UNIVERSITY OF THE PUNJAB, LAHORE, PAKISTAN

CURRICULUM OF PHYSICS (2018)

MPhil (2 Years) physics degree program under semester system

DEPARTMENT OF PHYSICS, UNIVERSITY OF THE PUNJAB, LAHORE, PAKISTAN
8/20/2018
MASTER OF PHILOSOPHY (MPhil) PHYSICS DEGREE PROGRAM

<table>
<thead>
<tr>
<th>Duration of Degree Course</th>
<th>Two years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching System</td>
<td>Semester System</td>
</tr>
<tr>
<td>Total Number of Credit Hours</td>
<td>30</td>
</tr>
<tr>
<td>Credit Hours for Taught Courses</td>
<td>24 (Semesters I, II)</td>
</tr>
<tr>
<td>Credit Hours for Research Thesis</td>
<td>06 (Semesters III, IV)</td>
</tr>
<tr>
<td>Session Starts</td>
<td>(Fall) September-October</td>
</tr>
<tr>
<td>Eligibility Qualification</td>
<td>BS (Physics) or equivalent</td>
</tr>
<tr>
<td>Number of Student Enrollment</td>
<td>25 including all reserved seats</td>
</tr>
</tbody>
</table>

MISSION STATEMENT

The mission of the Master of Philosophy (Physics) program is to equip students with theoretical and applied knowledge of physics for the solutions of complex problems related to understanding of physical world and to enable them to use that knowledge in solving various problems of human world. It is aimed to prepare the students to learn independently and critically in a constantly changing discipline.

OBJECTIVES

The MPhil (Physics) degree course is offered by the Department of Physics as a full-time period of teaching and research and introduces students to research skills and specialist knowledge in the subject of Physics. Main objectives of the program are

- to offer students graduate level courses in theoretical and applied physics
- to give students with relevant experience, the opportunity to carry out research in various disciplines of Physics under close supervision
- to give students the opportunity to develop various skills and expertise relevant to their research interests
- to give students the opportunity to engage in rigorous scholarly pursuit, and to contribute in academic and industrial research
- to prepare students with a theoretical physics background and applied research needed to enter a doctorate program in physics.
- to prepare students to join an appropriate and respectable level position in a physics related field, and to maintain their professional skills in rapidly evolving industry and academia.
- to develop research based scientific thinking and to enhance professional skills for teaching, research, managerial positions in wide range of professions in national and international organizations.

Semester-wise breakup and outline of courses for this program are given as under. In addition to compulsory courses, elective courses of graduate level are offered in various specializations in the subject of Physics. The program meets the standards of international graduate programs in the subject of Physics. Taught courses are offered in semesters I and II, while in semester III and IV, student
work towards their thesis projects. Graduate students are offered research projects from various research groups of the Department. Teaching and Examinations are held according to semester rules of University of the Punjab.

SCHEME OF STUDIES

COURSE CODE KEY
For the course code Phys xxxx, the first letter shows the year of degree course in the university (e.g. for first year course, it is written as 1xxx, for third year course it is 3xxx and for fifth year course it is 5xxx (first year of MPhil course), while second letter represents a number assigned to a specific subject area of physics (e.g. in general classification within the subject of Physics, a number is assigned to a set of similar subject titles i.e. for foundation courses, the number is 0 (Phys x0xx), for classical mechanics and related titles, the number is 1 (Phys x1xx), for electrodynamics and related titles it is 2 (Phys x2xx), for quantum mechanics and related titles, it is 3 (Phys x3xx), for solid state physics and related titles, it is 4 (Phys x4xx), for mathematical physics and related titles, it is 5 (Phys x5xx), for experimental physics and labs, it is 6 (Phys x6xx), for electronics and related titles, it is 7 (Phys x7xx), for materials and nanotechnology, it is 8 (Phys x8xx) etc. The last two letters of the course code show the sequence of the course titles in the specific subject and ranges from 01-99 (e.g. for solid state physics-I offered in third year, course code is Phys 3401 and for solid state physics-II offered in third year, it is Phys 3402, and for solid state physics-III offered in fourth year, code is Phys 4403 etc.).
## SCHEME OF STUDIES (MPhil PHYSICS PROGRAM)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hrs.</th>
<th>Course Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YEAR I</strong></td>
<td><strong>SEMESTER-I</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phys 5511</td>
<td>Advanced Mathematical Physics</td>
<td>3</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Phys 5611</td>
<td>Experimental Techniques in Physics</td>
<td>3</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-I</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-II</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td><strong>Credit Hrs.</strong></td>
<td></td>
<td><strong>12</strong></td>
<td></td>
</tr>
<tr>
<td><strong>SEMESTER-II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-III</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-IV</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-V</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td>Phys</td>
<td>Elective-VI</td>
<td>3</td>
<td>Elective</td>
</tr>
<tr>
<td><strong>Credit Hrs.</strong></td>
<td></td>
<td><strong>12</strong></td>
<td></td>
</tr>
<tr>
<td><strong>YEAR II</strong></td>
<td><strong>SEMESTER III</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phys 6000</td>
<td>Thesis</td>
<td>3</td>
<td>Research</td>
</tr>
<tr>
<td><strong>Credit Hrs.</strong></td>
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<td><strong>3</strong></td>
<td></td>
</tr>
<tr>
<td><strong>SEMESTER-IV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phys 6000</td>
<td>Thesis</td>
<td>3</td>
<td>Research</td>
</tr>
<tr>
<td><strong>Credit Hrs.</strong></td>
<td></td>
<td><strong>3</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total Credit Hrs.</strong></td>
<td></td>
<td><strong>30</strong></td>
<td></td>
</tr>
</tbody>
</table>

- Elective courses will be offered from the following list by the Department of Physics in view of availability of instructors and related resources.
- In semester-I, the students will have to opt both Elective-I and Elective-II courses from the same area of specialization.
- In semester-II, the students will have to opt at least three courses from the same area of specialization as those opted in semester-I.
- In case of two areas of specialization, the number of students in each specialization shall not exceed 60% of the total number of students enrolled in the programs.
### Specialization-1 (Theoretical Physics)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Cr. Hrs.</th>
<th>Code</th>
<th>Course Title</th>
<th>Cr. Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys 5111</td>
<td>Nonlinear Physics</td>
<td>3</td>
<td>Phys 5411</td>
<td>Introduction to Condensed Matter Physics</td>
<td></td>
</tr>
<tr>
<td>Phys 5211</td>
<td>Plasma Physics</td>
<td>3</td>
<td>Phys 5612</td>
<td>Applications of X-Ray Diffraction Method</td>
<td></td>
</tr>
<tr>
<td>Phys 5112</td>
<td>Classical Field Theory</td>
<td>3</td>
<td>Phys 5711</td>
<td>Physics of Semiconductor Devices</td>
<td></td>
</tr>
<tr>
<td>Phys 5512</td>
<td>Advanced Computational Physics</td>
<td></td>
<td></td>
<td>Spectroscopy</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5311</td>
<td>Quantum Electrodynamics</td>
<td>3</td>
<td></td>
<td>Introduction to Magnetism and Magnetic Materials</td>
<td></td>
</tr>
<tr>
<td>Phys 5312</td>
<td>Standard Model of Particle Physics</td>
<td></td>
<td></td>
<td>Lattice Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5313</td>
<td>Quantum Field Theory</td>
<td>3</td>
<td></td>
<td>Optoelectronics</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5512</td>
<td>Nonlinear Waves and Solitons</td>
<td>3</td>
<td>Phys 5412</td>
<td>Optical Properties of Solids</td>
<td></td>
</tr>
<tr>
<td>Phys 5212</td>
<td>Advanced Plasma Physics</td>
<td>3</td>
<td>Phys 5415</td>
<td>Superconductivity</td>
<td></td>
</tr>
<tr>
<td>Phys 5513</td>
<td>Integrable Systems in Mathematical Physics</td>
<td>3</td>
<td>Phys 5811</td>
<td>Nanomaterials (Science, Growth and Characterization)</td>
<td></td>
</tr>
<tr>
<td>Phys 5314</td>
<td>Advanced Quantum Field Theory</td>
<td></td>
<td></td>
<td>Applied Nuclear Physics</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5315</td>
<td>Supersymmetry</td>
<td>3</td>
<td></td>
<td>Spintronics, Applications and Devices</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5113</td>
<td>General Relativity</td>
<td>3</td>
<td></td>
<td>Quantum Computing and Information</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5514</td>
<td>Group Theory in Physics</td>
<td>3</td>
<td>Phys 5812</td>
<td>Physics of Surfaces and Interfaces</td>
<td>3</td>
</tr>
</tbody>
</table>

### Specialization-2 (Applied Physics)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Cr. Hrs.</th>
<th>Code</th>
<th>Course Title</th>
<th>Cr. Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys 5111</td>
<td>Introduction to Condensed Matter Physics</td>
<td></td>
<td></td>
<td>Applications of X-Ray Diffraction Method</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5612</td>
<td>Physics of Semiconductor Devices</td>
<td></td>
<td></td>
<td>Spectroscopy</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5311</td>
<td>Introduction to Magnetism and Magnetic Materials</td>
<td></td>
<td></td>
<td>Lattice Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5312</td>
<td>Optoelectronics</td>
<td></td>
<td></td>
<td>Optical Properties of Solids</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5313</td>
<td>Superconductivity</td>
<td></td>
<td></td>
<td>Nanomaterials (Science, Growth and Characterization)</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5314</td>
<td>Applied Nuclear Physics</td>
<td></td>
<td></td>
<td>Spintronics, Applications and Devices</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5315</td>
<td>Quantum Computing and Information</td>
<td></td>
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<td>Quantum Computing and Information</td>
<td>3</td>
</tr>
<tr>
<td>Phys 5316</td>
<td>Physics of Surfaces and Interfaces</td>
<td></td>
<td></td>
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<td>3</td>
</tr>
</tbody>
</table>

(More specializations and course titles in each specialization can be added from time to time subject to the approval by relevant academic bodies)
OUTLINES OF COURSES

COMPULSORY COURSES

<table>
<thead>
<tr>
<th>Phys 5511</th>
<th>ADVANCED MATHEMATICAL PHYSICS</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preq.</td>
<td>Phys 3503</td>
<td></td>
</tr>
</tbody>
</table>

Objectives
To demonstrate utility of advanced mathematical techniques in solving problems of physics and to develop working knowledge of Mathematical Physics at graduate level.

Syllabus

Recommended Books

<table>
<thead>
<tr>
<th>Phys 5611</th>
<th>EXPERIMENTAL TECHNIQUES IN PHYSICS</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preq.</td>
<td>Phys 4404</td>
<td></td>
</tr>
</tbody>
</table>

Objectives
To learn working principle and instrumentation of experimental techniques which are being applied by experimentalists to characterize materials.

Syllabus
Introduction to characterization methods of solid materials: Solid materials, an overview, growth, bulk characterization, surface characterization, interface characterization, ambient requirements and sample preparation. Experimental Characterization Techniques, optical microscopy, scanning electron

**Recommended Books**


**ELECTIVE COURSES**

**SPECIALIZATION-1**

<table>
<thead>
<tr>
<th>Phys 5111</th>
<th>NONLINEAR PHYSICS</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phys 3501</td>
<td></td>
</tr>
</tbody>
</table>

**Objectives**

To introduce students with basic knowledge of nonlinear dynamical systems and chaos. To develop mathematical problem solving skills related to nonlinear physics.

**Syllabus**


**Recommended Books**


<table>
<thead>
<tr>
<th>Phys 5211</th>
<th>PLASMA PHYSICS</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preq.</td>
<td>Phys 4202</td>
<td></td>
</tr>
</tbody>
</table>

**Objectives**
To make students acquire basic knowledge of plasma physics and its various applications in applied sciences

**Syllabus**
Introduction to plasma physics, and general properties of plasmas, occurrence of plasmas in nature, concept of temperature, Debye shielding, criteria for plasmas, applications of plasma physics, single particle motions in plasmas, motion of charged particles in uniform E and B fields, motion of charged particles in non-uniform B and E fields, motion of charged particles in time varying E and B fields, adiabatic invariants. Plasmas as fluids, relation of plasma physics to ordinary electromagnetics, the fluid equation of motion, equation of continuity, the complete set of fluid equations, fluid drifts, plasma approximation. Waves in plasmas, representation of waves, group velocity, plasma oscillations, electron plasma waves, sound waves, ion waves, validity of the plasma approximation, comparison of ion and electron waves, electrostatic electron oscillations perpendicular to B, electrostatic ion waves perpendicular to B, the lower hybrid frequency, EM waves with $B_0 = 0$, EM waves perpendicular to $B_0$, cutoffs and resonances, EM waves parallel to $B_0$, hydromagnetic waves, magnetostrictive waves.

**Recommended Books**

<table>
<thead>
<tr>
<th>Phys 5112</th>
<th>CLASSICAL FIELD THEORY</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Reqs</td>
<td>Phys 3101</td>
<td></td>
</tr>
</tbody>
</table>

**Objectives**
To introduce students with the concept of continuous dynamical systems and field equations. To develop an understanding of electromagnetism as a field theory.

**Syllabus**
Moving from classical particle mechanics to mechanics of continuous systems, examples Euler Lagrange equations., the concept of field, classical Lagrangians and Hamiltonians for fields, field equations, canonical formalism and Poisson brackets for fields, variational methods for field theory.
Introduction of special relativity and formulation of relativistic classical field theory, four dimensional formulation of fields and the stress-energy momentum tensor, scalar field. Linear fields and the Klein-Gordon equation, variational method and field equations, symmetries and conservation laws, Noether theorem, linear massless scalar fields and the Maxwell field equations, the electromagnetic energy-momentum tensor. Gauge invariance, the Lorenz gauge, charge conservation, four-currents, canonical stress tensor; conserved, traceless & symmetric stress tensor, Particle and field energy-momentum & angular momentum conservation. The massive vector (Proca) Field, the tensor field, the massless tensor field.

Recommended Books

<table>
<thead>
<tr>
<th>Phys 5512</th>
<th>ADVANCED COMPUTATIONAL PHYSICS</th>
<th>(CR3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preq.</td>
<td>Phys 3504</td>
<td></td>
</tr>
</tbody>
</table>

Objectives
To introduce students with advanced methods of computational techniques and simulation methods used in solving problems in the subject of physics

Syllabus
The course will cover topics in advanced MATLAB (or PYTHON or MATHEMATICA) programming based on topics in computational physics involving numerical methods and their application to many physical problems, data processing and expression evaluations, so, the concepts developed in this course will be helpful for both theoretical and experimental physicists. Advance data visualization, analysis and processing techniques, improved scalar, vector and matrix manipulation techniques. Improved data presentation, multidimensional data plotting. Dealing with missing data or observations, handling outliers, smoothing and filtering of noisy data, handling heterogeneous data types and storage, data structures. Animations and simulations for 2D and 3D plots. Comparisons of scalars, vectors and matrices by Distance calculations e.g, Euclidean, city block distance etc. Interpolation of multidimensional data, pattern matching, dimension reduction, Eigenvalues and Eigenfunctions, cf-tools and curve fitting. Introduction to advance problem solving techniques in Physics and mathematics, Symbolic differentiation and integration, expansion of diverse series (expression evaluation), advance numerical calculus and differential equations, extension to higher-order equations, ODE solvers. Problem solving and modelling for advance growth and decay problems (radioactivity, charge/current, disease and bacteria etc). Monte-Carlo method and its applications, random walk, diffusion, electron scattering, crystal structure analysis (BCC, FCC etc), atom-atom interactions and interaction potentials, Schrodinger wave equations, Monte Carlo Simulations.

Recommended Books
1. MATLAB for Engineers by H. Moore, Pearson, (2017)
Phys 5311 QUANTUM ELECTRODYNAMICS (CR3)
Preq. Phys 4302

Objectives
To acquaint students with quantization of electromagnetic field and to introduce them with techniques used to understand fundamental scattering processes.

Syllabus
The electromagnetic field in free space: classical and quantized. The electromagnetic interaction and gauge invariance, the geometry of gauge invariance, the Dyson expansion of the S-matrix and the Wick’s theorem, Feynman diagrams in position and momentum space, the Feynman rules of QED and their uses for all possible physical processes in the second order. Scattering of two particles; unpolarized cross-section for the electron-positron to muon-antimuon and the electron-muon scattering, scattering by a static electric field; elastic electron-nucleon scattering and the nuclear form factor, Bremsstrahlung and the infra-red divergence, an introduction to the charge renormalization in QED and the running QED coupling.

Recommended Books

Phys 5312 STANDARD MODEL OF PARTICLE PHYSICS (CR3)
Preq. Phys 4305

Objectives
To give an in-depth understanding and mathematical description of fundamental interactions of nature and their unification.

Syllabus
Brief review of relativistic Quantum Mechanics and building blocks of standard model, Gauge Theory of Electroweak Interactions, Gauge symmetry, non-Abelian gauge symmetry, weak interactions, electroweak interactions, spontaneous symmetry breaking, discrete and continuous symmetries, global symmetries and Goldstone’s theorem, local symmetries and Higg’s mechanism, properties of the Higgs boson, ultraviolet divergences, renormalizability, dimensions of fields and couplings, scattering cross sections, Quantum Chromodynamics Colour and properties of Lie group SU(3), SU(3) gauge symmetry, strong interactions, neutrino masses and oscillations, effective charge and asymptotic freedom, grand unification, supersymmetry.

Recommended Books

Phys 5313 QUANTUM FIELD THEORY (CR3)

Objectives
To give an understanding of the concept of second quantization and to introduce basic techniques of quantum field theory used in particle physics.

Syllabus

Recommended Books

Phys 5512 NONLINEAR WAVES AND SOLITONS (CR3)

Objectives
To give an introduction to nonlinear wave phenomena and to develop mathematical formulation of this phenomena. To give an introduction to waves called solitons.

Syllabus
Basics of linear and non-linear (ordinary and partial) differential equations, superposition principle, Some non-linear equations e.g. non-linear wave equation, non-linear Schrodinger's (NLS) equation, sine-Gordon equation, Liouville's equation, Korteweg-de-vries (KdV) equation, modified KdV
equation, Burger equation, Boussinesq equation etc. Conservation laws, basic idea, conserved quantities for the KdV equation, Gardner transformation, conservation laws for the sine-Gordon equation. Solutions of non-linear equations, travelling-wave solutions, solitary waves and solitons, Hirota’s method (the bilinear form), bilinearization of non-linear differential equations, solutions, of bilinear equations, Backlund transformation, Theorem of Permutability, Backlund transformations for the KdV equation, sine-Gordon equation etc., Riccati equation, Inverse methods, the AKNS scheme, eigen value problem, Lax pairs, Darboux transformation and multi-soliton solutions.

**Recommended Books**


**Phys 5212**

**ADVANCED PLASMA PHYSICS**

**Preq.**

**Phys 4202**

**Objectives**

To give an introduction to certain advanced techniques used in plasma physics.

**Syllabus**

Diffusion and mobility in weakly ionized gases, decay of plasma by diffusion, steady state solutions, recombination, diffusion across a magnetic field, collisions in fully ionized plasmas, the single-fluid MHD equations, diffusion in fully ionized plasmas, solutions of the diffusion equation, Bohm diffusion and neoclassical diffusion. Equilibrium and stability - introduction, hydromagnetic equilibrium, the concept of $\beta$, diffusion of magnetic field into a plasma, classification of instabilities, two-stream instability, the “Gravitational” instability, resistive drift waves, the Weibel instability. Kinetic theory, the meaning of , equations of kinetic theory, derivations of fluid equations, plasma oscillations and Landau damping, a physical derivation of Landau damping, ion Landau damping, kinetic effects in a magnetic field. Nonlinear effects – introduction, sheaths, ion acoustic shock waves, the pondermotive force, parametric instabilities, plasmas echoes, nonlinear Landau damping, equations of nonlinear plasma physics.

**Recommended Books**

Objectives
To enable students understand basis theory of integrable classical dynamical systems and to use mathematical methods in order to analyse such systems.

Syllabus
Hamiltonian formalism, Poisson structure, Hamiltonian systems, Integrability of a Hamiltonian system (Liouville integrability), Dynamical systems of classical mechanics, Harmonic oscillator, Action-angle variables, examples of integrable models solved by Liouville theorem, Kepler two-body problem, rigid body, systems with closed trajectories. Korteweg-de Vries (KdV) equation, KdV equation as a Hamiltonian systems, properties of the KdV solutions, conserved quantities, Miura transformation, Integrability of the KdV equation, higher order equations of hierarchy, involution of conserved quantities, Initial value problem for the KdV equation, Inverse scattering theory in one-dimension, action-angle variables for the kdv equation. 
Lax representation, Lax representation with a spectral parameter, Zakharov-Shabat formulation, zero-curvature method.

Recommended Books

Objectives
To introduce path integral quantization of fields and advanced methods of quantum field theory in particle physics

Syllabus
Path Integral Quantization, Quantum field theory and functional integration, path integral quantization, scalar field theory, Green function, S-matrix, Lehmann-Symanzik-Zimmerman reduction, perturbation theory, Wick’s theorem, Feynman rules for phi^4 theory, spectral representation., Renormalization, regularization, BPH renormalization, renormalization group, Callan-Symanzik equation, asymptotic freedom. Gauge theories, abelian and non-abelian theories, quantization of gauge theories, gauge fixing and Faddeev-Popov quantization, integration over Grassman variables, Berezin rules, Feynman rules for Quantum Chromodynamics (QCD), renormalization of QCD.

Recommended Books

**Phys 5315**  
**SUPERSYMMETRY**  
**(CR3)**

**Preq.**  
**Phys 4305**

**Objectives**  
To acquaint students with the transformation of fermions and bosons and the algebra behind this transformation and its applications in particle physics.

**Syllabus**  
Supersymmetry, symmetries, No-go theorem, Clifford Algebra and spinors, Dirac and Majorana spinors, supersymmetry algebra, superfields, vector superfields, 4D SUSY Lagrangians, Wess-Zummiw Lagrangian, 2D supersymmetry, 2D supersymmetric models, SUSY transformations on fields 2D examples, BPS solitions in d=2, central charges and BPS solutions, Extended supersymmetry, supersymmetry breaking, Grand unification schemes in terms of group theory, supersymmetry in particle and condensed matter physics, minimal supersymmetric standard model (MSSM) and related topics.

**Recommended Books**


**Phys 5113**  
**GENERAL RELATTIVITY**  
**(CR3)**

**Preq.**  
**Phys 4102**

**Objectives**  
To familiarize students with fundamental principles and mathematics of general theory of relativity.

**Syllabus**  
The curved space time of general relativity: testing of equality of gravitational and inertial mass, equivalence principle, geodesics, metric coordinate transformations, Christoffel symbols, geodesics and coordinate transformations. The physics and geometry of geodesics: geodesic equation from variational principle, from Einstein equivalence principle to the principle of general covariance, tensor algebra, the covariant derivative of vector fields, parallel transport and geodesics, generalizations. Physics in a gravitational field: particle mechanics and electrodynamics in a gravitational field, conserved quantities from covariantly conserved currents and tensors. Lie derivatives, symmetries and Killing vectors: symmetries of a metric, the Lie derivative for scalars, vector fields, tensor fields, metric and Killing vectors. Riemann curvature tensor, parallel transport, geodesic derivative equations, Einstein equations, Bianchi identities, cosmological constant, Weyl tensor, Einstein-Hilbert action, the matter Lagrangian and consequence of the variational principle. Tests of general relativity, black holes, relativistic star models, cosmological models, early stages of evolution of the universe, gravitational waves.

**Recommended Books**

**Phys 5514  GROUP THEORY IN PHYSICS (CR3)**

<table>
<thead>
<tr>
<th>Preq.</th>
<th>Phys 3501</th>
</tr>
</thead>
</table>

**Objectives**
To give an introduction to fundamental methods of group theory used in various areas of physics especially particle physics.

**Syllabus**
Elements of group theory; Normal subgroups; Quotient groups; Law of transformations; Homeomorphism and isomorphism; Matrix Lie groups, exponential map, examples SO(3) and SU(2), Lorentz group and Poincare’ group, Lie algebras, reducible and irreducible representations, Direct sums and tensor product, ideals, Killing form Classification of finite-dimensional. Algebras, Cartan subalgebra, Cartan-Weyl basis, Dynkin Ddiagrams, Weights and roots, comple semi-simple Lie algebras. applications in Physics. Matrix representations of generators of SU(2) and SU(3), roots of SU(2) and SU(3), weights of various representations of SU(2) and SU(3); Young’s tableaux and irreducible representations of the permutation group, SU(2) and SU(3); decomposition of the product of irreducible representations; Clebsh-Gordan coefficients; eightfold way; quark model; flavour, spin and colour wave functions of quark antiquark and three quark systems.

**Recommended Books**

**ELECTIVE COURSES**

**SPECIALIZATION-2**

<table>
<thead>
<tr>
<th>Phys 5411</th>
<th>INTRODUCTION TO CONDENSED MATTER PHYSICS (CR3)</th>
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<td>Phys 4405</td>
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**Objectives**
To equip students with understanding basic principles of condensed matter theory and its applications in physics and technology.

**Syllabus**
Crystals: Bloch theorem and band structure methods: Crystal and reciprocal space, Brillouin zone, X-ray diffraction, Independent particles in periodic potential, Bloch’s theorem, nearly free electron and tight binding methods, Periodicity and gap openings. Hartree and Hartree-Fock (HF) theories: The variational approach, HF equations, ionization potential and electron affinity, shortcomings of HF.

**Recommended Books**


**Phys 5612** | **APPLICATIONS OF X-RAY DIFFRACTION METHOD** | (CR3)
---|---|---
Freq. | Phys 3401 |

**Objectives**

To teach students to learn practical aspects of powder and single crystal X-ray diffraction methods, including the determination and refinement of crystal structures.

**Syllabus**

Basics of crystallography: Crystal symmetry, symmetry operations, point groups, plane groups and space group, principles of X-ray diffraction, geometry of X-ray diffractometer, instrumentation, diffraction pattern, structure refinement, least-squares, Debye-Waller factor, Rietveld analysis, the March-Dollase approach, single and powder crystal diffraction methods, single crystal diffractometer, powder diffractometer, limitations of uses, recording powder diffraction pattern, qualitative and quantitative phase analysis, integrated intensities, various factors effecting shape of intensity peaks, crystal structure determination, systematic shift in peak positions, lattice parameter determination for crystal systems, Scherrer method, particle size determination, residual stress measurements through X-ray diffraction, pole figures and rocking curves, limitations of X-ray diffraction technique, Synchrotron radiation, dipole radiation, insertion devices, synchrotron radiation and X-ray fluorescence analysis, metal-semiconductor interface study by X-ray synchrotron radiation, hard and soft X-ray synchrotron radiation, pair distribution function, nuclear resonant scattering, imaging the magnetic spin structure of magnetic layers, X-ray reflectivity at interfaces, synchrotron tomography.

**Recommended Books**

Phys 5711  
**PHYSICS OF SEMICONDUCTOR DEVICES**  (CR3)  
Preq.  
Phys 3402

**Objectives**

To give students an introduction to major developments in semiconductor devices and their application in science and technology.

**Syllabus**

Semiconductor Material and Device Fabrication: Silicon and other semiconductors as device materials; crystal structure, energy bands, statistics, Fermi level, carrier concentration at thermal equilibrium, Hall effect, recombination, basic properties for semiconductor operation. Effect on carrier lifetime and mobility; bulk crystal growth; crystal characterization, epitaxial growth, with molecular beam epitaxy and multi-layer structures, Dopants and Doping techniques with their limits of solubility; Ion implantation and diffusion doping, thermal oxidation, dielectric layer deposition, metallization, wet and dry etching, optical and next-generation lithographic methods, CMOS Process. Devices and Circuits: FET devices and theory; MOSFET; accumulation, depletion and inversion modes, enhancement and depletion modes of operation; n- and p-channel devices; I-V operating relations in active and saturation regions, threshold voltage, Metal-Semiconductor Contacts: equilibrium, idealized metal semiconductor junctions, nonrectifying (ohmic) contacts, Schottky diodes, tunneling. Metal-Oxide-Silicon System: MOS structure, capacitance, oxide and interface charge (charging of traps, tunneling through oxide). NMOS and CMOS inverters.

**Recommended Books**


Phys 5613  
**SPECTROSCOPY**  (CR3)  
Preq.  
Phys 4404

**Objectives**

The objective of this course is to learn working principle and instrumentation of spectroscopy techniques to apply for spectroscopic analysis of variety of materials.

**Syllabus**

Spectroscopic techniques: Nature of excitations, excitation measuring methods, signal measurement process, absorption spectroscopy, fluorescence spectroscopy, X-ray absorption spectroscopy, flame emission spectroscopy, UV/VIS spectroscopy, FTIR spectroscopy, laser spectroscopy, NMR spectroscopy, mass spectroscopy, atomic absorption (AA) spectroscopy, attenuated total reflection (ATR) and Raman spectroscopy. Sample preparation techniques: Sample preparation for spectroscopy analysis, limitations for materials in solid, liquid and thin film form. In addition to the established KBr pellet technique, systematic experimental comparison of different techniques, mutual advantages and
applications, Nondestructive method for determination of molecular conformation, determination of molecular orientation.

**Recommended Books**


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<tr>
<th>Phys 5412</th>
<th>INTRODUCTION TO MAGNETISM AND MAGNETIC MATERIALS</th>
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<td>Phys 4406</td>
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**Objectives**

*To introduce students magnetic materials their properties, processing and applications*

**Syllabus**


**Recommended Books**


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<tr>
<th>Phys 5413</th>
<th>LATTICE DYNAMICS</th>
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**Objectives**
To engage students in understanding dynamics of lattices and its implications in understanding various properties of solids

**Syllabus**


**Recommended Books**


**Phys 5712 OPTOELECTRONICS (CR3)**

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**Objectives**

To introduce students with fundamental concepts of optoelectronics and photonics

**Syllabus**

Photonic devices, Radiative transitions and optical absorption, semiconductors materials for opto electronics, visible LEDs, infrared LEDs, organic LEDs, Semiconductor Laser; Laser materials, Laser operating characteristics, carrier and optical confinement, optical cavity and feedback, distributed feedback Lasers and quantum-well Lasers, Photodectors, potoconductor, phptodiodes, natal-smiconductor, heterojunction, photodiode and phototransistors; photoconductor, quantum efficiency and response speed, Avalanche photodiode.

Solar Cells, Semiconductor and polymer solar cells, solar radiations and ideal conversion efficiency, p-n junction solar cell, amorphous and compound-semiconductor solar cells, interface and then film solar cells, optical concentration to reduce cost, optical fiber sensor, CCD, optical information and processing, optical computing.

**Recommended Books**

Phys 5414  
**OPTICAL PROPERTIES OF SOLIDS**  
(CR3)

**Objectives**

To engage students in understanding optical properties of materials and related applications.

**Syllabus**

Classification of optical processes, optical coefficients, Absorption and Reflection, Complex refractive index and dielectric constant, optical materials, microscopic models, classical propagation of light in optical medium, the classical dipole oscillator model, interband optical transitions, transition probability from time dependent perturbation theory, wavevector conservation and parity selection rules, joint density of states, direct and indirect transitions, excitons, Wannier-Mott excitons – hydrogenic model, Exciton-Polariton, Frenkel excitons, low-dimensional systems, effect of confinement on the joint density of states, quantum well with infinite potential barriers: selection rules and band structure modifications, effect of confinement on excitons, optical response of an electron gas, dipole oscillator model for the free electron gas, AC conductivity, low/high-frequency regime, reflectivity from alkalis, transition metals and doped semiconductors, plasmons, optical studies of phonons, harmonic oscillator model for a linear chain of ions, lattice-response in the low-damping limit: Lyddane-Sachs-Teller relationship and Reststrahlen band, measurement of and examples for lattice reflectivity spectra, phonon-polariton, inelastic light scattering: Raman/Brillouin scattering, experimental details and examples, phonon lifetimes, optics of anisotropic media, electric susceptibility tensor, propagation of electromagnetic waves in an isotropic medium, ordinary and extraordinary rays in uniaxial crystals, refractive index ellipsoid.

**Recommended Books**


Phys 5415  
**SUPERCONDUTIVITY**  
(CR3)

**Objectives**

To provide the student with a working knowledge of superconductivity from an experimental point of view, both with respect to the mathematical understanding and physical application.

**Syllabus**

Discovery, zero resistance and critical temperature, magnetization, perfect diamagnetism, meissner effect, trapped flux, type I and II behaviour, superconducting elements and compounds, cuprate superconductors, structures and preparation, doing phase diagram, superconducting state, pair state, effective wave function, time and space dependence of the phase, Aharonov Bohm effect, London equations, penetration depth, flux quatisation, gauage invariance. Electrodynamics of
superconductors, London's model, flux quantization, Josephson Junctions, superconducting quantum devices, equivalent circuits, high-speed superconducting electronics, and quantized circuits for quantum computing. The course also provides an overview of type II superconductors, critical magnetic fields, pinning, the critical state model, superconducting materials, and microscopic theory of superconductivity, Ginzburg-Landau description of superconductivity, coherence length, the magnetic penetration depth, the distinctions between Type-I and Type-II superconductors, flux quantization, and the Josephson effects, leading to two important superconducting devices, the Josephson junction and the SQUID.

**Recommended Books**


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<tr>
<th>Phys 5811</th>
<th>NANOMATERIALS (SCIENCE, GROWTH AND CHARACTERIZATION)</th>
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**Objectives**

To provide students with knowledge and the basic understanding of nanotechnology and nanomaterials

**Syllabus**


**Recommended Books**

8. *Carbon Materials and Nanotechnology*, by A. Krüge , Publisher Wiley VCH, March (2010.)
Phys 5316  APPLIED NUCLEAR PHYSICS  (CR3)
Preq.  Phys 4304

Objectives
To communicate knowledge of basic techniques which exploit nuclear particles, and to develop an understanding of the underlying physics and applications.

Syllabus
Neutron Physics, the interaction of neutrons with matter in bulk, thermal neutrons, cross-section (measurement of total cross-section), diffusion theory, Fermi age equation. Quantum mechanical calculations of deuteron bound-state wave function and energy; n-p scattering cross section; transition probability per unit time and barrier transmission probability. It also covers binding energy and nuclear stability; interactions of charged particles, neutrons, and gamma rays with matter. Nuclear Energy Sources: Nuclear fission as a source of energy, four factor formula, the chain reacting system, the neutron cycle, critical dimensions of a thermal nuclear reactor, the calculation of the multiplication constant for a homogeneous thermal reactor, the heterogeneous thermal reactor, energy production in stars, thermonuclear reactions, CNO and P-P cycle in detailed, controlled thermonuclear reactions and fusion reactor, age of galaxy. Radioactive Measurement and Tracer Techniques: Energy measurement, coincidence measurements, time resolution, measurement of nuclear life times, trace element analysis, mass spectrometry with accelerators.

Recommended Books

Phys 5713  SPINTRONICS, APPLICATIONS & DEVICES  (CR3)
Preq.  Phys 4406

Objectives
To make students understand basic principles and applications of spintronic devices.

Syllabus
Historical Development: Two spin channel model, Spin Asymmetry, Spin Accumulation, Spin Diffusion Length, Two Terminal Spinelectronics, Spin Tunneling Process, Three Terminal Spinelectronics, Meso Magnetism, Domainwall in Spin Electronics, Hybrid electronics, Spin Transport in semi conductors, Direct Spin Injection, Spin Blockade. Coupling of Electron Spins to Nuclear Spins: Nuclear spin in a strong magnetic field, magnetic interactions and magnetic couplings, coupling mechanisms. Conservation of spin angular momentum, photochemical reaction mechanisms, spin polarization of the triplet state, spinomers, the dynamic radical pair, magnetic effects on chemical reactions, the magnetic isotope effect on radical pair reactions, electron spin, electron intrinsic angular momentum, electron spin magnetic moment, nano magnetic arrays.

Recommended Books

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<th>Phys 5317</th>
<th>QUANTUM COMPUTING &amp; INFORMATION</th>
<th>(CR3)</th>
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**Objectives**

To introduce students to the basics of the quantum model of computation and information theory.

**Syllabus**

Computer technology and historical background, Basic principles and postulates of quantum mechanics: Quantum states, evolution, quantum measurement, superposition, quantization from bits to qubits, operator function, density matrix, Schrodinger equation, Schmidt decomposition, EPR and Bell’s inequality, Quantum Computation: Quantum Circuits, Single qubit operation, Controlled operations, Measurement, Universal quantum gates, Single qubit and CNOT gates, Breaking unbreakable codes: Code making, Trapdoor function, One time pad, RSA cryptography, Code breaking on classical and quantum computers, Schor’s algorithm, Quantum Cryptography: Uncertainty principle, Polarization and Spin basis, BB84, BB90, and Ekert protocols, Quantum cryptography with and without eavesdropping, Experimental realization, Quantum Search Algorithm.

**Recommended Books**


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<tr>
<th>Phys 5812</th>
<th>PHYSICS OF-surfaces AND INTERFACES</th>
<th>(CR3)</th>
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**Objectives**

Surfaces and interfaces play an important role in defining the material’s properties in thin film form. The objective of this course is to understand the phenomenon, thermodynamics and physics of fundamental processes occurring at surfaces and interfaces.

**Syllabus**

electron, Auger electron data acquisition and analysis, chemical shifts in Auger spectra, contamination effects on Auger emission, application of Auger electron spectroscopy. X-ray photoelectron spectroscopy: Basic principles and theory, Photo-ionization cross-section, line-shapes and fine structure, chemical shifts inelastic scattering and sampling depth, instrumentation, X-ray sources, electron energy analyzers, data recording and processing, applications of XPS.

**Recommended Books**