DEPARTMENT OF PHYSICS
M.Sc. Syllabus

Semester	Code	Name of the Paper	Credit	Marks
I	PHY-PG-C101	Classical Mechanics	4	100
	PHY-PG-C102	Quantum Mechanics	4	100
	PHY-PG-C103	Mathematical Physics	4	100
	PHY-PG-C104	Practical I	4	100
II	PHY-PG-C201	Electromagnetic Theory	4	100
	PHY-PG-C202	Statistical Physics	4	100
	PHY-PG-OE203	Open Elective I	4	100
	PHY-PG-C204	Practical II	4	100
III	PHY-PG-C301	Solid State Physics	4	100
	PHY-PG-C302	Advanced Quantum Mechanics and EMT	4	100
	PHY-PG-OE303	Open Elective II	4	100
	PHY-PG-C304	Practical III	4	100
IV	PHY-PG-C401	Nuclear & Particle Physics	4	100
	PHY-PG-E402	Elective I	4	100
	PHY-PG-E403	Elective II	4	100
	PHY-PG-C404	Project Work	4	100

SEMESTER I
PHY-PG-C101: CLASSICAL MECHANICS

Unit I: Lagrangian& Hamiltonian Formalism

Hamilton principle-derivation of Lagrange equations. Simple applications of Lagrangian formulation, generalized momenta, cyclic coordinates, Routh's procedure, symmetry properties and conversation laws.

Hamilton equations of motion, preservation of phase volume under Hamilton flow (Liouville theorem), canonical transformations, generating functions, Poisson brackets, applications to simple problems.

Unit II: Applications

Hamilton-Jacobi equation, harmonic oscillator problem as an example, separation of variables in the Hamilton-Jacobi equation, action-angle variable, Solving Kepler's problem by HJ method.

Central force problem, Kepler's problem, inverse square law of forces, scattering in central force field, Rutherford formula, Virial theorem.

Unit III: Rigid Bodies

The kinematics of rigid body motion, Euler angles, infinitesimal rotations, the Coriolis force, rigid body equations of motion.

Unit IV: Small Oscillations & Chaos

Theory of small oscillations, normal modes of the system.

Non-linear equation of motions; phase diagram, simple examples like Duffing and van der Pol oscillators

Basic idea of chaotic solutions; fixed points and attractors; bifurcations; strange attractors; logistic maps, fractal dimensions and Lyapunov exponent.

Reference Books:

1. H. Goldstein, C. Poole and J. Safko: *Classical Mechanics*, 3rd Ed, Pearson Education (2002).
2. J. B. Marion: *Classical Mechanics of Particles and Systems*, Academic Press, (1999)
3. Rana and Joag: *Classical Mechanics*, Tata Mcgraw Hill, (1991)
4. A.K. Raychaudhuri: Classical Mechanics: A Course of Lectures, OUP, India 1983
5. MG Calkin, Lagrangian and Hamiltonian Mechanics; World Scientific Publishing Co Pte Ltd (18 March 1999)

PHY-PG-C102: Quantum Mechanics

Unit I: Exactly Solvable Problems

One dimension: Postulates of Quantum Mechanics. Free particle, position space and momentum space wave function, Heisenberg uncertainty relation, expectation values. Schrodinger equations, equation of continuity. Particle in a box, simple harmonic oscillator (ladder operator and wave functions), Ehrenfest theorem. classical limit.

Three dimension: Rotational Invariance and angular momentum, eigenstates and eigenvalues of angular momentum operators. Separation of variables, spherical harmonics. Particle in central force, free particle in spherical polar coordinate, hydrogen atom.

Unit II: Approximation Methods

Time independent perturbation theory, non-degenerate and degenerate cases, fine structure and Zeeman Effect (without spin), Stark effect, Fine structure, hyperfine structure, Lamb shift.

Approximation methods: WKB approximation, validity of WKB approximation, alpha emission. Variational method, ground state of helium atom.

Unit III: Interaction with radiation and identical particle

Time dependent Perturbation Theory:Heisenberg and Interaction pictures. Two state problem. First order perturbation, constant and periodic perturbation, sudden and adiabatic perturbation. Higher order perturbation. Transition rate, Fermi's Golden rule.

Dipole approximation, photoelectric effect, Absorption and stimulated emission, spontaneous emission, Einstein's A and B coefficient.

Identical Particles and Spins: Indistinguishability, symmetric and anti-symmetric wave functions, Pauli exclusion principle, electron spin functions, the helium atom, Spin angular momentum, Addition of angular momenta, Clebsch-Gordon coefficients, LS and JJ couplings.

Hartee-Fock method and self-consistent field.

Unit IV: Scattering Theory

One dimensional scattering by barrier, reflection and transmission coefficient. Three dimensional scattering, Lippman-Schwinger equation, Born approximation, optical theorem. Higher order Born approximation.Plane wave vs. spherical wave, method of partial wave analysis, scattering by hard sphere, attractive well and repulsive barrier potential. Low energy scattering and bound states, resonances. Coulomb scattering.

Text Books:

1. E. Merzbacher: *Quantum Mechanics*, 3rd Edition, John Wiley & Sons (2003)
2. J. J. Sakurai: Modern *Quantum Mechanics*, Pearson Education, Reprint(1967)
3. R. Shankar: Principles of Quantum Mechanics, Springer, 2ndedn. (1994).
4. P. T. Mathews and S. Venkatesan: *Textbook on Quantum Mechanics*, McGraw Hill (2002)
5. David J Griffiths, Introduction to Quantum Mechanics, Pearson Education, second edition, 2015

Reference Books:

1. L. I. Schiff: *Quantum Mechanics*, 3rd Edition, Mc Graw Hill Intl. Edition (1988)
2. J. M. Ziman: *Elements of Advanced Quantum Theory*, Cambridge University Press.(1975).
3. J. Powell and B. Crasemann: *Quantum Mechanics*, Narosa Publishing House, (1998).
4. R. Eisberg and R. Rensick: *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* (2nd Ed), John Wiley & Sons, (2003).

1. A. Ghatak and S. Lokanathan: *Quantum Mechanics (Theory and Application*) (4th Ed), Macmillan (2003).
2. L. D. Landau and L. M. Lifshitz: *Quantum Mechanics*: *Non-relativistic Theory*, Butterworth-Heinemann, 3rdEdn. (1981)..
3. K. Thankappan: *Quantum Mechanics*, New Age Intl. Pub (1996)
4. S. Gasiorowiz: *Quantum Mechanics*, Wiley (1995)
5. P. A. M. Dirac: Principles of Quantum Mechanics, Dover Publications
6. R. P. Feynman,: Feynman lectures on physics - volume III, Pearson
7. F. Schwabl: *Quantum Mechanics*, Narosa Pub. House (1998).

PHY-PG-C103: MATHEMATICAL PHYSICS

Unit I: Complex Analysis

Geometrical representation of complex numbers.Functions of complex variables, differentiation. Properties of analytical functions, Cauchey-Riemann conditions. Contours and contour Integration in complex plane, Cauchy theorem, Cauchy integral Formula. Taylor and Laurent series representation, Features of singular points, poles. Residues, Cauchy residue theorem. Applications of the residue theorem.

Unit II: Linear Algebra

Vector Spaces, linear independence, spanning set and basis, Linear operators, representations of vectors and linear operators with respect to bases and change of basis,.Inner Product space (Field of C-No.), Hermitian operators. Eigen values and eigenvectors and their determination, diagonalization of linear operators and matrices.

Unit III: Integral Transforms & Special Functions

Fourier transforms, Laplace transforms.Fuch's theorem, Frobenius method of series solution.

Bessel's, Legendre's, Hermite's and Laguerre's differential equations and solutions: Generating function, Rodrigue's formula, orthogonality. recurrence Associated Legendre and Laguerre polynomials, Green's function

Unit IV: Group Theory

Definitions and examples of physically important finite groups. Multiplication table, Homomorphism and Isomorphism. Subgroups, Cyclic groups, Center. Classes, Cosets, Factor groups. Representation, reducible and irreducible representation, Character table. Simple applications. Introduction to Lie groups.

Text Books:

1. H.J. Weber and G. B. Arfken: *Mathematical Methods for Physicists*,Academic Press6th Ed. (2005). ISBN-10: 0120598760 ISBN-13: 978-0120598762
2. Murray R. Spiegel: *Complex Variables*, Mc Graw Hill (1964). ASIN: B000LC6GMS

3. R. V. Churchill: *Complex Variables & Applications*, Mc Graw Hill Inc. 2nd Edn. (1960). ISBN-10: 0070108536 ISBN-13: 978-0070108530 1.
4. Lipschutz-Lipson: Schaum's outline of theory and problems of linear algebra: Tata McGraw Hill
5. S. Sternberg: Group Theory and Physics, Cambridge Univ. Press, (1994).

Reference Books:

8. P. Dennery and A. Kryzywicki: *Mathematics for Physicists,* Dover Publications, (1996).
9. K. F. Riley: Mathematical Methods for Physics and Engineering, CUP, New York (2002)
10. *B. D. Gupta: Mathematical Physics, Vikas Pub. House, New Delhi (2004).*
11. C. Harper : Introduction to Mathematical Physics, Prentice HallText Books:
12. J Mathews and R L Walker, Mathematical Methods for Physics, Addison-Wesley publishing company Inc. 1973
13. R. R. Halmos: *Finite-Dimensional Vector Spaces,* Springer, (1993).
14. C. Birkhoff and G.C. Rota, Ordinary Differential Equations (4th Ed), John Wiley &Sons, 2003.
15. Forsythe : A Treatise on Differential Equations, CBS(1995)
16. R. L. Rabenstein: Ordinary differential equations, Cambridge University Press, (2004)
17. G. Stephenson: Partial Differential Equation for Scientists and Engineers, World Scientific Publishing Company, (1996).
18. M. Hamermesh: Group Theory and its Application to Physical Problems, Addison-Wesley Publishing Company, (1962).

PHY-PG-C104: PRACTICAL I

[Minimum 5 experiments from Electronics Lab to be performed. Another minimum of 5 problems are to be solved in the computational lab.]

Electronics Lab:

There should be few lectures covering the relevant topics for the working of the following listed experiments.

1. Clipping and Clamping Circuits
2. Wien's Bridge Oscillator
3. F.E.T
4. Op-Amp (741)
5. Multivibrators
6. Semiconductor sensor
7. External effects on semiconductor devices (temperature, magnetic field, radiation etc)
8. Multiplexer and Seven Segment Display
9. J-K flip-flop and Up Down Counters
10. Adder/Substractor and Decoders

Computational Lab:

The purpose of this lab session is to train the students to solve the real life physical problems computationally. There will be few lectures covering the following topics:

Representing numbers in a computer, machine precision, Errors and approximations. Concept of computer language.

Fortran 90, Program structure, Data Types, Arithmatic Operators, Intrinsic functions, I/O, Arrays, Control Statements, Formatted I/O, File processing, Subprograms, Subroutines.

Introduction toMatlab, Mathematical functions, Basic plotting, Matrix generation, Array equations and Linear equations, Programming in Matlab, Script files, Function files, Control flow and operators, Saving output to a file

Introduction to Mathematica, Symbolic expressions, simple plot,

Matrices as list, Logical expressions, Functions and programming.

The students will require to make programmes to solve the real life applications. The course instructor will provide the relevant problems.

References:

Electronics Lab:

1. A. S. Sedra and K. C. Smith, *Electronics Circuits*, (6thEdn), Oxford University Press (2009)
2. R. Gaekwad, *Op-Amps and Linear Integrated Circuits*, (4^{th}Edn) Prentice Hall of India (2002).
3. Millman&Halkias, *Integrated Electronics: Analog & digital circuits systems,* Mc Graw Hill, 1972.
4. D. P. Leach, A. P. Malvino and G. Saha, *Digital Principles and Applications* (6^{th}Edn), Tata McGraw Hill (2007)
5. H. S. Kalsi, *Electronic Instrumentation*, Tata McGraw Hill Education, 2012.

Computational Lab

1. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling: *Numerical Recipe in Fortran,* Cambridge University Press India Ltd (2000)
2. G. Lindfield and J. Penny: *Numerical Methods: using Matalab*, Academic Press (2012)
3. R. Pratap: *Getting Started with MATLAB 7*, Oxford University Press, 2006.
4. S. Wolfram, Mathematica: *A System for doing mathematics by Computer*, Addison. Wesely, 1991
5. V. Rajaraman*: Computer based Numerical Methods* , Prentice Hall India, 1980,
6. N. Boccara: *Essentials of Mathematica*, Springer, 2009.
7S. Attaway: *MATLAB: A Practical Approach*, Elseiver, 2009.
8.A. Gilat: *MATLAB: an Introduction with applications*, John Wiley Sons, 2004.

Semester II

PHY-PG-C201: ELECTROMAGNETIC THEORY

Unit I: Electrostatics

Equations of electrostatics in differential and integral forms. Potential and field due to point charges and continuous charge distributions. Boundary value problems and their solutions by separation of variables, method of images and Green's functions. Multipole expansion: Electric dipole and quadrupole moments.

Electrostatics and dielectrics: Polarization and bound charge, displacement field, Poisson's equation in a uniform linear dielectric. Boundary value problems with dielectrics.

Unit II: Magnetostatics

Electric Current as a source of magnetic field, Equations of magnetostatics in differential and integral forms, Vector potential, magnetic dipole, multipole expansion of vector potential

Magnetic fields and matter: magnetization and bound currents, Amperes law for free currents and H, Boundary Conditions, magnetic scalar potential.

Unit III: Time varying fields & Maxwell's equations

Electromotive force, Faraday's Law of induction. Maxwell's displacement current and Maxwell's equations, covariant formulation of Maxwell's equations, Boundary conditions, Electromagnetic field energy, vector and scalar potentials, Wave equations, Gauge transformations, Poynting's theorem, Conservation laws.

Unit IV: Plane electromagnetic waves

Properties of the electromagnetic wave equations in different media (vacuum, conductor, plasma and waveguides). Rectangular waveguides and resonant cavities. Reflection and refraction of electromagnetic waves at the interface of non-conducting media.

Text Books:

1. D. J. Griffiths: *Introduction to Electrodynamics* (3^{rd} Ed.), Pearson Edn., (2002)
2. J. D. Jackson: *Classical Electrodynamics* ,Wiley Eastern, (2003)
3. G. L. Pollack, D. Stump and D. R. Stump: Electromagnetism, Addison-Wesley (2001).
4. W. H. Hayt, Jr. J. A. Buck: Engineering Electromagnetics, The McGraw-Hill (2001).

PHY-PG-C202: STATISTICAL PHYSICS

Unit I: Thermodynamic laws and functions

Entropy, Free energy, Internal Energy, Enthalpy, Chemical Potential, Systems with large number of degrees of freedom, Micro and macro states, Phase space of a classical system, Density of states, Liouville's Theorem.

Unit II: Basic principles of ensembles

Micro-canonical, Canonical and Grand canonical ensembles, Concept of ensemble average, Equation of state, specific heat and entropy of a classical ideal gas, Gibb's paradox and its resolution, Energy and Density fluctuations, Virial and equipartition theorems, Partition function, Determination of translational, rotational and vibrational motions to the partition functions of an ideal diatomic gas.

Unit III: Quantum Statistics

Inadequacy of classical theory, Quantum mechanical ensemble theory, density matrix, Ensembles in quantum statistical mechanics, Ensembles of ideal Boltzman, Bose-Einstein and Fermi gas, Identical particles, quantum distribution functions, Bose-Einstein and Fermi-Dirac statistics, Grand partition function for ideal Bose and Fermi gas.

Unit IV: Ideal Bose & Fermi Systems

Thermodynamics of Black body radiation, Stefan-Boltzman law, Wien's Displacement Law, Ideal Bose System: Thermodynamic behaviour of ideal Bose gas, Bose-Einstein condensation

Thermodynamic behaviour of an ideal Fermi Gas, Degenerate Fermi Gas, Fermi Energy and Mean Energy, Fermi Temperature, Fermi Velocity of a particle of a degenerate gas, Compact stars.

Text Books:

1. R. K. Patharia: *Statistical Mechanics* (2nd Ed) Butterworth Heinman, Elsevier (2005)
2. K. Huang: *Statistical Mechanics* (2nd Ed) John Wiley & Sons (2002)
3. K. Huang, *Introduction to Statistical Physics*, Taylor & Francis (2001).
4. F. Reif: *Statistical and Thermal Physics*, McGraw Hill (1985).
5. T. Guenault: *Statistical Physics* (2nd Ed), Kluwer Academic (1995).
6. S. Lokanathan and R.S. Gambhir, *Statistical and Thermal Physics*, Prentice Hall, (2000).

Reference Books:

7. B. B. Laud: *Fundamentals of Statistical Mechanics*, New Age Intl. Publishers (1998)
8. L. D. Landau and E. M. Lifshitz: *Statistical Physics*, Part I & II, Butterworth and Heinman, (1980).
9. B.B. Laud, Fundamentals of Statistical Mechanics, New Age International Publishers, 1998.
10. E.M. Lifshitz and L.P. Pitaevskii, Statistical Physics (Part 2), Butterworth-Heinemann (1980).

PHY-PG-C204: PRACTICAL II

[Minimum 10 experiments to be performed from the following list]

1. Fibre Optics
2. Fresnel Diffraction
3. Photoconductivity
4. Stefan's Law
5. Dielectric Constant
6. Ultrasonic Diffraction
7. Hall Effect
8. Planck's Constant
9. Michelson Interferometer
10. Susceptibility of Paramagnetic Solution
11. Hydrogen Spectrum and Rydberg Constant
12. Single Slit, Double Slit, Grating and Thin Wire Diffraction
13. Foaming and Foam Stability

SEMESTER III

PHY-PG-C301: SOLID STATE PHYSICS

Unit I: Crystal Structure

Simple crystal structures, atomic scattering factor, Structure factor, Bragg's law, Direct and reciprocal lattice, Laue diffraction, neutron diffraction, electron diffraction, crystal structure determination by Laue, powder and rotating crystal methods. Concept of point groups and space groups, Influence of symmetry on physical properties.

Unit II: Defects and Lattice Vibrations

Defects in Solids, Grain and twin boundaries, Point Defects, line defects and planar defects or dislocations and their effects on solid state properties, colour centres. Lattice vibrations, phonons and dispersion relations for acoustical and optical lattice vibrations in crystals (mono and diatomic linear lattice), phonons, normal and Umklapp processes, anharmonic vibrations, thermal expansions and thermal conductivity. Bloch theorem, Brillouin zones for simple lattices, crystal momentum, effective mass of electrons and holes, ideas of Fermi surfaces, band structure of simple elements.

Unit III: Electric polarization and Band Structure

Electric polarization, Static dielectric constant, complex dielectric constant, dielectric loss, dielectric relaxation, Debye equations, classical theory of electronic polarization, ferroelectricity, ferroelectric domains, anti-ferroelectricity. Electronic band structure calculations: Tight-binding method, pseudo potentials and Augmented Plane Wave (APW) methods, nearly free electron approximation, OPW, Fermi surfaces (FS), effects of electric and magnetic field on FS, de Haas van Alfen effect, Cyclotron resonance, anomalous skin effect.

Unit IV: Magnetism and Superconductivity

Magnetism, Diamagnetism; Paramagnetism (Quantum treatment); Crystal-field effects; John-Teller effects; Adiabatic demagnetization; Molecular field theory of ferromagnetism; Heisenberg-exchange interaction; Spin Waves; Ginzburg-Landau theory of the ferromagnetism; Shape, Origin and observation of ferromagnetic domains; Dynamic Phenomena : Linear Response Theory, Hall effect, quantum Hall effect.

Superconductivity: Phenomenological thermodynamic treatment, intermediate state, London's equations and penetration depth, Type I & II superconductivity, quantized flux, coherence length. Ginzburg-Landau theory, variation of the order parameter and the energy gap with magnetic field, isotope effect; Energy gap and its measurement; electron-phonon interaction and Cooper pairs, B.C.S. theory, dc and ac Josephson effects, critical currents of type-II superconductors.

Text Books:

1. 1. C. Kittel: *Introduction to Solid State Physics*, 7th Ed. Wiley (1996)
2. N. W. Ashcroft & N.D. Mermin: *Solid State Physics*, Harcourt Asia, 1st ed. (2001)
3. A. J. Dekker: Solid State Physics, Macmillan (2003).
4. L. V. Azaroff: Introduction to Solids, Tata McGraw-Hill (2002).
5. DG Pettifor: Bonding and Structure of Molecules and Solids, Oxford University Press; First Edition edition (December 7, 1995)
6. C Kittel, Quantum Theory of Solids,: Wiley 1987
7. H Ibach and H Luth, Solid-State Physics: An Introduction to Principles of Materials Science: 4th Ed. Springer 2009
8. S Blundell: Magnetism in Condensed Matter, OUP Oxford (4 October 2001)
9. James Patterson and Bernard Bailey, Solid-State Physics: Introduction to the Theory, Springer; 2nd ed. 2010 edition (January 11, 2011)

PHY-PG-302: Advanced QM and EMT

Unit I: Relativistic Quantum Mechanics

Klein-Gordon equation, probability density and probability current density, solution of free particle Klein-Gordon equation in momentum representation. Dirac equation, solution of free particle. Interpretation of negative probability density and negative energy solutions. Interaction with em field. Inadequacy of Relativistic Quantum Mechanics, requirement of Field theory.

Unit II: Quantisation of Fields

Classical field theory, Lagrangian and Hamiltonian formulations. Real and Complex scalar and Dirac fields. Symmetry and conservation, Noethers theorem.

Quantisations of scalar field, creation, annihilation and number operators, Fock space, momentum and Hamiltonian operator, time ordering, Green's functions, Feynman propagator. Quantisation of Dirac field, anti commutation, propagators

Unit III: Radiating fields

Retarded potentials, Lienard-Wiechert potentials. Radiation from a moving point charge, oscillating electric and magnetic dipoles. Multipole expansion for radiation fields, radiation from antennas. Dispersion, Lorentz's dispersion equation. Transformations of electromagnetic fields under Lorentz transformations, Covariant formalism of Maxwell's equations

Unit IV: Waves in plasma

Introduction to plasma, criteria for plasma, Debye's screening. Single particle motions, magnetic mirrors. Magnetohydrodynamics and fluid equations of motion. Plasma oscillations, electron plasma waves, Langmuir waves and ion sound waves, Alfven waves, magnetosonic waves. Nonlinear phenomena in plasma.

Text Books:

1. R. Shankar: Principles of Quantum Mechanics, Springer, 2nd edn. (1994).
2. J. S. Townsend: Modern Approach to Quantum Mechanics, University Science Books, California (2000)
3. J. J. Sakurai: Advanced *Quantum Mechanics*, Pearson Education, Reprint(1967).
4. M. Peskin and D. V. Schroeder: Introduction to Quantum Field Theory (Frontiers in Physics), Westview Press, (1995).
5. D. J. Griffiths: *Introduction to Electrodynamics* (3rd Ed.), Pearson Edn., (2002)
6. J. D. Jackson: *Classical Electrodynamics*,Wiley Eastern, (2003)
7. G. L. Pollack, D. Stump and D. R. Stump: Electromagnetism, Addison-Wesley (2001).
8. F. F. Chen: *Introduction to Plasma Physics and Controlled Fusion*, vol. I: plasma physics, 2nd edition, Springer, 1984.
9. R. J. Goldston and P. H. Rutherford: *Introduction to Plasma Physics*, Institute of Physics, London, 1995.

Reference Books:

1. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Mechanics, McGraw Hill Education, Edition 1 (2013).
2. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Fields, Dover Publications Inc., (2013).
3. Steven Weinberg, Quantum Theory of Fields, Cambridge University Press, 2008.
4. T-Y Wu and W-Y P. Hwang: *Relativistic Quantum Mechanics and Quantum Field,*World Scientific Publishing Co., (1991).
5. Claude Itzykson & Jean Bernard Zuber: Quantum Field Theory, Dover publications Inc. (2006).
6. Sylvan S. Schweber, An Introduction to Relativistic Quantum Field Theory, Dover Publications Inc. , (2005).
7. Franz Mandl and Graham Shaw, Quantum Field Theory, Wiley-Blackwell; 2nd Revised edition edition (9 April 2010)
8. Lewis H. Ryder, Quantum Field Theory, Cambridge University Press (2008)
9. G. L. Pollack, D. Stump: Electromagnetism, Addison-Wesley (2001).

PHY-PG-C304: PRACTICAL III

1. Four Probe
2. Electron Spin Resonance (ESR)
3. Converters: (A to D) & (D to A)
4. Automation
5. Knife edge and Polarisation (QW plate, Half wave plate)
6. Ionization potential
7. Specific heat of solids
8. Zeeman Effect
9. Raman effect
10. Emission and absorption
11. Laser Doppler Anemometry
12. Microprocessor
13. Faraday Rotation

SEMESTER IV

PHY-PG-C401: NUCLEAR & PARTICLE PHYSICS

Unit I: Nuclear Physics

Properties of nuclear forces-deuteron problem, n-p scattering.Nuclear models, liquid drop model, shell model and collective Model.

Radioactivity, Alpha Decay, Beta Decay, Fermi Theory, Gamma Decay and internal Conversion, selection rules.

Unit II: Elementary Particles

Elementary particles, their quantum numbers and their weak, strong and electromagnetic interactions, quarks and leptons, quark model of hadrons, standard model.

Relativistic kinematics; Symmetries and conservation laws; P,C and T discrete symmetries; CP violation.

Unit III: Quantum Electrodynamics

Lagrangian formulation of relativistic theory: Dirac equation and trace theorems. Perturbation expansion of correlation functions, Wick's theorem, Feynman diagrams. Cross sections and S-matrices, Feynman rules for QED, elementary processes

Unit IV: Gauge Theory

Gauge symmetry, local gauge invariance, Yang-Mills theory, Spontaneous symmetry breaking, Higgs mechanism. One loop structure, renormalization prescriptions, Ward identities.

Text Books:

1. S N Ghoshal: Nuclear Physics, S. Chand and Co. Ltd. 2010, ISBN-10: 8121904137ISBN-13: 978-8121904131.
2. R. Roy and B.P. Nigam: Nuclear Physics (Theory & Experiment), New Age Intl., (1967).
3. D. J. Griffiths: Introduction to Elementary Particles, John Wiley & Sons (1987).
4. Francis Halzene & Alan D. Martin: Quarks & Leptons: An introductory course in modern particle physics, Wiley, 2008, ISBN-10: 8126516569; ISBN-13: 978-8126516568
5. Ta Pei Cheng & Ling-Fong: Gauge theory of elementary particle physics, Oxford University Press, 1984, ISBN-10: 0198519567, ISBN-13: 978-0198519560
6. Ian J R Aitchison & Anthony J G Hey: Gauge theories in particle physics: A practical introduction, CRC Press, 2013 ISBN-10: 1466513179ISBN-13: 978-1466513174.
7. M. Peskin and D. V. Schroeder: Introduction to Quantum Field Theory (Frontiers in Physics), Westview Press, (1995).

Reference Books:

1. S. Krane: Introductory Nuclear Physics, John Wiley, (1988).
2. Emilio. Segre: Nuclei and Particles: An introduction to nuclear and subnuclear physics, Dover, (2013).
3. W. E. Burcham: Elements of Nuclear Physics, Longman, (1986).
4. W. N. Cottingham and D. A. Greenwood: An Introduction to Nuclear Physics. Cambridge University Press, 2nd Edn. (2001).
5. W. Greiner and A. Schafer, Quantum Chromodynamics, Springer-Verlag, (1994).
6. F. J. Yndurain: The Theory of Quarks & Gluon Interactions, Springer-Verlag, (1999).
7. M. K. Pal, Theory of Nuclear Structure, Affiliated East-West, 1982
8. P. Marmier and E. Sheldon: Physics of Nuclei and Particles, Vol.I & II, Academic Press, (1969).

PHY-PG-C404: PROJECT WORK

A student's project work should be a guided study of an advanced topic not covered in the curriculum. It is expected that the student learns and applies some of the techniques and knowledge taught in the class through this Project Work. The main objective of the Project Work is to provide students with skill and knowledge in conducting research in fundamental and application aspects of physics/allied fields. Proper acknowledgement and permission of unavoidable earlier published work must be given in the thesis. If any kind of plagiarism is practised by the student, his/her dissertation or project work shall be liable to be rejected.

The Project Work will be evaluated at the end of the semester by an evaluation committee consisting of the following four members: Head of the Department, the Supervisor, an Internal Examiner and an External Examiner.

Textbooks:

1. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling: *Numerical Recipe in Fortran,* Cambridge University Press India Ltd (2000)
2. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling: *Numerical Recipe in C,* Cambridge University Press India Ltd (2007)
3. G. Lindfield and J. Penny: *Numerical Methods: using Matalab*, Academic Pres (2012)
4. R. Pratap: *Getting Started with MATLAB 7*, Oxford University Press, 2006.
5. S. Wolfram, Mathematica: *A System for doing mathematics by Computer*, Addison. Wesely, 1991.

Reference Books:

1. K. R. Rao, Do Nyeon Kim, Jae Jeong Hwang: *Fast Fourier Transform-Algorithms and Applications,* Springer (2012)
2. V. Rajaraman*: Computer based Numerical Methods* , Prentice Hall India, 1980,
3. N. Boccara: *Essentials of Mathematica*, Springer, 2009.
4. S. Attaway: *MATLAB: A Practical Approach*, Elseiver, 2009.
5. A. Gilat: *MATLAB: an Introduction with applications*, John Wiley Sons, 2004.

Open Elective Papers
Open Elective I for Semester II

PHY-PG-OE203A: NANO AND SOFT MATERIALS

Unit-I Nanomaterials and their properties

Introduction to nanotechnology. Various kinds of Nanostructures-Carbon fullerenes and nanotubes, Metal and metal oxide nanowires, Self-assembly of Nanostructures, Core-shell nanostructures, Nanocomposites. Thermodynamics of Nanomaterials. Physical Properties of nanomaterials - Photocatalytic, Dielectric, Magnetic, Optical, Mechanical.

Unit-IISynthesis of Nanomaterials

Bottom up and top down approaches. Synthetic methodologies including Sol-gel, Micromulsion, CVD,PVD,Molecular beam epitaxy, Vapor (solution)-liquid-solid growth, (VLS or SLS), Spray Pyrolysis, Template based synthesis, Lithography, Laser ablation.

Unit-IIICharacterization Techniques and Applications

Absorption and PL spectroscopy, Electron Microscopic techniques, X-ray and electron diffraction, AFM, Auger Electron Spectroscopy, X-ray Photoelectron Spectroscopy. Applications of Nanomaterials.

Unit IV: Soft Materials

Introduction to Soft Condensed Materials and their properties: Plastic and Liquid Crystals, Thermotropic (Nematic, Smectic and Discotic) and Lyotropic Liquid Crystals; Surfactants and Polymers; Colloids: Foams, Gels and Microemulsions; Biomaterials; Applications of Soft Materials

References:

1. Guozhong Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press 2004.
2. T. Pradeep, Nano: The Essentials Understanding nanoscience and nanotechnology, Tata McGraw- Hill Publishing Company Limited NEW DELHI, 2007.
3. Nanomaterials Synthesis, Properties and Applications Edited by A S Edelstein and R C Cammarata, IOP Publishing Ltd 1996.
4. Principles of Condensed Matter Physics, Chaikin and Lubensky, Cambridge University Press 1995.
5. The Physics of Liquid Crystals, P-G de Gennes, J Prost, Oxford University Press, 1994.

PHY-PG-OE203B: RENEWABLE ENERGIES (SOLAR AND HYDROGEN)

Unit I: Solar Energy

Fundamentals of photovoltaic energy conversion Physics and material properties basic to photovoltaic energy conversion: optical properties of solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

Unit II:Types of Solar Cells

p-n junction solar cell, transport equation, current density, open circuit voltage and short circuit current, brief descriptions of single crystal silicon and amorphous silicon solar cells, elementary ideas of advanced solar cells e.g. tandem solar cells. Solid liquid junction solar cells, nature of Semiconductor, electrolyte junction, principles of photo electrochemical solar cells.

Unit III:Hydrogen Energy & Production

Relevance in relation to depletion of fossil fuels and environment considerations. Solar Hydrogen through photo electrolysis and photo catalytic process. Physics of material characteristics for production of solar hydrogen.

Unit IV: Storage and Safety

Brief discussion of various storage processes, special features of solid state hydrogen storage materials, structural and electronic characteristics of storage materials. New Storage Modes. Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular Transport, Hydrogen for Electricity Generation, Fuel Cells, Elementary concepts of other Hydrogen Based devices such as Air Conditioners and Hydrides Batteries.

Text Books:

1. GD. Raj: *Solar energy utilization*, Khanna Publishers, New Delhi, 2005.
2. H.P. Garg and J Prakash: *Solar Energy: Fundamental and Applications,* Tata McGraw Hill, 2000.
3. Charles E.: *Solar cells,* IEEE Press, 1976.
4. K. L. Chopra and S. Ranjan Das: *Thin film solar cells,* Plenum, New York, 1983.

PHY-PG-OE203C: Numerical Methods and Computational Physics

Unit I: Roots of Equations:

Roots of Nonlinear Equations: Bisection, Newton-Raphson, secant method. System of Nonlinear equations, Newton's method for Nonlinear systems. Applications in Physics problems.

Solution of linear systems: Gauss, Gauss-Jordan elimination, matrix inversion and LU decomposition. Eigenvalues and Eigenvectors. Applications.

Unit II: Interpolation and Curve fitting:

Introduction to interpolation, Lagrange approximation, Newton and Chebyshev polynomials. Least square fitting, linear and nonlinear. Applications in Physics problems.

Unit III Numerical Differentiation & Integration:

Approximating the derivative, numerical differentiation formulas, Numerical Integration: Quadrature Formula, trapezoidal and Simpson's rule, Gauss-Legendre integration. Applications.

Unit IV: Solution of ODE: Initial value and boundary value problems, Euler's and Runge-Kutta methods, Finite difference method. Applications in Chaotic dynamics, Schrodinger equations. Solution of PDE: Hyperbolic, Parabolic, and Elliptic Equations by finite difference. Application to 2-dimensional Electrostatic Field problems.

Text Books:

1. K. E. Atkinson, Numerical Analysis, John Wiley (Asia) (2004).
2. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, Tata McGraw Hill (2002).
3. R.J. Schilling and S.L. Harries, Applied Numerical Methods for Engineers using MATLAB and C, Thomson Brooks/Cole, (2006).
4. S.S. Sastry, Introductory methods of Numerical analysis, Prentice Hall India,(2012).

References:

1. J. H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, Prentice Hall of India (1998).
2. S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).
3. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling: *Numerical Recipe in C,* Cambridge University Press India Ltd (2007)
4. W. H. Press, B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling: Numerical Recipe in Fortran ,Cambridge University Press India Ltd (2000)
5. G. Lindfield and J. Penny: Numerical Methods: using Matalab, Academic Pres (2012)
6. S. Wolfram, Mathematica: *A System for doing mathematics by Computer*, Addison. Wesely, (1991).

Open Elective II for Semester III
PHY-PG-OE303A: SPACE PHYSICS

Unit I: Motion of plasma particles and models

Characteristics of a plasma, Plasmas in space. Particle orbit theory: particles in constant external fields, guiding centre drifts, nonuniform magnetic fields, gradient and curvature drifts, magnetic bottling. Adiabatic invariatns. Models to study plasma: kinetic, fluid and MHD models, Boltzmann equation, Vlasov equation, Fokker-Planck equation. Ideal MHD.

Unit II: Waves in Plasmas

Linearized MHD equations. Magnetohydrodynamic waves: Alfven waves, magneto-sonic waves, MHD waves oblique to the field. Electrostatic waves in non-magnetic plasmas: plasma oscillations, Langmuir waves, ion-acoustic waves. Electrostatic waves in magnetized plasmas: upper hybrid frequency, lower hybrid frequency, ion cyclotron waves. Electromagnetic waves in non-magnetized and magnetized plasmas.

Unit III: Space Plasmas

Sun and Solar Wind: Structure of the Sun, Solar neutrinos, solar atmospheres, coronal magnetic field. Solar wind model. Coronal heating and solar wind acceleration, A simple model of the solar cycle. Stellar activity. Flares and coronal mass ejections. Interplanetary shocks. Energetic particles in the heliosphere. Turbulence and stochastic acceleration. Interplanetary magnetic field. Plasma waves in interplanetary space. Planetary magnetospheres and their comparisons.

Unit IV: Sun-Earth Connection and Instrumentation

Terrestrial Magnetosphere: Geomagnetic field, Structure of the Magnetosphere. Interaction of the solar wind with the terrestrial magnetic field. Formation of aurora. Magnetospheric currents. Magnetic activity and substorms. Solar activity and its effect to climate and culture. Energetic particles and the atmosphere.

Instruments to measure fields and waves. Plasma instruments. Energetic particle instruments. Supplementary ground-based observations

Text Books:

1. May-Britt Kallenrode: *Space Physics: An Introduction to plasmas and Particles in the Heliosphere and Magnetospheres,* 3rd Ed. Springer, 2004.
2. Tamas I. Gombosi: *Physics of the Space Environment*, Cambridge University Press, 1998.
3. J. T. Houghton: *The Physics of Atmosphere*, Cambridge University Press, 3rd Edn. (2001).
4. Margaret G. Kivelson Christopher T. Russell: *Introduction to Space Physics*, Cambridge University Press, 1996.
5. George K. Parks: Physics of Space Plasmas: An Introduction, 2nd Ed., Westview Press, 2004.
6. Thomas E. Cravens: Physics of Solar System Plasmas, Cambridge University Press, 2004.

PHY-PG-OE303B: BIOPHYSICAL TECHNIQUES

Unit I: Light scattering and Electron Microscopy

Elastic and inelastic scattering, light scattering by macromolecules, dynamic light scattering, radius of gyration and molecular mass. Transmission and scanning microscopy, negative staining, cryo-electron microscopy.

Unit II: Chromatography and Mass spectrometry

Electrospray MS, MALDI, applications. Paper Chromatography, TLC, column, gas-liquid, ion-exchange, size-exclusion and affinity chromatographies, HPLC and FPLC, applications to macromolecules.

Unit: III: IR and Raman spectroscopy

Rotational and vibrational spectra, oscillator, molecular symmetry, optical density, investigations of molecular structure, hydrogen bonding. Examples and comparison of IR and Raman spectra, resonance Raman spectroscopy

Unit IV: Absorption, Fluorescence and NMR Spectroscopy

UV and Visible spectra, chromophores, Circular Dichroism and Optical Rotatory Dispersion, cotton effect, applications to proteins and nucleic acids, Frank-condon principle, classical picture, resonance condition, Bloch condition, relaxation phenomenon, Fourier transform technique. NMR, chemical shifts, coupling constraints, Karplus equation, analysis of simple NMR spectra, Nuclear Overhauser Effect, proton magnetic resonance, 13C and 31P spectra.

Text Books:

1. K.Wilson and K. H. Gouldberg: *Principles and Techniques of Bochemistry*, Edward Arnold (Publishers) Ltd, London, UK, (1986).

2. K. E. van Holde: *Physical Biochemistry,* Prentice-Hall Inc., New Jersey, USA, (1971)
3. D. Freifelder: *Physical Biochemistry*, W.H.Freeman and Company, NewYork, USA, (1982).

Reference Books:

1. C. R. Cantor and P. Schimmel: *Biophysicsal Chemistry*, Vol 1, W. H. Freeman and Company, NewYork, USA. (1985).
2. L. Stryer: *Biochemistry*. W.H.Freeman and Company, NewYork, USA, (1995).

PHY-PG-OE303C: COGNITIVE SCIENCE

Unit I: Introductionand Cognitive Psychology

Historical overview, Analyzing Information processes at several levels, Interdisciplinary nature of cognitive science, Application related system in the Cognitive Science.

Nature of cognitive psychology, notion of cognitive architecture, propositional and schematic representation, cognitive processes: working memory and attention, mental images, reasoning. automatic and controlled processes, acquisition of skills.

Unit II: Artificial Intelligence and Neuroscience

History and background of Artificial Intelligence, Knowledge representation, Human information processing and problem solving: Search, Control and Learning

Introduction to nervous system, organisation of nervous system, neural representation, computational neuroscience, neural network and distributed information processing, neural network models of cognitive processes, strategies for brain mapping.

Unit III: Cognitive Modelling

Different types of Cognitive Models: Symbolic Model, Connectionist Model etc. and their implications to Memory, Learning, Reasoning, Attention, Mood Detection, Visual Perception, Pattern recognition, Mental Imagery.

Vector and Matrix Algebra, Rigid Body Geometric transformations, Spatial Filtering, Convolution, Frequency Filtering, Fourier Transform.

Unit IV: Biomedical Imaging Techniques

An overview of X-ray, CT scan, PET scan, MRI scan, fMRI, EEG, MEG. Fundamental concepts of Image acquisition / Signal acquisition, Spatial Normalization, Affine and Non-linear Image Registration, Spatial resolution, Temporal resolution, Contrast resolution, Image representation, Image Database, Image Data Communication and Data Compression, Image visualization such as various types of 2D and 3D rendering techniques.

Text Books:

1. D. Kolak et. al.: *Cognitive Science: An Introduction to Mind and Brain,* Routledge, 2006.
2. J.L. Bermudez: *Cognitive Science,* Cambridge University Press, 2010.
3. Neil A. Stilings et al*.: Cognitive Science; an Introduction*, A Bradford Book, 1998
4. David Papineau, *Thinking about Consciousness*, Oxford University Press, 2002.
5. J. Copeland: *Artificial Intelligence: A Philosophical Introduction*, Oxford Blackwell, 1993.
6. H. van Oostendorp*, Cognition in a digital world,* Lawrence Erlbaum Associates, Publishers: Mahwah, N.J. 2003.
7. M. Felix Goodson,.: *The evolution and function of cognition*, Lawrence Erlbaum Associates, Publishers: Mahwah, N.J. 2003.
8. Cornelius T. Leondes: *Image Processing and Pattern Recognition*, Academic Press, London, 1998.
9. I. N. Bankman, *Handbook of Medical Image Processing and Analysis,* Elsevier, 2009.
10. Konar Amit: *Artificial Intelligence and Soft Computing – Behavioural and Cognitive Modelling of the Human Brain,* CRC Press, Florida, 2000.

Electives for Semester IV
(Any Two to be Chosen)

PHY-PG-E403/4-A: COSMOLOGY

Unit I: Expansion of universe

GTR: Equivalence principle, metric tensor, covariant derivative, curvature tensor. Currents and conservation law, energy momentum tensor, Einstein's equation.
Robertson-Walker metric, cosmological redshift, Hubble constant. Cosmic distance ladder. Dynamics of expansion.

Unit II: CMBR & Early Universe

Discovery of cosmic microwave background radiation, Equilibrium era, Recombination and last scattering, dipole anisotropy, primary fluctuations. Thermal history, Nucleosynthesis, Baryosynthesis, Leptosynthesis, cold dark matter.

Unit III: Inflation

Flatness, horizons, monopoles; slow roll inflation, chaotic inflation, eternal inflation. Perturbed Ricci and EM tensor, scalar, vector and tensor modes; Fourier decomposition, choice of gauge.

Unit IV: Cosmological Fluctuations & CMBR Anisotropy

Scalar perturbation: kinetic theory, hydrodynamic limit, long and short wavelength. Tensor perturbation. General formula for temperature fluctuation, temperature multipole coefficients, vector and tensor modes, polarisations.

Text Books:

1. Steven. Wineberg: *Cosmology, Oxford University Press, 2008 .ISBN-10: 0195699378ISBN-13: 978-01956993712.*
2. Hermann Bondi and I W Roxburgh, Cosmology, Dover Publications Inc. 2009, ISBN-10: 0486474836*ISBN-13: 978-0486474830*
3. Marc Lachieze-Rey, John Simons, Cosmology: A first course, Cambridge University Press, 1995,ISBN-10: 0521479665, ISBN-13: 978-0521479660
4. Fred Hoyle and J V Narlikar, Introduction to Cosmology, Cambridge University Press, 1993, ISBN-10: 052142352X, ISBN-13: 978-0521423526
5. Andrei Linde, Particle Physics and Inflation, CRC Press, 1999, Kindle Edition

PHY-PG-E403/4-B: ASTROPHYSICS

Unit I:

Telescopes: basic optics, optical telescopes, radio telescopes, IR, UV, X-ray and Gamma-ray Astronomy, all-sky surveys and virtual observatoriesOverview of major contents of universe, Black body radiation, specific intensity, flux density, luminosity, Basics of radiative transfer (Emission/absorption coefficients, source functions), Magnitudes, distance modulus, Color index, Extinction, Color temperature, effective temperature, Brightness temperature, bolometric magnitude/luminosity, Excitation temperature, kinetic temperature, Utility of stellar spectrum, basic knowledge of stellar atmospheres

Unit II

HR diagram, a discussion on the variety of stellar phenomena. Stellar Structure, stellar opacities, stellar polytropes, Energy Generation in Stars: Calculation of thermonuclear reaction rates for non-resonant and beta-decay reactions, The various reaction chains: pp-I, II, III, CNO, He-burning, C-burning, Si-burning, photo-dissociation . Neutrino emission from Stars: The solar neutrino "problem" and its solution, terrestrial detection of stellar neutrinos - solar and supernovae (Arnett, Bahcall). Stellar degeneracy and Equations of State: Stellar degeneracy (Clayton), Chandrasekhar mass, EoS of matter at near-nuclear and nuclear densities (Shapiro &Teukolsky).

Unit III

Final stages of stellar evolution: Supernovae and neutron stars - a basic knowledge of NS structure, the problems associated with determining a unique equation of state for NS, various manifestations of NS. Binaries, variable stars, clusters, open and globular clusters, Laws of planetary motion, Motions and Distances of Stars, Statistical and moving cluster parallax, Velocity Dispersion, Compact objects (BH-systems, Accretion rate/efficiency, Eddington luminosity),

Unit IV

Shape, size and contents of our galaxy, Normal and active galaxies, High energy physics (introduction to X-ray and Gamma-ray radiation processes), Newtonian cosmology, microwave background, early universe.

Text Books:

1. William K. Rose: *Atrophysic,* Dover Publications, (2010).
2. Padmanabhan, T., Theoretical Astrophysics, Vols.1-3, Cambridge University Press, 2005.
3. BadyanathBasu: *An introduction to Astrophysics,* Prentice Hall of India, (2003).
4. D. D. Clayton: *Principle of Stellar evolution and nucleosynthesis,* University Chicago Press, (1984).
5. R. Kippenhahn and A.Weigert: *Stellar structure and evolution(Astronomy and Astrophysics Library),* Springer, (1994).
6. K. D. Abhayankar: *The Physics of Stars and Galaxies*
7. H. L. Duorah and KalpanaDuorah.: *Introduction to Astrophysics*
8. Frank H. Shu: *The Physical Universe: An Introduction to Astronomy*, University Science Books, California, (1982).
9. Bradley W. Ostlie and Dale A. Carrol: *An introduction to Modern Astrophysics*, Addision-Wesley, (1996).

References

1. Harwit, M., Astrophysical Concepts, 3rd ed, Springer-verlag, 2006.

2. Erika Bohm-Vitense, Introduction to Stellar Astrophysics, Vol. 3 : Stellar structure and evolution --
3. Shapiro &Teukolsky,Black Holes, White Dwarfs & Neutron stars --.

PHY-PG-E403/4-C: QUANTUM FIELD THEORY

UnitI: Scalar and Spinor Fields

Need for Field Theoretic description, Klein-Gordon Field: Lagrangian formulation, symmetries and conservation laws, canonical quantization, propagators, Feynman diagrams

Dirac Field: Canonical quantization, propagators, Symmetries: Gauge Symmetries, Gauge Field: Elementary realization of BRST symmetry and gauge fixing.

Unit II: Interactions

Hamiltonian formulation, S-matrix, Interacting Fields and Feynman Diagrams, Yukawa Theory, Elementary processes of Quantum Electrodynamics, radiative corrections.

Unit III: Renormalization

Functional Methods, Systematics of Renormalization, Renormalization and Symmetry, Renormalization Group, Critical Exponents. Wilsonian renormalization.

Unit IV: Non-Abelian Gauge Field

Non-AbelianGauge invariances,Quantizations, Quantum Chromodynamics, Operator products, effective vertices, Gauge theory with spontaneous symmetry breaking, Higgs mechanism.

Text Books

1. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.
2. F. Mandl and G. Shaw: *Quantum Field Theory*, John Wiley, 1992.
3. S. Weinberg, The Quantum Theory of Fields, Vol. I and II, Cambridge University Press, 2005
4. C. Itzyksion and J B Zuber, Quantum Field Theory, Dover Publications, 2006

Reference Books:

1. T. P. Cheng and L.-F. Li: *Gauge Theory of Elementary Particle Physics*, Oxford University Press, 1984.
2. S. Pokorski: *Gauge Field Theories*, Cambridge University Press, 2000.

3. L. H. Ryder: *Quantum Field Theory*, Cambridge University Press, 1996.
4. D. Bailin and A. Love: *Introduction to Gauge Field Theory*, IOP Publishing, Graduate Student Series in Physics, 1986.
5. P. B. Pal and A. Lahiri: *A First Book of Quantum Field Theory*, CRC Press, 2001.
6. A. Zee, Quantum Field Theory in a nutshell, Princeton University Press, 2010.

PHY-PG-E403/4-D: ADVANCED ELECTRONICS

Unit I

Modulation & Demodulation: Modulation, types (AM, FM and PM), mathematical analysis of Amplitude Modulated and Frequency modulated carrier wave, AM signal detection using diode detector & transistor detector, FM detection using quadrature detector, basic concept of vestigial side band modulation.

Unit II

Optical Fibre Communication: Introduction, advantages & disadvantages over transmission lines, classification of optical fibres, light propagation through optical fibres: Snell's law, total internal reflection, acceptance angle and numerical aperture, block diagrammatic description of fibre- optic communication system, Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM), Losses in optical fibres.

Unit III

Satellite communications: Introduction to digital communication techniques, satellite orbits, satellite orbital patterns, Geo-synchronous satellites, Satellite system link models: Uplink model, transponders & downlink model (*Block diagrammatic description only*).

Unit IV

Cellular communication: Introduction to cellular telephone service, evolution of cellular telephone, fundamental concepts, frequency re-use, interference (co-channel and adjacent channel)

Text Books:

1. Simon Haykin: *Communication Systems* : 4th Ed., John-Wiley & Sons (2000)
2. W. Tomasi: *Advanced Electronic Communication Systems*, 6th Ed., P.H.I. (2005)
3. Martin S. Roden: *Analog & Digital Communication Systems*, 3rd Ed., PHI (2005)
4. B. P. Lathi: Modern digital and Analog *Communication Systems,* Oxford University Press, 3rd ed., (1998).
5. Das, Mallik and Jain:*Communication Systems.*

PHY-PG-E403/4-E: ADVANCED STATISTICAL PHYSICS AND ATOMIC,

MOLECULAR & OPTICAL PHYSICS

Unit I:Statistical Mechanics of Interacting System

Imperfect gases at low temperature: Method of pseudopotential: two body problem, N-body problem, imperfect Bose gas, Fermi gas. Cluster expansion: classical gas, quantum mechanical system; Virial coefficients.

Phase transitions: Formulation of the problem; Theory of Yang and Lee; Lattice gas, binary alloy, Ising model in one and two dimensions, liquid Helium.

Unit II:Fluctuations

Thermodynamic fluctuations, spatial correlations in fluid; Brownian motion, Einstein-Smoluchowski theory, Langevin theory; Fokker-Planck equation, Spectral analysis, fluctuation-dissipation theorem, Onsagar relations.

Unit III: Interaction of Atoms with Radiation

Perturbation by an oscillating electric field, The rotating-wave approximation, Interaction with monochromatic radiation, The concepts of π-pulses and $\pi/2$-pulses, The Bloch vector and Bloch sphere, Ramsey fringes, Radiative damping, The damping of a classical dipole, The optical Bloch equations, The optical absorption cross-section, Cross-section for pure radiative broadening, The saturation intensity, Power broadening, The a.c. Stark effect or light shift. Doppler free spectroscopy.

Unit IV: Non-linear Optical Susceptibility

Introduction, Schrödinger calculation of non-linear optical susceptibility, Perturbation solution of the Density matrix equation of motion, density matrix calculation of the Linear and second order susceptibility, Electromagnetic Induced transparency, Intensity dependent refractive Index. Experimental evidences: Optical Cooling and Trapping of Atoms, Magnetic trapping of neutral atoms, quantum information processing of the trapped ions.

Text Books:

1. R. K. Patharia: *Statistical Mechanics* (2nd Ed) Butterworth Heinman, Elsevier (2005)
2. K. Huang: *Statistical Mechanics* (2nd Ed) John Wiley & Sons (2002)

3. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules, Longman,1996.
4. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw Hill, 1994.
5. Atomic Physics- C J Foot, Oxford master series in Physics
6. Wolfgang Demtröder- Laser Spectroscopy Vol. 1: Basic Principles(4th edition)- Springer (2008)
7. Rober Boyd- Nonlinear Optics – 3rd edn. – Elsevier (2008)
8. H Metcalf and P V der Straton, Laser cooling and Trapping, 1994, Springer)
9. K Thyagarajan and Ajoy Ghatak, Lasers: Fundamentals and Applications, Springer, 2011, 2nd edition.

Reference Books:

1. G. K. Woodgate, Elementary Atomic Structure, Clarendon Press, 1989.
2. F. L. Pilar, Elementary Quantum Chemistry, McGraw Hill, 1990.
3. H. E. White, Introduction to Atomic Spectra, Tata McGraw Hill, 1934.
4. J. M. Hollas, Modern Spectroscopy, John Wiley & Sons, 2004.
5. R.J. Abraham and J. Fishe and P. Loftus, Introduction to NMR Spectroscopy, John Wiley & Sons. 1994.
6. J. A. Weil, J.R. Balton & J.E. Wertz, Electron Paramagnetic Resonance: Elementary Theory and Practical Applications. John Wiley and Sons, 1994.

PHY-PG-E403/4-F: X-RAY CRYSTALLOGRAPHY AND MOLECULAR BIOPHYSICS

Unit I

The Crystalline state of solids: the crystalline and amorphous state, covalent solids, ionic solids, hydrogen bonded solids and metals.
Space lattice, unit cell, Bravais lattices, crystal planes and Miller indices, spacing of planes in crystal lattices, symmetry operations, point groups and crystal classes, screw axis and glide planes, space groups.

Unit II

Origin of X-rays, Continuous and Characteristics spectra, Absorption of X-rays, Absorption edge, filters, production of X-rays, modern X-ray generator.Scattering of X-rays by an electron, an atom and a unit cell, atomic scattering factors, Diffraction of X-rays, the Bragg's law.

Unit III

Diffraction methods- Laue method, powder method, precision determination of lattice parameters, x-ray diffractometer. Reciprocal lattice, sphere of reflection, rotating crystal method, use of oscillation photograph, determination of lattice parameter from oscillation photograph. Integrated intensity and their measurement, Lorentz polarization correction, Debye-Waller temperature factor.Structure analysis by Fourier Synthesis.

Unit IV `

Bio molecules: chemistry of monomers and polymers, amino acids, lipids, nucleic acids, proteins, DNA, RNA, Protein crystallization, X-ray diffraction from Protein crystals, crystals structures of some protein molecules, Fibre diffraction , interpretation of fibre-pattern x-ray diffraction.

Text Books:

1. B. D. Culity: *Elements of X-ray diffraction*, Addison-Wesley, 3rd Printing, (1967).
2. Henry, M. F. M.Lipson, W.A. Wooster, Henry: *Interpretation of x-ray diffraction*
3. *Photograph.* Macmillan, London, (1961)
4. Harold, P. Klug and E. L. Alexender: *X-ray diffraction procedures for polycrystalline and Amorphous Materials*. Wiley-Interscience, 2nd Edn. (1974).
5. Wolfram Saenger: *Principle of Nucleic Acid Structure.* Springer, (1988).
6. J. M. Berg, J. L. Tymoczko, LubertStryer: *Bio Chemistry*. W. H. Freeman, 5th Edn. (2002).