PHYSICS DEPARTMENT

North Eastern Hill University
NEHU Campus, Shillong – 793 022 (Meghalaya)

B.Sc. (Physics) Syllabus (2012)

Semester	Paper	Paper nos.	Marks
Semester I	Paper I	PHY01(T)	100
Semester II	Paper II	PHY02(T)	60
Semester II	Paper II	PHY02(P)	40
Semester III	Paper III	PHY03(T)	60
Semester III	Paper III	PHY03(P)	40
Semester IV	Paper IV	PHY04(T)	60
Semester IV	Paper IV	PHY04(P)	40
Semester V	Paper V	PHY05(T)	70
Semester V	Paper V	PHY05(P)	30
Semester V	Paper VI	PHY06(T)	70
Semester V	Paper VI	PHY06(P)	30
Semester VI	Paper VII	PHY07(T)	70
Semester VI	Paper VII	PHY07(P)	30
Semester VI	Paper VIII	PHY08(T)	70
Semester VI	Paper VIII	PHY08(P)	30

Note: T = Theory; P = Practical

GENERAL NOTES ON THE SYLLABUS

1. The duration of examination for each theory paper will be of three hours.

2. Marks distribution of theory papers will be as follows:

	Full Marks	**Questions**
PHY01(T)	100	One compulsory problem oriented question carrying 20 marks and 4 other questions from the remaining 7 questions .
PHY02(T), PHY03(T) & PHY04(T)	60	One compulsory problem oriented question carrying 12 marks and 4 other questions out of the remaining 7 are to be answered each carrying 12 marks.

PHY05(T), PHY06(T), PHY07(T) & PHY08(T)	70	One compulsory problem oriented question carrying 14 marks and 4 other questions from the remaining 7 questions are to be answered each carrying 14 marks.

3. The Practical Examinations for each paper in B.Sc. that is PHY02(P), PHY03(P) , PHY04(P), PHY05(P) , PHY06(P), PHY07(P) and PHY08(P) will be of six hours duration and each student has to perform one experiment in the examination.

Semester-I

PHY01(T) Mechanics, Optics, Acoustics
(Lectures =150)
(Marks = 100)

UNIT-I

Inertial and Non-inertial frames: Components of velocity and acceleration in different co-ordinate systems (planar motion only). Uniformly rotating frame, centripetal force and coriolis force with applications.

Central forces: Conservative nature of central forces, gravitational potential and field due to a thin spherical shell and solid sphere.

Systems of many particles: Motion of the centre of mass, linear momentum and angular momentum of system of particles, elastic and inelastic collisions, loss of kinetic energy due to direct impact of inelastic collision of two rigid bodies.

Relativity: Galilean relativity and its failure. Galilean transformations. Michelson-Morley experiment. Basic postulates of special relativity. Lorentz transformation, length contraction, simultaneity, time dilation,. Einstein velocity addition rule. Variation of mass with velocity, mass energy equivalence. (35)

UNIT-II

Degrees of freedom: Moment of inertia – parallel and perpendicular axes theorems, moment of inertia of shell, solid sphere, disk and cylinder about axis of symmetry. Euler's equations for force free motion of rigid bodies.

Hooke's law, elastic constants for an isotropic solid, inter relationship of elastic constants, torsion of cylinder, bending of beams, cantilever (weightless) supporting weights at free ends, beam supported at both ends.

Equation of continuity for fluids, Bernoulli's theorem (with proof and applications), fluid motion through a capillary tube(streamline flow), Poiseuille's equation, surface tension, capillarity and formation of droplets, pressure on the curved surface of a liquid, excess pressure inside an air bubble. (30)

UNIT III

Fermat's principle: Principle of extremum path. Application of Fermat's principle to reflection and refraction at plane and curved boundaries.

General theory of image formation: Cardinal points of an optical system, refraction through a thick lens , relation between the distances of cardinal points, combination of thin lens separated by a distance, cardinal points of Ramsden and Huygen's eye pieces, ideas of matrix optics, lens formula by matrix method.

Aberration in images: Chromatic aberration, achromatic combination of lenses in contact and separated lenses. Monochromatic aberrations and their reductions, aplanatic points of a sphere with proof, oil immersion objectives.

Optical instruments: eyepieces- Ramsden and Huygens. Relative merits and demerits of Ramsden and Huygen's eyepiece. (25)

UNIT IV

Interference of light: Fringes produced by a wedge-shaped thin film, fringes of equal thickness and equal inclination, Haidinger fringes. Theory of Newton's rings and experimental determination of wavelength of monochromatic light. Michelson interferometer, construction and production of fringes, its applications for the determination of wavelength, wavelength difference, standardization of the metre. Intensity distribution in multiple beam interference. Fabry-Perot interferometer, construction and production of fringes.

Diffraction of light: Fresnel diffraction, Fresnel half period zones, zone plates, straight edge, rectilinear propagation. Fraunhofer diffraction: Diffraction from a double-slit, N slits, theory of plane diffraction grating. Resolution of images, resolving power of Fabry-Perot interferometer and plane gratings.

Polarization: Different methods of polarization, methods of producing elliptically and circularly polarized light. Quarter wave plate and half wave plate, double refraction in uniaxial crystals (its electromagnetic theory). Rotation of plane of polarization, Fresnel's theory of optical rotation.

Dispersion and scattering: Theory of dispersion of light, absorption bands, normal and anomalous dispersion. Theory of Rayleigh scattering. (40)

UNIT V

Velocity of sound in fluid and solid. Ultrasonics: Production, detection and applications of ultrasonic waves. Principle of ultrasonography.

Sound and Noise: Intensity of sound, bel and decibel, limit of human audibility. Noise and noise reduction (qualitative discussions only).

Acoustics of buildings: Requirements of good auditorium, reverberation and optimum reverberation, Sabine's formula for reverberation time, live and dead room. (20)

Text Books recommended:

1. H. Chatterjee & R. Sengupta, A Treatise of General Properties of Matter, Central Book Agency Ltd. (2004)
2. A.B. Bhattacharya, R. Bhattacharya, Undergraduate Physics, Vol I, New Central Book Agency Pvt Ltd.
3.D.S. Mathur, Elements of Properties of Matter, S. Chand & Co. (2006)
4. N .Subramanyam , Brij Lal, A Text Book of Optics, S.Chand & Co (2005).
5. A.K.Ghatak, Physical Optics, Tata McGraw Hill of India, 2nd Edition (1997)
6 B.Ghosh, Principles of Acoustics, Sreedhar Publishers (2004)
7 A.B. Gupta, Modern Optics, Books and Allied (P) Ltd.(2006)

Reference Books recommended

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, Pearson (2002).
2. J.C. Upadhyay ,Classical Mechanics, Himalaya Publishing House (2005)
3.G. Aruldhas ,Classical Mechanics, Prentice Hall of India (2008)
4.Chakrabarti and Chowdhury, A Text book on Waves and Acoustics, Central 2nd Edition (1982.)
5.P. K Chakrabarti, Geometrical and Physical Optics , New Central Book Agency (P) Ltd. (1997)
6. A.B. Bhattacharjee & R. Bhattacharjee , University Physics I , New Central Book Agency (2007).

Semester –II

PHY02(T) Electromagnetism, Electronics – I
(Lectures =90)
(Marks = 60)

UNIT- I

Electric field due to a continuous charge distribution. Gauss' law in electrostatics. Calculation of electric field in simple cases like: charged rod, infinite plane sheet charge.

Work done in electrostatic field expressed as line integral, conservative nature of electrostatic field. Electrostatic potential and potential energy due to charge distribution, calculation of potential and field of an electric dipole, charged circular discs, charged hollow and solid spheres. Method of electrical images and field near the surface of a conductor (plane and spherical).

Vector form of Biot-Savart law; calculation of magnetic field due to a straight conductor carrying current, circular coil carrying current and a solenoid.

Gauss's law in a dielectric medium, displacement vector. Magnetic dipole moment and its relation to angular momentum, gyromagnetic ratio, magnetization vector, magnetic susceptibility and permeability(linear cases only), hysteresis, B-H curve. (30)

UNIT-II

Non-steady currents and continuity equation, rise and decay of current in LR and CR circuits, decay constants, transients in LCR circuit.

Alternating current: Complex impedance, reactance; impedance of LCR series and parallel circuits, resonance, Q-factor, power dissipation, power factor.

Generators : Three phase electrical power supply, delta and star connections, voltage regulation, current regulation.

Integral and differential forms of Faraday's law, mutual and self inductance, transformer, energy in a static magnetic field, Maxwell's displacement current, Maxwell's equations in free space and in a medium. (20)

UNIT-III

Basic circuit analysis: Kirchhoff's laws and applications. Superposition theorem, Thevenin's theorem and Norton's theorem. Two port analysis of an electrical network, hybrid parameters.

Rectifier: ripple factor, filter circuits. BJT, Characteristics of BJT, CB and CE configurations, active and saturation regions, load line analysis, Q point. Current amplification factors in CB and CE configuration, h parameters of transistors (CB and CE). (20)

UNIT IV

Single stage transistor amplifiers (CE), multistage transistor amplifiers, RC coupled amplifier (qualitative analysis only). Principle of feedback amplifiers, negative feedback voltage amplifiers, transistor oscillators, Barkhausen criteria.

Diodes as clippers and limiters/clampers. Operational amplifier and its characteristic features. Logic gates, OR, AND, NOT, NOR, XOR and NAND gates . (20)

Text Books recommended:

1. D.J. Griffith, Introduction to Electrodynamics, PHI, 3rd edition (2004)
2. B.B. Laud, Electromagnetics, New Age Pub. 2nd edition, (1987) reprint, 2005
3. Chattopadhyay & Rakshit ,Electricity and Magnetism, Central Book Agency , Pvt Ltd.
4. P. Chakraborty, *Electricity and Magnetism*, New Age Int.(2002)
5. J. R. Reitz, F.J. Milford & R.W Christy, Foundations of Electromagnetic Theory , Narosa Publishing House
6.S.L. Gupta & V. Kumar, Handbook of Electronics: Pragati Prakashan. Latest Edn. 2008.

Reference Books:

1. D.C. Tayal, Basic Electronics: Himalaya Pub. (2005).
2.. B.L. Theraja, Basic Electronics : Solid State, S. Chand Ltd
3. B.G. Streetman, Solid State Electronic Devices: Prentice Hall of India Pvt. Ltd.
(2003)
4. V.K. Mehta & R. Mehta, Principles of Electronics: S. Chand & Co. (2005).
5. The Feynman Lectures on Physics II, Pearson Education India 2008.

PHY02(P) **List of experiments** Marks = 40

1. Determination of the value of acceleration due to gravity ('g') by using bar pendulum.
2. Determination of the value of acceleration due to gravity ('g') by using Kater's pendulum.
3. Determination of the moment of inertia of a regular solid (called unknown body) about its axis through its centre of gravity by using torsional pendulum.
4. Determination of the rigidity modulus of a cylindrical body by static torsion apparatus.
5. Determination of the co-efficient of viscosity of liquid by capillary tube method.
6. Determination of the surface tension of a liquid by Jaeger's method.
7. Determination of the angle of dip at a place by using dip circle.
8. Determination of the resistance of a lamp at room temperature and when it is incandescent.
9. Determination of the resistance per unit length of the potentiometer wire by Carey-Foster method.
10. To find the refractive index of a liquid using traveling microscope.

Text Books recommended:

1. C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar A Text Book on Practical Physics , Syndicate Press (2006)
4. D.P. Khandelwal, A laboratory manual of Physics for Undergraduate classes, Vani Publication House.

Reference Books:

1. B.L. Worsnop and H.T. Flint, Advanced Practical Physics, Asia Publishing House, New Delhi.
2.M.Nelkon and Jon Ogborn, Advance level Practical Physics 4th Edition
3. Chauhan & Singh, Advanced Practical Physics, Pragati Prakashan.
4. B. Saraf et al, Physics through experiments Vol I & II

Semester –III

PHY03(T) Thermal Physics, Waves
(Lectures =90) (Marks=60)

UNIT I

Review of kinetic theory of gases. Limitations of the perfect gas equation PV=RT. Van der Waals correction, Van der Waals equation and evaluation of critical constants of a gas. Law of equipartition of energy with proof and its application to obtain $\gamma = C_P/C_V$ of a gas, determination of γ by Ruchartd's method.

Transport phenomena: Concept of calculation of mean free path, Claussius mean free path and estimation of molecular diameter. Viscosity and thermal conductivity of a gas. Theory of Brownian motion (Einstein's approach).

Laws of thermodynamics: The zeroth law, indicator diagram, work done, the first law, internal energy. Reversible and irreversible changes, Carnot cycle, Carnot theorem, second law of

thermodynamics, entropy as thermodynamic variable, principle of increase of entropy, entropy of a perfect gas, entropy and unavailable energy. Thermodynamic scale of temperature and its identity with perfect gas scale. Impossibility of attaining absolute zero, third law of thermodynamics.

(25)

UNIT II

Liquefaction of gases. Boyle temperature and inversion temperature. Principle of regenerative cooling and cascade cooling.

Black body radiation, temperature dependence, Planck's quantum postulate, Planck's Law, Stefan-Boltzmann law, pressure of radiation, spectral distribution of black body radiation. Wein displacement law, Rayleigh-Jeans laws, agreement with experiment.

Phase space, μ-space, Γ-space, Gibb's ensemble, division of phase space into phase cells and volume of a phase cell, calculation of number of states in terms of volume in phase space. Qualitative ideas of microcanonical, canonical and grand canonical ensembles with examples. (20)

UNIT III

Simple harmonic motion: Superposition of two SHM's acting at right angles to each other having (a) same frequencies and (b) different frequencies in the ratio 1:2. Lissajous figures and their uses. Oscillations of two masses connected by a spring.

Damped and forced oscillations : Damped SHM, energy of damped SHM, Q-value of damped oscillations , forced vibrations with one degree of freedom, transient and steady state oscillations, power in forced vibrations, sharpness of resonance and quality factor.

Waves: Linear equation of plane progressive wave and its general solution. Plane waves and spherical waves. Energy and energy density of plane progressive waves.

Waves in continuous media: Speed of transverse waves on a uniform string, speed of longitudinal waves in a fluid, interference of sound waves, combination of tones. Group velocity and phase velocity.

Vibrating Strings: Theories of plucked string and struck string. Energy of vibrating strings.

Fourier Analysis: Fourier series and Fourier coefficients, simple examples – square wave, saw-tooth wave, triangular wave. Fourier analysis of non-periodic functions. (30)

UNIT IV

Failure of classical physics. Old quantum theory. Wave nature of matter and de-Broglie relation. Demonstration of probabilistic nature of quantum mechanics by the two-slit experiment. Statement and significance of Heisenberg uncertainty principle and illustration of this principle by a single-slit electron diffraction and Heisenberg's microscope. Application of uncertainty principle to prove the non-existence of electron in the nucleus and calculation of binding energy of electron in hydrogen atom.

Concept of wave function and physical interpretation of the wave function. Normalization of a wave function with examples. Derivation of one dimensional time-dependent and time-independent Schrodinger equations (without use of operator).

(15)

Text Books recommended:

1. M.W. Zemansky & R.H. Dittman, Heat and Thermodynamics, McGraw Hill, Singapore, 7th Edition, 1997.
2. B.K. Agarwal and M. Eisner,Statistical Mechanics, New Age International Publishers,2nd Edition, 1998.
3. H.J Pain, The Physics of Vibrations and Waves, John Wiley & Sons 3rd Edition (1998)
4. B. Ghosh , Principles of Acoustics, Shreedhar Publishers
5. S.N. Sen, Acoustics, Waves and Oscillations, New Age Int. (2002)
6.Undergraduate Physics , A.B.Bhattacharya , New Central Book Agency (2007)
7.R .N. Choudhuri, Waves and Oscillations, New Age Int. (2007).
8. A.K. Ghatak and S. Lokanathan, Quantum Mechanics, Mc Millan, 1992.
9.P. T. Mathew Quantum Mechsnics, Tata McGraw Hill
10. R. Murugeshan, Modern Physics, S.Chand & Co., 2006.

Reference Books recommended:

1. B.B. Laud ,Fundamental Statistical Mechanics, New Age International Publishers, 1994.
2. Franks Crawford, Waves: Berkeley Physics Course (SIE), Tata Mc Graw Hill, 2007.

PHY03(P) **List of experiments** Marks = 40

1. Determination of the co-efficient of linear expansion of a solid by using Pullinger's apparatus and optical lever.
2. Determination of the specific heat of a liquid by the method of cooling.
3. Determination of the co-efficient of thermal conductivity of a good conductor by Searle's method.
4. Determination of the refractive index of a prism by a spectrometer using monochromatic light.
5. Determination of the magnifying power of a telescope by angular method.
6. Determination of the radius of curvature of a lens by Newton's ring method.
7. Determination of the grating constant by using a spectrometer.
8. Determination of the power of the combination of two thin convex lenses in contact by displacement method.
9. Determination of the speed of waves on stretched strings.
10. Determination of the frequency of a tuning fork by Melde's method.

Text Books recommended:

1. C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar A Text Book on Practical Physics , Syndicate Press (2006).

4. B.L. Worsnop and H.T. Flint, Advanced Practical Physics, Asia Publishing House, New Delhi.
5.M. Nelkon and Jon Ogborn, Advanced level Practical Physics.4th Edition .
6.D.P. Khandelwal, A laboratory manual of Physics for Undergraduate classes, Vani Publication House.
7. Chauhan & Singh, Advanced Practical Physics, Pragati Prakashan.
8. B. Saraf et al, Physics through experiments Vol I & II

Semester –IV

PHY04(T) Atomic, Nuclear and Solid State Physics
(Lectures =90)
(Marks = 60)

UNIT I

Atomic structure. Methods of producing ionization in atoms and measurement of ionization current. Excitation and ionization potentials. Mobility of ions, determination of e/m by Thomson's method, measurement of electronic charge e by Millikan's oil-drop experiment. Measurement of mass of the electron, principle of cathode ray oscilloscope.

Positive ray analysis and mass-spectrographs: Thomson mass spectrograph, Bainbridge mass-spectrograph and Aston's mass-spectrograph.
Review of Bohr's theory of hydrogen atom and different spectral series. Introduction of quantum numbers with their significance, Pauli's exclusion principle and use of this principle to show that the maximum number of electrons in an orbit $2n^2$

Principle of production of x-rays. Hard x-ray and soft-x-ray spectra: continuous spectrum and characteristic spectrum.

Moseley's law, Duane & Hunt law. Absorption of x-ray and exponential law. Compton scattering of x-rays and expression for wavelength change due to scattering.
Laser: Purity of a spectral line, condition for laser action, existence of metastable state, population inversion by pumping and cavity. He-Ne laser (basic principle). (30)

Unit II
Review of natural radioactivity, mean life (deduction). Basic ideas of α, β and γ decay. Interaction of γ rays with matter: photo electric effect, Compton scattering, pair production. Applications of radioactivity: radiography, radioactive tracers, radioactive dating: carbon dating.
Particle accelerators : Linear accelerators, cyclotron and its limitations, betatron and synchrotron (proton).
Particle detectors: Ionization chamber, GM counter, scintillation counter.
Artificial transmutation of elements: Artificial transmutation, scheme of nuclear reactions, nuclear reaction energy, discovery of neutron, properties of neutron.

Nuclear fission: Discovery, energy released in fission, secondary neutrons and their importance, multiplication factor (elementary idea), chain reaction, concept of critical size, nuclear reactor, types of reactors.

Nuclear fusion: Origin of stellar energy, calculation of fusion energy, qualitative ideas of nuclear models – liquid drop model, shell model and collective model, calculation of binding energy.

Cosmic rays and elementary particles: General characteristics, latitude effect, east-west effect, altitude effect, origin of cosmic rays, primary and secondary cosmic rays, classification of elementary particles and their properties. (30)

UNIT III

Cohesive energy of solids. Crystal structure: Lattice translation vectors, crystal structure with basis and Bravais lattice, primitive cell and unit cell. Symmetry in crystals: viz translational, rotational, inversion symmetry and crystal types in 2- and 3-dimensions allowed by symmetry; sc, bcc, and fcc crystals and their coordination numbers and nearest neighbour distances. Closed-packed crystals and packing fraction of sc, bcc, and fcc lattices, Miller indices and interplanar spacing.

Diffraction by crystals: Bragg's law; Laue's treatment of diffraction and Laue's equations, need for reciprocal lattice vectors, Wigner-Seitz cell.

Free electron theory of solids: Classical treatment and Drude's theory of electrical conductivity, inadequacy of free electron model. Introductory concepts of Fermi level. Qualitative explanation of energy band and band gap, distinction between conductors, semiconductors and insulators in terms of band gap.

Magnetic properties of materials: Magnetic induction, magnetization and magnetic susceptibility, Qualitative idea of diamagnetism, paramagnetism, and ferromagnetism.

Superconductivity: Discovery of superconductivity in Hg by Kamerlingh Onnes. Phenomenon of superconductivity, persistent current, behaviour of a superconductor in a magnetic field, Meissner effect, destruction of super-conductivity by a magnetic field and critical fields (upper and lower) leading to distinction between type-I and type-II superconductors. (30)

Text Books recommended:

1. R. Murugeshan, K. Sivaprasath, Modern Physics (13th revised Multicolour Edition 2007)
2. S. L. Gupta . & S. Gupta , Concepts of Modern Physics, Dhanpat Rai & Co.,1998.
3. S.B. Patel, Nuclear Physics: an introduction, New Age International (P) Limited, Publishers.
4. A.B. Gupta and Dipak Ghosh, Atomic and Nuclear Physics, Books and Allied (P) Ltd. (1999).
5. J. P. Srivastava, Elements of Solid State Physics, Prentice Hal of India, 2001.
6. C. Kittel, Introduction to Solid State Physics, John Wiley, 1999.
7. R.K. Puri, B.K. Babbar, Solid state Physics & Electronics, S. Chand.
8. S.O. Pillai, Solid State Physics, New Age International.

Reference Books:

1. T.A. Littlefield and N. Thorley, Atomic and Nuclear Physics, E.L.B.S. Publications, 1980.
2.R.K. Puri, B.K. Babbar, Introductory Nuclear Physics, Narosa Publishing House, Delhi.
3. Omar M.A., Elementary Solid State Physics, Addison Wesley, 1999
4.Concepts of Modern Physics by Arthur Beiser (Mc Graw Hill Book Company), 1987
5. A.J. Dekker, Solid State Physics , Mc Millan, Latest edition

PHY04(P) **List of experiments** Marks = 40

1. Determination of the mechanical equivalent of heat (J) by Joule's calorimeter.
2. Determination of the magnetic moment of a bar magnet (M) and the value of horizontal component of the earth's magnetic field (H) by using deflection and vibration magnetometer.
3. To verify the inverse square law in magnetism.
4. Determination of the energy gap of a semiconductor diode.
5. Determine the characteristics of a semiconductor diode and find its static resistance.
6. Determine the forward and reverse bias characteristics of a Zener diode and to measure the value of breakdown voltage.
7. Determination of the value of the capacitance of an unknown capacitor by using the De-Sauty's bridge.
8. To study the OR and AND logic gates and to verify their truth tables (using Transistors or ICs).
9. To draw the characteristics of a LDR
10. To draw the characteristics of a photo-diode.
11. Determination of an unknown resistance by using a PO box.

Text Books recommended:

1. C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar A Text Book on Practical Physics , Syndicate Press (2006)
4. Harnam Singh, B. Sc Practical Physics, latest edition.
5. B.L. Worsnop and H.T. Flint, Advanced Practical Physics, Asia Publishing House, New Delhi.
6. M. Nelkon and Jon Ogborn, Advanced level Practical Physics (4^{th} edition).

7. D.P. Khandelwal, A laboratory manual of Physics for Undergraduate classes, Vani Publication House.

Semester –V

PHY05(T) Mathematical Physics, Quantum Mechanics
(Lectures =105)
(Marks = 70)

UNIT I

Vectors: Gradient of a scalar, divergence and curl of a vector field, line, surface and volume integrals, flux of a vector field, Gauss' divergence theorem, Green's theorem, Stokes' theorem (with proofs).

Curvilinear co-ordinates, orthogonal curvilinear co-ordinates. Conditions for orthogonality. Gradient in terms of curvilinear co-ordinates, divergence and curl in terms of curvilinear co-ordinates. Laplacian in terms of orthogonal curvilinear co-ordinates, cylindrical and spherical polar co-ordinates as a special curvilinear system.

Matrices: Different types of matrices, properties of symmetric, skew- symmetric, hermitian and skew-hermitian matrices. Characteristic equation, eigenvalues and eigenvectors of a matrix and diagonalization of matrix (only for 2x2 matrices).

Complex variables: Preliminary ideas of Complex number, functions of complex variables, analytic functions, Cauchy-Riemann conditions, Cauchy's theorem (with proof), Cauchy's integral formulae (with proof), simply and multiply connected regions. Taylor series and Laurent series (both without proof), poles and residues, Cauchy residue theorem (with proof), application of residue theorem in integrals of functions having simple poles. (24)

UNIT II

Ordinary differential equations: General method of solutions of second order linear equations, meaning of ordinary point, singular point and regular singular point. Frobenius method of solution.

(a) Legendre polynomial: Convergent solution of Legendre differential equation, its transformation to polynomial solution $P_n(x)$. Generating function of $P_n(x)$, recurrence relation for $P_n(x)$, Rodrigue's formula for $P_n(x)$, orthogonality of $P_n(x)$. Calculation of potential and intensity at a point for an electric dipole with the help of $P_n(x)$.

(b) Hermite Polynomial:

Convergent solution of Hermite differential equation, its transformation to polynomial solution $H_n(x)$. Generating function, recurrence relations, Rodrigue's formula, orthogonalityof $H_n(x)$.

Partial differential equations: Solutions of partial differential equations by the method of separation of variables. Application to solution of : heat flow equation in one dimension, equation of vibrating string, Laplace's equation in two dimension (cartesian and polar co-ordinates). (24)

UNIT III

Gamma and Beta functions:

Definition of gamma and beta functions as definite integrals, recursion formula for gamma functions, evaluation of $\Gamma(1/2)$. Relationship between gamma and beta functions, Legendre Duplication formula, Evaluation of definite integrals of the types:

$$\int_0^\infty x^2 e^{-ax^2}\,dx \;;\quad \int_0^\infty \frac{x^3}{e^x-1}\,dx \;;\quad \int_{-\infty}^{+\infty} e^{-ax^2+bx}\,dx$$

Tensor analysis: Concept of tensor with examples, contravariant and covariant tensors up to rank 2, mixed tensors, addition and subtraction, outer and inner products of tensors, contraction of a tensor, symmetric and anti-symmetric tensors, the Kronecker delta.

(9)

UNIT IV

Particle as a wave packet, Gaussian wave packet, phase velocity and group velocity, velocity of wave packet, spreading of a wave packet, probability density, probability current density, conservation of probability density.

Postulates of quantum mechanics, quantum mechanical operators, eigenvalues and eigenvectors of an operator, Schrodinger equation as an operator equation, Hamiltonian operator, Hermitian operator and its properties, adjoint of an operator, linear operator, commutation and anti-commutation of operators, momentum operator, energy operator, matrix representation of an operator.

Expectation values of an operator with examples, Ehrenfest theorem. Derivation of Heisenberg's uncertainty relation $\Delta p_x \Delta x \geq \hbar/2$ by operator method. (24)

UNIT-V

One-dimensional applications of time independent Schrodinger equations: particle in an infinitely-deep potential well, quantum tunneling through a potential barrier, step potential-reflection and transmission coefficients, particle in a shallow well and linear harmonic oscillator .

Angular momentum: Orbital angular momentum operators in Cartesian coordinates and their commutation relations, e.g. $[l_i, l_j]$ and $[l_i, l^2]$. Angular momentum operators in spherical polar coordinates; eigenvalues and eigenvectors of l_z and l^2 ; spin operators and their eigenvalues and eigenvectors, Pauli's spin operators and their properties. Schrodinger equation for hydrogen atom in spherical polar coordinates, separation into radial part and angular part, solution of the radial equation for obtaining energy eigenvalues. (24)

Text Books recommended:

1. B.D. Gupta, *Mathematical Physics*, Vikash Publishing House, (2002)
2. A.W. Joshi, Matrices and Tensors, Wiley Eastern (2004)
3. A.K. Ghatak and S. Lokanathan, Quantum Mechanics, Mc Millan, 1992.
4. S. Gasiorowicz., Quantum Physics, John Wiley (2005).
5. G. Aruldhas, Quantum Mechanics, Prentice Hall of India (2002)

Reference Books recommended:

1. G.Arfken, *Mathematical methods for Physicists*, Academic Press Inc.(Indian edition- Prism Book Pvt. Ltd. 53/2 Bull Temple Road, Basabanagudi, Bangalore- 560019, India)

2. Schaum's outline series: Murray R Spiegel, *Vector Analysis and an introduction to Tensor Analysis*, Mc Graw Hill (2002)

3. Schaum's outline series: Murray R Spiegel, *Complex Variables,* Mc Graw Hill, (2002)

4. C. Harper, *Introduction to Mathematical Physics*, Prentice Hall of India Pvt. Ltd.(1993)
5. Mathew and Walker, Mathematical Physics
6. W. Greiner, Quantum Mechanics (An Introduction), Springer (2001).

PHY05(P) **List of experiments** Marks = 30

1.Determination of the co-efficient of thermal conductivity of a bad conductor by Lee's method.
2. Determination the velocity of ultrasonic waves in liquid.
3. To measure the width of single slit from the study of its Fraunhoffer diffraction.
4. Determination of the wavelength of sodium light using biprism.
5. Determination of the specific rotation of solution using polarimeter.

Text Books recommended:

1.C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar, A Text Book on Practical Physics , Syndicate Press (2006)
4. S. Ghosh, A Text Book of Advanced Practical Physics, New Central Book (2001).
5. B.L. Worsnop and H.T. Flint, Advanced Practical Physics, Asia Publishing House, New Delhi.
6.M.Nelkon and Jon Ogborn, Advanced level Practical Physics .4th Edition
7. D.P. Khandelwal, A laboratory manual of Physics for Undergraduate classes, Vani Publication House.

8. Chauhan & Singh, Advanced Practical Physics, Pragati Prakashan.
9. B. Saraf et al, Physics through experiments Vol I & II

PHY06(T) Electrodynamics, Electronics-II
(Lectures =105)
(Marks = 70)

UNIT I

Differential form of Gauss' law-Poisson and Laplace's equations, Uniqueness theorem (with proof). Maxwell's equations for time dependent electromagnetic field in vacuum and in material media, boundary conditions.

Electric field inside matter: Polarization and polarization vector, potential and field due to polarized matter, applied to sphere. Gauss' Law in dielectric and the displacement field, electric susceptibility and dielectric constant, boundary conditions satisfied by **E** and **D** at the interface between two homogeneous dielectrics, dielectric sphere in a uniform field, capacitor filled with dielectrics, polar and non-polar molecules, induced dipoles, Clausius-Mossoti relation. (22)

UNIT II

Electromagnetic Potentials: Magnetic vector potential **A** and scalar potential Φ, Poisson's equation for **A** in terms of current density, solution for line and surface current, calculation of vector potential for an infinitely long solenoid. Gauge transformations, Coulomb and Lorentz gauge.

Electromagnetic waves: The wave equation, plane wave solution for Maxwell's equations, orthogonality of E, B and propagation vector. Poynting vector, energy and momentum propagation, reflection and transmission at dielectric boundaries, normal incidence. (23)

UNIT III

FET. Similarities and dissimilarities of FET and BJT, JFET, static and transfer characteristics of JFET, pinch off voltage, idea of MOSFET.

Ideal OP AMP, differential amplifier, transfer characteristics of OP AMP, offset parameters, differential gain, CMRR. Applications of OP AMP as adder, integrator and differentiator.

Multistage amplifiers, analysis of RC coupled CE amplifier, transformer coupled amplifier, feedback amplifiers, gain with feedback. Analysis of Colpitt's and Hartley's oscillators.

Elements of communication systems, features of radio communication, elementary aspects of optical communication, optical fibres. (25)

UNIT-IV

Digital signals, analog vs digital, binary system, binary to decimal and decimal to binary, binary arithmetic-addition and subtraction, signed binary numbers, two's complement scheme.

Boolean algebra (elementary aspects only), de'Morgan's theorems, TTL Logic families, multiplexer, demultiplexer, digital comparator. (15)

UNIT V

Classification of computers: analog and digital. Flowchart and algorithm , to determine the roots of a of a quadratic equation, summation of arithmetic series. Fortran (77) characters: integer, constant, real constant, complex constant, logical constant. Fortran variables: real variables, double precision, logical variables, subscripted variables, arrays. Library functions.

Fortran statements :

(A) Executable statements :(with illustration):

(i) Assignment statement

(ii) Input statement: formatted and unformatted

(iii) Control statement and its classification, i.e.

(a) GOTO statement, unconditional GOTO statement, computed GOTO statement and assigned GOTO statement

(b) IF statement: arithmetic IF, logical IF, IF THEN, ELSE, ENDIF.

(c) DO statement: DO loop, ENDDO.

(d) CONTINUE statement

(e) STOP statement

(f) PAUSE

(iv) Output statement: formatted and unformatted

(v) RETURN statement (related to subprogram)

(B) Non-executable statement(with examples and illustration)

DIMENSION statement

IMPLICIT statement

EXPLICIT statement

FORMAT statement

NAMELIST statement

COMMON statement

EQUIVALENCE statement

EXTERNAL statement

END statement

OPEN FILE statement

(20)

Text Books recommended:

1. D.J. Griffith, Introduction to Electrodynamics, PHI, 3rd edition (2004)
2. B.B. Laud, Electromagnetics, New Age Pub. 2nd edition, (1987) reprint, 2005
3. D.C. Tayal, Electricity & Magnetism, Himalaya Pub. (1998)
4. J.D. Jackson, Classical Electrodynamics, 3rd edition, Wiley, New York 1998.
5. B.L. Theraja, Basic Electronics, S. Chand & Co. (2005).
6. S.L. Gupta & V. Kumar, Handbook of Electronics, Pragati Prakashan. Latest Edn. (2004).
7. D.C. Tayal, Basic Electronics, Himalaya Publications (2005).
8. C. Xavier, Fortran 77 and Numerical Analysis, New Age International (2001)
9. V. Rajaraman, Computer Programing in Fortran 77, PHI (2001)

Reference Books recommended:

1. E. M. Purcell, Berkeley Physics Course, *Electricity and magnetism*, McGraw Hill,
1965.
2. Edward C. Jordan & Keith G. Balmain, *Electromagnetic waves and Radiating*
systems, Prentice Hall of India Pvt. Ltd.(Eastern Economy Edition- 2nd Edition
2000 Indian reprint)
3. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundations of Electromagnetic theory*, Narosa Publishing House, 3rdedition,1993.
4. J. D. Ryder, Electronics Fundamentals and Applications, Prentice Hall of India Pvt. Ltd.(2003).

5. B.G. Streetman, Solid State Electronic Devices, Prentice Hall of India Pvt. Ltd. (2004).
6. V. K. Mehta and R. Mehta, Principles of Electronics, S. Chand & Co. (2005).
7 A.B. Bhattacharjee, R. Bhattacharjee, University Physics II, New Central Book Agency 2007
8.The Feynman Lectures on Physics Vol II, Pearson Education India , 2008

PHY06(P) **List of experiments** Marks = 30

1. Determination of Young's modulus (Y) of glass using Cornu's Method.
2. Determination of Plank's constant by photocell or by heating method.
3. Determination of the specific charge (e/m) of an electron by magnetron/Thomson's method.
4. Determination of the forward and reverse bias characteristics of a Zener diode and to measure the value of breakdown voltage.
5. Determination of the reduction factor of a tangent. galvanometer and also the value of horizontal component of earth's magnetic field by electrolysis method.
6. Determination of the monochromatic wavelength by Michelson interferometer.

Text Books recommended:

1.C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar, A Text Book on Practical Physics , Syndicate Press (2006)

4. S. Ghosh, A Text Book of Advanced Practical Physics, New Central Book (2001).
5. B.L. Worsnop and H.T. Flint, Advanced Practical Physics, Asia Publishing House, New Delhi.
6.M.Nelkon and Jon Ogborn, Advanced level Practical Physics .4th Edition.
9. D.P. Khandelwal, A laboratory manual of Physics for Undergraduate classes, Vani Publication House.
10. Chauhan & Singh, Advanced Practical Physics, Pragati Prakashan.
9. B. Saraf et al, Physics through experiments Vol I & II

Semester – VI

PHY07(T) Condensed Matter Physics
(Lectures =105)
(Marks = 70)

UNIT-I

Thermodynamics relations: Thermodynamic variables, extensive and intensive variables. Maxwell's relations and applications, TdS equations, heat capacity equations, internal energy equations. Joule-Thomson cooling, thermodynamic potentials. Clausius-Clapeyron equation. Equilibrium of thermodynamical variables.

Statistics and Probability: Fundamental probability laws. The binomial distribution, calculation of mean; Stirling approximation

(up to second order). The Gaussian or normal distribution, calculation of mean and variance; the Poisson's distribution.

Idea of generalized coordinates and momenta, constraints, Lagrangian and Hamiltonian. Density distribution in phase space and applications to one-dimensional harmonic oscillator and free particles, principle of equal a prori probability, ergodic hypothesis, Liouville theorem (with proof). Statistical equilibrium, probability calculations, behaviour of the density of states, sharpness of the probability distribution; probability distribution in microcanonical, canonical and grand-canonical ensembles. (30)

UNIT-II

Thermal equilibrium between two systems, β parameter and its identity with $1/(k_B T)$, probability and entropy, e.g. $S = k_B \ln\Omega$. Statistical interpretation of second law of thermodynamics. Partition function and its relation with thermodynamic quantities like free-energy, entropy and specific heat, law of equipartition of energy and its applications. Derivation of Maxwell-Boltzmann distribution function and its application to a perfect gas and derivation of Maxwell's distribution of molecular speeds with calculation of mean velocity, r.m.s. velocity and most probable velocity, Maxwell's mean free path.

Quantum statistics: Indistinguishability of particles, Bose-Einstein (BE) and Fermi-Dirac (FD) distributions. Classical limit of quantum statistics, application of BE statistics to a photon gas and FD statistics to free electron in metals and calculation of Fermi energy.

(25)

UNIT III

Crystal structure: Symmetry in crystals, point groups, space groups. Structure of sodium chloride, cesium chloride, diamond and zinc sulfide.

Brillouin zones. Reciprocal lattice of sc, bcc and fcc structures. Fourier analysis of basis, structure factor of bcc and fcc, atomic form factor. Experimental techniques, Laue method, powder method, neutron diffraction methods.

Crystal binding: Bonding in covalent crystals, ionic crystals, inert gas crystals, metallic crystals and hydrogen-bonded crystals, and properties of these crystals; Madelung energy and Madelung constant in ionic crystals, London-London interaction in inert gas crystals and cohesive energy.

Lattice vibration, quantization of lattice vibration, vibration of monatomic and diatomic chain of atoms. Lattice heat capacity, phonon density of states, Einstein and Debye theories of heat capacity. (25)

UNIT-IV

Free electron model: Quantum mechanical treatment of free electrons in metals, concept of Fermi level, density of states, heat capacity of the electron gas, experimental heat capacity of metals, electrical conductivity, experimental electrical resistivity of metals, Matthiessen's rule, plasma frequency, Hall effect, thermal conductivity of metals, Wiedemann-Franz law.

Band Theory: Nearly free electron model, origin of the energy gap, magnitude of the energy gap, concept of bands and band gap; equations of motion; effective mass, effective mass in semiconductors, silicon and germanium, intrinsic carrier concentration, intrinsic mobility; impurity conductivity.

Magnetism: Langevin theory of diamagnetism and paramagnetism; Weiss theory of ferromagnetism; anti-ferromagnetism and ferri-magnetism.

Superconductivity: Type-I and type-II superconductors, heat capacity, energy gap, isotope effect. Thermodynamics of the superconducting transition. Elementary ideas of BCS theory. Ideas of high temperature superconductivity. (25)

Text Books recommended:

1. M.W. Zemansky & R.H. Dittman, Heat and Thermodyanics, McGraw Hill, Singapore, 7th edition, 1997.
2. B.K. Agarwal and M. Eisner, Statistical Mechanics, New Age International Publishers, 2nd edition, 1998.
3. N.C. Rana, P.S. Joag, Classical Mechanics, Tata Mc Graw Hill Education Pvt Ltd (2010).
4. C. Kittel, Introduction to Solid State Physics, John Wiley, 1999
5. J.P. Srivastava, Elements of Solid State Physics, Prentice Hall of India, 2001.
6. K. Huang, Statistical Mechanics, Wiley India Edition, 2nd edition .

Reference Books recommended:

1. F. Reif, Fundamental of Statistical and Thermal physics, McGraw Hill Singapore, 1985.
2. B.B. Laud, Fundamental Statistical Mechanics, New Age International Publishers, 1994.
3. A.J. Dekker, Solid State Physics, McMillan (1969).

4. S.O. Pillai, Solid State Physics, New Age International (2002).
5. H. P. Myers, Introductory Solid State Physics, Viva Book (1998).
6. J. R. Chrisman, Fundamentals of Solid State Physics, John Wiley (1988).
7. M.A Omar, Elementary Solid State Physics, Addison Wesley, 1993

PHY07(P) **List of experiments** Marks = 30

1. To study the characteristics of a transistor in CB configuration and determine α .
2. To study the characteristics of a transistor in CE configuration and determine β.
3. To study the frequency response of a series LCR circuit.
4. To study the frequency response of a parallel LCR circuit.
5. To study AND, OR, NOT and NAND gates and to verify their truth tables, using transistors or ICs .

Text Books recommended:

1. C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar A Text Book on Practical Physics , Syndicate Press (2006)
4. S. Ghosh, A Text Book of Advanced Practical Physics, New Central Book (2001)

PHY08(T) Atomic and Molecular Spectroscopy, Nuclear Physics

(Lectures =105) (Marks = 70)

Unit I

Space quantization and spinning electron, Stern Gerlach experiment, quantum numbers associated with vector atom model and their physical significance; spin – orbit interaction and its explanation of fine structure. Spectral terms - s,p,d,f notation, magnetic moment due to orbital motion and spin, Bohr magneton, Lande g- factor, Larmor's theorem, gyromagnetic ratio. Zeeman effect, classical and quantum theory of normal Zeeman effect, quantum theory of anomalous Zeeman effect for one electron system only. Alkali spectrum and effect of screening on their spectrum, screening constant.

Two electrons system: L-S coupling, j-j coupling, Pauli's exclusion principle, spectra of helium atom and alkaline earth atoms, singlet and triplet fine structure, selection rules. (25)

Unit II

Introduction: Types of molecular spectra – rotational, vibrational and electronic spectra. Pure rotational spectra of a diatomic rigid body rotator – quantum mechanical derivation of energy levels of rigid body rotator, frequency of spectral lines, selection rule and the spectrum.

Vibrating diatomic molecule as a harmonic oscillator – frequency, energy levels, selection rules, spectrum, vibrational – rotational spectra, selection rules.

Electronic spectra: Electronic band systems, sequence and progression, Frank Condon principle.

Raman effect and its brief quantum mechanical explanation, Raman shifts, Stokes and anti-Stokes lines, selection rules, comparison of Raman and IR spectra.

Fundamental ideas of UV and IR spectroscopy, Atomic Emission Spectroscopy (AES), Atomic Absorption Spectroscopy (AAS) and basic ideas about X-ray Fluorescence (XRF) and its applications. (25)

Unit III

Structure, composition of the nucleus, basic properties: charge, mass, size, spin, magnetic moment, electric quadrupole moment, binding energy, binding energy per nucleon and its variation with mass number of the nucleus. Coulomb energy, volume energy, surface energy, other corrections, explanation of B-E curve, liquid drop model, shell model, Schmidt lines.

Properties of nuclear forces, two nucleon system, square well solution of the deuteron problem.

Radioactivity: Geiger – Nuttal law, Gamow's theory of α decay, Fermi's theory of β - decay (qualitative treatment), neutrinos and anti neutrinos, nuclear radiation, energy levels, biological effects of nuclear and electromagnetic radiations, Maximum permissible radiation levels for safety, precaution against radiation hazards.

Nuclear Reactions: Rutherford's experiments on artificial transmutations, conservation theorems, Q- value, threshold energy, cross section of nuclear reactions.

Artificial radioactivity: nuclear fission, Bohr Wheeler theory of nuclear fission, condition of spontaneous fission, four factor formula for a nuclear multiplication factor, chain reaction, criticality, moderators, types of reactors – power, breeder reactor.

Nuclear fusion reaction in the plasma, condition for maintaining fusion reaction, Tokamak experiment in fusion systems.

(40)

Unit IV

Cosmic rays: Primary cosmic rays: extensive air showers, solar modulation of primary cosmic rays, effect of earth's magnetic field on the cosmic ray trajectories, Discovery of muon, pion, heavy mesons and hyperons in cosmic rays.

Elementary particles: Concept of antiparticles, fundamental interactions, forces and fields. Resonant particles, discovery and important properties, strangeness, conservation and violation of strangeness in particle interactions, isospin, hypercharge. Symmetries and Conservation laws, Baryon and Lepton conservation. Basic ideas of quarks and quark model. (15)

Text Books recommended:

1.Gupta, Kumar & Sharma, Elements of Spectroscopy, Nineteenth edition, Pragati Prakashan (2008).
2.H.E. White, Introduction to Atomic Spectra, Mc Graw Hill, 1934.
3.A.B. Gupta and Dipak Ghosh, Atomic and Nuclear Physics, Books and Allied (P) Ltd.
4.R. Murugeshan, K. Sivaprasath, Modern Physics (13^{th} revised Multicolour Edition 2007), S. Chand
5.A Beiser, Perspectives of Modern Physics, Mc Graw Hill, 1969.
6.S.N. Ghoshal, Atomic and Nuclear Physics, Vols 1 & 2, S.Chand and Co. Ltd., 1994.
7.B.K. Sharma, Spectroscopy, 17^{th} Revised and enlarged edition, 2005, Krishna Prakashant Media (P) Ltd.

Reference Books recommended:

1. G.M. Barrow, Molecular Spectroscopy, McGraw Hill, 1962.
2. G. Herzberg, Atomic spectra and atomic structure, Dover Publications, 1944.
3. G. Herzberg, Spectra of Diatomic Molecules, Van Nostrand Reinhold Company (1950)
4. T.A. Littlefield and N. Thorley, Atomic and Nuclear Physics, E.L.B.S. Publications, 1980.
5. J.D. Graybeal, Molecular Spectroscopy, Mc Graw Hills International Edition 1988.
6. B.K. Sharma, Spectroscopy, 17th Revised and enlarged edition, 2005, Krishna Prakashant Media (P) Ltd.
7. G. Aruldhas, Molecular Structure and Spectroscopy, Eastern Economy Edition, Prentice Hall of India, Pvt. Ltd.
8. B.N. Srivastava, Basic Nuclear Physics and Cosmic Rays, Pragati Prakashan, 1993.
9. B.L. Cohen, Concepts of Nuclear Physics, Tata Mc Graw Hill, 1990.
10. R.R. Roy, B.P. Nigam, Nuclear Physics, New Age International (P) Limited, Publishers.
11. R.K. Puri, B.K. Babbar, Introductory Nuclear Physics, Narosa Publishing House, Delhi.
12. S.B. Patel, Nuclear Physics : An Introduction , New Age International Pvt.Ltd (1996)
13. Kenneth S. Krane, Introductory Nuclear Physics, John Wiley & Sons, 1988.
14. Bransden & Joachein, Physics of Atoms and Molecules

PHY08(P) **List of experiments** Marks = 30

1. To study Lissajous figures using C.R.O. and determine the frequency of an unknown source.
2. To study the frequency response of RC coupled amplifier.
3. To draw the BH curve of a ferromagnetic sample.
4. Study of integrating and differentiating circuit.
5. To compute the roots of a quadratic equation by using fortran programming.
6. To multiply two given matrices by using fortran programming.

Text Books recommended:

1. C.L. Arora, B.Sc. Practical Physics, S Chand (2005)
2. S. Ghosh, A Text Book of Practical Physics, New Central Book (2001)
3. K.G. Mazumdar A Text Book on Practical Physics , Syndicate Press (2006)
4. S. Ghosh, A Text Book of Advanced Practical Physics, New Central Book (2001)
5. C. Xavier, Fortran 77 and Numerical Analysis, New Age International (2001)
6. V. Rajaraman, Computer Programing in Fortran 77, PHI (2001)