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

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Marks</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS 401</td>
<td>Classical Mechanics</td>
<td>100</td>
<td>4</td>
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<tr>
<td>PHYS 402</td>
<td>Quantum Mechanics –I</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 403</td>
<td>Electromagnetic Theory &amp; Electrodynamics</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 404</td>
<td>Nuclear &amp; Particle Physics</td>
<td>100</td>
<td>4</td>
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<tr>
<td>PHYS 405/410</td>
<td>Laboratory course I/II</td>
<td>100</td>
<td>4</td>
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II SEMESTER

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
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<th>Credits</th>
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<tbody>
<tr>
<td>PHYS 406</td>
<td>Quantum Mechanics –II</td>
<td>100</td>
<td>4</td>
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<tr>
<td>PHYS 407</td>
<td>Statistical Mechanics</td>
<td>100</td>
<td>4</td>
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<tr>
<td>PHYS 408</td>
<td>Radiation Theory</td>
<td>100</td>
<td>4</td>
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<tr>
<td>PHYS 409</td>
<td>Atomic &amp; Molecular Physics</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 405/410</td>
<td>Laboratory course I/II</td>
<td>100</td>
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1. **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)

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

3. **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

<table>
<thead>
<tr>
<th>COURSE</th>
<th>Marks</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>PHYS 501</td>
<td>100</td>
<td>4</td>
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</table>

(Computer Lab, Course of 6 hours/week for Lab & 2 hours/week for Lecture/Tutorial)

**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.
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-I
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 relative weightage vis-à-vis the complete course.

SEMESTER-I

PHYS 401– Classical Mechanics

Types of constraints on dynamical systems, generalized coordinates, d’Alembert principle, 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)

PHYS 402– Quantum Mechanics I


Suggested Books

PHYS 403 – Electromagnetic Theory & Electrodynamics


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.


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.

Suggested Books
2. Introduction to Electrodynamics by David Griffiths (3rd Ed., Benjamin Cummings, 1999)
Static properties of Nuclei: Nuclear size determination from electron scattering, nuclear formfactors. Angular momentum, spin and moments of nuclei. (2 Lectures)


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

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)


Suggested Books

PHYS 407 – Statistical Mechanics


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


Suggested Books

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 quantization and their removal and Lorentz gauge 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, Kramers-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

PHYS 409 – Atomic & Molecular Physics


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)


Suggested Books
5. Basic atomic & Molecular Spectroscopy by J. M. Hollas (Royal Society of Chemistry, 2002)
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

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 plasmas
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

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.
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)
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)


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.

Suggested Books

PHYS 531-Part II – Semester IV


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

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


Suggested Books

PHYS S12/S32 - 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.
5. Growth of nanomaterials by nanopores-template method.
6. Growth of semiconductor quantum dots in matrices (glass/polymer etc)
7. Structural characterization of nanomaterials by XRD- determination of average grain size, lattice parameters, strains etc.
8. Structural 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

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
2. Semiconductor Optoelectronic Devices by Pallab Bhattacharya (PHI-India, 1995)

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.

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

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 coefficient. (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

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, Electroluminescence. (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

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.

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

Suggested Books

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, ac 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.
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, La2B6Br3, 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, Wisskovff-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: Mossbauer effect and its applications, Activation method, Biological effects of radiation, Industrial and Analytical application, nuclear medicine. (8 Lectures)

Suggested Books
3. Techniques for Nuclear and Particle Physics Experiments by W.R. Leo (Springer-Verlag 1987)

PHYS 537-Part II – Semester IV


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

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 half-life 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).
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 lasers, Non-linear spectroscopy. (16 lectures)

Suggested Books

PHYS 539-Part II – Semester IV


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
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.
CPT 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)
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 mechanism, 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 Elementary Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008)
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

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

Path integral formulation: functional methods of field quantization.

Suggested Books
2. Lectures on Quantum Field Theory by Ashok Dass (World Scientific, 2008)
3. Relativistic Quantum Mechanics by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
4. Relativistic 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)
8. Quantum Field Theory by F. Mandl and G. Shaw (Wiley, 1993)
11. Introduction to the Theory of Quantized Fields by N.N. Bogoliubov & D.V. Shirkov (Nauka, Moscow, 1984)

**PHYS 572-Part II – Semester IV**


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.

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.

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

Suggested Books
2. Lectures on Quantum Field Theory by Ashok Dass (World Scientific, 2008)
3. Relativistic Quantum Mechanics by J.D. Bjorken and S. Drell (Mcgraw-Hill, 1964)
4. Relativistic 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)
8. Quantum Field Theory by F. Mandl and G. Shaw (Wiley, 1993)
11. Introduction to the Theory of Quantized Fields by N.N. Bogoliubov & D.V. Shirkov (Nauka, Moscow, 1984)

**PHYS 553/573—Advanced Solid State Theory**

**PHYS 553-Part I—Semester III**


(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)


(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**

9. The Mossbauer Effect by Hans Fraunfelder (W.A. Benjamin, 1963)
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 antiferromagnetic 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
9. The Mossbauer Effect by Hans Fraunfelder (W.A. Benjamin, 1963)
10. Quasistatic neutron scattering for the investigation of diffuse motions in solids and liquids Springer tracts in modern physics Vol. 64, Tasso Springer (Springer-Verlag, 1972)
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)


Suggested Books

1. Introduction to Plasma physics by F. F. Chen (Plenum Press, 1984)
5. Introduction to Plasma Physics by R.J. Goldston and P.H. Rutherford (IOP, 1995)

PHYS 574-Part II – Semester IV


Suggested Books

1. Introduction to Plasma physics by F. F. Chen (Plenum Press, 1984)
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


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-multiplier tube and CCD based photometers, Spectroscopy and Polarimetry using CCD detectors.
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
2. Introduction to Astronomy & Cosmology by I. Morrison (Wiley, 2008)
5. An Introduction to Astronomical Photometry by E. Budding (Cambridge Univ. Press, 1993)
7. Fundamental Astronomy by H. Karttunen et al. (Springer, 2003)

PHYS 575-Part II - Semester IV


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, Lenticulars 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
5. The Physical Universe by F. Shu (University Science Books, 1982)
7. An Introduction to the Study of Stellar Structure by S. Chandrasekhar (Dover, 1968)
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


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)

PHYS 576 – Part II – Semester IV


Suggested Books
1. Cosmology by Steven Weinberg (Oxford University, 2008)

**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

**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 crossover, 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 differential 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

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)

(8 Lectures)

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)


(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

PHYS 378 - 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
2. Superstring Theory, Volume-I by M.B. Green, J.H. Schwarz and E. Witten (Cambridge Monograph on Mathematical Physics, 1988)

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
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 and 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 $\mu$ lifetime
3. Study of passage of $\mu$ 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 muon 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

2. Techniques for Nuclear and Particle Physics Experiments by William R. Leo (Narosa, 1995)

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 polars.
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.
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

2. Observational Astrophysics by R. C. Smith (Cambridge Univ. Press, 2000)
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)
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
5. Evaluation of Functions: special functions, evaluation of functions by path integration, incomplete gamma, beta function, $\chi^2$.
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.

Suggested Books
1. The Fast Fourier Transform and its Applications by E.O. Brigham (Prentice-Hall, 1988)
5. Numerical Recipes by Press et al. (Cambridge Univ. Press, 2007)
## MINOR MODIFICATIONS IN THE SYLLABUS OF M.Sc. PHYSICS

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