DEPARTMENT OF PHYSICS
M.SC SYLLABUS

Semester	Code	Name of the Paper	Credit	Marks
I	PHY-PG-C101	Electronics & Numerical Methods	4	100
	PHY-PG-C102	Classical Mechanics	4	100
	PHY-PG-C103	Mathematical Physics & Quantum Mechanics I	4	100
	PHY-PG-C104	Electronics Laboratory	4	100
II	PHY-PG-C201	Mathematical Physics & Electromagnetism	4	100
	PHY-PG-C202	Quantum Mechanics II	4	100
	PHY-PG-E203	Elective I	4	100
	PHY-PG-C204	General Laboratory	4	100
III	PHY-PG-C301	Electrodynamics	4	100
	PHY-PG-C302	Statistical Physics I	4	100
	PHY-PG-E303	Elective II	4	100
	PHY-PG-C304	Modern Physics and Digital Electronics Laboratory	4	100
IV	PHY-PG-C401	Solid State Physics	4	100
	PHY-PG-C402	Statistical Mechanics II & Atomic, Molecular & Optical Physics	4	100
	PHY-PG-C403	Nuclear & Particle Physics	4	100
	PHY-PG-C404	Project work & Programming Techniques	4	100

SEMESTER I
PHY-PG-C101: ELECTRONICS & NUMERICAL METHODS

Unit I: Amplifiers

BJT & FET amplifiers, types of amplifiers, DC biasing analysis, determination of operating points, Transistor equivalent models: h-parameters and r_e model, Power amplifiers, Transistor frequency response. Feed back in amplifiers. Oscillator (Hartley, Phase shift, Crystal oscillators), Operational amplifier: Ideal and practical properties, Virtual ground, CMRR. Op-amp as analog computer (adder, subtractor, integrator, differentiator). Applications of op-amp as: Comparator, Schmitt Trigger, Active filters.

Unit II: Combinational logic circuit

Boolean operation, simplification of Boolean expression, De Morgans theorem, Adder and subtractor (half and full), Multiplexer and Demultiplexer, encoder and Decoder, RTL, DTL, TTL, ECL, CMOS families. Sequential logic circuit: Flip flops: RS, JK, Master slave, D and T. Counters, registers. RAM & ROM. Introduction to microcomputer, memory, input/output and interfacing devices, INTEL8085 CPU-Architecture, BUS timing, demultiplexing the address bus generating control signals, instruction set, addressing modes and assembly language programmes for simple mathematical operations.

Unit III: Instrumentation

Error analysis. Noise: Various types of noises, signal to noise ratio.

Electronic Analog Meter: DC and AC voltmeters, differential voltmeters, AC current measurements: multimeters, vector impedance meter, power meter. Review of signal sources, signal generator, wave analyzer, harmonic distortion analyzer, spectrum analyzer. Digital Measurement: Digital multimeters, digital frequency meter, digital measurement of time, universal counter, electronic counter, automation in digital instruments, digital phase meter, digital capacitance meter. Microprocessor based instruments.

CRO & Recorders: General purpose oscilloscope, CRT screen characteristics, vertical & horizontal amplifiers, delay line, time base and sweep trigger circuits, synchronization, sampling oscilloscope, digital storage oscilloscope, typical measurements using CRO, Recorder: Galvanometer type recorder, XY recorders, magnetic recorders, digital data recording.

Unit IV: Numerical Methods

Roots of algebraic and transcendental equations: One point and two-point iterative methods such as bisection method, inverse interpolation and Newton Raphson methods.Matrix operations and simultaneous linear equations: Matrix addition, multiplication and inversion. Solution of simultaneous linear equations by matrix inversion methods.

Interpolation: Linear interpolation, Lagrangian interpolation, Newton's interpolation (different forms).

Integration: Newton-Cotes formulae, Gauss quadrature. Ordinary Differential equations: Initial value problem, Taylor's algorithm, Euler's methods, Runge-Kutta, and Predictor-corrector methods.

Texts Books:

1. R. L. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory* (10th Edn), Prentice Hall (2008)
2. D. P. Leach, A. P. Malvino and G. Saha, *Digital Principles and Applications* (6^{th} Edn), Tata McGraw Hill (2007)
3. R. S. Gaonkar, *Microprocessor Architecture, Programming and Applications with the 8085*, (5^{th} Edn) Prentice Hall 2002.
4. H. S. Kalsi, *Electronic Instrumentation*, Tata McGraw Hill Education, 2012.
5. S.S. Sastry, *Introductory methods of Numerical analysis*, Prentice Hall India, 5^{th} edition (2012).
6. G. Lindfield and J. Penny: *Numerical Methods: using Matalab*, Academic Pres (2012)

References:

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. E.W. Golding and F.C. Widdis: *Electrical Measurements and Measuring Instruments*, Pitman (London), 1963.

PHY-PG-C102: 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-C103: MATHEMATICAL PHYSICS & QUANTUM MECHANICS I

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.
Tensor Analysis

Unit III: Quantum Mechanics: 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 IV: Quantum Mechanics: Approximation Methods
Perturbation Theory: Time independent perturbation theory, non-degenerate and degenerate cases, fine structure and Zeeman effect (without spin), Stark effect, Fine structure, hyperfine structure, Lamb shift.
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.
Approximation methods: WKB approximation, validity of WKB approximation, alpha emission.Variational method, ground state of helium atom.

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. R. Shankar: Principles of Quantum Mechanics, Springer, 2nd edn. (1994).
6. G. Aruldhas: *Quantum Mechanics,* Prentice Hall of India (2002)
7. R. L. Liboff: Introductory Quantum Mechanics, Pearson Education (2006)
8. A. Ghatak and S. Lokanathan: Quantum Mechanics: Theory and Application, 4th Ed,Macmillan (2004).

Reference Books:

1. P. Dennery and A. Kryzywicki: *Mathematics for Physicists,* Dover Publications, (1996).
2. K. F. Riley: Mathematical Methods for Physics and Engineering, CUP, New York (2002)
3. *B. D. Gupta: Mathematical Physics, Vikas Pub. House, New Delhi (2004).*
4. C. Harper : Introduction to Mathematical Physics, Prentice Hall Text Books:
5. R. R. Halmos: *Finite-Dimensional Vector Spaces,* Sringer, (1993).
6. L. D. Landau and L. M. Lifshitz: *Quantum Mechanics*: *Non-relativistic Theory*, Butterworth-Heinemann, 3rd Edn. (1981)..
7. K. Thankappan: *Quantum Mechanics*, New Age Intl. Pub (1996)

8. S. Gasiorowiz: *Quantum Mechanics*, Wiley (1995)
9. P. T. Mathews and S. Venkatesan: *Textbook on Quantum Mechanics*, McGraw Hill (2002)
10. L. I. Schiff: *Quantum Mechanics*, Mc Graw Hill (1998)
11. P. A. M. Dirac: Principles of Quantum Mechanics, Dover Publications
12. R. P. Feynman,: Feynman lectures on physics - volume III, Pearson

PHY-PG-C104: ELECTRONICS LABORATORY
[A minimum of 10 experiments has to be performed from the following list.]

1. Shunt Voltage regulator using zener diode.
2. Diode Applications: Clipping and Clamping circuits.
3. BJT characteristics. Determination of h-parameters in the CE configuration using the measured input and output characteristics of a BJT (e.g.2N 2218)
4. Common Emitter Amplifier with and without feedback.
5. Wien's Bridge Oscillator.
6. Multivibrators – Bistable, Monostable and Free Running multivibrators using BJT's (e.g.2N 2218).
7. Op-Amp (741) characteristics: $V_{io,}$ I_b, $V_{ol,}$ CMRR, Slew Rate. Applications of Op-amps: inverting Amplifier, Unity Gain Buffer, Summing Amplifier, Differentiator and Integrator.
8. Series Dissipative Voltage Regulator using 723 IC.
9. Universal Gate,
10. Adder/Subtractor
11. Multiplexer
12. BCD-to-7 segment decoder
13. J-K flip-flop
14. parallel up/down counter
15. A to D and D to A Converters

SEMESTER II

PHY-PG-C201: MATHEMATICAL PHYSICS AND ELECTROMAGNETISM

Unit I: Integral Transforms & Special Functions
Fourier series and applications. Fourier transforms, Laplace transforms.
Linear ordinary differential equations with constant coefficients. 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 II: 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. Lie groups, SU(2) and SU(3) groups

Unit III: 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, Clausius Mossotti formula, Poisson's equation in a uniform linear dielectric. Boundary value problems with dielectrics.

Unit IV: 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.

Text Books:

1. G. B. Arfken and H.J. Weber: *Mathematical Methods for Physicists*, Academic Press, 6th Ed. (2005).
2. Mathew and Walker
3. D. J. Griffiths: *Introduction to Electrodynamics* (3rd Ed.), Pearson Edn., (2002)
4. J. D. Jackson: *Classical Electrodynamics* ,Wiley Eastern, (2003).

Reference Books:

1. B. D. Gupta: Mathematical Physics, Vikas Pub. House, New Delhi (2004).
2. C. Harper : Introduction to Mathematical Physics, Prentice Hall Text Books: L. Jansen and M. Boon: Theory of Finite Groups.
3. C. Birkhoff and G.C. Rota, Ordinary Differential Equations (4th Ed), John Wiley &
4. Sons, 2003.
5. A.W. Joshi: Matrices and Tensors in Physics (3rd Ed), New Age Intl., (1995).
6. S. Sternberg: Group Theory and Physics, Cambridge Univ. Press, (1994).
7. Forsythe : A Treatise on Differential Equations, CBS(1995)
8. R. L. Rabenstein: Ordinary differential equations, Cambridge University Press, (2004)
9. G. Stephenson: Partial Differential Equation for Scientists and Engineers, World Scientific Publishing Company, (1996).
10. M. Hamermesh: Group Theory and its Application to Physical Problems, Addison-Wesley Publishing Company, (1962).
11. K. F. Riley: Mathematical Methods for Physics and Engineering, CUP, New York (2002)
12. G. L. Pollack, D. Stump: Electromagnetism, Addison-Wesley (2001).

PHY-PG-C202: QUANTUM MECHANICS II

Unit I: Interaction with radiation and identical particle

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

Identical Particles and Spins: Indistinguishability, symmetric and anti-symmetric wave functions,, Pauli exclusion principle, electron spin functions, the helium atom, para and ortho states. Afbau principle, Hund's rule and periodic model, Spin angular momentum, Addition of angular momenta, Clebsch-Gordon coefficients, LS and JJ couplings.

Central field approximation, Thomas-Fermi model, Hartee-Fock method and self-consistent field.

Unit II: 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.

Unit III: Relativistic Quantum Mechanics

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

Unit IV: 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,

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, 2nd edn. (1994).
4. J. J. Sakurai: Advanced *Quantum Mechanics*, Pearson Education, Reprint(1967).
5. Bjorken and Drell, Relativistic Quantum Mechanics
6. M. Peskin and D. V. Schroeder: Introduction to Quantum Field Theory (Frontiers in Physics), Westview Press, (1995).

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. T-Y Wu and W-Y P. Hwang: *Relativistic Quantum Mechanics and Quantum Field,*
5. World Scientific Publishing Co., (1991).
6. R. Eisberg and R. Rensick: *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* (2nd Ed), John Wiley & Sons, (2003).
7. *and I. D. Gupta: Advanced Quantum Field Theory, S. Chand & Co. (1990)*
8. *Claude Itzykson & Jean Bernard Zuber: Quantum Field Theory, Dover publications Inc. 2006,* ISBN-10: 0486445682. ISBN-13: 978-0486445687
9. A. Ghatak and S. Lokanathan: *Quantum Mechanics (Theory and Application*) (4th Ed), Macmillan (2003).
10. F. Schwabl: *Quantum Mechanics*, Narosa Pub. House (1998).

PHY-PG-C204: GENERAL LABORATORY

[A minimum of 10 experiments has to be performed from the following list]

1. Determination of velocity of ultrasonic wave by using Ultrasonic interferometer of in solid/ liquid.
2. To study the Hall effect (i) to find the variation of temperature dependence of Hall coefficient (ii) to find the type of charge carriers.
3. Determination of Planck's constant by using LED
4. Verification /determination of Stefan's Law/Stefan's constant.
5. Determination of resistivity and energy gap of semiconductor by Four Probe method.
6. Michelson interferometer.
7. Determination of thickness of a thin wire with laser.
8. Measurement of Susceptibility of paramagnetic solution by Quinkes' Tube method.
9. Determination of Refractive Index of liquid using laser.
10. Study of Hydrogen spectrum and determination of Rydberg's constant.
11. Determination of Dielectric Constant (Solid & liquid).
12. To study Photoconductivity of the given sample.
13. Fresnal Diffraction
14. Fibre Optics
15. Holography

SEMESTER III
PHY-PG-C301: ELECTRODYNAMICS

Unit I: Time varying fields & Maxwells 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 II: 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.

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.

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. 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. F. F. Chen: *Introduction to Plasma Physics and Controlled Fusion*, vol. I: plasma physics, 2nd edition, Springer, 1984.
5. R. J. Goldston and P. H. Rutherford: *Introduction to Plasma Physics*, Institute of Physics, London, 1995.

PHY-PG-C302: STATISTICAL PHYSICS I

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, Fluctuations-dissipation theorem, Gaussian distribution, Brownian motion (Langevin’s Theorem).
Ising Model

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-C304: MODERN PHYSICS AND DIGITAL ELECTRONICS LABORATORY

1. Measurement of the energy gaps of (i) Silicon and (ii) Germanium
2. Determination of spin-spin relaxation time of a given sample and the value of the spectroscopic splitting factor (g).
3. Determination of the concentration of colour centers in an alkali halides crystal.
4. Experiment on superconductivity.
5. Experiments on dielectric constants of solid/liquid.
6. Ionization potential
7. Specific heat of graphite
8. Determination of e/m by Zeeman Effect
9. Study of Raman effect using spectrometer
10. Determination of numerical apertures and divergence of given laser
11. Laser Doppler Anemometry with Cassy
12. Emission and absorption/optical pumping
13. Doppler free spectroscopy
14. Polarisation (QW plate, Half wave plate)

SEMESTER IV

PHY-PG-C401: SOLID STATE PHYSICS

Unit I: Symmetry of Crystals

Bragg's law in direct and reciprocal lattice, Laue diffraction, simple crystal structures, atomic scattering factor, neutron diffraction, electron diffraction, crystal structure determination by Laue, powder and rotating crystal methods. Concept of point groups, Influence of symmetry on physical properties, space groups, derivation of equivalent point positions, triclinic and monoclinic systems.

Unit II: Vibrations and Defects

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, application to simple cubic lattices, ideas of Fermi surfaces, band structure of simple elements.

Unit III: Electric polarisation 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 Hass 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, 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, brief discussion of the B.C.S. theory, its results and experimental verification;dc and ac Josephson effects, Type II superconductivity, mixed state, 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-C402: STATISTICAL MECHANICS II 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, The Einstein *B* coefficients, 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. Special Topic: 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* (2^{nd} Ed) Butterworth Heinman, Elsevier (2005)
2. K. Huang: *Statistical Mechanics* (2^{nd} 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, 2^{nd} 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-C403: 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 diagrammes. 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. BRST symmetry.

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 AND PROGRAMMING TECHNIQUES

This course consists of two components: Project Work for dissertation/thesis for 2 credits (50 marks) and programming techniques for 2 credits (50 marks).

A student's project work should be a guided study of advanced topics 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 of total 50 marks 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. Another 50 marks of this course coming from Programming Techniques will be evaluated through internal assessment throughout the semester.

Programming Techniques: Representing numbers in a computer, machine precision, errors and approximations. Concept of computer language, Fortran 90 programming, Python, Matlab syntax, Mathematica syntax, Origin Syntax. Random number generator, Monte Carlo simulation, Fast Fourier Transform. Applications in solving some important non-linear ordinary differential equations.

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

PHY-PG-E203A: COSMOLOGY

Unit I: Expansion of universe

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.

Books:

1. Steven. Wineberg: *Cosmology, Oxford University Press, 2008 .ISBN-10: 0195699378 ISBN-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 Narlekar, 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-E203B: 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-E203C: PHYSICS OF NANO AND SOFT MATERIALS

Unit I: Free electron theory [qualitative idea] and its features

Idea of band structure, metals, insulators and Semi-conductors. Density of state in bands, variation of density of states with energy, variation of density of state and band gap with size of crystal.

Unit II: Quantum Size Effect

Electron confinement in infinitely deep square well, confinement in two and one dimensional well, Idea of quantum well structure, quantum dots, quantum wires. Characterisation: Raman XRD, PL, RBS, TEM. Determination of particular size, Increase in width of XRD peaks of nanoparticles, Shift in photoluminescence peaks, variation in Raman spectra of nanomaterials.

Unit III: Methods of preparation of Nanomaterials

Bottom up: Cluster beam evaporation, Ion beam deposition, Ion implantation, Sputtering methods (Ion beam, Atom beam and RF sputtering, ultra high vacuum deposition), chemical bath deposition with capping techniques and top down: Ball Milling.

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.

Text Books:

1. D. Bimerg, M. Grundmann and N. N. Ledentsov: *Quantum Dot Heterostructure*, John Wiley & Sons, (1988).

2. B. C. Crandall: *Nano Technology*: Molecular speculations on global abundance. MIT Press, (1996).
3. John H. Davies: *Physics of low dimensional semiconductors*, Cambridge University Press, (1997).
4. K. P. Jain: *Physics of Semi-conductor nano structures*, Narosa, (1997).
5. Principles of Condensed Matter Physics, Chaikin and Lubensky, Cambridge University Press 1995.
6. The Physics of Liquid Crystals, P-G de Gennes, J Prost, Oxford University Press, 1994.

Reference Books:

7. Gan-Moog Chow, Kenneth E. Gonsalves: *Nanotechnology, Molecularly designed materials*, American Chemical Society, (1996).
8. Simple Views on Condensed Matter, 3rd Ed., P-G de Gennes, World Scientific, 2003.
9. Harvey C. Hoch, Harold G. Craighead and Lynn Jelinski: *Nano fabrication and bio system: Integrating materials science engineering science and biology*, Cambridge University Press, (1996).
10. Nano Particles and Nano Structured Films: Preparation characterization and applications Ed. J. H. Fendler, John Wiley & Sons, (1998).

PHY-PG-E303A: SOLAR HYDROGEN AND OTHER RENEWABLE ENERGIES

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.

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-E303B: 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. Raman spectra of amino acids, IR and Raman comparison, resonance Raman spectroscopy

Unit IV: Absorption and Flourescence Spectroscopy
UV and Visible spectra, chromophores, CD and ORD, cotton effect, applications to proteins and nucleic acids, Frank-condon principle, classical picture, resonance condition, Bloch condition, relaxation phenomenon, Fourier transform technique, chemical shifts, coupling constraints, Karplus equation, analysis of simple spectra, NOE, 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 Compnay, NewYork, USA, (1982).

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

PHY-PG-E303C: COGNITIVE SCIENCE

Unit I: Introduction and 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.

PHY-PG-E303D: QUANTUM FIELD THEORY

Unit I: 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: Elemantary 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-Abelian Gauge invariances, Quantizations, Quantum Chromodynamics, Operator products, effective vertices, Gauge theory with spontaneous symmetry breaking, Higgs mechanism.

References

1. F. Mandl and G. Shaw: *Quantum Field Theory*, Wiley, 1992.
2. T. P. Cheng and L.-F. Li: *Gauge Theory of Elementary Particle Physics*, Oxford University Press, 1984.
3. S. Pokorski: *Gauge Field Theories*, Cambridge University Press, 2000.
4. L. H. Ryder: *Quantum Field Theory*, Cambridge University Press, 1996.
5. D. Bailin and A. Love: *Introduction to Gauge Field Theory*, IOP Publishing, Graduate Student Series in Physics, 1986.
6. F. Mandl and G. Shaw *: Quantum Field Theory*, John Wiley, 2009.
7. P. B. Pal and A. Lahiri : *A First Book of Quantum Field Theory*, CRC Press, 2001.
8. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.