MSc (Physics) Syllabus

Revised and Approved, May 2015

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MSc (Physics) Syllabus
Department of Physics
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May 2015

Legends : L - Lecture P - Practical H - Home Assignments T - Tutorial

Structure of MSc (Physics) Syllabus, 2015

	Paper	Subject	Credit	Marks
Semester I	PHY-101	Mathematical Physics	6	80 + 20 = 100
	PHY-102	Classical Mechanics	6	80 + 20 = 100
	PHY-103	Quantum Mechanics I	6	80 + 20 = 100
	PHY-104	Electrodynamics	6	80 + 20 = 100
	PHY-105	General Practical	6	80 + 20 = 100
Semester II	PHY-201-A PHY-201-B	Atomic, Molecular, & Laser Physics I Nuclear Physics I	3 3	40 + 10 = 50 40 + 10 = 50
	PHY-202	Condensed Matter Physics I	6	80 + 20 = 100
	PHY-203	Electronics I	6	80 + 20 = 100
	PHY-204	Computational Physics	6	40 + 40 + 20 = 100
	PHY-205	General Practical	6	80 + 20 = 100
Semester III	PHY-301	Atomic, Molecular, & Laser Physics II	6	80 + 20 = 100
	PHY-302	Nuclear Physics II	6	80 + 20 = 100
	PHY-303-A PHY-303-B	Condensed Matter Physics II Electronics II	3 3	40 + 10 = 50 40 + 10 = 50
	PHY-304-E1 PHY-304-E2 PHY-304-E3 PHY-304-E4 PHY-304-E5 PHY-304-E6	Advanced Mathematical Physics Astrophysics High Energy Physics Molecular & Laser Spectroscopy Nanophysics Physics of Thin Films	6 6 6 6 6 6	80 + 20 = 100 80 + 20 = 100 80 + 20 = 100 80 + 20 = 100 80 + 20 = 100 50 + 30 + 20 = 100
	PHY-305	Advanced General Practical	6	80 + 20 = 100
Semester IV	PHY-401	Quantum Mechanics II	6	80 + 20 = 100
	PHY-402	Statistical Mechanics	6	80 + 20 = 100
	PHY-403	Experimental Methods	6	80 + 20 = 100
	PHY-404-E1 PHY-404-E2 PHY-404-E3 PHY-404-E4 PHY-404-E5 PHY-404-E6	Advanced Electronics Applied Nuclear Physics Cosmic Rays Gauge Theories GTR & Cosmology Plasma Physics	6 6 6 6 6 6	50 + 30 + 20 = 100 50 + 30 + 20 = 100 50 + 30 + 20 = 100 80 + 20 = 100 80 + 20 = 100 50 + 30 + 20 = 100
	PHC 4.5	Dissertation	6	80 + 20 = 100

First Semester (August - December)

PHY-101
Mathematical Physics

Total marks : 100 (80 + 20) **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Linear Vector Spaces and Matrices* (Lectures 08)

N–dimensional linear vector space, basis, scalar product, metric spaces. Orthonormal basis. Linear operators and their algebra, commutativity. Infinite dimensional space – Hilbert space. Matrix representation of operators, Unitary and Hermitian matrices. Diagonalisation of matrices, eigen values and eigen vectors.

Unit II : *Tensors* (Lectures 06)

Contravariant and covariant tensors. Outer product and contraction. Kronecker delta and Levi Civita tensor. Metric tensor and Christoffel symbols. Covariant derivatives. Tensor representation of Laplacian.

Unit III : *Differential and integral equations* (Lectures 10)

Hermite and Legendre polynomials. Gamma and beta functions. Hypergeometric equation (solution only). Dirac δ functions. Partial differential equations: One dimensional wave equation, one dimensional heat flow equation (finite and infinite rod). Laplace's equation and its solution. Green's function. Integral equations and their classifications: Fredholm and Volterra types. Method of substitution.

Unit IV : *Complex variables* (Lectures 05)

Analyticity, Cauchy integral theorem, residue theorem and complex integrations.

Unit V : *Integral transforms* (Lectures 06)

Laplace transform and inverse Laplace transform. Fourier transform. Shifting theorem and convolution. Solution of differential equations with the help of Laplace and Fourier transform.

Unit VI : *Group theory* (Lectures 10)

Introduction to groups, subgroups, coset, classes and factor groups. Homomorphism and isomorphism. Direct and semi-direct products. Group representation: reducible and irreducible representation. Symmetry group, Unitary group, Lie groups: SU (2), SU (3). Point groups and applications.

Recommended books

1. Mathematical methods for physicists : Arfken and Weber
2. Mathematical Physics : P K Chattopadhyay
3. Mathematical Physics : B S Rajput
4. Matrices and tensors in Physics : A W Joshi

5. Mathematical methods in the Physical Sciences : Mary L Boas
6. Mathematics for physicists : P Dennery and A Krzywick
7. Partial differential equations of Mathematical Physics : A G Webster
8. Differential equations and their applications : Zafar Ahsan
9. Mathematical Physics : A G Ghatak, I C Goyal and S J Chua

PHY-102
Classical Mechanics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I (Lectures 11)

Lagrangian and Hamiltonian formalisms and equations of motion-their applications to physical problems. Cyclic coordinates, relativistic form of Lagrangian and Hamiltonian. Special theory of relativity, addition of velocities, Lorentz transformations, relativistic kinematics and mass–energy equivalence, Covariant form of electromagnetic equations and their Lorentz invariance.

Unit II (Lectures 04)

Central-force motion - Two-body collisions, scattering in laboratory and centre-of-mass frames. Variational principle, Symmetry, invariance and conservation laws.

Unit III (Lectures 06)

Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudo forces. Principal axes and principal moments of inertia. Euler's equation of motion. Symmetric top motion and Foucault's pendulum.

Unit IV (Lectures 04)

Poisson brackets and their properties, Theory of canonical transformations and generating function. Hamilton's equation in terms of Poisson bracket, Jacobi identity.

Unit V (Lectures 05)

Action–angle variables, application to simple harmonic oscillator, planetary motion, adiabatic invariants. Hamilton's Jacobi theory and its application to solve central force problem.

Unit VI (Lectures 05)

Theory of small oscillations, normal coordinates, normal modes, coupled oscillations, diatomic and triatomic molecules.

Unit VII (Lectures 05)

Perfect fluid motion, Euler's and Bernoulli's equations, vorticity, Navier-Stoke's equation.

Unit VIII (Lectures 05)

Introduction to nonlinear systems, concept of catastrophe, bifurcation, chaos and strange attractors, fractals, physical examples.

Recommended books

1. Classical Mechanics - H. Goldstein
2. Classical Mechanics - Rana and Joag
3. Mechanics - Landau and Lifshitz
4. Classical Mechanics - V. B. Bhatia
5. Classical Mechanics - A. K. Raychaudhury
6. Classical Mechanics of Particles and Rigid Bodies - K. C. Gupta
7. Introduction to Mathematical Physics, Methods and Concepts - C. W. Wong
8. Chaos and Nonlinear Dynamics - S Strogatz

PHY-103
Quantum Mechanics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Basic Principles of quantum mechanics* (Lectures 20)

Physical interpretation of wave function, Schrödinger wave equation and its application in 1, 2, and 3 dimensional potential well, step potential barrier, motion in a central potential (Hydrogen atom), angular momentum representation using spherical coordinates and spherical harmonics, matrix formulation of quantum mechanics, concept of probability, properties of state vectors – Ket and Bra algebra, operators, Heisenberg's uncertainty principle – proof (wave and matrix mechanics) and applications, linear harmonic oscillator problem in operator method using Bra and Ket vectors, Heisenberg's equation of motion and its physical equivalence with Schrödinger equation

Unit II : *Symmetry and invariance principle and conservation* (Lectures 06)

Space and time translations, rotational invariance under infinitesimal and finite rotations. Angular momentum operators, ladder operators, addition of angular momenta – Clebsch-Gordan coefficients

Unit III : *Indistinguishable and identical particles in quantum mechanics* (Lectures 04)

Pauli spin matrices and SU(2) group, identical particles, symmetric and antisymmetric wave functions, combination of wave functions for a system of particles, spin statistics connection, exchange symmetry and exchange degeneracy.

Unit IV : *Approximation methods in quantum mechanics* (Lectures 15)

Time independent perturbation theory, Stark and Zeeman effects, variational method and its applications, WKB approximation, time dependent perturbation theory, transition to continuum states, Fermi's Golden rule, adiabatic and sudden approximation.

Recommended books

1. Quantum mechanics – L. Schiff
2. Quantum Mechanics – S. N. Biswas
3. Quantum Mechanics – A. K. Ghatak and S. Lokanathan
4. Introductory Quantum Mechanics – R. L. Liboff
5. Principles of Quantum Mechanics – R. Shankar
6. Quantum Mechanics: concepts and applications – N. Zettili

PHY-104
Electrodynamics

Total marks : 100 $(80+20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I (Lectures 05)

Electrostatic boundary value problems, solution of problems involving Laplace's and Poisson's equations in spherical, cylindrical and Cartesian coordinates, use of Green's function approximation.

Unit II (Lectures 03)

Review of Maxwell's equations, electromagnetic potentials, gauge transformation, Lorentz and Coulomb gauge, gauge invariance.

Unit III (Lectures 08)

Propagation of e.m. waves in free space, non conducting and conducting media, reflection and transmission at the boundary of two non conducting media, reflection from a metal surface, propagation of e.m. waves in bounded media, wave guides.

Unit IV (Lectures 04)

Scattering of e.m. waves due to free electrons, Thomson scattering, scattering from bound electrons, Rayleigh scattering and resonance fluorescence, dispersion– normal and anomalous.

Unit V (Lectures 05)

Non relativistic motion of a charged particle in uniform constant fields, in a slowly varying field, gradient drift, magnetic mirror.

Unit VI (Lectures 08)

Retarded potential, radiation from oscillatory dipole, radiation fields, radiation from a point charge in motion, Lienard – Wiechart potential, fields of a point charge in motion, power radiated by a point charge, Larmor formula, Bremsstrahlung.

Unit VII (Lectures 04)

Four dimensional Lorentz transformation, covariance of Maxwell's equations, electromagnetic field tensor.

Unit VIII (Lectures 08)

Propagation of plane electromagnetic waves in low pressure ionised gases, Conductivity of ionised gas, plasma frequency, Debye screening length, propagation of transverse waves in a perfectly conducting fluid embedded in a magnetic field (frozen-in field), and MHD, (Alfvén) waves, basic idea of plasma confinement.

Recommended books

1. Introduction to Electrodynamics – David J Griffiths
2. Foundation of Electromagnetic Theory – J R Reitz, F J Milford and R W Christy
3. Electricity and Magnetism - M H Nayfeh and M K Brussel,
4. Classical Electrodynamics - J D Jackson
5. The Feynman Lectures on Physics Vol II
6. Introduction to Plasma Physics - F F Chen
7. Plasma Physics - R J Goldstone and P H Rutherford.

Second Semester (January - June)

PHY-201-A
Atomic, Molecular, and Laser Physics I

Total marks : 50 $(40 + 10)$ **Total Lectures : 25** **Credits : 3 (2L + 1T)**

Unit I : *Atomic physics* (Lectures 08)

Pauli exclusion principle - spectral terms from two equivalent electrons, Vector model for three or more valence electrons and spectral terms, Branching rule, Lande interval rule, LS and JJ coupling schemes, Energy levels, selection rules, spectra of oxygen, nitrogen and manganese atoms.

Unit II : *Molecular physics* (Lectures 08)

IR spectra - Rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determination of rotational constants. Electronic spectra: Born-Oppenheimer approximation, vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck Condon principle. Raman spectra: Classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and antiStokes lines, Rotational Raman spectrum, selection rule.

Unit III : *Lasers* (Lectures 08)

Basic elements of laser, properties of laser light; spontaneous and stimulated emission - Einstein coefficients; light amplification, population inversion and threshold condition for laser oscillations; optical resonator modes of a rectangular cavity; ammonia maser, He-Ne laser.

Recommended books

1. Introduction to Atomic Spectra - H E White.
2. Physics of atoms and molecules - B H Bransden and C J Joachain
3. Fundamentals of Molecular Spectroscopy - C N Banwell and E M McCash.
4. Spectra of Diatomic Molecules (Vol. 1) - G Herzberg.
5. Lasers and Nonlinear Optics - B B Laud.
6. Lasers : Theory and Applications - K Thyagarajan and A K Ghatak.

PHY-201-B
Nuclear Physics I

Total marks : 50 $(40 + 10)$ **Total Lectures : 25** **Credits : 3 (2L + 1T)**

Unit I (Lecture 08)

Part A : ***General properties of nuclei and two-nucleon systems***

Basic Nuclear Properties: size, shape and charge distribution, spin, parity and iso-spin of nucleon and nuclei.

Part B : ***Bound State Problem and low energy n-p scattering***

Deuteron ground state with square well potential-magnetic dipole and electric quadruple moment of deuteron-experimental values, non-central nuclear force.

Part C : ***Scattering problem***

Low energy n-p scattering, partial wave analysis, scattering length and scattering cross-section.

Unit II : *Models of Nuclear Structure* (Lectures 12)

Part A : ***Liquid drop model and applications of mass formula***

Binding energy, Semi empirical mass formula – applications of mass formula – prediction of most stable member of an isobaric family, explanation for energy released in fission reactions, stability limits against spontaneous fission-Fission barrier and fission activation energy.

Part B : ***Shell Model***

Evidence of shell structure in nuclei, magic numbers, effective single particle potentials – square well, harmonic oscillator, Wood- Saxon with spin orbit interaction, extreme single particle model – its successes and failures in predicting ground state spin, parity, Nordheim rule.

Unit III : *Nuclear Reactions* (Lectures 10)

Part A : ***Kinematics and energetic of nuclear reactions***

Classification, conservation principles, Kinematics and Q-values - energetic of nuclear reaction – Q-value and threshold energy, exo-ergic and endo-ergic reactions, Laboratory and CMS frame of reference - energy and angle relationship for non-relativistic cases

Part B : ***Rutherford scattering and Compound nucleus model***

Basic concepts of flux and cross-sections, attenuation, Coulomb and Rutherford scattering, quantum mechanical and relativistic effects, extended particles, the compound nucleus hypothesis, Ghoshal experiment.

Recommended book

1. Introductory Nuclear Physics – Kenneth S Krane.
2. Introductory Nuclear Physics – Samuel S M Wong.
3. Atomic and Nuclear Physics (Vol. 2) – S N Ghoshal.
4. Concepts of Modern Physics - Arthur Beiser.
5. Techniques for Nuclear and Particle Physics Experiments – W R Leo.
6. Nuclear reactions and structure studies - P E Hodeson .
7. Techniques of radiation Measurements - G F Knoll.

PHY-202
Condensed Matter Physics I

Total marks : 100 (80 + 20) **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Crystalline Solids* (Lectures 10)

Fundamentals of crystal structure, symmetry operations, point groups and space groups, X-ray diffraction, reciprocal lattice, atomic scattering factor, geometrical structure factor, Quasicrystals, Imperfection in solids.

Unit II : *Lattice dynamics* (lectures 09)

Dispersion relations in monoatomic and diatomic linear lattices, normal modes, phonons, Phonon creation and annihilation operators, inelastic scattering of photons by phonons, inelastic scattering of neutrons by phonons including experimental details, inelastic phonon scattering, normal and umklapp processes.

Unit III : *Dielectric and ferroelectric properties* (Lectures 05)

Complex dc dielectric constant and dielectric loss, dielectric relaxation, Debye equations, dipole theory of ferroelectric domains, anti-ferroelectricity.

Unit IV : *Energy bands in solids* (Lectures 06)

Bloch function, Kronig-Penney model, Brillouin zones, effective mass of charge carriers. Tight binding and Wigner-Seitz method.

Unit V : *Semiconductors* (Lectures 06)

Intrinsic and extrinsic semiconductor, number density of carriers in intrinsic and extrinsic semiconductors, expression for Fermi levels, recombination processes, photoconductivity, Hall effect in metals and semiconductors.

Unit VI : *Magnetic properties* (Lectures 09)

Fundamental concepts, quantum theory of diamagnetism and paramagnetism, diamagnetic and paramagnetic susceptibilities of free electrons, molecular field theory of ferromagnetism, anti-ferromagnetism and ferrimagnetism, anisotropic energy, electron paramagnetic resonance and nuclear magnetic resonance, Bloch equations, Heisenberg Hamiltonian for exchange interaction, relationship between exchange energy and molecular field.

Recommended books

1. Introduction to Solid State Physics – C Kittel.
2. Lattice Dynamics – A K Ghatak and L S Kothari
3. Solid State Physics – A J Dekker.
4. Introductory Solid State Physics – H P Myers.

5. Solid State Physics – N W Ashcroft and N D Mermin.

6. Magnetism in solids – D H Martin.

PHY-203
Electronics I

Total marks : 100 $(80+20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Electronic devices* (Lectures 10)

Homo and hetero-junction devices, Opto Electronic Devices: Solar Cell, Photodetectors, LED;Thyristor devices: SCR, UJT, Triac; FET Devices: JFET, MOSFET, MESFET, CMOS; Microwave devices: Klystron and magnetron, tunnel diode, Gunn Diode and IMPATT/AVALANCHE diode; Fabrication of semiconductor devices, Noise in electronic devices.

Unit II : *Operational amplifier* (Lectures 15)

Differential Amplifier, differential mode and common mode operation, CMRR, Transconductance and Transresistance Amplifier, Instrumentation Amplifier, Analog Computation, Active Filter: Butterworth and Chebyshev filter, Filter transformation, Comparators, VCO, Saw tooth wave generator, Digital to Analog Converter, Binary Weighted DAC, R-2R ladder network.

Unit III : *Communication* (Lectures 20)

Basic Concepts of Communication; Transmission Line: Wave equation, characteristics impedance, SWR, impedance matching; Waveguide: fundamental concepts of signal transmission through wave guide, relation between cut off frequency and waveguide dimension of rectangular waveguide; Antenna: Radiation from short electric doublet, monopole and dipole antenna, antenna parameter, antenna array. Radio wave propagation: Tropospheric Propagation, Ionospheric Propagation, Surface Wave. Angle Modulation: FM modulation, Phase Locked Loops; Pulse Modulation: PAM, PCM Basic idea of digital carrier modulation schemes and Channel capacity.

Recommended books

1. Electronic devices and circuit theory - R L Boylestad.
2. OPAMPS and Linear Integrated Circuits - Ramakant A Gayakwad.
3. Operational amplifier and linear integrated circuits - R F Coughlin and F F Driscoll.
4. Modern Digital and Analog Communication Systems - B P Lathi.
5. Electronic Communication System - George Kennedy.
6. Communication Systems - Simon Haykin.

PHY-204

Computational Physics†

Total marks : 100 $(40 + 40 + 20)$ **Credits : 6**

† ***This paper has a theory and practical part combined together***

Unit I : *Computer Programming* (Marks 40)

Part A

Introduction to programming Basics of computer programming, concepts of file structure, directories, compilers and debuggers in relation to GNU Linux O/S. Basic commands in GNU Linux. Plotting with GNUPLOT.

Part B

Introducing FORTRAN 90 FORTRAN 90 as a structured programming language for solving scientific problems. Basic structure of FORTRAN 90 — concept of variables, operators, and precedence of operations. Difference between a mathematical statement and a FORTRAN statement — incrementing a variable. Global and local variables — concept of modules and indexed variables (arrays). Types of variables — integer, floating point, and character variables. Concept of logical statements — if-then-else, do-while statements. Structured programming — function and subroutine. I/O statements and formatting.

Unit II : *Numerical Analysis* (Marks 40)

Part A

Introduction to numerical analysis The need for numerical analysis and its limitations. Concept of errors with examples.

Part B

Solution of transcendental equations Solving an equation with Newton-Raphson method and bisection, comparison of their limitations, propagation of errors.

Part C

Solution of ordinary differential equations (ODEs) Concept of finite differencing. Solution of a first order ODE with Euler's method and its limitations. Need for a higher-order method — solution of a first order ODE with Runge-Kutta method. Solving higher order ODE — coupled ODEs.

Part D

Numerical integration The concept of numerical integration — quadrature. Trapezoidal and Simpson's rules and their relation to interpolation.

Part E

Partial differential equations (PDEs) The concept of initial and boundary value problems — solving the Poisson equation by Gauss-Siedel iteration. Concept of numerical stability—von Neumann stability analysis with examples and importance Courant-Friedrichs-Lewy (CFL) condition. Implicit and explicit schemes.

Part F

Manipulation of matrix Solution of linear equations — Gauss-Jordan elimination. Concept of pivoting.

Part G

Random numbers in numerical analysis The concept of random numbers — pseudo random numbers and their generators. Application — Monte-Carlo integration. Examples from Physics To be given.

Recommended books

1. Numerical Recipes - W H Press et al. (Cambrideg University Publication).

Third Semester (August - December)

PHY-301

Atomic, Molecular, and Laser Physics II

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Uni I : *Spectroscopy* (Lectures 29, Marks 50)

Part A : *Atomic spectra* (Lectures 11)

Zeeman effect, Paschen Back effect, Stark effect in hydrogen, Calculation of Zeeman pattern and intensity distribution in complex spectra, Hyperfine structure and determination of nuclear spin and nuclear g factors. Zeeman effect and Goudsmit effect in hfs, X-ray doublet laws and isoelectronic sequences. Breadth of spectrum lines: Natural broadening, Doppler broadening, Collision broadening and Stark broadening.

Part B : *Electronic spectra of diatomic molecules* (Lectures 11)

Coarse structure of electronic transitions: Deslandres table, vibrational analysis, determination of vibrational frequency, anharmonicity. Fine structure of electronic transitions: rotational analysis, combination relations with and without Q branches, determination of rotational constants, internuclear distance and moment of inertia, determination of band origins. Wave mechanical formulation of Franck Condon principle: overlap integral, band intensities in emission and absorption, vibrational sum rule and vibrational temperature. Intensity distribution in rotational structure: 'rotational' temperature, intensity distribution in homonuclear molecules. NMR & ESR spectra: Magnetic properties of nuclei, nuclear resonance, Spin-spin & spin-lattice interaction, chemical shift, nuclear coupling.

Part C : *Fluorescence spectra* (Lectures 07)

Luminescence: fluorescence and phosphorescence, Jablonski diagram, Characteristics of fluorescence emission, Fluorescence lifetimes and Quantum Yields, Fluorescence anisotropy, Resonance energy transfer, Steady state and Time-resolved fluorescence, Molecular information from fluorescence.

Unit II : *Laser* (Lectures 16, Marks 30)

Part A : *Resonators* (Lectures 07)

Modes of a resonant cavity: Longitudinal & transverse laser modes; stability condition; properties of Gaussian beams; single and multimode oscillations; Q switching: requirements, techniques, pulse duration and width; mode locking: intensity, pulse separation, techniques.

Part B : *Types of lasers* (Lectures 07)

2, 3 and 4-level lasers: rate equations; Ruby, CO2, semiconductor, Nd:YAG and dye lasers: excitation mechanisms. C. Selected applications of laser. Holography and optical communication (basic principles only).

Recommended books

1. Laser Fundamentals - W T Silfvast.

2. Principles of fluorescence spectroscopy - J R Lakowicz.

3. Essentials of Laser and Nonlinear Optics - G D Baruah.

4. Molecular Spectra and Molecular Structure (Vol. 2) - G Herzberg.

PHY-302
Nuclear Physics II

Total marks : 100 (80 + 20) **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Nuclear Models* (Lectures 10)

Part A : *Applications of shell model*

Independent particle model, total spin J for various configurations, magnetic dipole moment of various nuclei – Schmidt's one nucleon model and concept of total angular momentum and total magnetic moment, electric quadrupole moments of various nuclei in the light of extreme single particle shell model.

Part B : *Collective model*

Failure of shell model in understanding the excited states of even-even nuclei and other nuclear properties, Dynamics of collective motion, Vibrational model and vibrational energy levels of even-even nuclei, Rotational model and rotational energy levels.

Unit II : *Nuclear reaction* (Lectures 10)

Part A : *Types of nuclear reactions*

Optical model for elastic scattering, average interaction potential for nucleon, energy dependence of the potential, imaginary and absorption, analysis of scattering experiment.

Part B : *Direct reaction*

Kinematics of stripping and pick-up reactions, inelastic scattering, transfer reaction with grazing angle concept, plane wave and distorted wave Born approximation (DWBA)

Part C : *Compound nucleus resonance*

Breit-Wigner dispersion formula for $l = 0$ reaction mechanism –compound nucleus, continuum theory of cross section, statistical theory, evaporation probability.

Unit III : *Electromagnetic interaction with nuclei* (Lectures 08)

Multipole expansion of Radiation field, multipolarity, γ-ray transition probability, Angular momentum and Parity selection rules. Comparison with experiments, Nuclear Isomerism, Internal Conversion of γ-rays, Angular distribution of γ-rays, Angular correlation in γ-γ–cascade.

Unit IV

Part A : *Nuclear β decay* (Lectures 06)

Essential conditions for various types of beta decays, Fermi's theory of beta decay, comparative half-lives and forbidden decays, Curie plot, Reins & Cowen and Davis experiments for detection of neutrino. Concept of double beta decays and Majorana neutrino.

Part B : *Nuclear Radiation Detectors* (Lectures 07)

Interaction of radiation and (heavy) charged particles with matter, detector response, energy resolution – Fano factor

Part C : *Gas filled detectors* (Lectures 06)

Ionization, proportional and GM counters, telescopic detector. Scintillation counters

Part D : *Thermo-nuclear fusion and nucleosynthesis* (Lectures 04)

Particle and Nuclear interactions in the early universe, Primordial nucleosynthesis. Sources of energy production in stars- Hydrogen burning – PP and CNO cycles, He burning, Stellar nucleosynthesis up to $A < 56$ and $A > 56$, Solar neutrino puzzle, neutrino oscillation, experimental determination of solar neutrino.

Part E : Elementary particles (Lectures 06)

Classification of elementary particles and their interactions, conservation laws, symmetry principles & quantum numbers, strangeness and isospin, Gell-Mann Nishijima scheme, Quark model.

Recommended books

1. Introductory Nuclear Physics – Kenneth S Krane.
2. Introductory Nuclear Physics – Samuel S M Wong.
3. Atomic and Nuclear Physics (Vol.2) – S N Ghoshal.
4. Concepts of Nuclear Physics – Bernard L Cohen.
5. Techniques for Nuclear & Particle Physics Experiments – W R Leo.
6. Nuclear reactions and structure studies- P E.Hodeson.
7. Techniques of radiation Measurements- G F Knoll.
8. Cosmic Rays – A W Wolfendale.
9. Extensive Air Showers – M V Rao and B V Sreekantan.

PHY-303-A
Condensed Matter Physics II

Total marks : 50 $(40 + 10)$ **Total Lectures : 25** **Credits : 3 (2L + 1T)**

Unit I : *Optical properties of solids* (Lectures 08)

Optical constants, dispersion relation of optical constants from Maxwell's equations, Kramers-Kronig relations, optical absorption and emission in semiconductors, exciton absorption, impurity and inter-band transitions, luminescence, activators, Frank Condon principle, photoluminescence and thermoluminescence.

Unit II : *Superconductivity* (Lectures 06)

Thermodynamics of superconducting state, London equations, coherence length, BCS theory, flux quantization, Josephson effect, Isotope effect, electron-phonon interaction and BCS theory of superconductivity, Giaever tunneling, superconducting quantum interference device (SQUID), Superconducting magnet.

0.0.1 Unit III : *Electrons in magnetic field* (Lectures 05)

Magneto-conductivity, cyclotron resonance, Quantization of energy levels in presence of magnetic field, Landau levels and Landau cylinders, Quantum Hall Effect, de Haas-van Alphen effect, Fermi surface studies.

Unit IV : *Soft Condensed Matter Physics and Nanophysics* (Lectures 06)

Liquid crystal, Conducting polymers, Definition of nanomaterials, Types of nanomaterials: Metal, semiconductor (elemental and compound), Quantum confinement: One, Two and Three dimensional.

Recommended books

1. Solid State Physics – A J Dekker.
2. Fundamentals of Solid State Physics - J Richard Christman.
3. Introduction to Solid State Physics – C Kittel.
4. Solid state theory – W Harrison.
5. Intermediate quantum theory of crystalline solids – A O E Animalu.
6. Introduction to Nanotechnology – C P Poole and F J Owens.
7. Soft Condensed matter – R A L Jones.
8. Superconductivity Today – T V Ramakrishnan and C N R Rao.

PHY-303-B
Electronics II

Total marks : 50 $(40 + 10)$ **Total Lectures : 25** **Credits : 3 (2L + 1T)**

Unit I : *Digital Circuits* (Lecturers 09)

Logic families; Signal levels and noise margin; Simplification of boolean functions: Mapping and function minimization (SOP and POS); Binary adders and subtractors; Sequential logic: RS, JK, D and T flip flop; Register; Counters; Encoders; Decoder; Multiplexer; Demultiplexer; Memory Concepts; Fault detection in digital circuits; Synthesis and design of sequential circuits: Analysis and synthesis of synchronous and asynchronous circuits, hazard free asynchronous circuits, sequential machine. Analog to Digital Converter: Flash Converter, Successive Approximation ADCs, Counting and Integrating ADC Architectures.

Unit II : *Microprocessor and Microcontrollers* (Lectures 06)

RISC and CISC Processor, 8085 CPU-Architecture, Bus Timing, Instruction Set, Addressing Mode, stack and subroutine. 8051 microcontroller Architecture, On chip peripherals, Instruction Set, SFR. Introduction to RISC processors.

Unit III : *Network analysis* (Lectures 05)

Network function ; Poles and Zeros; zero input and zero state response ; Effect of position of poles and zeros on system response, Routh array; Frequency response analysis: Bode plot, Nyquist Criterion for stability, Nyquist Path, Gain, Margin, Phase Margin.

Unit IV : *Digital Signal Processing* (Lectures 05)

Discrete Time Signals and systems, z transform and its application to the analysis of Linear Time Invariant Systems, Sampling of signal in time domain and frequency domain, Finite impulse response (FIR) and infinite impulse response filters (IIR) Design of Digital Filters, discrete Fourier transform, fast Fourier transform, digital signal processor.

Recommended books

1. Digital Signal Processing - John Proakis, Dimitris Manolakis.
2. Microprocessor architecture, Programming and applications with 8085 - Ramesh Gaonkar.
3. The 8051 microcontroller and embedded System-using assembly and C - Muhammad Ali Mazidi, Janice Mazidi, Rolin D McKinlay.
4. Analog-Digital Conversion - Walt Kester.
5. Analog to digital conversión - Marcel J. M. Pelgrom.
6. Digital Principles and Applications - Malvino, Leach, Saha

PHY-304-E1
Advanced Mathematical Physics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Integral Equations* (Lectures 15)

General classification of integral equations, Volterra and Fredholm equations of first and second kind, linear, non linear and homogeneous equations, advantages of integral equations over differential equations, transformation of differential equation to integral equations, example - Schröndinger equation, linear harmonic oscillator equation. Solution of integral equations: Iterative technique (successive approximation or Neumann series), separable kernels (degenerate kernel), eigenvalue and eigenfunction problem, Fredholm method of solution, resolvent kernel(reciprocal kernel) in method of successive approximation, illustrative examples with problems and solutions.

Unit II : *Group Theory* (Lectures 15)

Schur's lemmas and the orthogonality theorem, characters of representation, reducibility criteria, direct product of representations, Lorentz group, Lie algebra and representations of Lie group, Young tableau in reduction of direct product of representations, adjoint representation, regular representation , fundamental representation.

Unit III : *Path Integral Method* (Lectures 15)

Functional calculus, path integral method for a free particle, path integral for a general quadratic action, equivalence with Schrödinger equation, simple applications to a free particle and harmonic oscillator, path integral for a partition function and partition function for an SHO system.

Recommended books

1. Mathematical Methods for Physicists - George Arfken.
2. Integral Equations - Shanti Swarup.
3. Group Theory and its application to physical problems - Morton Hamermesh.
4. Elements of Group Theory for physicists - A W Joshi.
5. Introduction to Topology, Differential Geometry, and Group Theory for Physicists - S. Mukhi and N. Mukunda.
6. Quantum Mechanics and Path Integrals - R P Feynman and A R Hibbs.
7. Techniques and applications of Path Integrals - L S Schulman.
8. Path Integral Methods and their applications - D C Khandekar, S V Lawande, and K V Bhagawat.

PHY-304-E2
Astrophysics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit 1 : *Observational astronomy* (Lecture 08)

The celestial sphere, coordinate systems and transformation equations. Concept of time — solar time and sidereal time. Magnitude scales, colour index, apparent, absolute, and instrumental magnitudes. Measuring stellar distance — method parallax and other methods to determine stellar distances. Constructing the HR diagram of stars and star clusters and its importance in evolution of stars. Different types of astronomical telescopes and their mounts. Basic instrumentations — use of photometers and CCD. Atmospheric extinction.

Unit 2 : *Structure formation* (Lecture 06)

Interstellar matter. Jeans theory for formation of stellar structure and its limitations. Jeans process in early universe. Formation of galaxies and star clusters. Free-fall collapse and formation of stars.

Unit 3 : Transport of energy in stars (Lecture 06)

Radiation theory. Equation of radiative transfer — concepts of flux, intensity, and temperature. Formation of emission and absorption lines, limb darkening. Ionisation and the concept of mean molecular weight. Saha's ionisation equation. Stellar opacity — radiative transfer of energy as convection, Rosseland mean opacity. Fully convective stars and pre main sequence stars and Hayashi track.

Unit 4 : *Stellar structure, evolution, and neucelosynthesis* (Lecture 10)

Integral theorems of hydrostatic equilibrium of stars. Polytropic gas sphere, Lane-Emden equation and its solutions, Virial theorem and stability of ploytropes, mass-radius relations of polytrope, Eddington's quartic equation. Spectral classification and HR diagram, thermonuclear reactions and rates. Nucleosynthesis – hydrogen burning (*pp* chain and CNO cycle), triple alpha reaction. Advanced stages of nuclear burning. Supernovae and their types.

Unit 5 : *Compact objects* (Lecture 06)

Degenerate stars, white dwarf, mass–radius relation and Chandrasekhar mass limit. Maximum mass of neutron star, Tolman-Oppenheimer-Volkoff equation. Basics of X-ray astronomy, black holes, and gamma ray bursts.

Unit 6 : *Galaxies* (Lecture 04)

Shapley–Curtis debate, external galaxies. Hubble's classification of galaxies, properties of spirals, ellipticals and lenticular galaxies, surface brightness, distribution of light and mass, the galactic centre, 21 cm line, Active galactic nuclei.

Recommended Text Books

1. Introduction to stellar structure - S Chandrasekhar.

2. Introduction to stellar astrophysics - D Prialnik.
3. Introduction to stellar astrophysics (Vol I, II, and III) - Erika Böhm-Vitense.
4. Physics of Stars - A C Phillips.
5. Principles of stellar evolution and nucleosynthesis - D D Clayton.
6. Astrophysics - Baidyanath Basu.
7. Astrophysics - V Kourganoff .
8. The fundamentals of stellar astrophysics - G W Collins.
9. Astrophysics - R Kippenhahn and A Weigert.

PHY-304-E3
High Energy Physics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Introduction to elementary particles and quark model of hadrons* (Lectures 20)

Classification of elementary particles, spin and parity determination of pions and strange particles, properties of particles : C, P, G Conjugation, GellMann and Nishijima scheme, the eightfold way classification (GellMann and Neeman classification), quark hypothesis of GellMann and Zweig, properties and types of quarks, elementary idea of Lie groups, spin SU(2) and flavour SU(3) symmetry, colour quantum number, hadron wave functions and classification (spin and flavour), Parton model. Four fundamental interactions and their characteristics in terms of decay lifetimes, strengths, ranges; conservation laws and decay modes, charged leptonic weak interactions, decay of muon, neutron and charged pions, neutral weak interactions.

Unit II : *Introduction to Quantum Field Theory* (Lectures 15)

Concept of fields, classical fields as generalized coordinates, Lagrangian of a field, Euler-Lagrange equation, Canonical quantization of a one dimensional classical system, Fock space, the method of second quantization, canonical quantization of free fields (Hermitian and nonHermitian scalar fields, electromagnetic field, Dirac field), Noether's theorem, conservation of energy, momentum and charge of the field, the vacuum in field theory; C, P, T transformation of scalar and e.m. Fields.

Unit III : *Quantum Electrodynamics* (Lectures 10)

Covariant perturbation theory, Feynman rules in momentum space, reduction of time-ordered products, calculation of second order process, Compton scattering, Klein-Nishima formula, Mott scattering, elements of renormalization of charge and mass.

Recommended books

1. Introduction to Elementary Particles - David Griffiths.
2. Quarks and leptons : An introductory course in Modern Particle Physics - Francis Halzen and Alan D Martin.
3. Gauge Theory of Elementary Particle Physics – Ta-Pei Cheng and Ling Fong Li.
4. Quantum Field Theory - L H Ryder.
5. (a) Relativistic Quantum Mechanics (VolI), (b) Relativistic Quantum Fields (Vol II) - James D Bjorken and Sidney D Drell.

PHY-304-E4

Molecular and Laser Spectroscopy

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Molecular Spectroscopy* (Lectures 23, Marks 40)

Part A : S*pectra of diatomic molecules* (Lectures 06)

Hund's coupling cases, symmetry properties of electronic states and rotational levels, selection rules, types of electronic transitions: ${}^1\Sigma - {}^1\Sigma$, ${}^2\Sigma - {}^2\Sigma$, ${}^1\Pi - {}^1\Sigma$, ${}^2\Pi - {}^2\Sigma$. Continuous and diffuse spectra: pre-dissociation, Auger effect. Heats of dissociation: determination of dissociation limits, band convergence, Birge-Sponer extrapolation.

Part B : *Molecular orbital approximation* (Lectures 05)

United and separated atom constructs, correlation of molecular orbitals, LCAO/MO theory, determination of terms and multiplicities from molecular orbitals.

Part C : *Spectra of polyatomic molecules* (Lectures 06)

Normal modes of vibrations, symmetry elements and symmetry operations as point group, elements of group theory and its applications in the analysis of normal modes; UV, visible, IR and Raman spectroscopy (instrumentation only).

Part D : *Applications of molecular spectroscopy* (Lecture 06)

In nuclear physics: spin & statistics; *In astrophysics:* absorption and emission in earth's atmospheres, terrestrial Fraunhofer lines, planetary atmospheres, comets, stellar atmospheres and interstellar space.

Unit II : *Laser Spectroscopy* (Lectures 22, Marks 40)

Part A : *Selected applications of lasers in science and technology* (Lectures 04)

Isotope separation, laser-induced fusion, basic ideas of cooling of atoms with laser and optical molasses, optical frequency comb.

Part B : *Nonlinear optics* (Lectures 08)

Nonlinear susceptibility, second harmonic generation, phase matching, parametric oscillation, intensity-dependent refractive index: self-focusing, phase conjugation: four wave mixing.

Part C : *Laser spectroscopy* (Lectures 10)

Preliminary ideas only: Laser Raman spectroscopy: experimental techniques, resonance Raman, stimulated Raman, hyper Raman and coherent antiStokes Raman spectroscopy; Doppler limited spectroscopy: photo-acoustic spectroscopy and laser-induced fluorescence; Time-resolved spectroscopy: phase shift method, pulse excitation and quantum beat spectroscopy.

Recommended book

1. Chemical Applications of Group Theory - F A Cotton.
2. Laser age in optics - V Tarasov.
3. The principles of nonlinear optics - Y R Shen.
4. Laser Spectroscopy: Basic concepts and instrumentation - W Demtröder.

PHY-304-E5
Nanophysics

Total marks : 100 (80 + 20) **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Introductory idea* (Lectures 02)

Nanoscale regime, Emergence of nano science, Top down and bottom up approaches, Nanoparticles, Nanowires, Nanotubes, Nanoscience to nanotechnology, Challenges of nanotechnology.

Unit II : *Nanostructure synthesis and characterization* (Lectures 15)

Natural occurrence, Chemical route, Chemical bath deposition, Sol-gel techniques, Chemical vapour deposition, MOCVD, PECVD, Physical vapour deposition, Magnetron sputtering, Pulsed laser deposition, Molecular beam epitaxy, Lithography, Mechanical alloying, Crystallization of melt-spun ribbons, Biosynthesis, Nano manipulation. X-ray diffraction: crystallite size and strain, X-ray line profile analysis - broadening of diffraction line, Size and strain broadening, Electron microscopy, Spectroscopic techniques, X-ray photoelectron spectroscopy. Electron and neutron diffraction, Magnetometry.

Unit III : *Nucleation and growth* (Lectures 06)

Homogeneous and heterogeneous nucleation, Volmer analysis of nucleation, Growth of nanocrystals in solution, Ostwald ripening, LaMer's mechanism, Supersaturation, LSW theory.

Unit IV : *Properties of nanostructures* (Lectures 15)

Increased surface to volume ratio, Interface effect, Physics of low dimensional structures, Quantum mechanical treatment of quantum dots, wells and wires, Widening of band gap in quantum dots, Strong and weak confinement, Size dependent absorption spectra and blue shift, Coulomb blockade, Metallic nanoparticles, Surface Plasmon Resonance, Particle size and magnetic behaviour, Super-paramagnetism, Ultra soft-magnetism, Magnetotransport, Ferrofluids, Spintronics, Catalytic activity.

Unit V : *Carbon nanostructures* (Lectures 03)

Nature of carbon bond, Small carbon clusters, Discovery of C60, Structure of C60, Carbon nanotubes; types, synthesis, properties, applications.

Unit VI : *Nanocomposites* (Lectures 04)

Ceramic/metal nanocomposites, Polymer based nanocomposites, Natural nanobiocompsites, Biomimetic nanocomposites, Biologically inspired nanocomposites, Mechanical, electrical and optical properties of nanocomposites. Applications of nanocomposites.

Recommended books

1. K. D. Sattler (Ed.), Handbook of Nanophysics, CRC Press, 2011.

2. B. Bhushan (Ed.), Springer Handbook of Nanotechnology, Springer, 2004.
3. G. Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press, 2004.
4. C. P. Poole, J. F. J. Owens, Introduction to Nanotechnology, Wiley Interscience, 2003.
5. B. D. Cullity and S. R. Stock, Elements of X-ray Diffraction, Prentice Hall, 2001.
6. H. P. Klug and L.E. Alexander, X-ray Diffraction Procedures for Polycrystalline and Amorphous Materials, Wiley–VCH, 1974.
7. G. Schmid, Nanotechnology: Principles and Fundamentals, Wiley-VCH Verlag, 2008.
8. B. S. Murty, P. Shankar, Baldev Raj, B. B. Rath, James Murdy, Textbook of Nanoscience and Nanotechnology, University Press, 2012.
9. K. K. Chattopadhyay, A. N. Banerjee, Introduction to Nanoscience and Nanotechnology, Prentice Hall, 2009.
10. T. Pradeep, Nano: The Essentials, Understanding Nanoscience and Nanotachnology, Tata McGraw Hills, 2007.

PHY-304-E6

Physics of Thin Films

Total marks : 100 $(50 + 30 + 20)$ **Total Lectures : 25** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Definition of a thin film* (Lectures 05)

Different methods of film preparation: thermal evaporation, sputtering.

Unit II : *Film thickness measurement* (Lectures 06)

Optical interference methods and other methods, Analytical techniques for chemical, structural and surface studies.

Unit III : *Nature of thin films* (Lectures 07)

Theories of nucleation: the capillarity and the atomistic model, growth processes, epitaxial films and their growth.

Unit V (Lectures 05)

Electrical (Continuous and discontinuous films, Size effect), optical and magnetic properties of thin films, Galvano-magnetic size effect.

Unit VI (lectures 02)

Some thin film devices (Electronic, Spintronic, GMR).

Recommended books

1. Materials Science of Thin Films - M Ohring.
2. Handbook of Thin Films - Maissel and Glang.
3. Thin Film Phenomena - K L Chopra.
4. Thin Film - Ashok Goswami.

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Fourth Semester (January - June)

PHY-401
Quantum Mechanics II

Total marks : 100 (80 + 20) **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Relativistic Quantum Mechanics* (Lectures 18)

Concept of four vectors, natural units, Minkowski space, Klein Gordon (KG) equation, Problem with KG equation, Dirac equation, Plane wave solution of Dirac equation, concept of negative energy and vacuum. Non relativistic limit of Dirac equation, prediction of spin of electron. Covariant formulation of Dirac equation, Dirac matrices, Dirac bilinear, Dirac gamma matrices and their trace calculation.

Unit II : *Scattering theory* (Lectures 14)

Introduction to scattering cross section, differential cross section. Scattering by a potential, partial wave analysis, optical theorem, Lippman Schwinger equation, Green function solution, transition matrix. Born series and Born approximation, scattering cross section for Yukawa, Coulomb and square well potential. Resonance scattering, Breit–Weigner formula.

Unit III : *Interaction of radiation with matter* (Lectures 07)

Electromagnetic field and its interaction with single electron atom, harmonic perturbation and transition rates, spontaneous and stimulated emission, absorption, Einstein A and B coefficients. Selection rules.

Unit IV : *Path Integral Approach to Quantum Mechanics* (Lectures 06)

Feynman's Path Integral method, equivalence of Feynman and Schrödinger equations, Dirac-Feynman Action Principle.

Recommended books

1. Quantum Mechanics (second ed.) - B H Bransden and C J Joachain.
2. Advanced Quantum Mechanics - J J Sakurai.
3. Quantum Mechanics - Eugene Merzbacher.
4. Quantum Mechanics - L I Schiff and J Bandhyopadhyay.
5. Quantum Mechanics - A Ghatak.
6. Principles of Quantum Mechanics - R Shankar.

PHY-402
Statistical Mechanics

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Classical Statistical Mechanics* (Lectures 17)

Part A (Lectures 03)

Statistical basis of thermodynamics, probability concepts, microstate and macrostate, link between statistics and thermodynamics, classical ideal gas, entropy of mixing and Gibbs paradox

Part B (Lectures 04)

Theory of ensembles, phase space and Liouville's theorem, microcanonical ensemble, postulate of equal a priori probability.

Part C (Lectures 06)

Canonical ensemble, system in canonical ensemble, thermodynamic quantities, partition function, classical systems, energy fluctuations in canonical ensemble, system of harmonic oscillators, theory of paramagnetism, thermodynamics of magnetic systems, negative temperatures.

Part D (Lectures 04)

Grand canonical ensemble, system in grand canonical ensemble, various thermodynamic quantities, grand partition function, density and energy fluctuations in grand canonical ensemble, equivalence to other ensembles

Unit II : *Quantum Statistical Mechanics* (Lectures 28)

Part A (Lectures 03)

Framework of quantum statistics, inadequacy of classical theory, density matrix, quantum mechanical ensembles, principle of detailed balance, microcanonical, canonical, and grand canonical ensembles, postulates of quantum statistical mechanics

Part B (Lectures 04)

Theory of gases, Maxwell–Boltzmann, Bose–Einstein and Fermi–Dirac statistics, partition and grand partition functions, statistics of occupation numbers, distinction between classical and quantum statistics, fluctuations.

Part C (Lectures 06)

Ideal Bose gas, equations of state, properties of ideal Bose gas, Bose–Einstein condensation (BEC) and experimental evidences, thermodynamics of black body radiation.

Part D (Lectures 06)

Ideal Fermi gas, thermodynamic behaviour and properties of ideal Fermi gas, degenerate and non-degenerate Fermi gas, electrons in metals, thermodynamic equilibrium of white dwarf stars.

Part E (Lectures 03)

Fluctuations, Gaussian distribution, Brownian motion: Einstein–Smoluchowski theory, Langevin theory, approach to equilibrium: Fokker–Planck equation.

Part F (Lectures 03)

Phase transitions, formulation of the problem, Ising model, lattice gas and binary alloy, the theory of Lee and Yang.

Part G (Lectures 03)

Liquid Helium, two fluid hydrodynamics, Tisza's two fluid model, Landau two fluid theory, second sound, Landau criterion, theory of Feynman.

Recommended books

1. R. K. Patharia and P. D. Beale, Statistical Mechanics, 3rd Edition, Elsevier, 2011.
2. K. Huang, Statistical Mechanics, 2nd Edition, Wiley India Edition, 2009.
3. S. R. A. Salinas, Introduction to Statistical Physics, Springer, 2001.
4. W. Greiner, L. Neise, H. Stöcker, Thermodynamics and Statistical Mechanics, Springer, 1995.
5. L. D. Landau and E. M. Lifshitz, Statistical Physics, Pergamon, 1980.
6. F. Reif, Statistical Physics, McGraw Hill Education (India) Pvt. Ltd., 2011.

PHY-403

Experimental Methods

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Uncertainty in measurements* (Lectures 20)

Part A : *Measurement fundamentals*

Measurement, Calibration, Errors, Accuracy, Precision, Uncertainty, Repeatability, Reproducibility.

Part B : *Measure of central tendency*

Mean, median and mode of discrete and grouped data, geometric mean, harmonic mean and weighted mean. Dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis.

Part C : *Uncertainty in measurement*

Kinds of errors - Gross, Systematic and random errors. Types of Uncertainty: Type A and B, Measurement of Uncertainty, Propagation of errors.

Part D : *Correlation and Regression*

Positive and negative correlation, scatter plot, Karl Pearson coefficient of correlation. Regression – line of regression.

Part E : *Probability distribution*

Permutation and combination, Binomial theorem, Meaning of probability distribution, Binomial distribution, Poisson's distribution and its applications in radioactive decays, Gaussian or Normal distribution. Confidence levels, Central limit theorem.

Part F : *Goodness of Fit test*

least square method, chi-square test

Unit II : *Experimental Techniques* (Lectures 25)

Part A : *Elements of signal acquisition and analysis* (Lectures 06)

Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors) Signal conditioning, Noise, Filtering, grounding, shielding, box car integrator, lock in amplifier, Fourier Transform.

Part B : *Low pressure* (Lectures 04)

Gas flow at low pressures, Principles of pumping, parameters and classifications of vacuum pumps, Mechanical pumps, Vapour pumps, Ion pumps, Sorption pumps, Cryopumps, Classification and selection of vacuum gauges, Gauges using liquids, Thermal conductivity gauges, Ionization gauges, Calibration of vacuum gauges.

Part C : *Low temperature* (Lectures 04)

Properties of cryoliquids, Helium-4 cryostats, Helium-3 cryostats, Pomeranchuk cooling, Refrigeration by adiabatic demagnetization, Laser cooling, Low temperature thermometry.

Part D : *Measuring equipments* (Lectures 07)

XRD, XRF, SEM, TEM, AFM, STM, VSM, Absorption spectrophotometer, Spectrofluorometer, Raman Spectrometer, FTIR, ESR, NMR.

Part E

Charged particle accelerator – linear accelerator, PIXE. Nuclear Data Acquisition System- NIM bins and NIM modules – pre-amp, spectroscopic amplifier, discriminator, ADC, SCA, MCA etc.

Recommended books

1. A. Roth, Vacuum Technology, 3rd edition, Elsevier Science B.V., 1996.
2. F. Pobell, Matter and Methods at Low Temperatures, Springer-Verlag, 1992.
3. B. D. Cullity and S. R. Stock, Elements of X-ray Diffraction, Prentice Hall, 2001
4. K. K. Chattopadhyay, A. N. Banerjee, Introduction to Nanoscience and Nanotechnology, Prentice Hall, 2009.
5. Les Kirkup and Bob Frenkel. An Introduction to Uncertainity in Measurement, Cambridge University Press.

PHY-404-E1
Advanced Electronics

Total marks : 100 $(50 + 30 + 20)$ **Total Lectures : 30 Credits : 6** $(2\mathrm{L} + 1\mathrm{H} + 0.5\mathrm{T} + 4\mathrm{P})$

Unit I : *Communication* (Lectures 20)

Part A : *Information theory* (Lectures 04)

Uncertainity, Information and Entropy, Source Coding Theorem, Channel Coding theorem, Channel Capacity Theorem. Digital Carrier Modulation schemes (8 Lectures): ASK, FSK, PSK, DPSK, MSK, M-ary signalling , QPSK, Noise, Power, bandwidth, Error Control Coding, Spread Spectrum modulation; Multiplexing, Waveform Coding Techniques: Differential PCM, Delta Modulation.

Part B : *Fibre Optic Communication* (Lectures 03)

Propagation of optical signal through fibre, single mode, step index, graded fibre, Optical fibre performance; Optoelectronic communication circuits; Fibre optic links. Satellite communications((2 Lectures): Orbital satellites, Geostationary satellites, orbital patterns, satellite system, GPS.

Part C : *Radar* (Lectures 02)

Radar block diagram, Radar performance factors: range equation, noise; radar frequencies, Pulse system, antenna and scanning, display.

Part D : *Cellular Communication* (Lecture 01)

Basic concepts

Unit II : *Antenna* (Lectures 05)

Parabolic antenna; Horn Antenna; lens antenna: single surface dielectric, stepped lenses and metal plate lens antenna, aperture and field, Microstrip antenna: cavity model, impedance, radiation pattern, smart antenna: switched beam, adaptive array, SDMA; Overview of mobile adhoc network.

Unit III : *Programmable Logic Devices and Hardware Description Language* (Lectures 03)

CPLD and FPGA basics, Concept of Hardware description Language, Structure of VHDL code, implementation of simple combinational and sequential logic; test bench.

Unit IV : *Servomechanism and control system* (Lectures 02)

Open loop system, First and Second order system with derivative & integral control, Servomotor and its simple control circuits.

Recommended books

1. Modern Digital and Analog Communication Systems - B P Lathi.
2. Digital Communications - Simon Haykin.
3. An introduction to Analog and Digital Communication - Simon Haykin.
4. Electronic Communication System - George Kennedy.
5. Fundamental logic design - Charles H Roth.
6. Microprocessor architecture, Programming and applications with 8085 - R Gaonkar.
7. The 8051 microcontroller and embedded System - using assembly and C - Muhammad Ali Mazidi, Janice Mazidi, Rolin D McKinlay.
8. VHDL Programming by Example - Douglas L Perry.

Laboratory works

1. Implementation of simple electronic circuit in FPGA.
2. Use of MATLAB in signal processing and communication system design.
3. Optical Fibre Communication.
4. Servomechanism.
5. Antenna and microwave.

PHY-404-E2
Applied Nuclear Physics

Total marks : 100 $(50 + 30 + 20)$ **Total Lectures : 30** **Credits : 6** $(2\text{L} + 1\text{H} + 0.5\text{T} + 4\text{P})$

Unit I : *Nuclear Magnetic Resonance* (Lectures 04)

Concept of nuclear magnetic resonance, Resonance condition, Experimental technique – Purcell and Bloch method, Applications of NMR – Determination of nuclear spin, Chemical shift.

Unit II : *Particle Accelerators* (Lectures 06)

Need of nuclear particle accelerator, Linear accelerator – Construction and working principle, Pelletron, Cyclic accelerator – Limitation of Linear Accelerators, Cyclotron – Construction and working principle, limitation. Synchrotrons. A review of Indian nuclear accelerators.

Unit III : *Neutron Physics and Nuclear Reactor* (Lectures 08)

Neutron Physics: Sources of neutron, detection of neutrons, classification of neutrons, slowing down of neutrons. Fissionable and fertile materials, enriched uranium, Characteristics of fission- energy and mass distribution of fission product, emission of neutrons in fission – fast and delayed neutrons, Multiplication factor and self sustaining chain reactions, nuclear reactor, neutron balance in nuclear reactor, four factor formula, Resonance escape probability in homogeneous and heterogeneous reactors, thermal utilization factor, Effect of fast and delayed neutrons in nuclear reactor, Reactor material, Production reactor, India's peaceful nuclear programme.

Unit IV : *Radiation Physics* (Lectures 06)

Radiation Hazard : Radioactivity and some important terminology – Half life, Mean life and total activity, Units of radioactivity – Becquerel, Curie, Rutherford, Radiation doses and its unit – quality or weighting factor - equivalent dose, effective dose, committed effective dose, collective effective dose, Biological effect of radiation and nuclear medicine.

Unit V : *Relativistic Heavy Ion Collision* (Lectures 04)

Review on relativistic heavy ion accelerators, relativistic kinematics, observables of heavy ion collisions, QGP and signatures of QGP, Elementary idea of heavy ion data analysis platform ROOT.

Unit VI : *Experiments*

1. To find soil radon activity using SSNTD and spark counting system.
2. To study a few characteristics of heavy ion collisions using nuclear emulsion technique.
3. To determine the energy resolution of a $p - n$ junction detector for alpha particles using PHOENIX
4. To study NMR spectrum for water, glycerine, Teflon etc.
5. To find the efficiency of a GM counter used in gamma area monitor

Recommended books

1. Nuclear Moments - H Kopferman.
2. Source Book of Atomic Energy - S Glasstone.
3. Physical Chemistry - W J Moore.
4. Introduction to Atomic and Nuclear Physics - H Semat.
5. Introduction to Nuclear Physics - H S Krane.
6. Atomic and Nuclear Physics (Part – II) - S N Ghosal.

PHY-404-E3
Cosmic Rays

Total marks : 100 $(50 + 30 + 20)$ **Total Lectures : 45 Credits : 6** $(2\text{L} + 1\text{H} + 0.5\text{T} + 4\text{P})$

Unit I : Cosmic Rays (Theory - Lectures 30, Marks 50)

Part A: *Primary Cosmic Rays* (Lectures 08)

(a) Origin, composition and energy spectrum – knee, ankle and toe, GZK cutoff. Review of theories of origin–solar, galactic and extragalactic cosmic rays.

(b) Propagation and acceleration in the intersteller medium, propagation models–Leaky box model, diffusion model, shock acceleration, Fermi mechanism, escape probability, acceleration time scale, acceleration in supernova shock. (5 lectures)

Part B : *Phenomenology* (Lectures 08)

(a) Cascade process: Propagation through atmosphere. Electromagnetic cascade-Approximation A & B, Longitudinal development of photon-electron cascade (Heitler model) & lateral distribution function (NKG). Numerical & Monte Carlo method : EAS initiated by primary nuclei.

(b) Radiation component: Optical Cerenkov and Fluorescent light from EAS. Theoretical models of radio emission from extensive air showers.

(c) Muon component: Passage of muons through matter, muons underground, theory for depth intensity relation and energy spectra. Determination of mean life time of muons in cosmic rays.

Part C : *High energy interactions* (Lectures 04)

Characteristics of high energy collision : Inclusive cross section and Feynman scaling. Multiplicity, Inelasticity, variation of p-air interaction cross section with primary energy.

Part D : *Techniques* (Lectures 10)

(a) Detectors : Electron detectors : Yes/no type, proportional and fast timing detectors, muon detectors, hadron detectors.

(b) Elements of coincidence circuits and their use in cosmic ray studies.

(c) Simulation techniques: Monte-Carlo method, simulation of individual interactions, simulation of air shower cascade.

Unit II : Cosmic Rays (Practical - Marks 30)

Part A : *Computer Lab*

1. To generate uniformly distributed random numbers and test uniformity.

2. To simulate given functions by Monte Carlo method using computer generated random numbers.
3. Simulation of EAS using CORSIKA code.

Part B : *Detector Lab*

To study East-West and North-South asymmetry of cosmic rays using GM coincidence.

Recommended books

1. Cosmic Rays – A W Wolfendale.
2. Extensive Air Showers – M V S Rao and B V Sreekantan.
3. Cosmic Rays and Particle Physics – Thomas K Gaisser.
4. High Energy Astrophysics – M S Longair.
5. Radiation detection and measurement – G F Knoll.
6. Data reduction and error analysis for the Physical Sciences - P R Bevington and D K Robinson. McGraw Hill (2003).

PHY-404-E4

Gauge Theories

Total marks : 100 $(80 + 20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Gauge Theories* (Lectures 08)

Introducton to Gauge symmetries – global and local gauge transformations, Abelian group U(1) (QED), Yang-Mills (Non-Abelian) groups – SU(2) (isospin), SU(3)C (QCD).

Unit II : *Spontaneous Symmetry Breaking (SSB)* (Lectures 08)

Ground state with spontaneous symmetry breaking, some examples; global symmetry breaking and Goldstone bosons, proof of Goldstone theorem, local symmetry breaking and Higgs mechanism for giving masses to vector bosons, examples U(1), SU(2).

Unit III : *Standard Model (SM)* (Lectures 08)

Standard model of electroweak unification, gauge bosons W^+, W^-, Z^0, charged weak current and neutral current, Higgs particle, experimental status.

Unit IV : *Beyond Standard Model* (Lectures 15)

(a) Introduction to Grand Unified Theories (GUTs) – SU(5) and SO(10), and proton decay predictions; (b) Minimal Supersymmetric Standard Model (MSSM) and its extension, its predictions; (c) Introduction to String Theories and Planck scale physics.

Unit V : *Neutrino Physics* (Lectures 06)

Solar and atmospheric neutrino puzzles, theory of neutrino oscillations in vacuum and medium (MSW mechanism), neutrino masses and leptonic mixings, survey of various neutrino oscillation experiments, seesaw mechanism for small neutrino masses.

Recommended books

1. Gauge Theory of elementary particle physics - Ta-Pei Cheng and Ling-Fong Li, (Oxford University Press, 1983).
2. Quarks and leptons: An introductory Course in Modern Particle Physics - Francis Halzen and Alan D. Martin (John Wiley & Sons, 1984.
3. Introduction to Elementary Particles - David Griffiths (John Wiley & Sons, 1987).
4. A First Course in String theory - Barton Zwiebach (Cambridge Univ. Press, 2004).
5. Grand Unified theories - Graham G Ross (Oxford University Press, 1984).
6. Massive Neutrinos in Physics and Astrophysics - R N Mohapatra and P B Pal (World Scientific, Singapore).

PHY-404-E5
General Theory of Relativity (GTR) and Cosmology

Total marks : 100 $(80+20)$ **Total Lectures : 45** **Credits : 6 (4L + 1H + 1T)**

Unit I : *Extragalactic Astronomy* (Lectures 06)

This unit introduces scale of the universe by the study of distance measurements by astrophysical probes. Contents: Cepheid variables and cosmic distance measurements, standard candles, main sequence fitting, Tully – Fisher and Faber – Jackson relation, quasars. Large scale structure of the universe.

Unit II : *Theory of gravitation* (Lectures 10)

This unit surveys the general theory of relativity, its application to astrophysical phenomena and cosmology, early universe and recent developments in cosmology. Contents: General relativity – principle of equivalence, gravity as metric phenomenon, geodesic, curvature, energy – momentum tensor, Einstein's law of gravitation (field equations), Newtonian approximation, Symmetries in general relativity – Killing vector, test particle orbits for massive and massless particles. Exact solutions – Schwarzschild black holes and Kerr solution (rotating black holes) and their astrophysical importance. Experimental tests – Precession of perihelion of Mercury, binary pulsars, gravitational redshift and bending of light, gravitational waves (qualitative discussion only).

Unit III : *Relativistic cosmology* (Lectures 08)

This unit covers the formulation of Standard Cosmology, cosmological parameters, physics of early universe and recent developments in cosmology. Contents: Cosmological principle, redshift and Hubble's law from Robertson – Walker metric, Friedmann models, Singularity. Cosmological parameters, magnitude -redshift relations. Age of the universe. Early universe – Planck scale (qualitative discussion only), inflation. Thermal history of the universe: Big Bang Nucleosynthesis, matter radiation decoupling, Cosmic Microwave Background (CMB), CMB anisotropy – Sachs-Wolfe effect, Synyaev – Zeldovich effect.

Unit IV : *Recent developments* (Lectures 05)

This unit covers recently developed scenarios in cosmology and their observational status. Students may take challenging problems for presentations and these will be evaluated. Contents: Large scale structure formation (introduction only), Qualitative introduction to dark matter and dark energy, gravitational waves. Growth of large scale structures.

Recommended books

1. Gravity - J B Hartle.
2. Gravitation - Misner, Thorne, and Wheeler.
3. Relativity, Gravitation, and Cosmology - T P Cheng.

4. Astrophysics - stars and galaxies - K D Abhyankar.
5. Relativistic Astrophysics - Zeldovich and Novikov.
6. Introduction to Cosmology - J V Narlikar.
7. First course in general relativity - B F Schutz (Cambridge University Press).
8. Introduction to relativity - J V Narlikar.
9. General Relativity - R M Wald (Chicago University Press).
10. Courses in Theoretical physics : Classical theory of fields vol II - Landau and Lifhshitz.
11. General relativity, astrophysics, and cosmology - Raychoudhry, Banerji, and Banerjee.
12. Cosmology - S Weinberg.
13. Gravitation and Cosmology - S Weinberg.
14. Early Universe - Kolb and Turner.

PHY-404-E6
Plasma Physics‡

Total marks : 100 $(50 + 30 + 20)$ **Total Lectures : 30 Credits : 6** $(2\text{L} + 1\text{H} + 0.5\text{T} + 4\text{P})$

‡ ***This course is conducted in Credit Sharing basis with Institute of Advance Studies in Science and Technology (IASST), Guwahati***

Unit 1 : *Review* (Lecture 03)

Review of basic concepts of plasma physics : Concept of Plasma Temperature and Debye Shielding, Guiding centre motion and drifts, Adiabatic Invariants.

Unit 2 : *Development of linear theory of plasma waves and instability with MHD* (Lecture 08)

Development of Ideal MHD theory. Plasma as a Fluid. Linear theory of Plasma Waves with MHD description - Electron and Ion Waves. Concept of Plasma Resistivity. Single Fluid MHD equations and MHD Waves. Two-stream Instability.

Unit 3 : *Kinetic theory of plasma and its application* (Lecture 06)

Need for kinetic theory and MHD as approximation of kinetic theory. Application of Kinetic Theory to Electron Plasma Waves and Landau Damping.

Unit 4 : *Introduction to nonlinear theory of plasma waves* (Lecture 06)

Development of Nonlinear Theory of Plasma Waves. Introduction to Reductive Perturbation Method of Nonlinear Plasma Wave. Concept of Pseudo Potential (Sagdeev Potential). Theory of Plasma Sheath and its relation to Nonlinear Waves (Soliton).

Unit 5 : *Laboratory Work (at IASST)*

Production of plasma in laboratory by DC/RF discharge. Measurement of plasma parameters by Electrostatic Probes. Observation of instability in plasma.

Recommended Text Books

1. Plasma Physics - R J Goldstone and P H Rutherford.
2. Introduction to Plasma Physics and Controlled Fusion - F F Chen.
3. Plasma Physics - J A Bittencourt.