active galactic nuclei, The rotation of our galaxy. Dark matter. The expansion of the Universe and the Big Bang Theory.

Books Recommended:
1. Introduction to Astronomy, Franck H Shu, (University Science Books)
2. Astronomy: The evolving Universe, Michael Zeilik, (Wiley)
3. Practical Astronomy, Peter D Smith, (Cambridge Press)
4. An introduction to Galaxies and cosmology, Mark Jones, Lambourne, (Cambridge)
5. Steller structure and Evolution, Kippenhahn, (sringer)
6. Observational Astrophysics, Lena, Rounan, (Springer)

Concepts of Physics: Inventions and Applications

1. Important Developments of Physical Science before 20th century:
Archimedes' principle, Inertia: Galileo Galilei, Laws of motion and law of gravity: Newton, Concept of Classical Mechanics, Wave theory of light: Young, Atomic theory of matter: Dalton, Electrical resistance, etc.: Ohm, Electromagnetic induction: Michael Faraday, Electromagnetic waves: Hertz, Electron: Thomson.

2. Progress of Physics in 20th century:
Introduction**,** Photoelectric effect: Einstein, Discovery of the atomic nucleus: Rutherford, Superconductivity: Kamerlingh Onnes, Concept of Quantum Mechanics, Radioactivity, Introduction to electronics, chip, Crystal, Nano materials, Glass, fibre optics, Advancement of technology in 20th century,

3. Physics in daily life**:**
Working principle of Optical camera, Valve radio, Transistor radio, AM and FM radio, Television, Digital Camera, Mobile, Smart Phone, Electric heater, Microwave oven, Induction oven, Fan, electric generator, Refrigerator.
Development of different light sources: Incandescent bulb, Vapour lamp, Arc Lamp, Fluorescence Lamp (Tube light, CFL), Light Emitting Diode (LED), LASER, Field emission.

4. Medical Instrumentation:
X-ray, Electrocardiograph (ECG), Ultrasonography(USG), Magneto Resonance Imaging (MRI), Photodynamical Therapy (PDT), Spectrophotometry, Chromatology, Electrophoresis.

5. Physics of Nature:
Blue sky, Scattering of light, Colour of Sun, Rainbow, Halo, Refraction and reflection of light, Mirage.

Books recommended:

1. Bowler, Peter J. and Iwan Rhys Morus (2005), Making Modern Science: a Historical Survey (Chicago: University of Chicago Press)
2. History of Science, Samarendra Nath Sen (Saibya Prakasan Bibhag, in Bengali)
3. Itihase Bijnan, J.D. Barnal (Ananda Publishers, in Bengali)
4. Medical Instrumentation Application and Design, John G. Webster(Editor) (Wiley)
5. Handbook of Biomedical Instrumentation, Dr R.S. Khandpur, (McGraw Hill Education)
6. Introduction to Light: The Physics of Light, Vision, and Color, Gary Waldman, (Dover Publications)

MPHYOPT 306 – Outreach Programme

Students will undertake one Outreach Programme involving the visit to a national experimental facility.

FOURTH SEMESTER

MPHYCCT 401 – Numerical Methods and Computational Physics

Computer fundamentals:
Functional units. CPU. Memory. I/O units. Information representation. Integral and real number representation. Character representation. Alphanumeric codes. BCD. Gray. ASCII codes. Computer Software and Operating Systems: System software and application software. Classification of operating systems. Elements of DOS and Windows. Basic commands. CPU. RISC and SISC. Storage system- primary and secondary memory. Semiconductor, magnetic and optical memory. Cache memory. Virtual memory. Memory management. IO Units – keyboard, mouse, VDU, printers; (principle of operation only).

Elements of C 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. Application to solve eigen value equations and some electronic circuits

Numerical Analysis:
Approximation of numbers, Significant figures, Absolute, Relative & Percentage errors, Round off errors and significant errors. Solution of Polynomial equations – Bisection, Regula-Falsi and Newton-Raphson algorithms. Solution of a system of simultaneous equations- Gauss elimination, Gauss-Seidel algorithms. Interpolation - Newton's Forward & Backward interpolation formulae, Newton Lagrange equation, Hermite difference equations. Numerical integration – Trapezoidal formula, Simpson's 1/3rd & 3/8th formula. Numerical solution of differential equations- Euler and Runge-Kutta formulae. Numerical solution of partial differential equations - discussion of algorithms only. Matrix inversion, diagonalization, eigenvalue and eigenvector determination. Least square technique: Problems of linear least squares fit, applications.

Books Recommended:

(1) P.K. Sinha and P. Sinha: Computer Fundamentals.
(2) Anita Goel: Computer Fundamentals.
(3) B. Gottfried: Programming with C.
(4) E. Balaguruswamy: Programming in ANSI C.
(5) H.M. Antia: Numerical Methods for Scientists and Engineers.
(6) S. Sastry: Introductory Methods of Numerical Analysis.
(7) W.H. Press et al: Numerical Recipes in C.
(8) S.A. Mollah: Numerical Analysis and Computational Procedures.

MPHYCCT 402 - Relativity, Cosmology and Astrophysics

1. Tensor calculus

Idea of 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.

2. Einstein's field equations

Inconsistency of Newtonian gravitation with the special theory of relativity. Principles of equivalence. Principle of general covariance. Metric tensors and Newtonian Gravitational potential. Logical steps leading to Einstein's field equations of gravitation. Einstein's equation from action principle, Linearised equation for weak fields. Poisson's equation.

3. Applications of general relativity

Observational tests of Einstein's theory, gravitational lensing, Schwarzschild's exterior solution. Singularity. Event horizon and black holes. Isotropic coordinates. Birkhoff's theorem. static and rotating black holes (Schwarzschild and Reissner-Nordstrom). Kerr metric (derivation not required), event horizon. Kerr-Neumann Metric (no derivation). No hair theorem. Cosmic censorship hypothesis.

4. Cosmology

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. Brief discussions on: Big bang, Early universe (thermal history and nucleosynthesis), Cosmic microwave background radiation, Particle horizon.

5. Astrophysics

Luminosity, Effective Temperature, Stellar Magnitudes. Boltzmann and Saha Ionization Equations. Spectral Classification of Stars. Hertzsprung-Russel (H-R) diagram. Hydrostatic Equilibrium, Equilibrium of a gas of Non-relativistic and Ultra-relativistic particles. Gravitational energy and Virial theorem. Jeans criteria for Star Formation, Fragmentation of Collapsing clouds. Free-Fall Times.

Heat transfer by random motion and convection, Temperature gradient in stars. Equations of stellar structure and evolution. Polytropic stellar model, Lane-Emden equation. Thermonuclear reactions in stars, PP chains and CNO cycle. Solar Neutrino problem. Helium and advanced burning phases. Nucleosynthesis beyond iron, r- and s- processes. Evolutionary tracks in the H–R diagram of low mass and massive stars. Novae and Supernovae. Compact stars, Equation of state and degenerate gas of fermions. White dwarf and Chandrasekhar limit. Neutron Stars and Pulsars. Black Holes.

Books Recommended:

(1) J.B. Hartle: Gravity (Pearson)
(2) B. Schutz: A First Course in General Relativity (Cambridge University Press)
(3) Ray D'Inverno: Introducing Einstein's Relativity (Oxford University Press)
(4) S. Banerjee and A. Banerjee: General Relativity and Cosmology (Elsevier)
(5) S. Weinberg: Gravitation and Cosmology (Wiley)
(6) B.W. Carroll and D.A. Ostlie: An Introduction to Modern Astrophysics (Pearson)
(7) A.C. Phillips: The Physics of Stars (Wiley)
(8) V.B. Bhatia: Textbook of Astronomy and Astrophysics (Narosa Book House)
(9) S. Palen: Theory and Problems of Astronomy (Schaum's Outlines) (McGraw-Hill)

MPHYMET 303 – Elective I (Anyone of the following)
Advanced Electronics II / Photonics II / Nano Science and Technology / Nuclear Reaction

Advanced Electronics II

1. Memories
Sequential and Random access memories. RAM bipolar and MOS static and dynamic memories. Programmable memories: PROM, EPROM, EEPROM.

2. Microprocessors and their applications
Architecture of 8 bit (8085) and 16 bit (8086) microprocessors. Addressing modes and assembly language programming of 8085 and 8086. Machine cycles and their timing diagrams. Interfacing concepts. Memory and I/O interfacing. Interrupts and interrupt controllers. Microprocessor based system design. Comparison of different microprocessors.

3. Microwave Devices
Klystron, Reflex Klystron, magnetrons, Travelling wave tubes, Gunn, Impatt, Trapatt, transistors, GaAs-InP FET, HEMT, BARITT.

4. Elements of Information Theory
Information, average information, information rate, Effect of coding on average information per bit. Shanon's theorem; Channel capacity. Optimum modulation system in AWGN channel.

5. TV Systems
Color TV standards – NTSC, PAL, SECAM; Transmission format of intensity and color signal. Transmitter and receiver systems of broadcast TV. Advanced TV. Cable TV.

6. RADAR System
Types of RADAR (CW, MTI, FM & Chirp pulse radar), Radar system and range equation.

7. Specialized Communication Systems
Mobile Communication – Concepts of cell and frequency reuse description of cellular communication, development of mobile generation 1G to 5G (idea only).
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, Basics of protocol.

Books Recommended:
(3) A Mathur: Microprocessors.
(4) R. Gaonkar: Microprocessor Architecture, Programming and Applications with 8085/8085A.
(5) Lin and Gibson: Microprocessor.
(6) S Soelof: Applications of Analog Integrated Circuits.
(7) B. Brey: Intel Microprocessors Architecture, Programming and Interfacing.
(8) Franz and Jain: Optical Communication Systems.
(9) A. Dhake: Television and Video Engineering.
(10) Gulati: Monochrome and Color TV.
(11) Kennedy and Davis; Electronic Communication Systems.
(12) Taub and Schilling: Principle of Communication Systems.
(13) B. P. Lathi: Modern Digital and Analog Communication Systems.

Photonics II

1. Nonlinear optics
Review of Nonlinear optics, Parametric generation of light, Crystal optics, Nonlinear optics in Crystals, 2HG in KDP, Pockels cell and Pockels effect, Stimulated Raman Scattering. (5 L)

2. Non-linear Optical fiber
Step index optical fiber ; Concept of TEM modes in cylindrical fiber; Optical communication through wave guide ; Types of optical fiber ; Losses in optical fiber: Propagation of electromagnetic radiation through a planar waveguide; concept of TE and TM modes ; Propagation of electromagnetic radiation through 3-dimensional cylindrical waveguide, Dispersion in optical fiber; multi-mode dispersion, material dispersion, and wave guide dispersion; Derivation of the expressions of the three dispersions; Dispersion free fiber and dispersion compensated fiber; Propagation of electromagnetic radiation through nonlinear wave guide; Nonlinear Schrodinger equation; Optical soliton formation; Wavelength division multiplexing and demultiplexing. (16 L)

3. Optical amplifiers
Semiconductor Optical Amplifier (SOA) and its operation ; Self phase modulation, cross phase modulation , Cross gain modulation and wavelength conversion of SOA ; Erbium doped fiber amplifier (EDFA) and its principle of operation. (5 L)

4. Photonic measurement systems
Homodyne and Heterodyne detectors for phase and intensity measurements of light , Optical time domain reflectometer (OTDR). (4 L)

5. Optical devices and sensors
Principle of operation of Liquid Crystal Display; Charge Coupled Devices ; Fiber optic displacement, current , pressure and temperature sensors . optical directional coupler, optical biological sensor. (7 L)

6. Optical Communication
Optical free space communication; Components of coherent communication systems ; Coherent signal, Transmitter, transmission channel, coherent receivers; Probability error and bit error rate; Calculation of Worst-case bit error rate; maximum bit rate and bit error rate in digital communication through optical fiber; Power budget equation and Time budget equation. LIDAR, Optical free-space communication, Optical submarine communication. (8 L)

7. Optical Networks
Local area network, Broadcast and distribution network; Optical Bus topology (Single fiber and dual fiber bus topologies). (5 L)

Recommended Books :

(1) A. Yariv and P.Yeh (Oxford University Press , 2007)- Photonics : Optical electronics in modern communication.

(2) J. Wilson and J.F.B.Hawkes (Prentice Hall Europe, 1998)- Optoelectronics : An introduction .

(3) C.K. Sarkar (New Age international (p) Limited , 2004)- Opto Electronics And Fiber Optics Communication.

(4) J Franz and V K Jain (NAROSA ,1996)-Optical Communication Systems.

Nano Science and Technology

1. Background to Nano Science and Technology

Scientific revolution: Atomic structures-Molecular and atomic size-Bohr radius; Emergence of Nanotechnology: Challenges in Nanotechnology; Carbon age: New form of carbon (from Graphene sheet to Carbon Nanotubes).

2. Types of Nanostructures and Size Effects

Definition of a Nano system; Types of Nanocrystals: Zero dimensional (0D), One Dimensional (1D), Two Dimensional (2D), and Three Dimensional (3D) nanostructured materials (Quantum Dots, Wires and Wells); Conduction Electrons and Dimensionality; Properties Dependent on Density of States; Bulk to Nano Transitions.

3. Nucleation

Influence of nucleation rate on the size of the crystals; macroscopic to microscopic crystals and nanocrystals; large surface to volume ratio; grain boundary volume in nanocrystals; defects in nanocrystals; surface effects on the properties.

4. Synthesis of Nanoparticles

Bottonm up and Top down approaches; Method of Synthesis: Physical Vapour Deposition, RF Plasma Chemical Methods, Thermolysis, Pulsed Laser Methods, Biological Methods.

5. Nanomaterials and properties

Carbon Nanotubes (CNT); Metals (Au, Ag); Metal oxides (TiO_2 , ZnO), Semiconductors (Si, Ge); Composites; Dilute magnetic semiconductor; Biological system: DNA, RNA and – Lipids; Size dependent properties - Mechanical, Physical and Chemical properties.

6. Bulk Nanostructured Materials

Methods of Synthesis: Compaction & consolidation, and Ion implantation, Solid Disorders Nanostructures: Mechanical and Electrical Properties, Nanostructure Multilayers, Metal Nanocluster Composite Glasses, Porous Silicon.

7. Analysis Techniques for Nano Structures/Particles

Scanning Probe Microscopes (SPM): Scanning Tunneling Microscopes (STM) and Atomic Force Microscope (AFM); Diffraction Techniques: X-ray Diffraction (XRD), Transmission Electron Microscope (TEM); Spectroscopic Techniques: Optical absorption, Photoluminescence and Raman spectroscopies, Magnetic Measurements.

8. Applications of Nanomaterials: Molecular electronics and nanoelectronics; Quantum electronic devices; CNT based transistor and Field Emission Display; Biological applications; Biochemical sensor; Membrane based water purification.

References

1. Poole and Owners: Introduction to Nanotechnology
2. M. Wilson, K. Kannangara, G Smith, M. Simmons, B. Raguse, Nanotechnology: Basic
3. Jacak, Hawrylak and Wojs: Quantum Dots
4. H S Nalwa (Editor): Handbook of Nanostructured Materials and Nanotechnology
5. S K Kulkarni : Nano Technology/ Principles and Practices
6. Silvana Fiorito : Carbon Nanotubes
7. R Booker and El Boysen: Nanotechlongy
8. C.S.S.R.Kumar, J.Hormes, C.Leuschner, Nanofabrication towards biomedical applications
9. W. Rainer, Nano Electronics and information Technology
10. G.Cao, Naostructures and Nanomaterials: Synthesis, properties and applications

Nuclear Reaction

1. Compound Nuclear Reactions

Formation and decay, multilevel Breit-Wigner formula, Weiskopff – Ewing formula; continuum states. Evaporation model, level density Erickson's formula, Nuclear temperature. Hauser-Feshbach formalism.

2. Direct reactions

a) Formalism: Gell-Mann Goldberger two potential formula, PWBA and DWBA, Method of Coupled Channels.

b) Optical Model: Its properties and calculation of its parameters, elastic and inelastic collisions, rearrangement collisions. Stripping, pick up, knock on reactions; Form factors and spectroscopic factors – connection with nuclear structure (calculation of a single-nucleon transfer reaction)

c) Photon-induced reactions; photo excitation, photodisintegration of the Deuteron.

3. R-matrix

Definition and properties. Giant resources. Feshback's unified theory of nuclear reactions.

4. Heavy Ion collisions

a) Collisions near the Coulomb barrier: Semi-classical concepts, Elastic scattering, Coulomb excitation, Deep inelastic collisions, Fusion, Collisions near Fermi velocity.

b) Collisions near the speed of light: Classifications of reactions and products. Ultra relativistic nuclear collisions: Phase diagram of nuclear matter.

5. Nuclear Fission

Spontaneous Fission, Mass energy distribution of fission fragments, Bohr-Wheeler theory, Fission isobars, Super-heavy nuclei.

Books Recommended**:**

(1) A. Kamal: Nuclear Physics (Springer)
(2) H.S. Hans: Nuclear Physics – Experimental and Theoretical (New Age)
(3) G.R. Satchler: Introduction to Nuclear Reactions (Oxford University Press)
(4) C.A. Bertulani and P. Danielewicz: Introduction to Nuclear Reactions (IoP Publishing)
(5) R. Singh and S.N. Mukherjee: Nuclear Reactions (New Age International)
(6) H. Feshbach: Theoretical Nuclear Physics – Nuclear Reactions (Wiley)
(7) N.K. Glendenning: Direct Nuclear Reactions (Academic Press)

MPHYMEP 404 – Project/Term Paper and Grand Viva

Project/Term paper to be made on the basis of subject-interest of the students in different areas of Physics discipline and under the supervision of a teacher of the department. Seminar talk based on the Project/Term paper work to be conducted by the department. Record to be maintained by the department.

Grand Viva is to be conducted by the Department. At least one external examiner should be appointed for the Grand-Viva. Students may be asked questions from any part of the MSc syllabus. However, any relevant question outside the mentioned syllabus may also be asked.

MPHYCCS 405 – Computer Practical

Several numerical methods will be tested in the computer lab namely, numerical differentiation and integration, solution of first-order differential equations, interpolation and extrapolation, least square fitting, Monte Carlo Technique etc.

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