CURRICULUM:

M.SC. Physics (SEMESTER-I)

Mathematical Physics

Aims and Objectives : For learning this paper, student should have a knowledge of algebraic operations, integration and differentiation. After learning this paper student will gain knowledge about the solution of special forms of second order differential equations, matrix methods, complex functions which are having importance in science as well as in technology.

Vector Spaces and Matrices (10)

Linear dependence and independence of vectors, Inner product, Schmidt's orthogonalization method. Matrices – Inverse, Orthogonal, Hermitian and unitary matrices, Transformation of vectors and matrices, System of linear equations, eigenvalues and eigenvectors of square matrix, diagonalisation of a matrix, rotation matrix.

Special functions : (20)

i) Legendre equation, Rodrigues formula for Pn(x), generation functions and recurrence relation, Associated Legendre polynomial.

ii) Bessel equation, Bessel function of first kind, generating functions and recurrence relation, Associated Legendre polynomial.

iii) Hermite Equation, generating function and recurrence relation for Hermite polynomial.

iv) Leguerre equation, generating function and recurrence relation, Rodrigue formula, Associated Lagurre polynomials.

v) Fourier Series : General properties of Fourier series, Simple applications, properties of Fourier series, convergence, integration, differentiation.

Integral Transform (8)

Fourier Transform, Laplace Transforms, Properties of Fourier and Laplace transforms (Linearity, first shifting and second shifting property), Fourier sine and cosine transforms, Fourier and Laplace transform of derivatives, elementary Laplace transform, Inverse Fourier and Laplace transforms, shifting theorm, step function, Solution of simple differential equation using Laplace Transform technique.

Complex function and Calculus of Complex function (7)

Definition of complex function, exponential function and properties, circular function and properties, hyperbolic function and properties, Inverse hyperbolic function, logarithmic function, limit of a complex function, continuity, derivative (theorm), anlytic functions, harmonic functions, complex integration, Cauchy's theorm, Cauchy's integral formula, Series of complex term-Taylor's series, Laurentz series. Zeros of an analytical function, Singularities of an analytical function (isolated, removable, poles and essential singularity), Residue Theorm-Calculus of residues.

Reference Books :

1) A. W. Joshi, Matrices and Tensors in Physics,
2) Mathematical Physics, B. S. Rajput
3) Higher Engineering Mathematics, By B. S. Grewal.
4) Mathematical Physics, S. L. Kakani.
5) Mathematical Physics, S. Chandra

Classical Mechanics **(4 credits)**

Max. Marks. 50 Total Periods 48

I **Elementary Principles :- Inertial reference frame; Newton laws of motion; Motion of a charged particle in electromagnetic field; Galilean transformations; Conservative and non-conservative forces; Mechanics of a single particle; Mechanics of a System of particles; Motion in a resistive medium; Constraints; Gen-eralized coordinates and degrees of freedom; Virtual displacement and virtual work; D' Alembert's principle.**

II **Lagrangian Formulation :-Lagrangian equation of motion; Variation technique; Kinetic energy in terms of generalized corrdinates; Jacobi integral; Rayleigh's dissipation function; Gauge transformation for Lagragian; symmetry properties and conservation laws; Invariance of Lagrangian equations under Galilean Transformation; Variational principle**

III **Hamiltonian Formulation**

Hamiltonian equations of motion; Principle of least action; Canonical transformation; Poisson brackets; Hamilton-Jacobi method

IV **Central Force :-Reduction of two-body problem into one-body problem; Central force; Kepler's laws; Rutherford scattering; Virial theorem**

V **Small Oscillations :- Stable and unstable equilibriums; Small oscillations in a system with one degree of freedom; small oscillations in a system with more than one degree of freedom; Normal coordinates and normal frequencies of vibration;**

VI **Rigid-body Dynamics :- Rotating frame; Euler angles; Inertia tensor; Angular momentum of a rigid body; Euler's equations of motion of a rigid body; Free motion of a rigid body**

Books recommended

1. **Classical Mechanics by N. C. Rana and P. S. Joag, Tata Mc Graw Hill Publishing Co. Ltd., New Delhi**
2. **Classical Mechanics by V. B Bhatea, Joag, Tata Mc Graw Hill Publishing Co. Ltd., New Delhi**
3. **Classical Mechanics by P. V. Panate, Joag, Tata Mc Graw Hill Publishing Co. Ltd., New Delhi**
4. **Classical Mechanics by S. L Gupta, V Kumar and H. V Sharma Pragati Prakashan Meent.**
5. Classical Mechanics by Suresh Chandra, Narosa Publishing House, New Delh

ELECTRONIC DEVICES & APPLICATIONS
Unit1:
Semiconductor and Microwave Devices (11)
Semiconductor diode and its applications as clipper and clamper.
BJT (PNP & NPN transistors, Construction, Static & Dynamic characteristic, Biasing methods)
JFET (N-Channel & P-Channel FETs, Construction, static characteristics)
MOSFET (Construction, Static characteristics, Depletion & Enhancement mode)
SCR (Construction, V-I Characteristic, Applications as half & full wave rectifier)
Tunnel Diode (Construction, Working & Characteristics)
IMPATT (Construction Working & Static Characteristics)
Gunn Diode (Transferred Electron Effect) , UJT (Construction, working)
Unit 2:
Photonic Devices (6)
Radiative transitions, Light emitting Diodes (Visible & Infrared), Photoconductors (LDR), Photodiodes, Solar cells (Solar radiations and ideal conversion efficiency P-N junction solar cell, spectral response, I-V characteristics), Phototransistor
Unit 3:
Operational Amplifier & Its Applications (12)
Basic Differential Amplifier, Differential versus single input amplifier, improving the basic differential amplifier
OP-AMP Characteristics and Parameters.
OP-AMP as an 1)Inverting amplifier 2) Non –Inverting amplifier 3)Adder 4)Subtractor 5)Differentiator 6)Integrator 6)Schmitt trigger 7)Comparator
8) Active filters: First order High pass, Low Pass & Band Pass Filters, study of IC555, & IC556
Unit 4**:**
Digital Electronics (9)
Number system: Binary, Decimal & Hexadecimal no. system and its algebra
Logic gates: AND, OR, NOR, NAND, XOR. (Symbols, working and truth tables)
Flip –flops-S, J-K, T, D (logic symbols, working and truth tables)
Shift registers: 4-bit left and right
Digital counters: Asynchronous (Mod-10, Mod-16)
Encoder & decoder: 1:4 and 4:19 (logical diagram and truth table)
Multiplexer and demultiplexer: Logical diagram and truth table
DAC: R-2R ladder network, ADC using comparators
Unit 5:
Microprocessors 8085 And Memory Devices: (12)
Architecture, pin-diagram, instruction set, Simple programming: addition and subtraction only, SRAM, DRAM, CMOS and NMOS
Reference Books
Digital Electronics: Malvino and Leech
Microprocessors: B.Ram
Introduction to microprocessors: Gaonkar
Electronic devices: Milman and Halkias
Electronic devices:Thomas Flyod
Digital and Microprocessor:Flyod
Principles of electronics : V K Mehta

General Electronics laboratory
List of experiments.
1) Study of common emitter transistor amplifier.
2) Firing characteristics of SCR.
3) FET characteristics
4) Transistor characteristics
5) Astable/monostable/bistable multivibrator.
6) Differential amplifier.

7) Inverting and noninverting amplifier using OPAMP.
8) Characteristics of a phototransistor.
9) Regulated power supply using zener diode.
10) Voltage Controlled Oscillator.

Numerical Techniques and Programming

Aims and Objectives :

After learning this paper, students should be able to appreciate logics, and will get the knowledge of algebraic operations, integration and differentiation. After learning this course the students will learn various numerical techniques, which have vast applications in science, technology and engineering.

Computer programmes of these numerical methods are not expected in this paper. Programmes for these numerical techniques will be studied in the Numerical Technique Laboratories. Only algorithms of these methods are expected.

1) Curve fitting and interpolation : (6)

The Principle of Least squares, fitting a straight line, fitting a parabola, fitting an exponential curve, fitting curve of the form $y=ax^b$, fitting through a polynomial, Cubic spline fitting, Linear interpolation, difference schemes, Newton's forward and backward interpolation formula.

2) Roots of equation (6)

Polynomial and transcendental equations, limits for the roots of polynomial equation. Bisectional method, false position method, Newton Raphson method, direct substitution method, synthetic division, complex roots.

3) Numerical integration : (6)

Newton cotes formula, trapezoidal rule, Simpson's one third rule, Simpson's three eight rule, Gauss quadratics method, Monte Carlo method.

4) Solution of simultaneous equation: (5)

Gaussian elimination method, pivotal condensation method, Gauss-Jordan elimination method, Gauss-Seidal iteration method, Gauss-Jordan matrix inversion method, Gaussian-elimination matrix inversion method

5) Eigenvalues and eigenvectors of a matrix: (4)

Computation of real eigenvalues and corresponding eigenvectors of a symmetric matrix, power method and inverse power method.

6) Solution of differential equation: (4)

Taylor series method, Euler method, Runge Kutta method, predictor-corrector method

7) Partial differential equations (2)

Difference equation method over a rectangular domain for solving elliptic, parabolic and hyperbolic partial differential equation

8) Random numbers: (2)

Random numbers, Random walk, method of importance sampling.

9) Programming: (10)

Elementary information about digital computer principles, compliers, interpreters, and operating systems, C programming, flow charts, integer and floating point arithmetic, expression, build in functions, executable and non-executable statements, assignment, control and input-output elements, user defined functions, operation with files (structures and unions and pointers are not expected)

Text and Reference books:

1. H. M. Antia: Numerical methods for scientists and engineers.
2. Suresh Chandra Computer Applications in Physics with FORTRAN, BASIC and C, Narosa Publishers
3. Vetterming, Teukolsky, press and Flannery: Numerical recipes.
4. Sastry: Introductory method of numerical analysis.
5. Rajaraman: Numerical analysis.
6. Numerical Computational methods, P. B. Patil and U. P. Verma.
7. Numerical methods and computation – B. K. Bafna.
8. Advanced engineering mathematics – Erwin Kreszing 5th or 7th edition john Willey and sons inc.
9. C Programming : Balgurusamy
10. Suresh Chandra Applications of Numrical Techniques with C Narosa Publishers

Computational Methods and Programming – I

Paper No. 50 Marks

List of Experiments:-

1. Finding the roots of quadratic equation.
2. finding roots of a polynomial equation using Bisectional method
3. Gauss elimination method
4. Integration by trapezoidal rule
5. Integration by Simpson rule
6. Linear least square fitting

Computational Methods and Programming – II

Paper No. 50 Marks

List of Experiments :-

1. LaGrange's Interpolation
2. Solution of differential equation using Euler's method
3. Solution of differential equation using Runge- Kutta method
4. Eigen values & eigen vectors of real asymmetric 2 X2 materix.
5. Generation of Random numbers
6. Power method

M.Sc. Physics Semester III

Electrodynamics

Max. Marks: 100 Total lectures: 40

Unit I. Maxwell's equations and Electromagnetic waves: (8 lectures)

Maxwell's equations and their physical significance. Equation of continuity & relaxation time, Vector and scalar potentials, Lorentz and Coulomb gauge, electromagnetic energy and Poynting's theorem, electromagnetic wave equations in free space, their plane wave solutions, waves in conducting medium: skin depth, waves in ionized medium (ionospheric propagation), polarization of EM waves. Concept of radiation pressure

Unit III. Electromagnetic waves in bounded media: (**8 lectures**)

Reflection and refraction of plane electromagnetic waves at a plane interface: normal incidence, oblique incidence, Fressnel's equations, Brewster's angle. Total internal reflection. Reflection and refraction from metallic surfaces, Electromagnetic wave propagation between two parallel conducting plates, waves in hollow conductors, Rectangular wave guides - TE and TM modes.

Unit IV. Radiations from moving charges: (**7 lectures**)

Concept of retarded potential, The Lienard-Wiechert potentials, Fields produced by moving charges, radiations from an accelerated charged particle at low velocities, radiations from a charged particles with co-linear velocity and acceleration.

Radiations from an accelerated charged particle at low velocities in circular orbits-Larmor formula

Radiations from an accelerated charged particle at relativistic velocities in circular orbits-relativistiv generalization of Larmor formula

Unit V. Radiating Systems: (9 lectures)

Multipole expansion of EM fields, Electric dipole radiations, field due to oscillating electric dipole, magnetic dipole radiations, electric quadrupole radiation, fields due to linear, centre-fed antenna, simple array of antennas.

Unit VI. Relativistic Electrodynamics: (**8 lectures**)

Galilean transformations, Lorentz transformations and basic kinematical results of special relativity (length contraction, time dilation, addition of velocities, charge invariance, field transformation, etc), relativistic momentum and energy of a particle, mathematical properties of space-time in special relativity.

4-potential and 4-current, 4-vectors in electrodynamics, electromagnetic field tensor, covariance of electrodynamics, Lorentz force and the equation of motion of a charged particle in an electromagnetic field, Covariance of Maxwell's equations, transformation of EM fields and field tensor.

Electromagnetic wave equation and plane wave solution in 4-vector form.

Text Books :

1. Classical Electrodynamics - J.D.Jackson (John Wiley & Sons)
2. Classical Electromagnetic Radiation - J.B.Marion (Academic Press)

Books Recommended for reference :

3. The Classical theory of Fields - Landau & Lifshitz *(Pergman Press)*
4. Electrodynamics of continuous media - Landau & Lifshitz *(Butter Worth)*
5. Electricity and Magnetism - David J.Griffiths *(PHI)*
6. Electricity and Magnetism - Panofsky and Philips
7. Electromagnetic waves and fields - R.N.Singh *(Tata McGraw Hill)*
8. Electromagnetic Waves and Radiation system - Jordan and Balman *(PHI)*
9. Electromagnetic Fields and waves -Paul Lorrain and Dale Corson *(CBSPub)*
10. Electromagnetics - B.B.Laud *(New Age Intl. Pub.)*

<u>Experimental Technique</u>

List of Experiments

1) OP-AMP parameter
2) High pass and Low pass Filters
3) UJT relaxation oscillator
4) h-parameters of transistor
5) Colorimeter
6) Frequency Meter
7) Optical communication using IR LED
8) Diode clipper and clamper
9) Schmitt trigger
10) Half and Full wave rectifier using SCR

Nuclear & Particle Physics

Chapt. I Basic Nuclear properties

Nuclear size & its determination, nuclear radia by Rutherford scattering, electron scattering & mirror nuclei method, nuclear quantum numbers, angular Momentum, nuclear dipole moment, electric quadruple moment.

Chapt. 2. Interaction of nuclear radiation with matter

Interaction of charged particles & em rays with matter, range, straggling, stopping power, ionization chamber, proportional counter, GM counter, scintillation detector, semiconductor detector.

Chapt. 3 Nuclear forces

Elements of two body problem, charge independence & charge symmetry of nuclear forces, Meson theory of nuclear forces.

Chapt. 4 Nuclear Models

B.E., Semi empirical mass formula & applications, nuclear shell model, liquid drop model collective model, collective model, fermi gas model.

Chapt. 5 Nuclear decay & Reactions

Radioactive decay, laws of successive transformation, dosemetry nuclear reactions, fission & fusion.

Chapt. 6 Nuclear decay

B – decay, three forms of B- decay, Fermi theory of B- decay, kurie plot, selection rule, non conservation of parity in B- decay.

Chapt. 7 Elementary particles

Weak, strong & electromagnetic interaction, classification of elementary Particles, conservation laws, quark theory.

Nuclear Physics Lab

1. Gamma ray spectrometer – I (calibration)
2. Determination of operating voltage of G-M tube
3. Random nature of radio active decay
4. Absorption coefficient of Al
5. Determination of half – life of In
6. Specific heat of a solid
7. Susceptibility of solids/liquids
8. Dead time of G-M tube using single source
9. Dead time of G-M tube using double source
10. Inverse square law
11. Ionic conductivity of NaCl/ Agl
12. Gamma ray spectrometer - II

Astrophysics-I

Unit I Fundamentals of astronomy: (5 Lectures)

Brief history of astronomy, co-ordinate systems (celestial sphere, horizon, equatorial, ecliptic co-ordinate systems), mean solar time, sidereal time, zonal time, various windows in astronomy (multi-wavelength astronomy), 21-cm line and its astronomical importance.

Astronomical distances: astronomical unit (AU), light year, parsec, distance measurement in astronomy-stellar parallax and other methods.

Unit II The Solar system: (5 Lectures)

Planetary system, elliptical orbits and Kepler's laws, terrestrial planets, Jovian Planets, their satellites, atmospheres of planets, ring systems of planets, asteroids, meteors and meteorites, comets, solar and lunar eclipses, formation of solar system.

Search for extra-terrestrial life, extra-solar planetary systems.

Unit III Observational Tools: (7 Lectures)

Telescopes: Optical telescopes- reflecting and refracting type, various focusing methods used in reflecting telescopes, telescope mountings, new technology telescopes: HST.

Radio Telescopes and interferometers, very large array (VLA), concept of Very long baseline interferometry (VLBI)

Infrared, Ultraviolet and X-ray telescopes

Detectors: Photographic plates, photometers, CCDs. Filter systems.

Unit IV Stellar physics: (6 Lectures)

Black body radiation- Planck laws, Wien displacement law, Intensity, Flux density, Luminosity, magnitude systems, Color index.

Formation of spectral lines, classification of stars, Hertzsprung-Russell diagram and its salient features.

Stellar atmospheres: description of the radiation field, stellar opacity, radiative transfer, structure of spectral lines.

Unit V Stellar Structure: (9 Lectures)

Stellar interiors, equations of stellar structure, Hydrostatic equilibrium, pressure equation of state, stellar energy sources and nucleo-synthesis (p-p chain reaction, CNO cycle, triple alpha reaction, r & s processes), energy transport in stars, stellar model.

The Sun: solar interior – energy transport,

Solar atmosphere: photosphere, chromosphere, corona, magnetic activity in the Sun, Sunspots and sunspot cycle, solar limb darkening, solar neutrino puzzle.

Unit VI Stellar Evolution: (8 Lecture)

Star formation: Interstellar gas and dust, formation of protostar, pre-main sequence evolution of stars.

Post-Main sequence Evolution: Evolution on the main sequence, Late stages of stellar evolution- Giant, Super giant phase.

Fate of Low Mass stars: White dwarfs, degenerate matter, Chandrashekhar limit, mass-radius relation for a white dwarf star.

Fate of High Mass star: Neutron stars- its upper mass limits, pulsars, Black Holes.

References:

1. Modern Astrophysics – B.W. Carroll and D.A. Ostlie, 1996, Addison-Wesley Publishing Co., Inc.
2. The Physical Universe: An Introduction to Astronomy – Frank H. Shu, 1982, University Science Books, Sausalito, California.
3. Fundamental Astronomy – ed. H. Karttunen, P. Kroger, H. Oja et al., 1987, Springer-Verlag, Berlin.
4. The New Cosmos, 4th edition - A. Unsold and B. Baschek, 1991, Springer-Verlag, Berlin.
5. Astrophysics: Stars and Galaxies – K.D. Abhyankar, 1992, Tata McGraw Hill Publishing Co., New Delhi.
6. Astrophysics of Solar Systems – K.D. Abhyankar, 1999, University Press (India) Ltd. Hyderabad.
7. Text Book of Astronomy and Astrophysics with Elements of Cosmology – V.B.Bhatia, 2001, Narosa Publishing House, New Delhi.

Electronics I: Microprocessor & Its Applications

Unit I. Microprocessor Architecture: (6 lectures)

The 8085 Microprocessor Architecture & its operations, Address, Data and Control Buses, Internal Data operations and registers, Memory organization, Memory Map, Input/Output(I/O) devices, Pin configuration of 8085 Microprocessor.

Unit II. The 8085 Instructions : (6 lectures)

Instruction Classification, data transfer group, Arithmetic group, Logical group, branch group, stack, I/O and Machine control group, Interrupt control group, Instruction format, Addressing Modes, Instruction timings and operation status.

Unit III. Assembly Language Programming (ALP) : (6 lectures)

Programming Techniques: Looping counting and Indexing, Simple programs, Data transfer problem, Arithmetic problems, Logical problem, Counter and Timing Delays, Stack and subroutines, Delay subroutine.

Unit IV. Advanced Microprocessor's Architecture: (7 lectures)

The 8086 microprocessor Architecture, Execution unit (EI), Bus Interface Unit (BIU), 8086 Pin configuration, minimum and Maximum mode, 8086 Memory Addressing, Architecture of 80186, 80286, 80386, 80486 and Pentium processor.

Unit V. The 8051 Microcontrollers: (5 lectures)

Microcontrollers and Embedded processors, 8051 Microcontroller, Registers, Register Banks and Stack, Pin description of the 8051, instruction set.

Unit VI. Memory, I/O and Programmable Peripheral Devices Interfacing: (10 lectures)

Basic Interfacing concepts, Device Selection and Data transfer, Input Interfacing, Interfacing output display, The 8212 I/O Device, Interfacing Input Keyboard, Memory Mapped I/O, comparison of Memory-mapped I/O and Peripheral I/O, The 8151 Multipurpose programmable Device, The 8279 Progammable Keyboard/Display Interface, The 8255 Programmable Peripheral Interface, The 8253 Progammable Interval Timer, The 8259 progammable Interrupt Controller, The 8257 DMA Controller.

Text and Reference Books :

1. Microprocessor Architecture, Programming and application- R.. Gaonkar (Wiley Eastern Ltd)
2. Microprocessor and Microcontroller - B. Ram *(Dhanpati Rai and Sons Delhi)*
3. The 8085 Basics, programming and Interfacing - U.V. Kulkarni and T.R.Sontakke (Sadhu Sudha Prakashan *)*
4. 8085 Microprocessor Programming and Interfacing- N.K. Srinath *(PHI)*
5. The 8051 Microcontroller and Embedded systems- M. Ali Mazidi and J.G. Mazidi
6. Microprocessor and Interfacing – Douglas Hall (Tata Mc Graw Hill)

Fiber Optics & Lasers -I

Unit –I Lasers

Introduction Properties of Lasers, directionality, intensity, monochromaticity, coherence Einstein's quantum theory of Radiation, Einstein's coefficients, momentum transfer, lifetime, possibility of amplification

Basic properties of Lasers, Population inversion, Laser pumping, 2 Level & 3- Level Systems, Resonators

(Reference: BB Laud)

(Unit –II Types of Lasers

Gas Lasers: He-e Lasers, N2 Lasers, Excimer Lasers

Solid State Laser: Neodymium Laser, Ruby Laser

Pumping sources: Flash and Arc Lamps

(Reference: Young, shimoda and verdeyen)

Unit –II Applications of Lasers

Leasers in communications, Ranging & Navigation, Meterology, Machining, Surgery & Medcine, Chemical & Physical processes

Unit –IV Optical Fiber waveguides

Ray Theory, Total Internal refelction, Acceptance angle, Nuerical aperture,, Skew rays Electromagnetic mode theory: Electromagnetic waves, modes in planer waveguides, phase and group velocity. Phase shift with TIR and Evanscent field, Goose-Effective refractive index.

(Reference : Senior)

Books

1. Lasers & Nonliner Optics, B B Laud, Wiley Eastern
2. Introduction to Lasers, Koichi Shimoda, Springer Verlag
3. Optics and Lasers, M Young, springer Verlag
4. Masers & Lasers, J S Thorp, Mcmilan
5. Laser Electronics, Verdeyen Prentice Hall
6. Optical Fiber Communication: Principles & Practices, John M Senior, Phi.

Material Sciences

Univt – I Phase Diagram:

Definition and basic concepts, Solubility Limit, Phases, Microstructure Phase equilibrium, unary and binary phase Diagrams, Gibb's phase rule

Binary isomorphous systems: Copper-Nickel, Microstructure formation under equilibrium & non-equilibrium cooling

Binary Eutectic systems: silver-copper, Lead-Tin, Iron-Iron carbide systems, Microstructure formation under equilibrium cooling, salient features

Invariant reactions

Determination of Phases and Phase fractions

Unit – II Diffusion :

Introduction, Diffusion mechanism, Steady state and non-steady state diffusion, factors influencing diffusion, other diffusion paths, numerical examples

Unit-III Vacuum Physics and Techniques:

Vacuum Pumps: Rotary pumps. Oil diffusion pumps, sputter ion pumps, getter pump, Turbo molecular pump: Operating mechanism, advantages and limitations of pumping, Pressure Measurements: Thermocouple and Pirani gauges, Ionzation gauges, Penning guage, Principle of measurement, construction, limitation

Unit –IV Thin Films

Physical Vapor deposition, Gas glow discharge and charged particle interactions, sputtering techniques, e-beam techniques, CVD techniques, Mechanism, Processes,

Unit Crystal Growth

Techniques, and Processes, Basic of Nucleation, critical size rediuns

List of Experiments

Astrophysics Lab.-I; Semester-III

1. Analyzing Fraunhofer lines in the Sun spectrum
2. Measuring temperature of an artificial star
3. Temperature of flame by line reversal method
4. Estimating mass of Jupiter by studying motion of its satellites (CLEA)
5. Performing BVRI photometry of stars in Pleiades cluster and estimating their effective temperatures (CLEA)
6. Estimating distance of the Pleiades cluster by main sequence fit method (CLEA)
7. Spectral Classification of stars in the Pleiades cluster and identifying elements responsible for the absorption lines (CLEA)

List of Experiments : Electronics I: Microprocessor & its Application

1. Assembly Language Program (ALP): Data Transfer from Microprocessor to Memory and Vice-versa.
2. Assembly Language Program(ALP): Arithmetic operations
3. Assembly Language Program (ALP): Logical Operations
4. Assembly Language Program (ALP): Branch Operations
5. Assembly Language Program (ALP): Counters and Time Delays
6. Assembly Language Program (ALP): Stack and Subroutines
7. Assembly Language Program (ALP): Interfacing of Analog to Digital Converter
8. Assembly Language Program (ALP): Interfacing of Digital to Analog Converter
9. Assembly Language Program (ALP): Study of 8212
10. Assembly Language Program (ALP): Study of 8255
11. Assembly Language Program (ALP): Study of 8155
12. Assembly Language Program (ALP): Study of 8253

List of experiments is updated as and when need arises.

M.Sc. Physics (SEMESTER-II & semester IV)

Statistical Mechanics

Max. Marks. 50 Total Periods 48

I **Fundamentals :-**Macroscopic and microscopic states; Phase space; Ensemble and ensemble average; Liouville's theorem; Density matrix;

II Microcanonical Ensemble :- Microcanonical distribution; Equal a priori probability; Entropy; Entropy of a perfect gas in a microcanonical ensemble; Gibbs paradox; Thermodynamic quantities in a microcanonical ensemble; Sackur-Tetrode formula;

III **Canonical Ensemble :-**Canonical distribution; Canonical partition function; Maxwell distribution of velocities; Theremodynamic quantities in a canonical ensemble; Classical system in a canonical ensemble; Gibbs paradox;

IV **Grand Canonical Ensemble :-**Grand canonical distribution: Grand canonical partition partition function; Thermodynamic quantities in a grand canonical ensemble; Classical system in a grand canonical ensemble; Density and energy fluctuations in a grand canonical ensemble;

V **Maxwell-Boltzmann System :-** Maxwell-Boltzmann distribution; Maxwell-Boltzmann velocity distribution law; Thermodynamical quantities; Gibbs paradox; Ideal Boltzmannn gas with internal motions; Monoatomic ideal gas with internal motions; diatomic ideal gas; Ideal paramagnetism;

VI **Fermi-Dirac Gas:-**Weakly degenerate Fermi gas; Strongly degenerate Fermi gas; Thermionic emission; Statistical equilibrium in a white dwarf star;

VII **Bose-Einstein Gas :-**Bose-Einstein gas at high temperature; Bose-Einstein gas at low temperature; Planck's rediation law; Debye model of solids (Phonons); Liquid He;

VIII Interacting Systems ;-Van der walls equation; Critical constants of a real gas; Virial equation; Cluster expansion for a classical gas;

IX **Phase Transitions :-** First-order phase transitions; Equilibrium between two phases; Clapeyron-Clausius equation; Scaling hypothesis; Critical indices; Second-order phase transition; Ising model; Landau theory;

X **Kinetic and Dynamical Theories of Gases :-** Boltzmann transport equation; Mean free path; Transport properties; Fluctuations and thermodynamics Properties; Brownian motion; Langevin theory;

Books recommended

1. Statistical Mechanics by R. K Patharia, Pregamon Press, Oxford
2. Statistical Mechanics by J. K Bhaltacharjee, Allied Pubishers Limited, New Delhi
3. Fundamentals of Statistical Mechanics and thermal Physics by F. Reif, McGraw- Hill International Editions
4. Statistical Mechanics by S. K Sinha, Tata M2 Graw-Hill Publishing Co. Ltd. New Delhi
5. Statistical Mechanics by Suresh Chandra, CBS Publishers & Distributors, New De

Quantum Mechanics

Aims and objectives : Quantum mechanics is a basic subject. It distinguishes between microscopic and macroscopic world. Most of the phenomenon in solid state physics, atomic and molecular physics, Nuclear Physics have been explained and were placed as firm footing using quantum mechanical explanation. By way of studying quantum mechanics one can have a insight into the understanding of physical phenomenon. Techniques used in quantum mechanics are useful in many complicated subatomic problems. Results agree with experiments.

1) General formalism of Quantum mechanics and elementary Representation Theory : (7)

Derivation of time dependent and time independent Schrodinger equation, Physical significance of wavefunction, Quantum numbers, Postulates of Quantum Mechanics, Commutation relations for position and momentum operator, Dirac Delta function and its properties, Ket and Bra notations, Completeness of eigenfunctions, Matrix representation of an operator, Unitary Transformation.

2) Angular Momentum : (12)

Commutation relations for Spin, orbital and total angular momentum and Ladder operators, eigenvalues of L^2, L_z, J^2, J_z, J+ and J-, Angular momentum and rotations, Rotational symmetry and conservation of angular momentum, Reflection invariance and Parity, Addition of angular momentum – Clebsch Coefficient.

3) Approximation methods :

(a) **Time independent Perturbation Theory : (3)**

Non-degenerate case- First order perturbtion, Second order perturbation, application for the He atom. Degenerate case – Stark effect.

(b) **Time dependent perturbation Theory : (3)**

Zero order perturbation, First order perturbation, second order perturbation, Fermi Golden rule, adiabatic and suddent approximation.

(c) **Variational Method : (3)**

The basic Principle, Application to excited state, linear variation function application to two electron atom problem. (d) **WKB approximation : (4)**

The classical limit, One dimensional case, connection formulae, the Turning point application to barrier poten

4) Collision in 3-d and Scattering : (12)

Laboratory and Centre of Mass reference frames, scattering amplitude, differential scattering cross section, total scattering cross section, Asymptotic form of scattering states, Relation between angles and cross sections in the laboratory and center of mass systems, Scattering by spherically symmetric potentials, Integral equation of scattering, The Born approximation, Partial Waves and Phase shifts, Scattering by a perfectly rigid sphere and by square well potential, Complex potential and absorption.

Identical particles, symmetric and asymmetric wave functions and their construction for N particle system, Slater's determinant, Collision of identical particles (Mathematical derivations are not expected)

Reference books:

1) Quantum mechanics - L. I. Schiff (McGraw Hill)
2) Quantum mechanics - Ghatak and Loknathan
3) Quantum mechanics - A. P. Messiah
4) Modern quantum mechanics - J. J. Sakurai (Addison Wesely)
5) Quantum mechanics - Mathews and Venkatesar.
6) Quantum mechanics – V. K. Thankappan (New age international)

Condensed Matter Physics

Unit 1: Crystal structure (7)

Crystal lattice and crystal structure, Translational symmetry, space lattice, unit cell and primitive cell, Bravais lattice in two and three dimensions, co-ordination no., some important crystal structure: Simple cubic structure (SC), Body centered cubic (BCC) structure, Face centered cubic(FCC) structure, Hexagonal close packed(HCP) structure,Wigner-seitz cells, Miller indices, The spacing of a set of a crystal planes.

Unit 2: X-ray diffraction and Reciprocal lattice (8)

Interaction of X-rays with matter, X-ray diffraction according to Braggs law, reciprocal lattice, properties of reciprocal lattice to 1)Simple cubic (sc)lattice,2)Body centered cubic (BCC) lattice, 3) Face centered cubic (FCC) lattice, The Bragg condition and Ewald construction, Brillouin zones for 1)one dimensional lattice 2) Two dimensional square lattice3)simple cubic lattice 4) Body centered cubic (BCC) lattice, 3) Face centered cubic (FCC) lattice, Atomic scattering factor, Geometrical structure factor, Laue method, Rotating crystal method, powered method.

Unit3: Crystal imperfections (6)

Types of Imperfections A)**Point defects**: 1)Vacancy defects 2)Schottky defect 3)Self interstitial defect 4)Frankel defect 5) Interstitial or substitutional impurity 6) color centers 7)polarons 8)excitons B)**Line defects**: 1)Edge dislocation 2)Screw dislocation C)**Surface defects** 1)Grain boundaries 2)Stacking faults , Energies of dislocations.

Unit 4: Band theory (8).

Electron motion in crystal(one dimensional), Bloch theorem, kroning-penny model, the concept of effective mass, concept of holes, metals insulators and semiconductor, The nearly free electron model, Tight binding approximations, Wigner-seitz cellular method, orthogonalised plane wave (opw)method, pseudo potential method.

Unit 5: Fermi surface (6)

Brillouin zones of a square lattice in two dimensions, Fermi surface and Brillouin zones, **Experimental determination of Fermi surface**: 1) Magnetoresistance 2) De Hass-Van Alphan effect 3) Cyclotron resonance in metals, Quantum Hall effect.

Unit 6: Superconductivity (5)

Introduction, Meissner effect, critical temp., persistant current, the London theory, Type-1 & Type-II superconductors, cooper pair, BCS theory, Flux quantization.

Unit 7: Magnetic properties (5)

Origin of Magnetic properties of materials, Magnetic susceptibility, classification of magnetic materials, Weiss molecular field theory of ferromagnetism, Heisenberg model, curie Weiss law for susceptibility, Ferromagnetic domain and Hysteresis, closure domains, the Bloch wall and Bloch wall energy,Antiferromagetism:two sublattice model, Neel temp., susceptibility below Neel temp., Ferrimagnetism:Structure of ferrites, spin arrangement in Ferrite, Exchange interactions in Ferromagnets, Spin waves and magnons.

Reference Books:

Elementary solid state physics - Omar Ali
Solid state physics - Kittle.
Introduction to solids - Azaroft.
Solid state physics - Aschrott and Mermim
Solid state physics - Dekkar
Solid state physics - Ajay Kumar Saxena
Solid state physics - S.O. Pillai

Semester II

Atomic and Molecular Physics

1. Quantum states of one electron atoms, atomic orbitals, Hydrogen spectrum pauli's principle . Spectra of alkali elements, spin orbit interactions and fine structure in alkali spectra. Equivalent and non equivalent electrons, effect. Stark effect, Two electron systems, Interaction energy in LS and JJ coupling Hyperfine structure (qualitative), Line broadening mechanism
2. 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. Rotational spectra of polyatomic molecules.
3. Vibrational energy of diatiomic molecule as simple harmonic oscillator. Energy levels and spectrum, Morse energy curve molecules as a vibrating rotator, vibration spectrum of diatomic molecule, PQR branches, IR spectrometer.
4. Electronic spectra of diatomic molecules, Born-Open Heimmer approximations, progression, Intensity of vibrational electronic spectra, Frank condon principle Dissociation energy and dissociation product, the remission of energy by excited molecule.
5. Raman spectroscopy :-
   Introduction, quantum theory of raman effect, classical theory of Raman effect, pure rotational Raman spectra of liner molecules and symmetric top molecules, Raman activity of vibrations, rule of mutual exclusion, vibrational Raman spectra the nature of polarized light, vibrations of spherical top molecules, structures determination from raman and infrared spectroscopy, techniques & instrumentation

Reference Books

1. Introduction to atomic spectra H.E. White (T)
2. Fundamentals of molecular spectroscopy C. M. banwell and E.M. Mccash (T)
3. Spectroscopy Vol,II and III BP stranghen and S Walkar
4. Introduction to Molecular spectroscopy, C.M. Barrow
5. Spectra of diatomic molecules, G. Herzberg

Laboratory **<u>Solid state physics Lab</u>**

<u>List of experiments</u>

1) Determination of energy band gap using four probe method.
2) Measurement of Hall coefficient of given semiconductor: Identification of types of semiconductor and estimation of charge/current concentration.
3) Determination of energy band gap Eg of thermister.
4) Determination of electrical conductivity of graphite rod.
5) Determination of dielectric const. of liquids.
6) Determination of elastic const. using piezoelectric effect.
7) Ionic conductivity of AgI
8) To study the variation of energy band gap Eg of diode with temp.
9) Lattice dynamics (To study the dispersion relation in solids)
10) Thermionic emission.
11) Determination of electronic charge by investigating rectifier equation of solid state diode.
12) To determine the value of electronic charge by Milliken's method.

General Physics Lab

1. h by photocell
2. Ultrasonic interferometer
3. Transformer characteristics
4. e/m by helical method
5. Temp. to Freq. converter
6. Solar cell characteristics
7. Platinum resistance thermometer

SpectroscopyLab

Paper No. 50 Marks

1. Michelson Interferometer
2. Talbot's Bands
3. Constant deviation spectrometer
4. Hart's mann dispersion formula
5. λ by biprism
6. Polarigability of liquids

Plasma Physics

Introduction to the Plasma state elementary concepts and definitions of temperature and other plasma parameters, occurrence and importance of plasma for various applications production of Plasma in the laboratory. Physics of glow discharge, electron emission, ionization breakdown of gases Pashe's laws and different regimes of E/p in a discharge, Townsend discharge and the evolution of a discharge.

Plasma diagnostics :

Probles energy analyzers, magnetic probes and optical diagnostics, preliminary concepts.

Single particle orbit theory :

Dirifts of charged particles under the effect of different combinations of electric and magnetic fields. Crossed electric and magnetic fiends. Homogenous electric and magnetic fields, spatially varying electric and magnetic fields, time varying electric and magnetic fields, particle motion in large amplitude waves

Fluid description of plasmas :

Distribution functions and Liouville's equation, macroscopic parameters of plasma, two and on fluid equations of plasma, MHD approximations commonly used in one fluid equations and simplified one fluid and MHD equations.

Waves in fluid plasmas:-

Dielectric constant of field free plasma, plasma oscillations, space charge waves of warm plasma, dielectric constant of field free plasma, plasma oscillations, space charges waves of warm plasma dielectric constant of a cold magnetized plasm, io-acoustic waves, alfven waves, magnetosonic waves

Stability of fluid plasma :

The equilibrium of plasma, plasma instabilities, stability analysis, two stream instability, instability of Alfven waves, Plasma supported against gravity of magnetic field, energy principle

Kinetic description of plasma

Microscopic equations for may body systems statistical equation for a many body system, Viasov equationand its properties, Drift kinetic equation and its properties

Waves in Vlasov Plasma :

Vlasov equation and its Linearization, solutions of linearized Vlasov equation, theories of Langumuir waves, Landau damping, lon Acoustic waves, Drift waves in magnetized plasma.

Non-linear plasma theories :

Non linear electrostatic waves, solutions, shocks, nonlinearLandau Damping.

Thermonuclear fusion :

Status, problems and technological requirements.

Applications of cold low pressure and thermal plasmas.

References Books

1. Introduction to Plasma Physics, FF Chen.
2. Principles of Plasma Physics, Krall and Trevelpiece
3. Introduction to Plasma Theory, DR Nicholson
4. The Plasma State, JL Shohet
5. Introduction to Plasma Physics, M Uman
6. Principles of Plasma Diagnostic, IH Hutchinson

Astrophysics II

Unit I Stellar Systems and Pulsations: (6 Lectures)

Binary Stars: Classification of binary stars, estimation of mass, spectroscopic, eclipsing binaries.

Close binary star systems: Gravity in a close binary system, accretion disks, White dwarfs in semi-detached binaries,

Neutron stars and Black Holes in binaries.

Stellar clusters (open and globular clusters),

Observing pulsating stars.

Unit II The Milky Way: (4 Lectures)

True shape and size of the Milky Way, Morphology, Stellar populations, Differential rotation (kinematics) and estimation of mass of the Milky Way, Galactic center, spiral structure of the Milky Way, Interstellar medium

Unit III Galaxies: (6 Lectures)

Classification of galaxies: Hubble's tuning fork diagram, kinematics and dynamics of Elliptical galaxies, Lenticular galaxies, Spiral galaxies, Irregular galaxies, spiral structure, distribution of light and mass in regular galaxies.

Active galaxies: Seyfert galaxies, Radio galaxies, Quasars.

Unit IV. Clusters of Galaxies and Expanding Universe: (3 Lectures)

Interaction of galaxies, mergers, clusters of galaxies.

Extra-galactic distance scale, expansion of the universe: Hubble law.

Unit V. General Relativity: (10 Lectures)

Space, time and gravitation, vectors & tensors (basic ideas), metric tensor and its properties, space-time curvature, covariant differentiation, Parallel transport, Riemannian geometry, symmetries of *Riklm*, Ricci and Einstein tensors, Bianchi identities, geodesics, principle of equivalence, action principle and energy tensor.

Gravitational equations- Newtonian approximation, Schwarzschild solution.

Experimental tests of general relativity: gravitational red shift, perihelic shift of planet mercury, bending of star light-black holes.

Unit VI. Cosmology: (11 Lectures)

Newtonian cosmology, Einstein universe, expanding universe, simplifying assumptions of cosmology (Robertson-Walker line element), cosmological red-shift, Hubble's law.

Einstein field equations in cosmology, solution of Friedmann's equations- Euclidean, closed and open sections, luminosity distance (Einstein de Sitter model, closed model and open model), cosmological constant.

References:

1. The Physical Universe: An Introduction to Astronomy – Frank H. Shu, 1982, University Science Books, Sausalito, California.
2. Modern Astrophysics – B.W. Carroll and D.A. Ostlie, 1996, Addison-Wesley Publishing Co., Inc.
3. Fundamental Astronomy – ed. H. Karttunen, P. Kroger, H. Oja et al., 1987, Springer-Verlag, Berlin.
4. Introduction to Cosmology – J.V. Narlikar, 1995, Cambridge University Press, Cambridge.

5. General Relativity and Cosmology – J.V. Narlikar, Macmillan Co. of India Ltd., New Delhi.
6. The New Cosmos, 4th edition - A. Unsold and B. Baschek, 1991, Springer-Verlag, Berlin.
7. Astrophysics: Stars and Galaxies – K.D. Abhyankar, 1992, Tata McGraw Hill Publishing Co., New Delhi.
8. Astrophysics of Solar Systems – K.D. Abhyankar, 1999, University Press (India) Ltd. Hyderabad.
9. Text Book of Astronomy and Astrophysics with Elements of Cosmology – V.B.Bhatia, 2001, Narosa Publishing House, New Delhi.
10. Cosmology – Roose
11. Structure Formation in the Universe – T. Padmanabhan, Cambridge University Press.
12. General Relativity – I.R. Kenyon, Oxford University Pres

Astrophysics Lab.-II; Semester-IV

1. Measuring duty cycle and period of a pulsar (CLEA)
2. Verifying Hubble's law of expanding universe and estimating age of the universe (CLEA)
3. Studying limb-darkening effect of the Sun
4. Studying characteristics of a CCD camera for gain, read-noise, linearity, and flat field
5. Studying gravitational bending of star light
6. Classifying galaxies in the Virgo cluster and studying their properties
7. Image Processing and surface photometry of an elliptical galaxy

Astrophysics Laboratory-III; Semester-IV

1. Generating X-ray emission map of SN 1987A
2. Polar aligning Meade 8" reflecting telescope and studying its functioning. Measuring declination of the Polaris
3. Performing photometry of stars using B,V,R filters and estimating their effective temperatures
4. Measuring extinction of the atmosphere in B, V, R filters
5. Measuring distance to Moon by parallax method
6. Identifying and measuring diameters of Craters on the Moon surface
7. Finding rotation period of the Sun by measuring motion of sun-spots

Electronics II: Microwaves & Its Applications

Unit I. Microwave Fundamental: (8 lectures)

Microwave frequency spectrum, types and characteristics of Transmission lines, Transmission line equation and solution, standing wave and standing wave ratio, Reflection coefficient and Transmission coefficient and Line Impendance.

Unit II. Microwave Passive Devices : (8 lectures)

Microwave Rectangular waveguide, circular waveguide, and Cavities, Microwave Hybrid circuit, Scattering matrix, directional couplers, Attenuators, Ferrite devices, Isolator and circulators.

Unit III. Microwave Active Devices : (8 lectures)

Klystron, Reflex Klystron, Basic Principle and Velocity modulation, Magnetron, operation and Principle, Travelling wave Tube, Transfer Electron devices, Gunn diode, Pin diode.

Unit IV. Microwave Detection and Measurement: (8 lectures)

Microwave Detection, Point contact diode and Schottly Barrier diode, Frequency Measurements, Attenuation Measurement, Power Measurement, Voltage Standing Wave Ratio (VSWR), Reflection coeffcient measurement, Scattering Measurement.

Unit V. Microwave Applications: (8 lectures)

Microwave Antennas, Types of antennas, Rectangular Horn Antennas, E and H-Plane Horn Antennas, Pyramidal and Parabolic reflector antennas, Radiation Pattern, radiation resistance, efficiency, Directivity and Gain.

RADAR system, Basic radar system, radar range, moving Target Indicator

Time Domain Reflectometry (TDR) system (block diagram and Basic Principle)

Network Analyser (Block diagram and Basic Principle)

Text and Reference Books :

1. Microwave Devices and Circuits- Samull Y. Liao (PHI India)
2. Microwave fundamentals - Sanjeeva and Gupta *(Khanna Publication)*
3. Microwave Circuits and Passive Devices - Sisodiya and Raghuvanshi
4. Microwave and Radar Engineering- M. Kulkarni (Umesh Publication)
5. Introduction to Microwaves – K.C. Gupta
6. Electronic Communication Systems- Kennedy (McGraw Hill)

List of Experiments : Electronics II: Microwaves & its Application

1. Characteristics of Reflex Klystron.
2. Characteristics of Gunn Diode
3. Measurements of Microwave Frequency and Wavelength
4. Measurement of Voltage Standing Ratio (VSWR) and Reflection Coefficient
5. Measurement of Impedance using Smith Chart
6. To study the performance of Directional Coupler
7. To study the performance of Microwave E-Plane Tee
8. To study the performance of Microwave H-Plane Tee
9. To study the performance of Microwave Magic Tee
10. To study the Horn Antennas
11. Measurement of microwave dielectric constant of solid
12. To study microwave detector characteristics

Materials Science –II

Optical Fiber and its properties

Ray theory transmisson (Total internal reflection, acceptance angle, numerical aperture, skew rays)

Basic fiber construction, propagation of light, modes and the fiber, types of fiber, dispersion, attenuation, cutoff wavelength, bending losses, leaky modes, mode field diameter.

Polymers

Introduction, molecules of polymers, degrees of polymerization, average molecular weight, dispersion index, isomers, functionality, hydrocarbons and organics compounds, mechanisms of polymerzation, de-polymerization, structure of polymers.

Novel Materials

Structures, silicates, ceramics, phase diagram of ZrO2-Calo and Sio2-Al203, Brittle factures of cermics, stress strain behaviour, influence of porosity, composites biomaterials and biosensors.

Characterization Techniques

X – ray photolectron, Field emission and field – ion microscopy, X- ray diffraction. Differential thermal analysis thermo gravimetric analysis : Fundamentals, working and analysis.

Spectroscopic Techniques

Atomic absorption spectrometry Principle primary radiation source, sources of free atoms, optical dispersion systems, detectors, signal measurement, sensitivity, chemical and spectral interferences.

Nuclear Magnetic Resonance spectroscopy: Theory experimental methods of NMR. Applications of proton NMR applications of NMR to isotopes other than proton.

Semester IV
Fiber Optics and Lasers –II

Optical Sources

Types of optical light sources. Injection laser diodes: Optical emission from semiconductor, spontaneous emission carrier recombination. Other radiative recombination processes. Stimulated emission and lasing, heterojunctions, semiconductor materials, semiconductor injection lasers efficiency. Strip geometry, laser modes, injection laser structure: gain guided and index guided structures. Injection lasers characteristics

Light emitting diodes : LED power and efficiency, double hetrojunction LED, surface emitter LEDs and Edge emitted LEDs, LED characteristics

Optical Dectros :

PIN photodiodes, avalanche photodiode, photodiode parmeters, detectors noise, speed of response, signal to noise ratio, detectivity, beat error rate, noise equivalent power typical fiber optics sensor.

Optical Fiber Measurements –I

Fiber attenuation measurements,fiber dispersion measurements, fiber refractive index profile measurements.

Optical Fiber Measurements –II

Measurements: Fiber cutoff wavelength measurement, fiber numerical aperture measurements

Fiber diameter measurements, mode field diameter for single mode fiber. Reflectance and optical return loss and optical time domain reflectometry.

References Books

1. Optical Fiber communications: Principles and Practices – John M. Senor (Phi)
2. The Elements of Fiber Optics – S. L. W. Meardon (Regents and Ph)
3. Optical Fiber communications – Ger Keiser (Mcgraw Hill)
4. Introduction Of Fiber Optics- A Ghatak And Tyagrajan (Cambridge University Press)
5. Fiber Optic communications – Joseph C. Palais (Ph)