UNIVERSITY OF DELHI

SCHEME OF EXAMINATION

AND

COURSES OF READING

FOR

Two Year M.Sc. Course in Physics

Syllabus applicable for the students seeking admission to the
Two Year M.Sc. Course in Physics
for the Academic Year 2009-2010.

Department of Physics & Astrophysics
University of Delhi
Delhi - 110007

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Syllabus structure for I-IV Semester M.Sc. (PHYSICS) Course

ALL THE COURSES CARRY EQUAL MARKS (100) OR CREDITS (4)

I SEMESTER

Course		Marks	Credits
PHYS 401	Classical Mechanics	100	4
PHYS 402	Quantum Mechanics –I	100	4
PHYS 403	Electromagnetic Theory & Electrodynamics	100	4
PHYS 404	Nuclear & Particle Physics	100	4
PHYS 405/410	Laboratory course I/II	100	4

II SEMESTER

Course		Marks	Credits
PHYS 406	Quantum Mechanics –II	100	4
PHYS 407	Statistical Mechanics	100	4
PHYS 408	Radiation Theory	100	4
PHYS 409	Atomic & Molecular Physics	100	4
PHYS 405/410	Laboratory course I/II	100	4

NOTE-1: Each Core Theory course (PHYS 401-404 AND PHYS 406-409) of Semester I & II is of 3 lectures and 1 tutorial per week and Laboratory Courses (PHYS 405 and PHYS 410, one semester each) are of 9 hours/week (3 days of 3 hours/day)

PHYS 405	Course-I	Electronics & Nuclear Physics
PHYS 410	Course-II	Solid State Physics and Waves & Optics

NOTE-2:

1. In any course, 1 Credit corresponds to 25 marks.

2. There will be one Internal Assessment test of 30 marks of duration 1.5 hours and the End-Semester Examination of 70 marks of duration 3 hours for all the Core Theory courses of I and II Semesters.

3. For all the other Optional Theory courses (of semester III/IV) there will be one Internal Assessment of 30 marks (based on test/seminar/project/viva) and the End-Semester Examination of 70 marks of duration 3 hours for each course.

4. For all the Laboratory courses (namely, the Laboratory Courses I and II of Semesters I and II, the Computer Programming Course and other optional Laboratory courses of Semesters III and IV) a continuous evaluation (including Internal Assessment of 30 marks) will be done during the normal course work by the concerned Teachers and there will be no separate examination for these.

5. The semester examinations for the Theory courses will be conducted at the end of each semester only for the courses taught in that semester. There will be no repeat examinations at the end of semester II & IV for the courses of semester I & III. Students reappearing for any of the Theory courses of semester I & III will have to do so in the next regular examinations of semester I & III.

III SEMESTER

COURSE		Marks	Credits
PHYS 501	Computer Programming (Computer Lab. Course of 6hours/week for Lab & 2 hours/week for Lecture/Tutorial)	100	4

AND

EITHER

Opt Part-I of any ONE Module from the Modules A, B, C, D, E and TWO Theory (Specialization) Courses from the optional menu for III Semester. This could include the Dissertation as well.

OR

Opt any FOUR Theory (Specialization) Courses from the optional menu for III Semester. This could include the Dissertation as well.

IV SEMESTER

EITHER

Opt Part-II of the SAME Module opted in Semester III and THREE Theory (Specialization) Courses from the optional menu for IV Semester. This could include the Dissertation as well.

OR

Opt any FIVE Theory (Specialization) Courses from the optional menu for IV Semester. This could include the Dissertation as well.

NOTE-3:

1. For opting Part-II of any Specialization Course, Part-I of that course would be a pre-requisite.

2. Option of Dissertation could be either in III-Semester or IV-Semester. Option of Dissertation requires minimum of 60% marks (or equivalent credits) in I and II Semesters together.

3. Dissertation of one semester could be in any one of the specialization courses listed below for III and IV semesters. The course code for dissertation will be the course code of the chosen course followed by D (example: PHYS 555D for the dissertation in Astronomy & Astrophysics-I)

4. Dissertation also carries the same weightage of 100 marks (including Internal Assessment of 30 marks plus End-Semester Examination of 70 marks). End-Semester Examination will consist of evaluation by three examiners including the Supervisor on the basis of written document and the oral presentation.

OPTIONAL MENU FOR III SEMESTER

Module A- Part I

PHYS 511	Physics at Nanoscale-I (Theory course)
PHYS 512	Nanomaterials Lab-I (Lab Course)

Module B- Part I

PHYS 513	Electronics –I (Theory course)
PHYS 514	Advanced Electronics Lab –I (Lab Course)

Module C- Part I

PHYS 515	Solid State Physics-I (Theory course)
PHYS 516	Advanced Solid State Physics Lab-I (Lab Course)

Module D- Part I

PHYS 517	Nuclear Physics-I (Theory course)
PHYS 518	Advanced Nuclear Physics Lab-I (Lab Course)

Module E- Part I

PHYS 519	Laser & Spectroscopy-I (Theory course)
PHYS 520	Advanced Laser & Spectroscopy Lab-I (Lab Course)

NOTE-4:

In all the above Modules the Experimental (Specialization) Theory Courses are of 4 hours/week (including the tutorials) and the Laboratory Courses are of 8 hours/week (2 days of 4 hours/day)
The Interdisciplinary Courses (PHYS 560 & PHYS 561) could be opted from the options available in the Departments of Mathematics, Computer Science, Electronic Sciences and Chemistry.

Theory (Specialization) Courses of 4 hours/week (including the tutorials)

PHYS 551	Particle Physics-I
PHYS 552	Field Theory and Quantum Electrodynamics-I
PHYS 553	Advanced Solid State Theory-I
PHYS 554	Plasma Physics-I
PHYS 555	Astronomy & Astrophysics –I
PHYS 556	General Theory of Relativity & Cosmology-I
PHYS 557	Mathematical Physics
PHYS 558	Complex Systems and Networks
PHYS 559	Experimental High Energy Physics (Lab. Course of 8 hours/week)
PHYS 560	Interdisciplinary Course-1
PHYS 561	Interdisciplinary Course-2

OPTIONAL MENU FOR IV SEMESTER

Module A- Part II

PHYS 531	Physics at Nanoscale-II (Theory course)
PHYS 532	Nanomaterials Lab-II (Lab Course)

Module B- Part II

PHYS 533	Electronics –II (Theory course)
PHYS 534	Advanced Electronics Lab –II (Lab Course)

Module C- Part II

PHYS 535	Solid State Physics-II (Theory course)
PHYS 536	Advanced Solid State Physics Lab-II (Lab Course)

Module D- Part II

PHYS 537	Nuclear Physics-II (Theory course)
PHYS 538	Advanced Nuclear Physics Lab-II (Lab Course)

Module E- Part II

PHYS 539	Laser & Spectroscopy-II (Theory course)
PHYS 540	Advanced Laser & Spectroscopy Lab-II (Lab Course)

NOTE-5:
In all the above Modules the Experimental (Specialization) Theory Courses are of 4 hours/week (including the tutorials) and the Laboratory Courses are of 8 hours/week (2 days of 4 hours/day)
The Interdisciplinary Courses (PHYS 581 & PHYS 582) could be opted from the options available in the Departments of Mathematics, Computer Science, Electronic Sciences and Chemistry.

Theory Courses (Specialization) of 4 hours/week (including the tutorials)

PHYS 571	Particle Physics-II
PHYS 572	Field Theory and Quantum Electrodynamics-II
PHYS 573	Advanced Solid State Theory-II
PHYS 574	Plasma Physics-II
PHYS 575	Astronomy & Astrophysics –II
PHYS 576	General Theory of Relativity & Cosmology-II
PHYS 577	Nonlinear Dynamics
PHYS 578	Introduction to String Theory
PHYS 579	Observational Astronomy Lab (Laboratory Course of 8 hours/week)
PHYS 580	Advanced Numerical Techniques (Computer Lab. Course of 8 hours/week)
PHYS 581	Interdisciplinary Course-3
PHYS 582	Interdisciplinary Course-4

DETAILED COURSES OF READING

The total number of lectures for each course in a semester is expected to vary from 36 (for Core courses) to 48 (for optional courses). There will be 3 lectures and 1 tutorial per week for each Core course (PHYS 401-404 and PHYS 406-409) and 4 lectures per week (including the tutorials) for all theory optional courses. The number of lectures given against each subsection is only indicative of their relatives weightage vis-à-vis the complete course.

SEMESTER-I

PHYS 401– Classical Mechanics

Types of constraints on dynamical systems, generalized coordinates, d'Alembert priciple, Euler-Lagrange equations of motion, variational calculus and Hamilton's variational principle, Hamilton's canonical equations of motion, cyclic coordinates, Lagrangian and Hamiltonian for central forces, electromagnetic forces, coupled oscillators and other simple systems. Canonical variables, Poisson's bracket, Jacobi identity. (12 Lectures)

Canonical transformations, generators of infinitesimal canonical transformations, symmetry principles and conservations laws. Hamilton-Jacobi theory, Action and angle variables, Centre of mass and laboratory systems, Kepler problem, precessing orbits. (12 Lectures)

Small oscillations, normal coordinates and its applications to chain molecules and other problems. Degrees of freedom for a rigid body, Euler angles, Rotating frame, Coriolis force, Foucault's pendulum, Eulerian coordinates and equations of motion for a rigid body, motion of a symmetrical top. (12 Lectures)

Suggested Books

1. Classical Mechanics by H. Goldstein (Narosa, 2001)
2. Mechanics byL.D. Landau and E. M. Lifschz (Pergamon, 1976)
3. Classical Mechanics of Particles and Rigid Bodies by K. C. Gupta (John Wiley, 1988)
4. Classical Mechanics-J. W. Muller-Kirsten (World Scientific, 2008)
5. Advanced Classical and Quantum Dynamics by W. Dittrich, W. And M Reuter, M. (Springer, 1992)
6. Classical mechanics by T. W. B. Kibble and Frank H. Berkshire (Imperial College Press, 2004)
7. Mathematical Methods of Classical Mechanics by V. I. Arnold, (Springer, 1978)

PHYS 402– Quantum Mechanics I

Abstract formulation of Quantum Mechanics : Review of quantum postulates. Mathematical properties of linear vector spaces. Postulates of quantum mechanics. Eigenvalues and eigenvectors. Orthonormality, completeness, closure. Dirac's bra and ket notation. Matrix representation of operators. Position and momentum representations – connection with wave mechanics. Commuting operators. Generalised uncertainty principle. Change of basis and unitary transformation. Expectation values. Ehrenfest theorem. (15 Lectures)

Quantum Dynamics : Schrodinger picture. Heisenberg picture. Heisenberg equation of motion. Classical limit. Solution of harmonic oscillator problem by the operator method. Symmetries in Quantum Mechanics : General view of symmetries. Spatial translation – continuous and discrete. Time translation. Parity. Time reversal. (12 Lectures)

Angular Momentum : Commutation relations of angular momentum operators. Eigenvalues, eigen functions. Ladder operators and their matrix representations. Addition of angular momenta. Clebsch-Gordan coefficients. (9 Lectures)

Suggested Books

1. Quantum Mechanics by B.H. Bransden & C.J. Joachain (Pearson Education, 2000)
2. Principles of Quantum Mechanics by R. Shankar (3rd Ed., Springer, 2008)
3. Quantum Mechanics (II Vol. Set) by Claude Cohen-Tannoudji, Bernard and Frank Laloe, (2006)
4. Modern Quantum Mechanics by J.J. Sakurai (Addison-Wessley, 1993)
5. Advanced Quantum Mechanics by F. Schwabl (Sringer, 2000)
6. Quantum Mechanics by A.S. Davydov (2^{nd} Ed., Pergamon, 1991)
7. Quantum Mechanics by Eugen Merzbacher (3^{rd} Ed., Wiley, 1997)

PHYS 403– Electromagnetic Theory & Electrodynamics

Review of Maxwell's Equations : Fundamental problem of electromagnetic theory. Scalar and vector potentials. Gauge transformations. Coulomb and Lorentz gauges. Review of Special Theory of Relativity (STR) and its application to electromagnetic theory : Conceptual basis of STR. Thought experiments. Concepts of invariant interval, light cone, event and world line. Four-vectors, tensors. Lorentz transformation as 4-vector transformations. Transformation properties of electric and magnetic fields. E.M. field tensor. Covariance of maxwell's equations (from tensorial arguments). (12 lectures)

Relativistic Charged Particle Dynamics in Electromagnetic Fields : Motion in uniform static magnetic field, uniform static electric field and crossed electric and magnetic fields. Particle drifts (velocity and curvature) in non-uniform static magnetic fields. Adiabatic invariance of magnetic moment of a charged particle and torus principle of magnetic mirror. (6 lectures)

Radiation : Green function for relativistic wave equation. Radiation from localized oscillating charges. Near and far zone fields. Multipole expansion. Dipole and quadrupole radiation. Centre-fed linear antenna. Radiation from an accelerated point charge. Lienard-Wiechert potentials. Power radiated by a point charge : Lienard's form;ula and its nonrelativistic limit (Larmor's formula). Angular distribution of radiated power for linearly and circularly accelerated charges. (12 lectures)

Lagrangian Formulation of Electrodynamics : Lagrangian for a free relativistic particle, for a charged particle in an e.m. field, for free electromagnetic field, for interacting charged particles and fields. Energy-momentum tensor and related conservation laws. (6 lectures)

Suggested Books

1. Classical Electrodynamics by John David Jackson (3^{rd} Ed.,Wiley,1998)
2. Introduction to Electrodynamics by David Griffiths (3rd Ed., Benjamin Cummings, 1999)
3. Principles of Electrodynamics by Melvin Schwartz (Dover Publications, 1987)
4. Classical Electrodynamics by J. Schwinger, L.L. Deraad Jr, K.A. Milton, W-Y. Tsai and J. Norton (Westview Press, 1998)
5. Modern Problems in Classical Electrodynamics by Charles A. Brau (Oxford Univ. Press, 2003)
6. Electrodynamics: An introduction including quantum effects by H. J. W. Mueller-Kirsten (World Scientific, 2004)
7. Electrodynamics of Continuous Media by L. D.Landau and E. M. Lifshitz & L. P. Pitaevskii (Oxford, 2005)

PHYS 404 – Nuclear & Particle Physics

Static properties of Nuclei: Nuclear size determination from electron scattering, nuclear form-factors. Angular momentum, spin and moments of nuclei. (2 Lectures)

Two Nucleon Systems & Nuclear Forces: Dipole and quadrupole moments of the deuteron, Central and tensor forces, Evidence for saturation property, Neutron-proton scattering, exchange character, spin dependence (ortho and para-hydrogen),charge independence and charge symmetry. Isospin formalism. General form of the nucleon-nucleon force. S-wave effective range theory. Proton-proton scattering. Evidence for hardcore potential. (12 Lectures)

Nuclear Models: The shell model, Nilson model, Physical concepts of the unified model.(3 Lectures)

Nuclear Decays and Reactions: Electromagnetic decays:selection rules, Fermi theory of beta decay. Kurie plot. Fermi and Gamow-Teller transitions. Parity violation in beta-decay. Introduction to Nuclear Reactions. (5 Lectures)

Elementary Particles: Relativistic kinematics, Classification: spin and parity determination of pions and strange particles. Gell-Mann Nishijima scheme. Properties of quarks and their classification. Elementary ideas of SU(2) and SU(3) symmetry groups and hadron classification. Introduction to the standard model. Electroweak interaction-W & Z Bosons. (9 Lectures)

Nuclear Detectors: Interaction of radiation with matter, Ge and Si solid state detectors, calorimeters and their use for measuring jet energies. Scintillation and Cerenkov counters, qualitative ideas. Hybrid detectors. (5 Lectures)

Suggested Books

1. Introducing Nuclear Physics by K. S. Krane (Wiley India., 2008).
2. Nuclear Physics – Theory & Experiments by R.R. Roy & B.P. Nigam (New Age International, 2005)
3. Nuclear & Particle Physics : An Introduction by B. Martin (Willey, 2006)
4. Introduction to Elementary Particles by D. Crriftiths (Academic Press, 2nd Ed. 2008)
5. Nuclear Physics in A Nutshell by C. A. Bertulani (1st Ed., Princeton University Press, 2007)
6. Concept of Nuclear Physics by B. L. Cohen (McGraw – Hill, 2003)

SEMESTER II

PHYS 406– Quantum Mechanics II

Approximation Methods for Stationary Systems : Time-independent perturbation theory : (a) non-degenerate and (b) degenerate. Applications to Zeeman effect, isotopic shift and Stark effect. Variational method and its applications. (9 lectures)

Approximation Methods for Time-dependent Problems : Interaction picture. Time-dependent perturbation theory. Transition to a continuum of final states – Fermi's Golden Rule. Application to constant and harmonic perturtbations. Adiabatic and sudden approximations. (9 lectures)

Scattering : Wave packet description of scattering. Formal treatment of scattering by Green function method. Born approximation and applications. Partial wave analysis. Optical theorem. (9 lectures)

Relativistic Quantum Mechanics: Klein-Gordon andDirac equations. Properties of Dirac matrices. Plane wave solutions of Dirac equation. Spin and magnetic moment of the electron. Nonrelativistic reduction of the Dirac equation. Spin-orbit coupling. Energy levels in a Coulomb field. (9lectures)

Suggested Books

1. Quantum Mechanics by B.H. Bransden & C.J. Joachain (Pearson Education, 2000)
2. Principles of Quantum Mechanics by R. Shankar (Springer, 3rd Edition, 2008)
3. Modern Quantum Mechanics by J.J. Sakurai (Addison-Wessley, 1993)
4. Advanced Quantum Mechanics by Schwabl F. (Sringer, 2000)
5. Quantum Mechanics by A.S. Davydov (2^{nd} Ed., Pergamon, 1991)
6. Quantum Mechanics by Eugen Merzbacher (3^{rd} Ed., Wiley, 1997)
7. Introduction To Quantum Mechanics: Schrodinger equation and Path Integral by H. J.W. Muller-Kirsten, (World Scientific, 2006)
8. Quantum Field Theory by Lewis H. Ryder (2^{nd} Ed., Cambridge University .Press, 1996).
9. Relativistic Quantum Fields, Vol.II by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1978)
10. Relativistic Quantum Fields, Vol.I by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1964)

PHYS 407– Statistical Mechanics

Classical Ensemble Theory : Phase space, Liouvilles equation. Microcanonical, canonical and grand-canonical ensembles. Boltzmann relation for entropy. Application to classical system of interacting particles. (9 Lectures)

Quantum Ensemble Theory : Density operator, Quantum Liouvilles's equation. Density operator for equilibrium microcanonical, canonical and grand-canonical ensembles. Calculation of grand partition function and distribution function, Pauli paramagnetism. (12 Lectures)

General Theory of Phase Transitions : Bose-Einstein transition and nature of discontinuity of specific heat. Landau's theory of liquid Helium II. Phonon-roton spectrum, calculation of $^{\rho}$s and $^{\rho}$n. Order parameter. Landau's theory. Critical exponents. Order parameter fluctuations in Gaussian approximation. Scale invariance. Critical dimensionality. Concept of universality of phase transitions. Ising and Heisenberg models. Bethe approximation. (15 Lectures)

Suggested Books

1. Statistical Mechancis, by Kerson Huang (2^{nd} Ed., Wiley-India, 2008)
2. Statistical Mechanics by R.K. Pathria (Butterworth-Heinemann, 1996)
3. Statistical Mechanics: An Advanced course with problems and solutions by Ryogo Kubo (North-Holland, 1965)
4. Statistical Mechanics: An Advance course with problems and solutions by Ryogo Kubo, Hiroshi Ichimura, Tsunemaru Usui, Natsuki Hashitsume (North-Holland, 1967)

PHYS 408 – Radiation Theory

Classical Field Theory: Concept of a system with infinite degrees of freedom, Classical fields, Lagrangian and Hamiltonian formulations, Equations of motion. Symmetries and invariance principles, Noether's theorem (6 lectures)

Field Quantization: Fock space decomposition, Canonical quantization of a real scalar field and a complex scalar field (commutation relations). Interpretation of the quantized field (number density operators). (6 lectures)

Radiation Field: Classical Maxwell Field, Gauge invariance, Canonical quantization using radiation gauge. Discussion of ambiguities in qunatization and their removal and Lorentz guage quantization. (6 lectures)

Dirac Spinor Field and its quantization (anticommutation relations). (5 lectures)

Spontaneous symmetry breaking, Goldstone model, Higgs model. (4 lectures)

Applications: Interaction of radiation with matter (spontaneous, stimulated emission, absorption), Planck's law, Kramer-Heisenberg Formula, Coherent and Raman scattering, Theory of line width, Elementary theory of photo-electric effect, Non-relativistic theory of Lamb shift. (9 lectures)

Suggested Books

1. Advanced Quantum Mechanics by J.J. Sakurai (Pearson Education, Singapore,1998)
2. Quantum Field Theory by Lewis H. Ryder (2nd Ed., Cambridge University Press, 1996).
3. Relativistic Quantum Fields, Vol.II by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1978)
4. Relativistic Quantum Fields, Vol.I by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1964)

PHYS 409 – Atomic & Molecular Physics

Atomic Physics : Fine structure of hydrogenic atoms – Mass correction, spin-orbit term, Darwin term. Intensity of fine structure lines. The ground state of two-electron atoms – perturbation theory and variation method. Many-electron atoms – LS and jj coupling schemes, Lande interval rule. The idea of Hartree-Fock equations. The spectra of alkalis using quantum defect theory. Selection rules for electric and magnetic multipole radiation. Oscillator strengths and the Thomas-Reiche-Kuhn sum rule. (12 Lectures)

Molecular Structure : Born-Oppenheimer separation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Molecular orbital and valence bond methods for H_2^+ and H_2. Correlation diagrams for heteronuclear molecules. (9 Lectures)

Molecular Spectra : Rotation, vibration-rotation and electronic spectra of diatomic molecules. The Franck-Condon principle. The electron spin and Hund's cases. Idea of symmetry elements and point groups for diatomic and polyatomic molecules. (6 Lectures)

Lasers : Multilevel rate equations and saturation. Rabi frequency. Laser pumping and population inversion. He-Ne Laser, Solid State laser, Free-electron laser. Non-linear phenomenon. Harmonic generation. Laser accelerator, liquid and gas lasers, semiconductor lasers. (9 Lectures)

Suggested Books

1. Physics of Atoms and Molecules by B. H.Bransden and C. J. Jochain (2nd Ed., Pearson Education, 2003)
2. Atomic Physics by C. J. Foot (Oxford Univ. Press, 2005)
3. Atoms, Molecules and Photons by W. Demtroder (Springer, 2006)
4. Molecular Spectra and Molecular Structure by G. Herzberg (Van Nostrand, 1950)
5. Basic atomic & Molecular Spectrocopy by J. M. Hollas(Royal Society of Chemistry, 2002)
6. Laser Spectroscopy by W. Demtroder (3rd Ed., Springer, 2003)
7. Molecular Physics by W. Demtroder (Wiley-VCH, 2005)

PHYS 405/410 - Laboratory Courses

PHYS 405 - Paper I (Groups 1 and 2)

Group 1: Electronics

Unit I – Device Characteristics and Application
1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit II – Linear Circuits
1. Resonant circuits
2. Filters-passive and active, all pass (phase shifters)
3. Power supply-regulation and stabilization
4. Oscillator-design and study
5. Multi stage and tuned amplifiers
6. Multivibrators-astable, monostable and bistable with applications
7. Design and study of a triangular wave generator
8. Design and study of sample and hold circuits

Unit III – Digital Circuits and Microprocessors
1. Combinational
2. Sequential
3. A/D and D/A converters
4. Digital Modulation
5. Microprocessor application

Group 2: Nuclear Physics

Unit I – Detectors
1. G.M. Counters – characteristics, deadtime and counting statistics
2. Spark counter-characteristics and range of x-particles in air
3. Scintillation detector-energy calibration, resolution and determination of gamma ray energy
4. Solid State detector – surface barrier detector, its characteristics and applications.

Unit II – Applications
1. Gamma ray absorption-half thickness in lead for ^{60}Co gamma-rays.
2. Beta ray absorption – end point energy of betaparticles.
3. Lifetime of a short lived radioactive source.

Unit III – High Energy Physics
1. Study of pi-mu-e decay in nuclear emulsions.
2. Study of high energy interactions in nuclear emulsions.

PHYS 410-Paper II (Groups 3 & 4)

Group 3: Solid State Physics

Unit I – Experimental Techniques

1. Production and measurement of low pressures
2. Production and measurement of high pressures
3. Measurement and control of low temperatures
4. Production and characterization of plasma
5. Electron Spin Resonance
6. Nuclear Magnetic Resonance

Unit II – Electrical Transport Properties
1. Measurement of resistivity – Four probe and van der Paw techniques; determination of band gap
2. Measurement of Hall coefficient – determination of carrier concentration
3. Measurement of magneto resistance
4. Measurement of thermoelectric power
5. Measurement of minority carrier lifetime in semiconductors Hyne Shockley experiment.

Unit III – Phase Transitions and Crystal Structure
1. Determination of transition temperature in ferrites
2. Determination of transition temperature in ferroelectrics
3. Determination of transition temperature in high Tc superconductors
4. Determination of transition temperature in liquid crystalline materials
5. Crystal structure determination by x-ray diffraction powder photograph method

Group 4: Waves and Optics

Unit I – Waves
1. Velocity of sound in air by CRO method
2. Velocity of sound in liquids – Ultrasonic Interferometer method
3. Velocity of sound in solids – pulse echo method
4. Propagation of EM waves in a transmission line – Lecher wire
5. Determination of Planck's constant
6. Jamin's interferometer – refractive index of air
7. Study of elliptically polarized light

Unit II – Optical Spectroscopy
1. Constant deviation spectrometer-fine structure of Hg spectral lines
2. e/m or hyperfine structure using Febry Perot's interferometer
3. Band spectrum in liquids
4. Raman scattering using a laser source
5. Luminescence

Unit III – Laser Based Experiments
1. Optical interference and diffraction
2. Holography
3. Electro-optic modulation
4. Magneto-optic modulation
5. Acousto-optic modulation
6. Sound modulation of carrier waves

NOTE-6:
The list of experiments given above should be considered as suggestive of the standard and available equipment. The teachers are authorized to add or delete from this list whenever considered necessary.

SEMESTER – III

PHYS 501-Practical Computer Programming

There will be Continuous Evaluation of 70 Marks and the Internal Assessment Test of 30 Marks of duration 1.5 hours.

Number of contact hours per week: (6+2)
(a) In the lab: Six hours (b) Tutorial/Lecture : Two hours

Course Content
1. Introduction to Unix and C++
2. Introduction to graphics (gnuplot etc)
3. Finite and infinite series
4. Root finding (bisection, Secant, and Newton-Raphson methods)
5. Solving first and second order ordinary differential equations including simultaneous differential equations (Euler and Runge-Kutta methods).
6. Schroedinger equation (finding eigenvalues and eigenfunctions)
7. Numerial integration (trapezoidal, Simpson, Guass quadrature, Gauss- Laguerre, and Gauss-Hermite methods).
8. Matrices (arrays of variable sizes, addition, multiplication, eigenvalues, eigenvectors, matrix inversion, solutions of simultaneous equations.

SEMESTER – IV

OPTIONAL COURSES SEMESTER – III/IV

PHYS 511/531 – Physics at Nanoscale

PHYS 511-Part I – Semester III

Quantum confined systems: quantum confinement and its consequences, quantum wells, quantum wires and quantum dots and artificial atoms. Electronic structure from bulk to quantum dot. Electronic structure calculations by abinitio, tight binding, empirical potential and density functional methods. Electron states in direct and indirect gap semiconductors nanocrystals. Confinement in disordered and amorphous systems. (16 lectures)

Dielectric properties: Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons. Charging effects. Optical properties and radiative processes: General formulation-absorption, emission and luminescence. Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, tunnrlling and hopping conductivity. Deffects and impurities: Deep level and surface defects. (16 lectures)

Structure and thermodynamics at nanoscale: Crystalline phase transitions and geometric evolution of the lattice in nano crystals, thermodynamics of very small systems, evaporation-consequences,Growth of nanostructures- self-organization phenomena Characterization basics:

Direct imaging, TEM, diffraction and optical methods Magnetism at nanoscale and Mechanical properties at nanoscale. (16 lectures)

Suggested Books

1. Nanostructures-Theory & Modelling by C. Delerue and M. Lannoo (Springer, 2004)
2. Nanostructure by V. A. Shchukin, N. N. Ledentsov and D. Bimberg (Springer, 2004)
3. Characterization of Nanophase Materials by Z. L. Wang (Ed.) (Wiley-VCH, 2000)
4. Semiconductor Nanocrystal Quantum Dots by A. L. Rogach (Ed.) (Springer Wien NY, 2008)
5. Introduction to Nanotechnology by C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003)

PHYS 531-Part II – Semester IV

Growth: Self-assembled nanostructure growth-MBE and MOCVD methods, guided self-assembly and aimed structures, Specific features of the nanoscale growth, control of size, nucleation, growth and aggregation. Gas phase synthesis of nanopowders, chemical and colloidal methods, mechanical milling, dispersion in solids-doped glasses and sol gel method, nanoporous media. Processing and consolidation of nanoparticles. Functionalization of nanoparticles. Synthesis of Metal, semiconductor, carbon and bio nanomaterials. (18 lectures)

Characterization: Structural and chemical Characterizations-XPS, EXAFS. Grains and grain boundaries, distribution of grain sizes, pores, strains. (10 lectures)

Properties: Chemical- reactivity, Mechanical-superplasticity, Magnetic and electron transport- GMR and Optical- linear and nonlinear (10 lectures)

Applications of nanomaterials: Electronics and Electromagnetics-ceramic capacotors and magnetic recording Optics-nanophosphors and photonic crystals Mechanics- , Biology and environment. Nanomaterial Devices: Quantum dot heterostructure lasers, all optical switching and optical data storage. Single electron devices. (10 lectures)

Suggested Books

1. Nanostructured Materilas and Nano technology by H. S. Nalwa (Ed.) (Academic Press, 2002)
2. Nanomaterila and Nanochemistry by C. Brechignac, P. Houdy and M. Lahmani (Springer, 2006)
3. Characterization of Nanophase Materials by Z. L. Wang (Ed.) (Wiley-VCH, 2000)
4. Semiconductor Nanocrystal Quantum Dots by A. L. Rogach (Ed.) (Springer Wien NY, 2008)
5. Introduction to Nanotechnology by C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003)
6. Carbon Nanotubes by S. Reich, C. Thomsen & J. Maultzsch, (Wiley-VCH, 2004)

PHYS 512/532 - Nanomaterials Laboratory –I & II

Semester III / IV

LIST OF EXPERIMENTS (Part I & II)

1. Growth of nanoparticles by chemical routes.
2. Growth of nanophase by sputtering.
3. Growth of quantum dots by thermal evaporation.
4. Growth of nanoparticles by mechanical milling/attrition.
5. Growth of nanomaterials by nanopores-template method.
6. Growth of semiconductor quantum dots in matrices (glass/polymer etc)
7. Strucural characterization of nanomaterials by XRD- determination of average grain size, lattice parameters, strains etc.

8. Strucural characterization of nanomaterials by TEM - determination of grain size and its distribution
9. Surface morphological characterization of nanomaterials by AFM
10. Surface morphological characterization of nanomaterials by SEM
11. Surface morphological characterization of nanomaterials by TEM
12. Determination of pores size of nanomaterials
13. Measurement and analyses of uv/vis Absorption spectrum of nanomaterials
14. Measurement and analysis of Photoluminescence spectrum of nanomaterials
15. Measurement and analysis of Raman spectrum of nanomaterials
16. Measurement and analysis of photoluminescence/Absorption spectrum of nanomaterials at low temperatures.
17. Determination of optical constants of nanomaterials by ellipsometry.
18. Measurement of sensor property of nanomaterials
19. Determination of stoichiometry of nanomaterials by XPS/EDAX/ESCA

NOTE-7:
This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work.

PHYS 513/533 – Electronics

PHYS 513-Part I – Semester III

Basic Concepts in Communication: EM wave propagation; transmission lines, coaxial cable, wave guide, optical fibre and free space. Propagation of ground wave, space wave and surface waves. Sky wave transmission. Definition of characteristic impedance, reflection coefficient, standing wave ratio (microwave components) and measurement of impedance in various media. (12 Lectures)

Linear Systems and Signal Processing: Signal and system, linear time invariant systems, Fourier analysis for continuous time signals and systems, modulation of signals (AM, single sideband modulation, angle modulation and pulse modulation). Noise : Signal to noise ratio (SNR) and enhancement of SNR in instrumentation and communication. (15 Lectures)

Digital Systems and Signal Processing : Discrete time signals and system, Z-transform, sampling of signals in the time and frequency domain, structures of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) Filters, design of digital filters, discrete Fourier Transform and Fast Fourier Transform (DIT and DIF Algorithm). (21 Lectures)

Suggested Books
1. Electronic Communication by Rudy and Cohlen (4^{th} Ed.,Prentice Hall, India, 2007)
2. Electronic Communication System by G. Kennedy (4^{th} Ed.,Tata-Mc Graw Hill, 2008)
3. Understanding Optical Fibre Communication by A. J. Rogers (Artech House, 2001)
4. Optical Communication Systems by John Gowar (2^{nd} Ed.,Prentice Hall, India, 2001)
5. Digital signal processing by J. G. Proakins and D. G. Manolakis (4^{th} Ed.,Prentice Hall, 2006)

PHYS 533-Part II – Semester IV

Semiconductor Devices : Review of p-n junction, metal-semiconductor and metal-oxide semiconductor junctions, BJT, JFET, MESFET & MOSFET – their high frequency limits. (8 Lectures)

Microwave Devices : Tunnel diode, transfer electron devices (Gunn diode), Avalanche Transit time devices (Reed, Impatt diodes, parametric devices) vacuum tube devices-reflex klystron and magnetron. (13 Lectures)

Photonic Devices : Radiative transition and optical absorption, LED, Semiconductor lasers, heterostructure and quantum well devices, photodetector, Schottky barrier and p-I-n photodiode, avalanche photodiode, photomultiplier tubes, electro-optic and magneto-optic devices. (12 Lectures)

Memory Devices : Volatile-static and D-RAM, CMOS and NMOS, non-volatile-NMOS, ferroelectric semiconductors, optical memories, magnetic memories, charge coupled devices (CCD). (5 Lectures)

Other Devices : Piezoelectric, pyroelectric and magnetic devices. SAW and integrated devices. (5 Lectures)

Fabrication of Semiconductor Devices : Vacuum techniques, thin film deposition techniques, diffusion of impurities. (5 Lectures)

Suggested Books

1. Semiconductor Devices Physics & Technology by S.M. Sze (John Wiley, 1985)
2. Semiconductor Optoelectronic Devices by Pallab Bhattacharya (PHI-Inida, 1995)
3. Microwave Devices & Circuits by S. Y. Liao (3rd Ed., PHI-India, 2007)

PHYS 514/534 - Advanced Electronics Laboratory – I & II

Semester III / IV

LIST OF EXPERIMENTS

PHYS 514-Part – I

Group A :

Design of operational circuits (linear and digital) using discrete and I.C. components.

Phase sensitive detector, filters, multistage amplifiers, oscillators, wave shaping circuits. (Three experiments)

Group B :

Microprocessor/computer interfacing using standard self wave and interfacing circuits for physics experiments. (I.V. characteristics, temperature controller etc.) (Two experiments)

PHYS 534-Part – II

Group A :

Computer aided design using standard software for integrated circuit and device fabrication.

Group B:

Electronic material and device fabrication and characterization (p-n junction, diffusion thin film sensors, optical memory etc.).

PHYS 515/535– Solid State Physics

PHYS 515-Part I – Semester III

Crystal structure and binding: Diffraction of electromagnetic waves by crystals, Reciprocal Lattice, Powder and rotating crystal methods, neutron and electron diffraction. Types of crystal binding, London theory of van Der Waal forces, ionic bonding and Madelung constant. (10 Lectures)

Vibrations in Solids: Classical treatment, normal modes; quantum treatment, phonons, anharmonic effects, thermodynamic properties related to phonons, continuum approximation; measurement of phonon frequencies and inelastic scattering. Scattering mechanisms-impurity and phonon scattering; Normal and Umklapp processes. Mobility of charge carriers and Seebeck coffecient. (10 Lectures)

Electronic states in solids: Sommerfeld model, thermodynamic properties due to free electrons. Band structure: basic concepts, Bloch's theorem, density of states; nearly free electron approach and pseudopotentials; tight-binding and linear combination of atomic orbital method; modern band structure methods. (10 Lectures)

Motion of electrons in solids: Semiclassical model, band velocity, effective mass; Concept of electron, hole and open orbits. Effect of open orbits on electric and high magnetic fields; magnetoresistance. Experimental determination of Fermi surface, De-Haas - van Alphen effect, anomalous skin effect and cyclotron resonance. (14 Lectures)

Defects and diffusion in solids: Point defects, line defects and dislocations. Ficks's law, diffusion constant, self-diffusion, colour centres and excitons. (4 Lectures)

Suggested Books

1. Solid State Physics by Neil W. Ashcroft N. David Mermin (McGraw-Hill Education, 1976)
2. Principles of the Theory of Solids by J. M. Ziman (Cambridge University press, 2000)
3. Condensed Matter Physics by Michael P. Marder (Wiley-Interscience, 2000)

PHYS 535-Part II – Semester IV

Dielectrics and Ferroelectrics: Macroscopic electric field, local electric field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, phase transition, piezoelectricity, ferroelasticity, electrostriction. (8 Lectures)

Optical properties of materials: Optical constants and their physical significance, Kramers – Kronig Relations, Electronic inter bond and intra bond transitions Relations between Optical properties and band structure – colour of material (Frenkel Excitons), Bond Structure determination from optical spectra reflection, refraction, diffraction, scattering, dispersion, photoluminescence, Electroluminiscence. (9 Lectures)

Superconductivity: Phenomenological theories of superconductivity, BCS theory, two fluid and Pippard's theory. Flux quantization; BCS ground state and energy gap; Determination of energy gap. Electron tunnelling in various configurations; SQUID. High temperature superconductors. (9 Lectures)

Magnetism: Dimagnetism, paramagnetism; various contributions to para and dia magnetism and diamagnetic susceptibility. Quantum theory of paramagnetism: unfilled electron shells; Hund's rules. Ferromagnetism, antiferromagnetism: molecular field model, susceptibility above Curie temperature, magnetisation below Tc; domains, magnetic energy, Bloch walls, anisotropy energy. Hysteresis – soft and hard magnets; Magnetic force microscopy (8 Lectures)

Glasses and Polymers: Glass formation, types of glasses and glass transition, radial distribution function and amorphous semiconductors; Electronic structure of amorphous solids, localized and extended states, mobility edges, Density of states and their determination, transport in extended and localized states, Optical properties of amorphous semiconductors. Structure of polymers, polymerization mechanism, characterization techniques, optical electrical, thermal and dielectric properties of polymers. (8 Lectures)

Quantum Hall Effect: Integer quantum hall effect, two dimensional electron systems, Landau quantization and filling factor. Fractional quantum hall effect. (6 Lectures)

Suggested Books

1. Solid State Physics by N. W. Ashcroft & N. D. Mermin (McGraw-Hill Education, 1976)
2. Principles of the Theory of Solids by J. M. Ziman (Cambridge University press, 2000)
3. Introduction To Superconductivity by M. Tinkham (Dover Publications, 2004)
4. Condensed Matter Physics by M. P. Marder (Wiley-Interscience, 2000)
5. Solid State Physics by H. Ibach and H. Lüth (Narosa, 1991)

PHYS 516/536 - Advanced Solid State Physics Laboratory-I & II

Semester III / IV

LIST OF EXPERIMENTS (Part I & II)

1. Set the c-axis of the given crystal perpendicular to the incident x-ray beam.
2. Obtain the Laue photograph of the given single crystal, draw gnomonic projection, and index the reflections.
3. Obtain an oscillation photograph of the given single crystal about c-axis, calculate the c-dimension of the unit cell, and index the reflections.
4. Determine the cell dimensions and establish the face centring of copper by Debye-Scherrer method (Powder method).
5. Determine the value of the Hall coefficient for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (Transverse magneto-resistance coefficient is given)
6. Determine the transverse magneto-resistance coefficient and the resistivity for the given sample and calculate the value of the mobility of the carriers and the carrier concentration. (R_H is given).
7. Measure Hall coefficient, dc conductivity and mobility of a semiconductor at different temperatures (77 K to room temperature).
8. Determine the relaxation time (EPR) for a given sample and find the value of 'g'.
9. Determine the wavelength of the microwave output of a given reflex klystron oscillator and also to determine its repeller mode pattern.
10. Calibrate a cooper resistance thermometer and use it to measure temperature from 77 K to room temperature.
11. Calibrate a silicon resistance thermometer and use it to measure temperature from 77 K to room temperature.
12. Determine the specific heat of a given sample at room and liquid nitrogen temperature.
13. Determine the Curie temperature of a given ferroelectric material.
14. Programming and interfacing with a given microprocessor.
15. Measurement of the critical temperature of a HTc-sample.
16. Study the Thermoluminescence of F-centres in alkali halide crystals.

NOTE-8:
This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work.

PHYS 517/537 – Nuclear Physics

PHYS 517-Part I – Semester III

Nuclear Experimental Techniques and Applications: Accelerator, Type of accelerators and their basic principle, accelerator facilities in world, Beam optics (brief overview only), Vacuum Techniques, Target and thin film preparation. Nuclear electronics and Signal processing- NIM, ECL and TTL standard, Data acquisition systems - CAMMAC and VME, Digital pulse processing (introduction only). (12 Lectures)

Detector Techniques Gas detector: Ionisation chambers, Proportional counter, Multi-Wire proportional Counters (MWPC), G.M.Counter, Scintillation Detectors: NaI(Tl),CsI(Tl), BaF2, La2Br3, Organic and Plastic Scintillators. Solid states Detectors: Si(Li), Ge(li), HPGe, Clover and segmented HPGe Detectors, Surface Barrier Detectors, Passivated Detectors, Neutron Detectors. (13 Lectures)

Experimental Techniques: Charge particle, neutron and gamma-ray spectroscopy, methods for charge and mass identification: _E-E, TOF, mass spectrometer, Neutron: TOF and n- discrimination, Gamma-rays: Coincidence technique, Detector array, Multiplicity, Angular Distribution and correlation, Brief ideas of multipolarity and transition probabilities, Wisskoff-estimate, Internal conversion coefficient and their ratios, Polarization and its measurement, Doppler shift and Doppler broadening, Methods for life time measurements: Delay coincidence, pulse beam (slope and centroid shift), recoil distance and Doppler shift attenuation method, measurement of magnetic and quadrupole moment (g -factor), Hyperfine interaction, isomeric shift and lamb shift. (15 Lectures)

Application of Nuclear Technique: Mossbaurer effect and its applications, Activation method, Biological effects of radiation, Industrial and Analytical application, nuclear medicine. (8 Lectures)

Suggested Books
1. Radiation Detection and Measurement by G. F. Knoll (John Wiley & Sons, Inc. 3^{rd} Ed.,2000)
2. Physics & Engineering of Radiation Detection by S. N. Ahmed (Academic Press 2007)
3. Techniques for Nuclear and Particle Physics Experiments by W.R. Leo (Springer-Verlag 1987)
4. Nuclear Physics, Principles and Applications by J.S. Lilly (John Wiley & Sons, Inc. 2002)

PHYS 537-Part II – Semester IV

Nuclear Structure and Reaction Theory: Nuclear Structure: Shell model: Review of shell Model, magic numbers, single particle shell model, Self-consistent approach, Hartee Fock and Hartee Fock Bogallibog, Quasi-particle, Seniority Scheme, M and J-scheme, Transformation from M-scheme to J -Scheme, D-Matrix, Collective Model of Nucleus, Collective parameters, Rotational and Vibrational Spectra (brief derivation). Beta and Gamma vibration and bands, Nuclear moment of inertia, back bending, Variable moment of inertia Models for normal and deformed nuclei, Nillsson Models and Nillsson Diagram, Shell correction, Particle Rotor Model-one, two and three particle, Deformed and Rotational Alignment, Nuclear isomer and K-isomers. (20 Lectures)

Nuclear Reaction: Types of reaction, Briet-Winger and Resonances, Direct reaction-elastic and inelastic scattering, Transfer reaction (semi-classical approach), Fusion, Break-up, coupled channels approach, Compound nuclear reaction and statistical models, Coulomb excitation and its applications. (20 Lectures)

Exotic Nuclei: Nuclear landscape and drip lines, Production of exotic nuclei – ISOL and Fragmentation technique,Super Heavy Element (SHE) production, Structure of exotic nuclei and application in astrophysics, break down of magic numbers, exotic shapes, Halo nuclei, neutron skin, GDR and soft dipole resonance (reaction point of view). (8 Lectures)

Suggested Books

1. Theory of Nuclear Structure by M.K. Pal (Affiliated East-Wast Press,1982)
2. Nuclear Structure from a Simple Perspective by R. F. Casten (Press, 2nd Ed., Oxford Univ. 2000)
3. Theoretical Nuclear Physics, Vol. I, Nuclear Structure by DeShalit & Feshbach (Wiley - Interscience , 1998)
4. Nuclear Reaction and Nuclear Structure by P.E. Hodgson (Clarendon Press, 1971)
5. Heavy ion reactions, Vol. I & II by R. A. Broglia & Aage Winther.(Benjamin/Cummings, 1981)
6. Physics with Radioactive Beams by C. A Bertulani, M.S. Hussein, G. Munzenberg (Nova Science, 2002)

PHYS 518/538 - Advanced Nuclear Physics Laboratory-I & II

Semester III / IV

LIST OF EXPERIMENTS (Part I & II)

1. Study of radioactive isotopes by thermal neutron activation analysis (Neutron flux, growth of activity and halflife measurements).
2. Determination of the absolute disintegration rate of natural 40 K source using UX2 source as a standard. Deduction of the partial beta-decay half life of 40 K.
3. Extraction of active Bromine by Szilard-Chalmers process and determination of the decay halflives of ^{80}Br isomers.
4. Absorption of gamma-rays in material media at different energies.
5. Gamma-rays spectroscopy using a NaI (TI) scintillation spectrometer (energy response, energy resolution and detection efficiency determination).
6. Beta-ray spectroscopy using an anthracene scintillation spectrometer (energy calibration and end-point energy measurement by Kurie-plot).
7. Study of angular distribution of Compton scattered gamma rays using a scintillation spectrometer and the deduction of total scattering cross-section.
8. Resolving time of a Rossi coincidence circuit by the method of random coincidence using scintillation detectors and measurement of absolute source strength.
9. Study of fast-slow delayed coincidence system (resolving time as a function of clipping length, true-to-chance-ratio and coincidence efficiency).
10. Directional correlation measurements of cascading gamma rays and the determination of the cascade anisotropy using ^{60}Co source.
11. Proportional counter, its energy response and low energy X-ray measurements.
12. Alpha spectroscopy using a Si surface-barrier detector (energy response, energy resolution and energy determination).
13. Energy determination of alpha particles emitted in the thoriumdecay using nuclear emulsion plates.
14. Study of Mossbauer effect and evaluation of the natural line width. Measurement of the magnetic dipole moments of the 14.4 KeV state in ^{57}Fe.
15. 'g' factor, proton NMR method using Ferric Nitrate Solution.

NOTE-9:
This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work.

PHYS 519/539 – Laser & Spectroscopy

PHYS 519-Part I – Semester III

Molecular symmetry and Group theory: Symmetry operations and point groups, the representation of a group, irreducible representations, application to spectroscopy. (12 lectures)

Microwave, Infrared, Raman, far infrared and uv/vis spectra of diatomic and polyatomic molecules, Quantum theory of Raman effect, rotational, vibrational and rotation-vibration Raman spectra of diatomic and polyatomic molecules, correlation of infrared and Raman spectra, far infrared and uv/vis spectra of gases, liquids and solids, determination of force constants and force field from isotropic molecules and spectroscopic data, Thermodynamic functions from spectroscopic data, determination of partition function, electronic contribution to thermodynamic properties, enthalpy and specific heats from spectroscopic data. (20 lectures)

Laser spectroscopy: Lasers as spectroscopic light sources, spectral characteristics of laser emission, single and multi-mode lasers, Laser tenability, Fluorescence and Raman spectroscopy with lasrs, Non-linear spectroscopy. (16 lectures)

Suggested Books
1. Molecular Quantum Mechanics by P Atkins & R. Friedman (Oxford Univ. Press, 2005)
2. Group Theory and Physics by S. Sternberg (Cambridge Univ. Press, 1995)
3. Atoms, Molecules and Photons by W. Demtroder (Springer, 2006)
4. Molecular Spectra and Molecular Structure by G. Herzberg (Van Nostrand, 1950)
5. Modern Spectrocopy by J. M. Hollas(4^{th} Ed., John Wiley, 2004)
6. Laser Spectroscopy by W. Demtroder (3^{rd} Ed., Springer, 2003)
7. Molecular Physics by W. Demtroder (Wiley-VCH, 2005)

PHYS 539-Part II – Semester IV

Time resolved laser spectroscopy: Ultra short pulses and life time measurements with lasers, pump and probe technique, Coherent spectroscopy. Optical coupling, trapping of atoms and ions using lasers. Laser cooling. (12 lectures)
Nuclear Magnetic Resonance Spectroscopy: General theory of high resolution NMR spectroscopy, experimental technique, analyses of NMR spectra, spin-spin coupling, chemical shift. (10 lectures)

Electron Spin Resonance Spectroscopy: Experimental methods, ESR spectrum, hyperfine structure, anisotropic systems, the triplet state. (8 lectures)

Mossbauer Spectroscopy: The Mossbauer effect, experimental methods, hyperfine interactions, molecular and electronic structures. (8 lectures)

X-ray Photoelectron Spectroscopy: Experimental technique, XPS spectra and its interpretations, other derivative forms of XPS like ESCA, EDAX etc., chemical shift, stoichiometric analyses, electronic structure. (10 lectures)

Suggested Books

1. Laser Spectroscopy by W. Demtroder (3rd Ed., Springer, 2003)
2. Modern Spectrocopy by J. M. Hollas(4th Ed., John Wiley, 2004)
3. Electron Paramagnetic Resonance by J. A. Well & J. R. Bolton (2nd Ed.,Wiley, 2007)
4. Electronic & Photoelectron Spectroscopy by A. M. Ellis, M. Feher & T. G. Wright (Cambridge Univ. Press, 2005)
5. Introduction to Spectroscopy by D. L. Pavia, G. M. Lampman & G. S. Kriz (Thomson Learning, 2001)

PHYS 520/540 - Advanced Laser and Spectroscopy Laboratory-I & II

Semester III / IV

LIST OF EXPERIMENTS (Part I & II)

1. White light reflection holography
2. Transmission holography
3. Birefringence and photoelasticity
4. Kerr effect
5. Pockels effect
6. Measurement of radiant flux density and luminous intensity of an emission source
7. Prism spectrometer
8. Grating spectrometer
9. Interferometric method for film thickness measurement
10. Interferometric method for residual strain measurement in the film
11. Measurement and analyses of atomic spectra
12. Measurement and analyses of electronic spectra of molecules and liquids
13. Measurement and analyses of vibrational spectra of molecules and liquids
14. Measurement and analyses of rotational spectra of molecules and liquids
15. Measurement and analyses of absorption/transmission spectra of solids
16. Measurement and analyses of reflection spectra of solids
17. Determination of optical constants of thin films by ellipsometry
18. Measurement and analyses of Raman spectra of liquids/solids
19. Measurement and analyses of fluorescence spectra of liquids/solids
20. Measurement of absorption/transmission/reflection spectra at low temperatures
21. Measurement and analyses of photoluminescence spectra of nanomaterials
22. Measurement and analyses of XPS of nanomaterials/thin films/bulk samples

NOTE-10:
This list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations. Interested students may be allowed to do project work.

PHYS 551/571 – Particle Physics

PHYS 551-Part I – Semester III

Introductory survey of elementary particles: Nature of interactions, Characteristic life-times and strengths. Theory of beta decay, muon decay, Lepton conservation, Types of neutrinos. (4 lectures)

Relativistic dynamics: Scalar, Dirac fermion and electromagnetic fields, Invariance principles, Lorentz invariance of free fields, Noether's theorem and its applications, Quantization of free fields.

(12 lectures)

C,P,T transformations and symmetry operations, properties of bilinear covariants under C,P and T. Illustrations and applications of CPT theorem, SU(2) isospin symmetry, G-parity. (12 lectures)

Classification schemes for particles and resonances, Introductory quark physics, SU(3) classification. (8 lectures)

Path integral formalism: functional method of field quantization. (12 lectures)

Suggested Books
1. Introduction to Elementary Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008)
2. Quarks & Leptons by F. Halzen and A. D. Martin (John Wiley, 1984)
3. Elementary Particle Physics by S. Gasiorowicz (John Wiley, 1966)
4. Elementary Particles and the Laws of Physics by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
5. Introduction to Elementary Particle Physics by A. Bettini (Cambridge University Press, 2008)

PHYS 571-Part II – Semester IV

Conserved vector current hypothesis and related topics, Abelian and Non-Abelian gauge theory with examples (12 lectures)

Standard Model- SU(2) X U(1) electro-weak theory: two component left handed fermions, weak isospin, hypercharge assignment. (8 lectures)

SU(2) X U(1) symmetry breaking via Higgs mechansim, Masses of vector bosons. (4 lectures)

Weak charged and neutral currents, Coupling of W and Z-bosons with leptons and quarks. Gauge vs. mass eigen states, Calculation of processes like W-decay etc. (12 lectures)

Electro-weak interactions: neutrino-electron scatterings. (4 lectures)

QCD: Electron-positron annihilation to hadrons, QCD corrections (8 lectures)

Suggested Books
1. Introduction to Elementray Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008)
2. Quarks & Leptons by F. Halzen and A. D. Martin (John Wiley, 1984)
3. Elementary Particle Physics by S. Gasiorowicz (John Wiley, 1966)
4. Elementary Particles and the Laws of Physics by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
5. Introduction to Elementary Particle Physics by A. Bettini (Cambridge University Press, 2008)

PHYS 552/572 – Field Theory and Quantum Electrodynamics

PHYS 552-Part I – Semester-III

Canonical fields as generalized coordinates. Action principle, Euler-Lagrange equations, Noether's theorem (8 lectures)

Canonical quantization of free fields (scalar, Dirac spinor and Maxwell fields) (14 lectures)

Invariance principles, Lorentz invariance of free field theory, C, P, T and CPT transformations, CPT and spin statistics theorems (8 lectures)

Normal and Time-ordered products, Covariant commutation relations and theory of Feynman propagators, Local and global invariances in Gauge theories. (8 lectures)

Path integral formulation: functional methods of field quantization. (10 lectures)

Suggested Books

1. The Quantum Theory of Fields, Volume 1: Foundations by Steven Weinberg (Oxford University Press, 2005)
2. Lectures on Quantum Field Theory by Ashok Dass (World Scientific, 2008)
3. Reletivistic Quantum Mechanics by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
4. Reletivistic Quantum Fields by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
5. Quantum Field Theory by C. Itzykson and J-B Zuber (McGraw-Hill, 1980)
6. Introduction to Relativistic Quantum Field Theory by S. Schweber (Row, Peterson, 1961)
7. Quantum Field Theory by L. H. Ryder (Cambridge University Press, 1996)
8. Quantum Field Theory by F. Mandl and G. Shaw (Wiley, 1993)
9. Introduction to Quantum Field Theory by P. Roman (John Wiley, 1969)
10. The Quantum Theory of Fields, Vol.2: Modern Applications by S. Weinberg (Oxford Univ. Press, 2005)
11. Introduction to the Theory of Quantized Fields by N.N. Bogoliubov & D.V. Shirkov (Nauka, Moscow, 1984)
12. An Introduction to Quantum Field Theory by M. E. Peskin & D.V. Schroeder (Westview Press, 1995)

PHYS 572-Part II – Semester IV

Interacting fields: Interaction representation, S-matrix expansion, Wick's theorem. Calculation for the S-matrix by covariant perturbation theory or by functional methods. (8 lectures)

Feynman diagrams and rules in QED: Feynman diagrams in configuration space and in momentum space. Calculation of QED first and second order processes and Feynman amplitudes, Compton scattering, electron-electron scattering, electron self energy and photon self energy diagrams, electron scattering by an external field and Bremsstrahlung. (16 lectures)

Renormalization: Degree of divergences in a diagram, divergent amplitudes, UV and IR divergences and regularization. Renormalization of charge and mass in second order. Second order radiative corrections of QED, photon self energy, electron self energy, external line renormalization and vertex modification, Ward-Takahashi identities. Lamb shift and anomalous magnetic moment of the electron. (20 lectures)

Yang-Mills Theory: Interaction of non-Abelian gauge fields (Gauge interaction of other particles, self interaction of gauge bosons) (4 lectures)

Suggested Books

1. The Quantum Theory of Fields, Volume 1: Foundations by Steven Weinberg (Oxford University Press, 2005)
2. Lectures on Quantum Field Theory by Ashok Dass (World Scientific, 2008)
3. Reletivistic Quantum Mechanics by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
4. Reletivistic Quantum Fields by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
5. Quantum Field Theory by C. Itzykson and J-B Zuber (McGraw-Hill, 1980)

6. Introduction to Relativistic Quantum Field Theory by S. Schweber (Row, Peterson, 1961)
7. Quantum Field Theory by L. H. Ryder (Cambridge University Press, 1996)
8. Quantum Field Theory by F. Mandl and G. Shaw (Wiley, 1993)
9. Introduction to Quantum Field Theory by P. Roman (John Wiley, 1969)
10. The Quantum Theory of Fields, Vol.2: Modern Applications by S. Weinberg (Oxford Univ. Press, 2005)
11. Introduction to the Theory of Quantized Fields by N.N. Bogoliubov & D.V. Shirkov (Nauka, Moscow, 1984)
12. An Introduction to Quantum Field Theory by M. E. Peskin & D.V. Schroeder (Westview Press, 1995)

PHYS 553/573– Advanced Solid State Theory

PHYS 553-Part I – Semester III

Lattice dynamics in 3-dimensions. Relations among atomic force constants under various general operations. Acoustic and optical modes. Normal modes. Quantization of lattice vibrations. Phonons, zero-point energy, quantum crystals. Stefan-Boltzmann law. Van Hove singularities. Lindemann melting criterion. (15 lectures)

Theory of Thermal Neutron Scattering : Double differential scattering cross-section. Space-time dependent correlation functions and their properties. Dynamical structure factor of (i) a harmonic crystal, zero phonon and one phonon processes, (ii) non-interacting gas and (iii) a simple liquid. (12 lectures)

Mossbauer Effect : Lamb-Mossbauer recoilless fraction. Atomic motions, Isomer shift. Quadrupole splitting. Magnetic splitting. Second order Doppler shift. (9 lectures)

Free electron Green's function, its Fourier transform and their relationships to the density of states. Green function of a system subject to small perturbation Rigid band model and other applications to alloys etc. (12 lectures)

Suggested Books
1. Solid State Physics by Neil W. Aschroft & N. David Mermin (Harcourt Publishers, 1976)
2. Solid State Physics by Gerald Burns (Academic Press, 1985)
3. Solid State Physics by Wlater A. Harrison (Dover Publications, 1980)
4. Solid State Physics : An introductlion to Principles of Materials Science by Harald Ibach and Hans Luth (Springer, 2003)
5. Solid State Physics, Advances in research and applications, Supplement 3, F. Seitz and D. Turnbull (Eds.) Theory of lattice dynamics in harmonic approximation, A.A. Maraduddin, E.W. Montroll and G.H. Weiss (Academic Press, 1963)
6. Theory of thermal neutron scattering by W. Marshall & S.W. Lovessey (Oxford Univ. Press, 1971)
7. Quantum Theory of Solids Part A & B by Callaway (Academic Press, 1974)
8. Mossbauer Effect : Principles and Applications by G. K. Wertheim (Academic Press, 1964)
9. The Mossbauer Effect by Hans Fraunfelder (W.A. Benjamin, 1963)
10. Quasielastic neutron scattering for the investigation of diffusive motions in solids and liquids Springer tracts in modern physics Vol. 64, Tasso Springer (Springer-Verlag, 1972)
11. Superofnductivity by V.L. Ginzburg and E.A. Andryushin (World Scientific, 1994)
12. Introduction to Superconductivity and high-Tc materials by Michel Cyrot and Davor Pavuna, (World Scientific, 1992)

PHYS 573-Part II – Semester IV

Magnetic properties of solids: Diamagnetism, Paramagnetism of atoms with permanent magnetic moment, Pauli paramagnetism of conduction electrons, magnetic exchange interaction, Heisenberg model for ferro and antiferromanetic insulators, magnons in ferro and antiferro-magnets, magnon contribution to specific heat, Stoner theory of ferro-magnetism of itinerant electrons (brief), second quantization (brief), local moment formation in metals, brief discussion of Kondo effect and Heavy fermion systems. (22 lectures)

Superconductivity: Introduction and materials, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability, BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects, Ginzburg-Landau theory. (15 lectures)

Special topics: Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy, simple explanation of IQHE; Metal-Insulator transitions: Mott-Hubbard and impurity induced; Landau theory of Fermi liquid, Mott variable range hopping, Bose-Einstein condensation. (13 lectures)

Suggested Books

1. Solid State Physics by Neil W. Aschroft & N. David Mermin (Harcourt Publishers, 1976)
2. Solid State Physics by Gerald Burns (Academic Press, 1985)
3. Solid State Physics by Wlater A. Harrison (Dover Publications, 1980)
4. Solid State Physics : An introductlion to Principles of Materials Science by Harald Ibach and Hans Luth (Springer, 2003)
5. Solid State Physics, Advances in research and applications, Supplement 3, F. Seitz and D. Turnbull (Eds.) Theory of lattice dynamics in harmonic approximation, A.A. Maraduddin, E.W. Montroll and G.H. Weiss (Academic Press, 1963)
6. Theory of thermal neutron scattering by W. Marshall & S.W. Lovessey (Oxford Univ. Press, 1971)
7. Quantum Theory of Solids Part A & B by Callaway (Academic Press, 1974)
8. Mossbauer Effect : Principles and Applications by G. K. Wertheim (Academic Press, 1964)
9. The Mossbauer Effect by Hans Fraunfelder (W.A. Benjamin, 1963)
10. Quasielastic neutron scattering for the investigation of diffusive motions in solids and liquids Springer tracts in modern physics Vol. 64, Tasso Springer (Springer-Verlag, 1972)
11. Superofnductivity by V.L. Ginzburg and E.A. Andryushin (World Scientific, 1994)
12. Introduction to Superconductivity and high-Tc materials by Michel Cyrot and Davor Pavuna, (World Scientific, 1992)

PHYS 554/574 – Plasma Physics

PHYS 554-Part I – Semester III

Definition and properties of a plasma. Plasma production in laboratory and diagnostics. Microscopic description. Motion of a charged particle in electric and magnetic fields-curvature, gradient and external force drifts. Controlled thermonuclear devices, magnetically confined open and closed systems (linear pinch, mirror machine and Tokamak). Laser plasmas – inertially confined system. (15 lectures)

Statistical description of plasmas. B.B.G.K.Y. hierarchy of equations. Boltzmann-Vlasov equation. Equivalence of particle orbit theory and the Vlasov equation. Boltzmann and landau collision integral H-theorem. B.G.K. model. Fokker-Planck term. Solution of Boltzmann equation (brief outline). Transport coefficient-electrical conductivity, diffusion. (18 lectures)

Small amplitude plasma oscillations. Oscillations in warm field free plasma. Landau damping. Nyquist method-{Penrose criterion of stability. Two stream stability (linear and quasi linear theory). Vlasov theory of magnetized plasma. Loss cone instabilitly. Quasilinear theory of gently bump instability. Non-linear electrostatic waves, BCK waves. (15 lectures)

Suggested Books

1. Introduction to Plasma physics by F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Physics by N. A. Krall and Trivelpiece (San Fransisco Press, 1986)
3. Physics of High temperature Plasmas by G. Schimdt (2^{nd} Ed., Academic Press, 1979)
4. The framework of Plasma Physics by R.D. Hazeltine & F.L. Waelbroeck (Perseus Books, 1998)
5. Introduction to Plasma Physics by R.J. Goldston and P.H. Rutherford (IOP, 1995)

PHYS 574-Part II – Semester IV

Fluid description of plasmas. Moment equations. MHD and C.G.L. equations. Generalized Ohm's law, flux conservation. Decay of fields. Pressure balanced and force free fields. (14 lectures)

Alfven waves. Dissipative effect. Magneto-acoustic waves. Hydromagnetic shocks. KDV equation. Linear and nonlinear ion-acoustic waves. (14 lectures)

Magneto-hydrodynamic instabilities. Energy principle. Normal mode analysis and its application to Rayleigh-Tayler and Kelvin Helmholtz instabilities. Pinch instability. Firehose and mirror instabilities. Virial theorem and Jean's instability. (20 lectures)

Suggested Books

1. Introduction to Plasma physics by F. F. Chen (Plenum Press, 1984)
2. Principles of Plasma Physics by N. A. Krall and Trivelpiece (San Fransisco Press, 1986)
3. Physics of High temperature Plasmas by G. Schimdt (2^{nd} Ed., Academic Press, 1979)
4. The framework of Plasma Physics by R.D. Hazeltine & F.L. Waelbroeck (Perseus Books, 1998)
5. Introduction to Plasma Physics by R.J. Goldston and P.H. Rutherford (IOP, 1995)

PHYS 555/575– Astronomy & Astrophysics

PHYS 555-Part I – Semester III

Observational Data: Astronomical Coordinates- Celestial Sphere, Horizon, Equatorial, Ecliptic and Galactic Systems of Coordinates, Conversion from one system of co-ordinates to another, Magnitude Scale- Apparent and absolute magnitude, distance modulus. Determination of mass, luminosity, radius, temperature and distance of a star, Colour Index, Stellar classification – Henry-Draper and modern M-K Classification schemes, H-R Diagram, H-R Diagram of Clusters, Empirical mass-luminosity relation. (18 Lectures)

Telescopes & Instrumentation: Different optical configurations for Astronomical telescopes, Mountings, plate scale and diffraction limits, telescopes for gamma ray, X-ray, UV, IR, mm and radio astronomy, Stellar Photometry - solid state, Photo-multplier tube and CCD based photometers, Spectroscopy and Polarimetery using CCD detectors. (12 Lectures)

Sun: Physical Characteristics of sun- basic data, solar rotation, solar magnetic fields, Photosphere - granulation, sunspots, Babcock model of sunspot formation, solar atmosphere – chromosphere and Corona, Solar activity- flares, prominences, solar wind, activity cycle, Helioseismology (9 Lectures)

Variable Stars & Asteroseismology: Photometry of variable stars, differential photometry, extinction coefficients, Classes of variable stars, Period-Mean density relationship, Classical Cepheids as distance indicators, pulsation Mechanisms (9 Lectures)

Suggested Books

1. Astronomy, The Evolving Universe by M.Zeilik (Cambridge Univ. Press, 2002)
2. Introduction to Astronomy & Cosmology by I. Morrison (Wiley, 2008)
3. Telescopes and Techniques by C.R.Kitchin (Springer, 1995)
4. Astronomical Photometry by A.A. Henden & R.H. Kaitchuk (Willmann-Bell, 1990)
5. An Introduction to Astronomical Photometry by E. Budding (Cambridge Univ. Press, 1993)
6. Universe by R. A. Freedman & W. J. Kaufmann (W.H.Freeman & Co., 2008)
7. Fundamental Astronomy by H. Karttunen et al. (Springer, 2003)
8. Solar Astrophysics by P. V. Foukal (Wiley-VCH, 2004)
9. Fundamentals of Solar Astronomy by A. Bhatnagar & W.C. Livingston (World Scientific, 2005)

PHYS 575-Part II – Semester IV

Stellar Structure and Evolution: Virial Theorem, Formation of Stars, Hydrostatic Equilibrium, Integral Theorems on pressure, density and temperature, Homologous Trensforamtions, Polytropic gas spehers -- Lane Emden Equation and its solution, Energy generation in stars, P-P and C-N cycles, Radiative and Convection transport of energy, Equations of stellar structure and their solution, Evolution of stars of different masses, pre- and post main-sequence evolution. (24 Lectures)

Compact objects: Fate of massive stars, Degenerate electron and neutron gases, White dwarfs – mass limit, mass-radius relation, Neutron stars and pulsars. (9 Lectures)

Galaxies: The milky way Galaxy, Distribution of stars, Morphology, Kinematics, Interstellar medium, Galactic center. Classification of galaxies, Hubble sequence, Ellipticals, Lentreculars and spiral galaxies and their properties, distribution of light and mass in galaxies. (9 Lectures)

Overview of Modern Astronomy: 21-cm hydrogen line, cosmic radio sources, quasars, gravitational lensing, Expansion of the Universe and determination of Hubble's constant, gamma ray bursters. (6 Lectures)

Suggested Books

1. Stellar Interiors - Physical Principles, Structure, and Evolution by C. J. Hansen, S. D. Kawaler, V. Trimble (Springer, 2004)
2. Stellar Structure and Evolution by R. Kippenhahn and A. Weigert (Springer, 1996)
3. Basics of Astronomy -- IGNOU course book PHE-15 Astronomy and Astrophysics, 2006
4. Modern Astrophysicsby Carrol & Ostlie (Addison Wesley, 1996)
5. The Physical Universe by F. Shu (University Science Books, 1982)
6. Principles of Stellar Structure Vol. I & II by J. P. Cox & R. T. Giuli (Gordon & Breach, 1968)
7. An Introduction to the Study of Stellar Structure by S. Chanrdrasekhar (Dover, 1968)
8. Stellar Interiors by D. Menzel, P. L. Bhatnagar & H. K. Sen (Chapman & Hall, 1963)
9. Galactic Astronomy by J. Binney & M. Merrifield (Princeton Univ. Press, 1998)
10. Textbook of Astronomy & Astrophysics by V. B. Bhatia (Narosa, 2001)

PHYS 556/576– General Theory of Relativity and Cosmology

PHYS 556-Part I – Semester III

Equality of gravitational and intertial masses. Equivalence principle. Principle of general covariance. (5 Lectures)

Tensor Analysis : Covariant and contravariant tensors. Metric tensor. Parallel displacement and covariant differentiation. Affine connection and its relation to metric tensor. Curvature tensor and its symmetries. Bianchi identities. (10 Lectures)

Geodesics: Equation of motion of particles. Weak fields and Newtonian approximation. Time and distance in general theory, gravitational red and blue shifts, experimental verification, Einstein field equation Schwarzschild solution, Mach's principle. Radial motion towards centre. Nature of singularities, black holes, even horizon, Kruskal co-ordinates. (16 Lectures)

General orbits, constants of motion, deflection of light, precession of perihelion and radar echo. Standard, isotropic and harmonic coordinates. Parametrised post Newtonian formalism and status of observational verification. (8 Lectures)

Energy momentum tensor for a perfect fluid, equation of motion from field equation for equation for dust. Action principle for field equations. Conservation laws in curved space and pseudo energy tensor for gravitational field. (9 Lectures)

Suggested Books

1. Cosmology by Steven Weinberg (Oxford University, 2008)
2. Introducing Einstein's Relativity by Ray D'Inverno (Clarendon Press, 1992)
3. Gravity, Black Holes and the Very Early universe: An Introduction to General Relativity and Cosmology by Tai L. Chow (Springer, 2008)
4. Principles of Cosmology and Gravitation by M. Berry (Cambridge University Press, 1976)
5. General Theory of Relativity by P.A. M. Dirac (John Wiley, 1975)
6. The Classical Theory of Fields by L.D. Landau and E. M. Lifshitz (Pergamon, 1975)

PHYS 576-Part II – Semester IV

Relativistic Astrophysics : Schwarzschild solution for star, Birkhoft's theorem, Oppenheimer – Volkov and Tolman equation. Metric of uniform density stars. Polytropic stars, their potential and kinetic energies and stability. Radial oscillations and maximum rotational frequency. White dwarfs, neutron stars and pulsars. Stability of supermassive stars. Kerr metric. (18 Lectures)

Cosmology : Cosmological principle, maximally symmetric spaces, killing vectors, Robertson-Walker metric. Red shift Hubble's law. Magnitude red shift relation, Hubble's constant and declaration parameter. Einstein equation and standard models. Closed, flat and open universes. Age of the universe, critical density and problems of missing mass or missing light. History of early universe, helium formation, decoupling of matter and radiation, microwave background radiation. (18 Lectures)

Gravitational Radiation: Weak field approximation and linear wave equation. Plane waves, their polarization helicity and energy momentum. Eission of radiation by a rotating source. Effect of radiation on a test particle. Detection of gravitational radiation. (12 Lectures)

Suggested Books

1. Cosmology by Steven Weinberg (Oxford University, 2008)
2. Introducing Einstein's Relativity by Ray D'Inverno (Clarendon Press, 1992)
3. Gravity, Black Holes and the Very Early universe: An Introduction to General Relativity and Cosmology by Tai L. Chow (Springer, 2008)
4. Principles of Cosmology and Gravitation by M. Berry (Cambridge University Press, 1976)
5. General Theory of Relativity by P.A. M. Dirac (John Wiley, 1975)
6. The Classical Theory of Fields by L.D. Landau and E. M. Lifshitz (Pergamon, 1975)

PHYS 557 – Mathematical Physics

Semester III

Group Theory: Abstract groups: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples: cyclic, symmetric, matrix groups, regular n-gon. Mappings: homomorphism, isomorphism, automorphism. Representations: reducible and irreducible representation, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations. Introduction to continuous groups: Lie groups, rotation and unitary groups. Applications: point groups, translation and space groups, representation of point groups; introduction to symmetry group of the Hamiltonian. (32 Lectures)

Integral Equations: Conversion of ordinary differential equations into integral equations, Fredholm and Volterra integral equations, separable kernels, Fredholm theory, eigen values and eigen functions. (10 Lectures)

Boundary Value Problems: boundary conditions: Dirichlet and Neumann; self-adjoint operators, Sturm-Liouville theory, Green's function, eigenfunction expansion. (6 Lectures)

Suggested Books

1. Elements of Group Theory for Physicists by A.W. Joshi (John Wiley, 1997)
2. Mathematical Methods for Physicists by George B. Arfken and Hans J. Weber (Accademic Press, 2004)
3. Advanced Method of Mathematical Physics by R. S. Kaushal & D. Parashar (Narosa, 2008)
4. Group Theory and Its Applications to Physical Problems by Morton Hamermesh (Dover, 1989)
5. Chemical Applications of Group Theory by F. Albert Cotton (John Wiley, 1988)

PHYS 577–Nonlinear Dynamics

Semester IV

Introduction to ordinary differential equations (ODEs): linear and nonlinear, systems of ODEs, existence and uniqueness theorems, conservative versus dissipative systems, invariant curves and quasiperiodicity, review of KAM theorem, integrable and non-integrable systems. (8 Lectures)

Phase space analysis: phase portrait, linear stability, potential; fixed points, periodic orbits, limit cycles, Poincaré-Bendixson theorem, Lyapunov functions, gradient systems. (6 Lectures)

Bifurcations: saddle-node, transcritical, pitchfork, Hopf, period doubling, intermittency, local and global bifurcations; center manifold and normal form, structural stability. (4 Lectures)
Discrete systems: Poincaré crossections, linear stability and cobweb analysis; universality and renormalization, logistic and Henon maps. (4 Lectures)

Strange attractors: unstable periodic orbits, chaotic motions; characterization of strange motions: fractal dimension, Fourier transform, entropy and Lyapunov exponents; Cantor set and Koch curve. (4 Lectures)

Coupled systems: synchronization and riddling; multistability, introduction to pattern formation. (3 Lectures)

Introduction to partial different equations: linear and nonlinear, diffusive and dispersive; boundary value problems; methods of separation of variables, characteristics, inverse scattering, symbolic computation, similarity and Backlund transformations. (8 Lectures)

Soliton theory: periodic, cnoidal and solitary wave solutions of Korteweg-de Vries, Nonlinear Schroedinger and sine-Gordon equations; conserved densities. (6 Lectures)

Stochastic versus deterministic: random variables and functions, different moments of random variables; auto and cross correlation, mutual information; unstable sets, stochastic vs chaotic motions; effect of noise in excitable systems. (5 Lectures)

Suggested Books

1. Elementary Differential Equations and Boundary Value Problems by W. E. Boyce and R. C. DiPrima (Wiley, 2003).
2. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering by S. H. Strogatz (Westview Press, 2001).
3. CHAOS: An Introduction to Dynamical Systems by K. Alligood, T. Sauer and J.A. Yorke (Springer, 1996).
4. Solitons: An Introduction by P.G Drazin & R.S. Johnson,(Cambridge Univ. Press., 1989).
5. Nonlinear Science by Scott (Oxford Univ. Press, 1999).
6. Advanced Methods of Mathematical Physics by R.S. Kaushal and D. Parashar (Narossa, 2008).
7. Nonlinear dynamics: Integrability, Chaos and Patterns by M. Lakshmanan and S. Rajasekar, (Springer-Verlag, 2003).

PHYS 558- Complex Systems and Networks

Semester III

Examples of complex systems: organisms, ecosystems, brains, societies, the internet. Explaining how each of these systems is more than the sum of its parts. Description of the components of these systems: molecules, cells, species, agents, computers. Description of complex collective phenomena exhibited by these systems. Contrast with other collective phenomena in physics such as phase transitions. Adaptive nature of these systems. (8 Lectures)

Description of complex systems: Networks and graph theory. Complex networks of interaction as a unifying theme underlying complex systems. A graph with nodes and edges as a description of a network. Adjacency matrix of a graph. Undirected, directed, unipartite and bipartite graphs, hypergraphs. Measures of graph structure: degree distribution, path length, clustering coefficient, distribution of cycles, modularity and community structure, eigenvalues, graph Laplacian, etc. Random graph ensembles, small world, scale free, hierarchical and autocatalytic graphs. Network motifs. Nature of graphs appearing in various complex systems. (8Lectures)

Dynamics of complex systems: Dynamics on a fixed network. The influence of network structure on dynamics. Discrete and continuous dynamical systems, including Boolean networks, cellular automata, coupled maps, differential equations on networks. Attractors of a dynamical system: fixed

points and cycles. Chaos. Deterministic and stochastic dynamics. The role of positive and negative feedback. Examples to be taken from various complex systems, such as flux analysis of metabolic networks, rate equations for chemical networks, ecological food web dynamics, dynamics of genetic regulatory circuits, neural networks, spreading of disease on social networks, economic dynamics.
(12 Lectures)

Evolution of complex systems: Dynamics of networks. A dynamical system whose set of variables is itself a variable. Preferential attachment model of scale free networks. The origin of life puzzle. Model of autocatalytic network evolution and self-organization of a complex network. Emergence of system level coherence and order from a random initial condition. Community assembly models in ecology. Natural selection and evolution of life on earth. Evolution of biological networks.
(12 Lectures)

Some open questions in complex systems: The problem of defining complexity, attempts from computer science, information theory and dynamical systems, the "edge of chaos" hypothesis. Complexity arising from multiple length and time scales. The problem of robustness, fragility and evolvability; their relationship with network architecture. Crashes and recoveries in complex systems. Characterizing the fragility of the biosphere. Characterizing "innovation" in complex systems. (8 Lectures)

Suggested Books

1. Origins of Order by Stuart Kauffman (Oxford University Press, 1993)
2. Handbook of Graphs and Networks: From the Genome to the Internet by S. Bornholdt and H.-G. Schuster (Wiley-VCH, 2003)

PHYS 578 – Introduction to String Theory

Semester IV

Glance at strings: Why strings, Types of strings (Closed and Open), Action for a relativistic point particle, Reparametrization invariance, Equations of motion, Relativistic particle with an electric charge. Generalization to relativistic strings, Area functional for space-time surfaces, Reparametrization invariance of area, Nambu-Goto action, equations of motion, boundary conditions and D-branes, Static gauge, Tension and energy of a stretched string, Action in terms of transverse velocity, Motion of open string end points. (8 lectures)

World-sheet currents: Electric charge conservation, Conserved charges from Lagrangian symmetries, Conserved currents on the world-sheet, Momentum current, Lorentz symmetry and associated currents, String slope parameter (4 lectures)

Relativistic quantum open strings: Light-cone Hamiltonian and commutators, Commutation relations for oscillators, Strings as harmonic oscillators, Transverse Virasoro operators, Lorentz generators, Tachyons and D-brane decay. (8 lectures)

Relativistic quantum closed strings: Mode expansions and commutation relations, Closed string Virasoro operators, String coupling and the dilaton, Brief look at superstring theories. (8 lectures)

D-branes and gauge fields: Dp-branes and boundary conditions, Quantising open strings on Dp-branes, Open strings between parallel Dp-branes, Fundamental string charge and D-brane charges
(4 lectures)

T-duality symmetries: Duality symmetries and Hamiltonian in closed string theory, Winding closed strings, T-duality and D-branes, U(1) gauge transformations, Wilson lines on a circle. (8 lectures)

Electromagnetic fields on D-branes: Maxwell fields coupling to open strings, D-branes with electric fields, D-branes with magnetic fields, Born-Infeld theory and T-duality (8 lectures)

Suggested Books
1. A First Course in String Theory by Barton Zwiebach (Cambridge University Press, 2004)
2. Superstring Theory, Volume-I by M.B. Green, J.H. Schwarz and E. Witten (Cambridge Monograph on Mathematical Physics, 1988)
3. String Theory, Volume-I by Joseph Polchinski (Cambridge University Press, 1998)

PHYS 559- Experimental High Energy Physics

Semester III

A. Data Analysis Techniques
1. Introduction to error analysis, error propagation, covariance matrix
2. Log Likelihood and linear least square methods for fitting curves
3. Testing of hypothesis.
4. Generating Gaussian, Poisson, exponential, Landau, Lorentzian distribution using ROOT (rejection and transformation methods).
5. Introduction to minimization techniques in MINUIT.
6. Fitting histograms of various distribution using MINUIT.
7. Usage and manipulation of ROOT trees
8. Multivariate analysis of data using ROOT.

B. Event Generators
1. Generation of $e^+e^- \rightarrow e^+e^-$ using PYTHIA and analysis
2. Generation of $pp \rightarrow e^+e^-$ and analysis using PYTHIA
3. Generation of $pp \rightarrow H \rightarrow$ any channel using PYTHIA and fitting mass peak.

C. Detector Simulation
1. Writing a simple geometry using GEANT
2. Writing advanced multi volume geometry using GEANT
3. Simulation of a simple crystal calorimeter W an RPC with GEANT
4. Visualization in GEANT.
5. Study of passage of particle through matter, using GEANT

D. Hardware Experiments
1. Setting up of a coincidence circuit in a cosmic muon test bench
2. Measurement of μ lifetime
3. Study of passage of μ through a scintillator detector placed in cosmic muon stand.
4. Fabrication of a Resistive Plate Chamber.
5. Testing of a Resistive Plate Chamber in cosmic moun stand.
6. Simulation and characterization of silicon detectors.

NOTE-11:
The above list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations.

Suggested Books

1. Data Analysis Techniques for High Energy Physics Experiments by R. K. Bock, H. Grote, D. Notz, M. Regler (Cambridge University Press, 2009).
2. Techniques for Nuclear and Particle Physics Experiments by William R. Leo (Narosa, 1995)
3. Data reduction and error analysis for the Physical Sciences by Philip R. Bevington (Mc-Graw-Hill, 2002)
4. Statistics for Nuclear and Particle Physicists by Louis Lyons (Cambridge Univ. Press, 1986)
5. Statistical Data Analysis by Glen Cowan (Oxford, 1998)

PHYS 579-Observational Astronomy Laboratory

Semester IV

Students will be assigned one or more of the following observational astronomy experiments:

1. Polar aligning a telescope and measuring declination of polaris.
2. Calibration of plate scale of a given astronomical telescope
3. Determination of diameter of moon by transit.
4. Determination of diameter of sun by transit
5. Calibration of a photometer for astronomical measurements
6. Measuring distance to moon by parallax method.
7. Measuring limb-darkening of sun.
8. Finding rotation period of sun by measuring motion of sun-spots.
9. Measuring relative sensitivity of B.V. and R band of a photometer with sun and using this to find temperature of filament of a lamp.
10. Measuring color of a star by differential photometry.
11. Measuring extinction of the atmosphere in B.V. and R bands.
12. Characterizing the CCD camera for gain, read-noise linearity and flat field.
13. Estimating atmospheric seeing by measuring different zenith angles
14. Application of Image Processing Software (IRAF) to determine magnitudes of different stars in a star field.
15. Application of Image Processing Software (IRAF) to determine angular separations of different stars in a star field.

NOTE-12:
Students will be required to make night observations at the Astronomical Observatory of the department. In addition, telescope time will be made available to them on IUCAA telescope as well as other national and international facilities. The work done during the entire semester is to be submitted in the form of a Dissertation. Also the above list is tentative; changes in the list of experiments may be made, depending on the availability of the equipment and other relevant considerations.

Suggested Books

1. Astrophysical Techniques by C.R. Kitchin (CRC press, 1995)
2. Observational Astrophysics by R. C. Smith (Cambridge Univ. Press, 2000)
3. Telescopes and Techniques by C.R.Kitchin (Springer, 1995)
4. Observational Astronomy by D.S. Birney, G Gonzalez & D Oesper (Cambridge Univ. Press, 2006)
5. Observational Astrophysics by P. Lena (Springer, 1986)
6. Practical Astronomy with your calculator by P. Duffet-Smith (Cambridge Univ. Press, 1988)
7. Astronomical Photometry by A. A. Henden & R.H. Kaitchuk (Willmann-Bell, 1990)

8. Photoelectric Photometry by D.S. Hall & R.M. Genet (Willmann-Bell, 1988)
9. Astronomical Spectroscopy by C.R. Kitchin (IOP, 1995)
10. Spectrophysics by A.P. Thorne (Chapman & Hall, 1988)
11. Electronic Imaging in Astronomy-Detectors and Instrumentation by I.S. Mclean (Springer-Praxis, 2008)

PHYS 580- **Advanced Numerical Techniques**

Semester IV

1. Solution of Linear algebraic equation: Gauss Jordon elimination, Singular Value Decomposition, Sparse linear system, Cholskey decomposition, QR decomposition.
2. Interpolation/extrapolation : Polynomial interpolation and extrapolation, cubic spline, interpolation in two or more dimension
3. Advanced integration: Improper integrals, multidimensional integrals.
4. Variational Principle: Minimization and maximization of function, golden section, simplex, conjugate gradient/variable metric methods in multidimension.
5. Evaluation of Functions: special functions, evaluation of functions by path integration, incomplete gamma, beta function, χ^2.
6. Random Nambers : Uniform random numbers generators, statistical distributions and their properties, Rejection Method, transformation method, simple Monte Carlo integration, Adaptive and recursive Monte Carlo methods, Test of randomness.
7. Signal Processing: FFT, IFFT, Filtering with FFT, convolution and correlation functions, application to real time series data.
8. Modeling of Data: Introduction, least square and maximum likelihood estimator, example of straight line fitting, nonlinear models.
9. Eigen systems: Solving eigenvalues and finding eigen functions of schroedinger equation for analytically unsolvable potentials using variational principle.
10. Integral equations: Fredholm equations, Volterra equations integrals equations with singular kernels.

Suggested Books

1. The Fast Fourier Transform and its Applications by E.O. Brigham (Prentice-Hall, 1988)
2. Data reduction and error analysis for the Physical Sciences by P.R. Bevington & D.K. Robinson (McGraw-Hill, 1992)
3. Mathematical Methods for Physicists by G. B. Arfken & H. J. Weber (Academic Press, 2002)
4. Elementary Numerical Analysis by K. Atkinson (John Wiley, 1994)
5. Numerical Recipes by Press et al. (Cambridge Univ. Press, 2007)
6. Numerical Mathematical Analysis by J. B. Scarborough (Johns-Hopkins, 1966)

MINOR MODIFICATIONS IN THE SYLLABUS OF M.Sc. PHYSICS

EXISTING	AMENDED
Semester III Theory (Specializationa) Courses of 4 hours/week (including the tutorials) PHYS551 Particle Physics-I PHYS552 Field Theory and Quantum Electrodynamics-I PHYS553 Advanced Solid State Theory-I PHYS554 Plasma Physics-I PHYS555 Astronomy & Astrophysics-I PHYS556 General Theory of Relativity & Cosmology-I PHYS557 Mathematical Physics PHYS558 Complex Systems and Networks PHYS559 Experimental High Energy Physics (Lab. Course of 8 hours/week) PHYS560 Interdisciplinary Course-I PHYS561 Interdisciplinary Course-2	**Semester III** Theory (Specializationa) Courses of 4 hours/week (including the tutorials) PHYS511 Physics at Nanoscale –I (Theory Course) PHYS513 Electronics-I (Theory course) PHYS515 Solid State Physics-I (Theory Course) PHYS517 Nuclear Physics-I (Theory Course) PHYS519 Laser & Spectroscopy-I (Theory Course) PHYS551 Particle Physics-I PHYS552 Field Theory and Quantum Electrodynamics-I PHYS553 Advanced Solid State Theory-I PHYS554 Plasma Physics-I PHYS555 Astronomy & Astrophysics-I PHYS556 General Theory of Relativity & Cosmology-I PHYS557 Mathematical Physics PHYS558 Complex Systems and Networks PHYS559 Experimental High Energy Physics (Lab. Course of 8 hours/week) PHYS560 Interdisciplinary Course-I PHYS561 Interdisciplinary Course-2
Semester IV Theory (Specializationa) Courses of 4 hours/week (including the tutorials)	**Semester IV** Theory (Specializationa) Courses of 4 hours/week (including the tutorials) PHYS531 Physics at Nanoscale –II (Theory Course) PHYS533 Electronics-II (Theory course)

	PHYS535 Solid State Physics-II (Theory Course) PHYS537 Nuclear Physics-II (Theory Course) PHYS539 Laser & Spectroscopy-II (Theory Course)
PHYS571 Particle Physics-II PHYS572 Field Theory and Quantum Electrodynamics-II PHYS573 Advanced Solid State Theory-II PHYS574 Plasma Physics-II PHYS575 Astronomy & Astrophysics-II PHYS576 General Theory of Relativity & Cosmology-II PHYS577 Nonlinear Dynamics PHYS578 Introduction to String Theory PHYS579 Observational Astronomy Lab (Laboratory Course of 8 hours/week) PHYS80 Advanced Numerical Techniques (Computer Lab. Course of 8 hours/week) PHYS 581 Interdisciplinary Course-3 PHYS582 Interdisciplinary Course-4	PHYS571 Particle Physics-II PHYS572 Field Theory and Quantum Electrodynamics-II PHYS573 Advanced Solid State Theory-II PHYS574 Plasma Physics-II PHYS575 Astronomy & Astrophysics-II PHYS576 General Theory of Relativity & Cosmology-II PHYS577 Nonlinear Dynamics PHYS578 Introduction to String Theory PHYS579 Observational Astronomy Lab (Laboratory Course of 8 hours/week) PHYS80 Advanced Numerical Techniques (Computer Lab. Course of 8 hours/week) PHYS 581 Interdisciplinary Course-3 PHYS582 Interdisciplinary Course-4