SCHEME OF STUDIES

M. Phil/MS and PhD Physics

2018 and Onward

Department of Physics

University of Science and Technology Bannu

Khyber Pakhtunkhwa, Pakistan

SCHEME OF STUDIES

For

M. Phil/MS Physics (Two years/ Four semesters)

Course Work (1st and 2nd semester) = 24 Credit hours

Research Thesis (3rd and 4th semester) = 6 Credit hours

Total = 30 Credit hours

&

Ph.D. Physics (Three years/ Six semesters)

Course Work (1st and 2nd semester) = 18 Credit hours

Research Thesis (Onward semesters) = 9 Credit hours

Total = 27 Credit hours

Semester Wise Layout of the Courses

M.Phil/ MS Physics

1st Year			
Semester 1			12 Credit Hours
(One course must be taken from the list of optional courses)			
S. No.	**Course Code**	**Title of the Course**	**Credit hours**
1		Compulsory course I	3
2		Compulsory course II	3
3		Compulsory course III	3
4		Optional I	3
		Total credit hours	**12**

1st Year			
Semester 2			12 Credit Hours
(Three courses must be taken from the list of optional courses)			
S. No.	**Course Code**	**Title of the Course**	**Credit hours**
1		Compulsory course IV	3
2		Compulsory course V	3
3		Optional-II	3
4		Optional-III	3
		Total credit hours	**12**

Compulsory Courses			
S. No.	**Course Code**	**Title of the Course**	**Credit hours**
1	PHY601	Advanced Quantum Mechanics	3
2	PHY602	Electrodynamics	3
3	PHY603	Advanced Statistical Physics	3
4	PHY604	Advanced Classical Mechanics	3
5	PHY605	Mathematical Method of Physics	3

Ph.D Physics

1st Year		
Semester 1		**9 Credit Hours**
(Three courses must be taken from the list of optional courses)		
S. No.	**Title of the Course**	**Credit hours**
1	Optional I	3
2	Optional II	3
3	Optional III	3
	Total credit hours	**9**

1st Year		
Semester 2		**9 Credit Hours**
(Three courses must be taken from the list of optional courses)		
S. No.	**Title of the Course**	**Credit hours**
1	Optional IV	3
2	Optional V	3
3	Optional VI	3
	Total credit hours	**9**

Optional Courses				
S.No.	**Course Code**	**Title of the Course**	**Credit hours**	**Pre-requisite**
1	PHY621	Particle Physics I	3	
2	PHY622	Particle Physics II	3	Particle Physics I
3	PHY628	Advance Nuclear Physics	3	
4	PHY631	Quantum Field Theory I	3	
5	PHY632	Quantum Field Theory II	3	Quantum Field Theory I
6	PHY641	Heavy Ion Physics	3	
7	PHY642	Particle Collisions	3	Particle Physics I
8	PHY645	Data Analysis and Computational Methods	3	
9	PHY651	Advance Solid State Physics	3	
10	PHY652	Semiconductor Physics	3	
11	PHY654	Defects in Solids	3	
12	PHY655	Material Science	3	
13	PHY656	Experimental Techniques	3	
14	PHY657	Advance Computational Physics	3	
15	PHY703	Advance Statistical Mechanics	3	
16	PHY726	Neutrino Physics	3	Particle Physics I
17	PHY733	Finite Temperature and Density Field Theory in High Energy Physics	3	Quantum Field Theory I

18	PHY734	Quantum Chromo-Dynamics (QCD)	3	Quantum Field Theory I
19	PHY743	Quark Gluon Plasma (QGP)	3	Particle Physics I
20	PHY744	Kinematics of Nuclear Reactions at High Energies	3	Particle Physics I or Heavy Ion Physics
21	PHY753	Advance Condensed Matter Physics and Thin Films	3	
22	PHY 754	Advanced Materials	3	Material Science or Solid State Physics
23	PHY 658	Physics of Nuclear Medicine	3	
24	PHY 659	The Physics of Radiotherapy	3	
25	PHY 660	Radiation Protection	3	
26	PHY-755	Thermodynamics of Materials	3	

DETAILS OF COURSES

PHY 601

ADVANCED QUANTUM MECHANICS

1. **Review of Basic Concepts**

Eigen value equation, Hermitian operators and its properties, Schrodinger equation, Uncertainty principle, Commutation relations, Derivative of observable, Parity transformations

2. **Time Independent Perturbation Theory**

First order energy shift, Second order perturbation theory, Degenerate Perturbation theory, The Stark effect, Absence of linear shift for ground state, Electric dipole moments, Second order shift, Linear stark effect for n = 2 levels of hydrogen atom, Zeeman effect

3. **Hydrogen Atom**

Angular Momentum, Eigen function and Eigen values of L^2 and L_z, Matrix representation of Angular Momentum, Operators, Spin, Spin states of n spin ½ particles, Spherically symmetric system, separation of variables, The radial equation, Hydrogenic Eigen functions and Eigen energies, Matrix Elements of r^n and r^{-n} in the Hydrogen States, Degeneracy and electronic configuration of elements

4. **The Real Hydrogen Atom**

Relativistic mass correction, Spin-orbit coupling, Anomalous Zeeman effect, Hyperfine interaction

5. **The Helium Atom**

First approximation, First order shift due to e-e- repulsion, The first excited state, Exchange energy, The Ritz variational principle

6. **The Radiation of Atoms**

The electromagnetic interaction, Semi-classical description, The time-dependent perturbation theory, The Fermi Golden Rule, Matrix elements calculation, Selection rules, The 2p-1s transition rate, The effect of spin

Recommended Books

1. Quantum Mechanics by Griffith
2. Quantum Mechanics by Gasirowics
3. Reference Books on the subject available in the Seminar Library

PHY602

ELECTRODYNAMICS

Fundamental Concepts, Laplace Equation, Images Techniques and Applications, Maxwell's equations, Gauge Transformations, Continuity equation and conservation laws, Plane electromagnetic waves in a conducting and non-conducting media, Polarization in a dispersive medium, Reflection and refraction, Total Internal reflection, Radiation from a localized oscillating sources, Oscillating electric dipole, magnetic dipole and electric quadrupole fields, Covariance of electrodynamics, Lorentz transformations of electromagnetic fields, Covariance of the force equations and the conservation laws

Recommended Books

1. J. D. Jackson "Classical Electrodynamics" (John Wiley 1975).
2. D. Griffith "An Introduction to Dynamics" (Prentice Hall) 1984.

PHY-603

ADVANCED STATISITICAL MECHANICS

Review of the laws of thermodynamics, First second and third law of thermodynamics and their applications, The kinetic theory of gases, binary collisions, Boltzmann transport equation, transport phenomenon, the mean free path, the conservation laws, the zero order approximation, the first Statistical mechanics, the postulates of classical statistical mechanics, micro canonical ensemble, equipartition theorem, classical ideal gas, Gibbs paradox, canonical ensemble, energy fluctuation in the canonical ensemble grand canonical ensemble, equivalence of the canonical ensemble and the grand canonical ensemble, the meaning of the Maxwell construction, Quantum Statistical mechanics, quantum model of matter, the canonical distribution in quantum statistics, the quantum oscillator, Planks formula for the equilibrium radiation of a perfectly black body, Heat capacity of solids, heat capacity of a diatomic ideal gas, Quantum statistic s of a system lf a similar particles, Bose-Einstein and Fermi-Dirac statistics, Application of Bose-Einstein statistics to the, photon gas, application of Fermi-Dirac statistics to the electron gas in metal, Condensation of an ideal Bose-Einstein gas.

Recommended Books:

1. Statistical Mechanics,Kerson Huang, John Wiley and Sons, New York 1963.
2. Statistical Physics, Y. P. Terletslii, NorthHolland PublishingCo, 1971.
3. Classical Mechanics,Vol 1 &Vol 2, E.A. Desloge, John Wiley, New York 1982.
4. Introduction to Classical Mechanics,A.P. Arya Massachusetts 1990.
5. Classical Mechanics, T.L. Chow John Wiley, New York 1995. Page 9 of 25
6. Introduction to Classical and Quantum Harmonic Oscillators, S.C. Bloch John Wiley and Sons, Inc. 1997.
7. Statistical Physics. Volume5, Landau L. D and Lifshits E. M., 1980, Pergamon Press Ltd. NewYork.

PHY-604

ADVANCED CLASSICAL MECHANICS

Survey of the elementary particles, Variational principles and Lagrange's equations, Oscillations, The classical mechanics of the special theory of relativity, Hamiltonian equations of motion, canonical transformations, Hamilton Jacobi theory and action angle variable, Classical Chaos, Canonical formulations for continuous systems and field, classical mechanics of liquids and deformable solids, stress, deformation and strain flow.

Recommended Books;

1. Classical Mechanics (3rd Edition) by Herbert Goldstein, Charles P. Poole Jr., and John L.Safko, Pearson International Edition, 2001.

PHY-605

MATHEMATICAL METHOD OF PHYSICS I

Introduction to the course & Vector algebra, multiple vector products, Vector derivatives, Vector integrations, Gauss's and Stokes theorems and generalizations & potentials, Gauss's law, Poisson's equation, the Dirac delta function & Helmholtz theorem, Orthogonal coordinates and derivatives therein, Cylindrical and spherical coordinates, Tensor analysis & algebra, General tensors, Matrices, determinant and matrix algebra, Diagonalization of matrices & eigen system of a matrix, Introduction to group theory, Orbital angular momenta, The Lorentz group, discrete groups, Differential forms in physics, Infinite series, their convergence, algebra of series, Function series, elliptic integrals, Bernuolli numbers , Divergent series, Infinite products, Complex numbers, regular functions and their integrals, Cauchy's Integral, the Laurent series and singularities, Complex mappings, Residues & applications, The Gamma-Function and derivatives, Approximations and generalizations.

Recommended Books

1. Mathematical Methods for Physics, George Arfken Academics Press New York 1995.
2. Advanced Engineering Mathematics, ErwingKreyszig John Wiley & Sons New York 1993.
3. Applied Analytical Mathematics for Physical Scientists, James T. Cushing John Wiley 1978.
4. Methods of Mathematical Physics 2 Vol, Courant, R and D Hilbert, Wiley Inter-Science, New York, 1989.
5. Partial Differetial Equations, Epstein B and MalaberMcgraw Hill 1983.
6. Calculus and Analytic Geometry, G.B and R.L. Finney Addison Wesley, 1992.
7. Mathematical Physics, H. K. Dass, & Dr. Rama Verma, S. Chand & Company limited.

PHY621

PARTICLE PHYSICS I

The course aims to introduce the basic concepts about fundamental particles and their interactions. The basic properties of the particles and symmetries involved are to be studied through underlying mathematical and group theoretical concepts in order to classify them.

Basics of group theory: Group algebra, physical examples of groups, symmetries and conserved quantities.

The groups SU (N) and SO (N): infinitesimal transformations, characters, Clebsch Gordon series and coefficients, Wigner Eckart Theorem. Representations of the Lie algebras of SU(2), adjoint representations, SU(N) flavor, symmetry schemes for elementary particles, Gell Mann Nishijima formula. Tensor representations and Young tableaux, SU (3) and its Lie algebra, SU(N) Lie groups.

Introduction to Particles: Quarks and their bound states, leptons and the gauge bosons, need for baryon number and isospin, static quark model.

Symmetries and Interactions: Symmetries at classical and quantum level, Parity, Charge conjugation, CP-violation, Continuous symmetries, deep inelastic scattering and discovery of parton quarks.

Recommended Books:

i. Introduction to High Energy Physics by D. Perkins, (Addison-Wesley, 2000).

ii. Particle Physics by B. R. Martin and G. Shaw, (Wiley, 1997).

iii. Modern Elementary Particle Physics by G. Kane, (Addison-Wesley, 1993).

iv. Quarks and Leptons by F. Halzen and A. D. Martin, (Wiley, 1994).

v. Six easy pieces, six not so easy pieces by R. Feynman, (Perseus Press, 2001).

vi. Groups, Representations and Physics by H. F. Jones, (Taylor and Francis, 1998).

vii. Group Theory and its Applications to Physical Problems by Morton Hammermesh, (Dover Publications, 1989).

viii. Introduction to Group Theory in Physics by J. F. Cornwell, (Academic Press, 1997).

PHY622

PARTICLE PHYSICS II

The course aims to study the interactions of fundamental particles. The forces involved in particle interactions are to be dealt with in detail. Thoroughly well tested theory of Salam Weinberg and Glashow on the basis of gauge symmetries and their breaking is to be well understood. The experimental tests of the basic interactions and the discoveries of particles will also be discussed.

These aspects will be a focus of studies in experimental studies such as LHC (Large Hadron Collider) at CERN.

Propagation of Particles, Interactions, Decay and Scattering. Lamb shift, anomalous magnetic moment of the electron, Lande' g-factor, fine structure. Fermi theory and its non renormalizability, IVB theory, Symmetry Breaking, Massive Gauge Fields, Weinberg Salam electroweak theory for leptons and gauge bosons

Weinberg Salam Glashow electroweak theory, electromagnetic and weak interactions of quarks, hadronic decays of Z and W bosons, experimental tests of the theory.

Particle accelerators and detectors: First discoveries, Detection of particles, Cosmic rays and discoveries of particles, Acceleration of particles; Quarks, Heavy leptons (charged and neutral) and quarks, Discoveries of the gauge bosons.

The structure and representations of semi simple Lie algebras, Cartan subalgebra, roots and root vectors, Dynkin diagrams, Lorentz group, Poincare group and their algebra.

Recommended Books:

i. Particle Physics by B. R. Martin and G. Shaw, (Wiley, 1997).

ii. Modern Elementary Particle Physics by G. Kane, (Addison-Wesley, 1993).

iii. Quarks and Leptons by F. Halzen and A. D. Martin, (Wiley, 1994).

iv. An Introduction to the Standard Model of Particle Physics by W. N. Cottingham and D. A. Greenwood, (Cambridge University Press, 2005).

v. An Introduction to Quarks and Partons by F. Close, (Academic Press, New York, 1979).

vi. Gauge Theory of Elementary Particle Physics by T. P. Cheng and L. F. Li, (Oxford, Clarendon Press, 1984).

vii. Dynamics of the Standard Model by John F. Donoghue, Eugene Golowich, and Barry R. Holstein, (Cambridge University Press, 1984).

viii. Groups, Representations and Physics by H. F. Jones, (Taylor and Francis, 1998).

PHY628

ADVANCE NUCLEAR PHYSICS

General Properties of Nuclei (mass, size, spin etc.,), sizes of proton and neutron, Nuclear Forces, Nuclear Models (Fermi Gas, Liquid Drop, Shell, Collective), Theories of Alpha, Beta and Gamma Decay, Nuclear Reactions and kinematics, Cross sections: Classical and Quantum Mechanical derivation, Nuclear and Nucleon Form Factors, Nuclear Fission and its Mechanism, Bohr and Wheeler theory of Nuclear Fission, Chain fission reaction, Nuclear reactor, Reproduction of nuclear fuel, Nuclear Fusion and thermonuclear explosion, Evolution of the Universe, Nucleosynthesis before formation of stars, Elementary Particles, Cosmic Rays, Some Famous Experiments (Past, Current and Future).

Recommended Books:

i. Introductory Nuclear Physics by Kenneth S. Krane, (John Wiley and Sons, 1988).

ii. An Introduction to Nuclear Physics by W. N. Cottingham and D. A. Greenwood, (Cambridge University Press, 2004).

iii. Nuclei and Particles by E. Segre, (W. A. Benjamin, 1977).

iv. Subatomic Physics: Nuclei and Particles (Vol. 1 and 2) by L. Valentin, (Hermann, North-Holland, 1981).

v. Concepts of Nuclear Physics by B. L. Cohen, (McGraw-Hill, New York, 1971).

vi. Fundamentals of Physics by N. A. Jelley, (Cambridge University Press, 1990).

PHY631

QUANTUM FIELD THEORY I

The course will cover the basic concepts involved in quantum field theory with emphasis on free field theory. Specific focus will be on dealing with particle phenomena at high energies. The concepts of interacting field theory will also be introduced. It will provide basic knowledge of the subject to students aiming to go for research in theoretical and experimental physics.

Preliminaries and revision: Motivation for QFT, Special relativity, causality, light cone, space-like, time-like and light-like separations, classical fields, Schrödinger-, Heisenberg- and Interaction-pictures, quantum oscillators; creation and annihilation operators.

Quantized Fields-free field theory: Bosons-, fermions-, photons- and (massive) vector-field- quantization, Noether's theorem, symmetries and conservation laws, free particle propagators and **Green's functions**: Boson and fermions propagators and causality.

Interacting field theory: S-matrix in interaction picture, perturbation theory, time-ordered expansion of S-matrix elements, Wick's theorem, Feynman graphs, Fourier transform of Feynman amplitudes, momentum space Feynman rules, quantum electrodynamics (QED), Calculation of Feynman amplitudes in Born approximation in QED, Application to: calculation of scattering cross-section for: lepton-lepton scattering, Compton scattering, Coulomb scattering.

Discrete Symmetries: P, T, C and their combined operation;

Renormalization: higher order (in fine structure constant) radiative corrections, self-energy, vertex function, electromagnetic form factors, vacuum polarization in QED, elements of renormalization theory, regularization techniques,

Recommended Books:

i. Quantum Field Theory by F. Mandl and G. Shaw, (Wiley, 1994).

ii. Quantum Field Theory: A Modern Primer by P. Ramond, (Addison Wesley, 1993).

iii. Quantum Field Theory by Lewis H. Ryder, (Cambridge University Press, 1996).

iv. An Introduction to Quantum Field Theory by Michael E. Peskin and Daniel V. Schroeder, (Harper Collins Publishers, 1995).

v. Quarks and Leptons by F. Halzen and A. D. Martin, (Wiley, 1994).

vi. The Quantum Theory of Fields (Volume 1) by Steven Weinberg, (Cambridge University Press, 1995).

PHY632

QUANTUM FIELD THEORY II

The students, after this advanced course on the subject, should be able to calculate any process in lowest order of perturbation theory for both QED (Quantum Electrodynamics) and the standard electro-weak theory. This would enable them to calculate the radiative corrections in QED using the powerful technique of dimensional regularization. A basic knowledge of QCD (Quantum Chromodynamics) as a theory of interactions of quarks and gluons will also be imparted in the course.

Systematics of renormalization theory; use of functional derivative and dimensional regularization methods, higher loop effects in QED, scalar particles interactions and functional methods.

Renormalization and symmetries, renormalization group, evolution of coupling constants, Wilson's approach, Callan-Symanzik equation, application to QED and scalar interactions, Critical exponents.

Non-Abelian gauge theories and their one loop divergences, running coupling constant for strong interactions, asymptotic freedom, gluon and jets, deep inelastic scattering, perturbation theory anomalies, anomalies cancellation, gauge theories with spontaneous symmetry breaking, perturbative and non-perturbative QCD.

Recommended Books:

i. Quantum Field Theory by F. Mandl and G. Shaw, (Wiley, 1994).

ii. Quantum Field Theory: A Modern Primer by P. Ramond, (Addison Wesley, 1993).

iii. Quantum Field Theory by Lewis H. Ryder, (Cambridge University Press, 1996).

iv. An Introduction to Quantum Field Theory by Michael E. Peskin and Daniel V. Schroeder, (Harper Collins Publishers, 1995).

v. Quarks and Leptons by F. Halzen and A. D. Martin, (Wiley, 1994).

vi. The Quantum Theory of Fields (Volume 1) by Steven Weinberg, (Cambridge University Press, 1995).

vii. The Quantum Theory of Fields, Volume 2: Modern Applications by Steven Weinberg, (Cambridge University Press, 2005).

PHY641

HEAVY ION PHYSICS

Heavy Ion Physics at relativistic and ultra-relativistic energies are of enormous renewed interest due to the latest studies involving collision of heavy nuclei at RHIC and CERN. The recent experimental setups of accelerators and detectors aim to study in detail the underlying physics. The theoretical concepts involved in such studies will be extensively covered in this course.

Motivation for study of heavy-ion collisions at high energies: the study of QCD at high temperature and/or high baryon-chemical potential. QCD phase diagram, different predicted phases (hadronic matter, quark-gluon plasma, color superconductor) and possible phase transitions between them (order of the phase transition, deconfinement transition, chiral symmetry restoration).

Some simple estimates of the conditions for the phase transition to deconfined phase.

Experimental signatures for the phase transition: collective flow, particle correlations, critical fluctuations, strangeness and charm enhancement, J/psi and Upsilon suppression, change of resonance parameters and other exotic phenomena.

Recommended Books and Literature:

i. Nuclear Reactions with Heavy Ion Physics by R. Bass, (Springer, 2010).

ii. Treatise on Heavy Ion Science, Ed. D. A. Bromley, (Springer, 1985).

iii. Heavy Ion Collisions, Ed. R. Bock, (North Holland, Amsterdam, 1980).

i. Ultra relativistic Heavy-Ion Collisions by Ramona Vogt, (Elsevier, 2007).

ii. Relativistic Heavy-Ion Collisions: "Re-creating the Early Universe in the Laboratory", B. Muller (Duke U.) in Proceedings of "Workshop on pre-equilibrium Parton Dynamics", Berkeley 1993, p 1 - 39.

iii. Microscopic Models for Ultra relativistic Heavy Ion Collisions, S. A. Bass et al., Prog. Part. Nucl. Phys. 41, 1998 p 225 - 370.

iv. Proceedings of Quark Matter '97: Nucl. Phys. A 638, 1998 1 - 2.

v. J/psi; Production and Suppression; R. Vogt, Phys. Rep. 310, 1999, p 197 - 260.

PHY642

PARTICLE COLLISIONS

The aim of the course is to study the relativistic and ultra-relativistic processes as seen from the point of view of an experimentalist. This is to teach students doing research in the field to gain a detailed insight in the diagnostics and detection of new phenomena involving various experimental parameters.

Overview of relativistic quantum mechanics, Phase space model of particle production; Collisions of particles in accelerators.

QGP in Relativistic Heavy Ion Collisions; Fluid Dynamics and flow; Electromagnetic signals; Relativistic hydrodynamics for heavy ion collisions; Transport theory for pre-equilibrium process; Formation and evolution of QGP.

Fundamentals of QGP diagnostics; Results from CERN experiments and BNL; Density Interferometry; Chiral condensates.

Special experimental setups erected until now and foreseen in future, SPS and LHC (CERN), AGS and RHIC (BNL), SIS (GSI), Nuclotron (JINR).

Major Physics details in; Design; Main Detectors; Data Processes; and getting results pertaining to specific experimental setups in CERN, BNL and JINR.

Recommended Books/References:

i. Ultrarelativistic Heavy-Ion Collisions by Romana Vogt, (Elsevier, 2007).

ii. Introduction to High Energy Heavy-Ion Collisions by Cheuk-Yin Wong, (World Scientific, 2007).

iii. Quark-Gluon Plasma: From Big Bang to Little Bang by Kohsuke Yagi, Tetsuo Hatsuda, and Yasuo Miake, (Cambridge University Press, 2008).

iv. *European Organisation for Nuclear Research (CERN, Switzerland),* Programmes, http://greybook.cern.ch/

v. Brookhaven National Lab (BNL, USA) Experiments by Number and Name, http://www.phy.bnl.gov/newphysics/experiments.html

vi. GSI, Darmstadt, Germany, http://www-aix.gsi.de/

vii. Nuclotron (JINR, Russia), http://nucloserv.jinr.ru/index-e.htm

viii. Current research papers.

PHY645

DATA ANALYSIS AND COMPUTATIONAL METHODS

Data Analysis

Errors of observation: accidental and systematic errors, Errors and fractional errors, estimate of error in compound quantities, error in product, in quotient, in a sum or difference; frequency distributions and related terminology, method of least squares, weighted mean and its standard error, curve fitting; and accuracy of coefficients, Graph plotting and analysis.

Computational Methods

Fritiof Model, Dubna Cascade Model, QGSM, Hijing, Fortran, Ubuntu, Origin, Paw, Mathlab, Mathematica.

Recommended Book:

i. Error of observation and their treatment by J. Topping, (John Wiley and Sons, 1977).
ii. Research Papers and concerned Literature.

PHY651

ADVANCE SOLID STATE PHYSICS

Periodic array of atoms; Lattice translational vectors, Basis and the crystal structure, Primitive lattice cell, Two dimensional lattice types, Three dimensional lattice types, Planes and directions, Simple crystal structures; Sodium chloride structure, Cesium chloride structure, Hexagonal closed packed structure, Diamond structure, Cubic zinc sulfide structure, Perovskite structure, Symmetry and symmetry elements, Diffraction of waves by crystal; X-ray diffractions, Bragg law, Laue equations, Ewald construction, Reciprocal lattice; Reciprocal lattice to sc, bcc, and fcc lattices, Bonding, Electronegativity, Types of Bonds, Forces Between Atoms: Mechanism of Bond Formation and Bond Energy, Properties of Solid Materials, Periodic Table and Chemical Bonding; Approximations; Born Oppenheimer approximation, Adiabatic approximation, Harmonic approximation, Normal modes, Bose Einstein distribution function, Linear monatomic lattice, First brillouin zone, Group velocity, long wavelength limit, Linear diatomic lattice, Acoustical and Optical phonons, 2-D square lattice, Density of states, Debye and Einstein model, Specific heat at high and low temperature, Phonon-phonon interactions, Electron-phonon interactions; The Bloch theorem, The Kronig-Penny model, Construction of Brilliouin Zones, Symmetry, properties of the energy Function, extended, reduced and periodic zone schemes, Effective mass of an electron, Hartree Approximation, Free and nearly free electron model, the Tight binding model, Conductors semiconductors and insulators, Augmented plane wave method, Orthogonalized plane wave (OPW) method, the pseudopotentail method

Recommended Books

1. C. Kittle, “Introduction to Solid State Physics” 7th edition 1996, (John-Wiley).
2. C. Kittle, “Quantum theory of Solids” (John-Wiley and Sons).
3. H. Craft, “The Elements of Solid State Physics”
4. S. O. Pillai, “Solid State Physics” (6th Edition, New Age International).

PHY652

SEMICONDUCTOR PHYSICS

Introduction/Elementary Properties of Semiconductors; Crystal Structure, Atomic Bonding, Intrinsic and Extrinsic Semiconductors, Energy Bands, Density of States, Nearly Free Electron Model, Kronig-Penny Model, Energy Bands for Intrinsic and Extrinsic Semiconductors. Semiconductor Statistics: Fermi-Dirac Statistics, Carrier Concentrations in Thermal Equilibrium in Intrinsic Semiconductors and Semiconductors with Impurity Levels. Transport Phenomena: Constant Relaxation Time, Electrical conductivity, the Hall Effect, Transverse Magnetoresistance, Scattering Mechanisms The Boltzmann Equation: The Boltzmann Transport Equation, Conductivity and Magnetoconductivity in Parabolic and Ellipsoidal Bands, Thermoelectric and Thermomagnetic Effects, Quantum Transport Excess Carriers in Semiconductors: Diffusion processes, Diffusion and Drift of Carriers, The Continuity Equation, Direct and Indirect Recombination of Electrons and Holes, Steady State Carrier Injection, Optical Absorption, Interband Transitions, Photoconductivity, Luminescence. Metal- Semiconductor Contacts and PN-Junction Theory: Ohmic, Blocking and Neutral Metal-Semiconductor Contacts, PN-Junction under Equilibrium Conditions, Forward and Reverse-Biased Junctions, Reverse-Bias Breakdown, Deviations from the Simple Theory

Recommended Books

1. Ben G. Streetman and Sanjay Banarjee, “Solid State Electronic Devices” Printice Hall (5th edition).
2. C. Kittle, “Introduction to Solid State Physics” 7th edition 1996, (John-Wiley).
3. S. O. Pillai, “Solid State Physics” (6th Edition, New Age International).

PHY654

DEFECTS IN SOLIDS

Introduction, types of defects, Concentration of point imperfection; review of some thermodynamics, first law of thermodynamics, 2nd law of thermodynamics; vacancies, stoichiometric and non stoichiometric defects, extrinsic defects, interstitial and substitutional point defects; Line imperfection, Dislocation, Dislocation motion, Burger vector and Burger circuit, Slip planes and slip directions, Perfect and Imperfect dislocation, Dislocation multiplication, Dislocation densities, energy of dislocation, stress field around dislocation, importance of line imperfection; Planer defects, grain boundaries, Twin boundaries, tilt boundaries, twist boundaries, voids; Color centers; F centers, other centers in alkali halides.

Diffusion, Types of Diffusion, Diffusion Mechanisms, Diffusion Coefficient: Flick's Laws of Diffusion, Dependence of Diffusion Coefficient on Temperature, Factors Affecting Diffusion Coefficient (*D*), Self Diffusion, Inter-Diffusion , Experimental determination of *D* using a Diffusion Couple, Diffusion with Constant Concentration (Case Hardening), The Kirkendall Effect, Diffusion in oxides and ionic Crystals, Surface Diffusion, Activation Energy of Diffusion, Industrial applications of Diffusion processes

Recommended Books

1. Material Science by Smith
2. Material Science by S. L. Kakani and Amit Kakani
3. Electronic Material Science by Eugene. A. Irene

PHY655

MATERIALS SCIENCE

Crystallography, translational periodicity, Crystal Classes, Crystal forms, point and space Group, Structure factor; Structure factor of the bcc and fcc lattice, Stereographic projection and its Applications, Phase Diagrams, Construction of a Phase Diagram, Binary and Ternary phase Diagrams, Applications of Phase Diagrams, Mechanical properties of Metals' Elastic and Plastic deformation, Deformation by Twinning, Comparison between Slip and Twinning, Plastic Deformation of Polycrystalline Materials, Work Hardening or Strain Hardening, Anelasticity, Fracture, Creep and fatigue phenomena, Strengthening mechanism, Annealing, Effect of Imperfections on the Mechanical properties of the materials, Dielectrics, Classifications of Dielectrics, Polarization and its mechanism, Dielectric properties; Electrical Properties of Dielectrics; Ferroelectricity and anti-ferroelectricity, ferrielectricity, Piezoelectricity, and pyroelectricity

Recommended Books

1. Material Science by S. L. Kakani and Amit Kakani
2. Material Science an Intermediate text by William E. Hosford
3. Material Science by Smith
4. Elecreoceramics, Materials Properties, Applications by A. J. Moulson and J. M. Herbert

PHY656

EXPERIMENTAL TECHNIQUES

Crystal structure and phase analysis; X-rays sources, X-ray detectors, X-ray scattering by matters, Principles of X-ray diffraction, Bragg's law, structure factor, sample preparation for X-ray diffraction, data collection, Phase analysis, Structure and unit cell determination and refinement, indexing of the X-ray diffraction pattern; Microstructural analysis, Limitations of the Human Eye, the Light-Optical Microscope, the Transmission Electron Microscope, Scanning Electron Microscope, Chemical analysis in the electron image, Specimen preparation for SEM and TEM, Electron diffraction and its indexing; Electrical properties in solids; Dielectric properties; Dielectric constant, loss tangent or the inverse Quality factor, temperature coefficient of resonant frequency, permeability, Network analyzer, impedance analyzer, LCR meter, Fixture, Software. Measurement of the microwave dielectric properties, Hakki and Coleman (Courtney method), TE01δ mode dielectric resonator method, Stripline excited by cavity method, Whispering gallery mode resonator method, split post dielectric resonator method, cavity perturbation method, Ferroelectric properties, Polarization hysteresis loop and its mechanism, Sawyer tower circuit, Sample dimension for ferroelectric measurements, Piezoelectric properties; direct and converse piezoelectric constant, Measurement of direct piezoelectric constant by d_{33} meter, poling of the sample, Construction of linear variable differential transducer for strain measurement

Recommended Books

1. Crystals and Crystal Structure by Richard Tilley
2. Electron Microscopy and Ananlysis by Peter J. Goodhew, John Humphreys and richatd Beanland
3. Dielectric materials for wireless communication by Mailadil T. Sebastian
4. Elecreoceramics, Materials Properties, Applications by A. J. Moulson and J. M. Herbert

PHY 657

Advance Computational Physics

Resume of Practical approach of learning operating systems (Linix, Ubuntu, Windows) and Graphical packages (Origin, Paw, Plot Digitizer) Latex. Fortran Programming using Fortran 77, 90.

Mathematica: Running mathematica, Numerical calculations, Graphics, 3D plots. Equation solving, matrices, mathematical relations, complex numbers, simplifications, algebraic expressions, Mathematical operations, in built functions, differentiation, integration, series, limits, Advanced Mathematics: Procedural programming, loops conditional programming, producing output, linking external programme, functional programming, numerical operation on data, statistical calculations, minimization. Derivatives of unknown functions.

Matrices: products of matrices, inversion using iterative methods and accuracy,
Numerical Linear Algebra: Solution of systems of linear equations, direct methods, error analysis, Curve Fitting: least squares fitting method etc., iterative methods. Numerical differentiation and integration methods: Numerical methods for derivatives, minima and maxima of a function, numerical integration methods for one dimension to multi-dimensional integrations using Simpson's rule, quadrature formula and Monte Carlo methods. Interpolation: splines, Numerical methods for Ordinary and partial

Differential equations: Euler's method, Runge- Kutta method for ordinary differential equations: stability and convergence. Partial differential equations using matrix method for difference equation, relaxation method, initial value problems, stability, convergence and qualitative properties and qualitative properties. Random numbers, Monte Carlo Integral methods, Importance sampling, Fast Fourier Transform.

Physical Simulations: N body methods and particle simulations, Molecular dynamics and Monte Carlo methods.

Books Recommended:

1. Numerical Methods: A Computer Oriented Approach, BPB Publ. 1996 R.S.
Salaria

2. Fortran Programming – V. Rajaraman

3. Computer based Numerical Methods 3rd Ed. Prentice Hall India 1980, V.
Rajaraman

4. The C++ Programming Language/Addison Wesely
5. Mathematica, S. Wolfram, Addison. Wesely
6. Application of the Monte Carlo Method, K. Binder, Springer Veriag
7. Numerical Recipes in Fortran: The Art of Scientific Computing, W.H. Press et al., Cambridge Press.
8. Numerical Recipes in Fortran: the Art of Scientific Computing, W.H. Press et. al, Cambridge Press
9. An Introduction to Computer Simulation Methods, H.Gould and J. Toobochnlik, Addison Wesley, 1996.
10. Computational Physics by S.E. Koonin

PHY703

ADVANCE STATISTICAL MECHANICS

Review of the laws of thermodynamics, First second and third law of thermodynamics and their applications, The kinetic theory of gases, binary collisions, Boltzmann transport equation, transport phenomenon, the mean free path, the conservation laws, the zero order approximation, the first Statistical mechanics, the postulates of classical statistical mechanics, microcanonical ensemble,equipartition theorem, classical ideal gas, Gibbs paradox, canonical ensemble, energy fluctuation in the canonical ensemble grand canonical ensemble, equivalence of the canonical ensemble and the grand canonical ensemble, the meaning of the Maxwell construction, Quantum Statistical mechanics, quantum model of matter, the canonical distributionin quantum statistics,the quantum oscillator, Planks formula for the equilibrium radiation of a perfectly black body, Heat capacity of solids, heat capacity of a diatomic ideal gas, Quantum statistic s of a system lf a similar particles,Bose-Einstein and Fermi-Dirac statistics, Application of Bose-Einstein statistics to the,photongas, application of Fermi-Dirac statistics to the electron gas in metal, Condensation of an ideal Bose-Einstein gas.

Recommended Books:

1. Statistical Mechanics,Kerson Huang, John Wiley and Sons, New York 1963.
2. Statistical Physics, Y. P. Terletslii, NorthHolland PublishingCo, 1971.
3. Classical Mechanics,Vol 1 &Vol 2, E.A. Desloge, John Wiley, New York 1982.
4. Introduction to Classical Mechanics,A.P. Arya Massachusetts 1990.
5. Classical Mechanics, T.L. Chow John Wiley, New York 1995.
6. Introduction to Classical and Quantum Harmonic Oscillators, S.C. Bloch John Wiley and Sons, Inc. 1997.
7. Statistical Physics. Volume5, Landau L. D and Lifshits E. M., 1980, Pergamon Press Ltd. NewYork.

Course 2: PHY-658

Physics of Nuclear Medicine

1. Radiation Detectors: Types of radiation detectors, ionization chambers, Geiger counters, scintillation counters, principles of operation, concept of dead time.
2. The Gamma Camera: Principle of operation, Collimators, NaI(Tl) Crystal, Performance Parameters.
3. Quality Control of the Gamma Camera: All quality control procedures as per NEMA and Tecdoc 602, Additional procedures recommended in publications.
4. Computers in Nuclear Medicine: Organisation of Gamma Camera Computer, Programming Principles, Applications in Nuclear Medicine, Gated Cardiac Studies, Functional Images.
5. Principles of SPECT: Acquisition, Filtered Back projection, Iterative Reconstruction, Attenuation Correction, Quality Control.
6. Principles of PET: Principles of PET, Acquisition, Reconstruction, Attenuation Correction, Quality Control.
7. Statistics of Counting: Poisson Distribution, Chi-squared test, Combination of Errors.
8. Basic Principles of Tracer Studies: Terminology, Blood Volume, Fick's Principle, Cardiac Shunts, Compartmental Analysis, Kidney function investigations.
9. Whole Body Counters: Theory and Principle of Operation, Minimum Detectable Activity.

Reference Books:

1. Performance Measurements of Scintillation Cameras. NEMA Standards Publication NU1-2001
2. Physics in Nuclear Medicine, Second Edition, J.A. Sorenson, M.E. Phelps. Grune & Stratton 1987.
3. Basic Science of Nuclear Medicine. Second Edition. R.P. Parker, P. H. S. Smith, D. M. Taylor Churchill Livingstone 1984.
4. Quality Control of Nuclear Medicine Instruments. IAEA Tecdoc 602, 1991
5. Principle of Nuclear Medicine, (2nd edition), Henry N Wagner, 1995, WB Saunders, ISBN 0-7216-9091-2

Course 3: PHY-659

The Physics of Radiotherapy

1. Dosimetry of Teletherapy: Phantom materials; Dose parameters: backscattering factor, percentage depth dose, tissue-air-ratio, tissue-phantom-ratio, isodose curves; Dose measuring.
2. Filters: Beam hardening; Shielding; Beam flatness; Compensation; Wedges.
3. Geometry of the Beam: Beam shaping; Penumbra.
4. Teletherapy units: Therapeutic x-ray units; Cobalt unit; Medical linear accelerator; Patient set-up.
5. Quality assurance: Acceptance of equipment; Calibration of a teletherapy unit; Quality control programme.
6. Electron therapy: Energy of electron beams; Characteristics of electron beams; Dose distributions; Dose measurement.
7. Brachytherapy: Techniques; Dosimetry; Radiographic techniques; Paris system; Radiation protection.
8. Unsealed sources and Beta irradiators: Radionuclides; Dosimetry; Radiation protection; Surface therapy.

Reference Books:

1. Faiz M Khan, The Physics of Radiation Therapy, Second Edition, Williams and Wilkens, 1994.
2. Radiotherapy Physics in practice, JR Williams and DI Thwaites, Oxford Medical Publications,1994.
3. HE Johns, JR Cunningham, The Physics of Radiology, Fourth Edition, Charles C Thomas Publisher, 1984.
4. EB Podgorsak, Radiation Oncology Physics: A Handbook for Teachers and Students, 2005

Course 4: PHY-660

Radiation Protection

1. Radiological protection

The following subjects are treated, using the 2005 recommendations of the ICRP as basis:

Physical quantities used in radiological protection: The absorbed dose, equivalent dose, effective dose, and the committed effective dose. Radiation and tissue weighting factors, Biological aspects of radiological protection. Deterministic and stochastic effects of ionising radiation.

The Dose and Dose-Rate Effectiveness Factor (DDREF). Additive and multiplicative risk projection models. Aggregated detriment. The conceptual framework of radiological protection. Practices and intervention. The system of protection in practices. Generic scientific principles of radiological protection. The control of occupational exposure.

The control of public exposure. Internal dosimetry calculations.

2. The shielding of neutrons and gamma-rays

(i) Fundamental concepts of radiation transport: Particle density in phase space; directional fluence rate; scalar fluence rate; reaction rates; response.

(ii) Radiation transport calculations: The Boltzmann transport equation. The multigroup approximation to the solution of the Boltzmann transport equation. Important sources of ionising radiation at radiation facilities and the nuclear industry - radionuclides, nuclear reactors, particle accelerators, accelerator-driven target bombardment facilities; neutron & proton radiotherapy facilities. - Response functions and response functionals. The fluencerate to dose-rate response functions for neutrons and ionising photons. Ranges of charged particles in matter – electrons, protons & alpha particles. The optimal shielding of electrons.

(iii) Fundamental principles of neutron and gamma-ray shielding: The shielding of neutrons: neutron moderation, neutron reaction dynamics, neutron scattering kinematics, angular distribution of scattered neutrons, average energies and emission angles of scattered neutrons.

(iv) The shielding of photons: Bremsstrahlung, photo-electric absorption, Compton scattering and pair production.

(v) Complementary shielding materials.

(vi) Fundamental principles of shield optimisation.

Reference Books:

1. Handout notes
2. James E Martin, Physics for Radiation Protection: A Handbook, 2nd Edition, 2006
3. Landolt-Bornstein, Radiological Protection, Group VIII: Advanced Materials and Technologies, Volume 4, 2005

PHY726

NEUTRINO PHYSICS

It is now established that the neutrinos carry light mass. Even if one flavor neutrino carries mass, neutrino mixing can be introduced in the SM (Standard Model) through neutrino oscillations which have been observed in several accelerator and reactor based experiments as well. The course aim the study of neutrino with finite mass that holds interesting prospects in cosmology and astronomy in addition to shedding light on fundamental questions related with physics beyond the SM.

History, Standard Model (SM) and neutrinos, neutrino flavors or types of neutrinos, cosmological limits on light mass, sterile neutrino, neutrino mass determination and Kurie Plot, neutrino mass types: Dirac and Majorana neutrinos, Grand unification and See-saw mechanism, neutrino oscillation: muon neutrino oscillation, electron neutrino oscillation, neutrino oscillation and mixing parameters, experimental evidence, the MSW effect, large mixing angle (LMA), and small mixing angle (SMA), KEK to Kamiokande (K2K) experimental results, atmospheric-, accelerator-, reactor- based experiments, KamLAND-, Solar neutrinos and SNO- , LSND- results, neutrino mass spectra and neutrino mixing, and mass hierarchy, Effective Majorana mass and neutrino less double beta decay, Leptonic mass mixing and CP violation, massive neutrino and magnetic moment, spin-flavor neutrino oscillations, neutrino mass mixing models and their experimental status.

Recommended Books/References:

i. Neutrino Physics by J. Bahcall, (Cambridge Univ. Press, Cambridge, U.K., 1989).

ii. S. Mikheyev and A. Smirnov, Yad. Fiz. 42, 8441, 1985 (Sov. J. Nucl. Phy. 42, 913, 1986), Nuovo Cim., 9C, 17, 1986.

iii. L. Wolfenstein, Phys. Rev. D 17, 2369, 1978.

iv. M. Nagakawa and S. Sakata, Prog. Th. Phys. 28, 870, 1962.

v. B. Pontecorvo, Zh. Eksp. Teor. Fiz. 53, 1717, 1967 (Sov. Phys. JETP, 26, 984, 1968).

vi. B. Kayser, Proc. of the 17th Workshop on Weak Interactions and Neutrinos, eds., C. Dominigues & R. Viollier, World Scientific, Singapore, 2000.

vii. Superkamiokande Collaboration, Y. Ashie et al., Phys. Rev. D 71, 112005 2005.

viii. M. Shiozawa, XXth Int. Conf. on Neutrino Physics and Astrophysics, Munich, 2002.

ix. B. Kayser, J. Phys. G, Nuclear and Particle Physics and Astrophysics, pp 156-164 2006.

x. Current research papers.

PHY733

FINITE TEMPERATURE AND DENSITY FIELD THEORY IN HIGH ENERGY PHYSICS

The study of many body systems from the field theoretic point of view is to be carried out in this course. Based on the statistical mechanics framework and starting from a thorough study of the basic principles involved, the student will be able to calculate the various processes involved in abelian as well as non-abelian gauge theories in a background of other particles, at high temperatures and densities. These processes are still ongoing in astrophysical environments. Such studies are also involved in QCD for the detection of quark gluon plasma.

Review of Quantum Statistical Mechanics: Bosonic and fermionic degrees of freedom, non-interacting particles in a box.

Functional Integral Representation of Partition Function: transition amplitudes, partition function for bosons. Bose-Einstein condensation, fermions.

Interactions and diagrammatic Techniques: Perturbative expansion, diagrammatic rules for λφ4, summation of infra-red divergences, Yukawa theory, real time perturbation theory.

Renormalization: renormalization, renormalization group, applications to partition functions.

QED: Photon self-energy, loop corrections, higher loops, applications to primordial nucleosynthesis, astrophysics etc.

Linear Response Theory: Linear response to external field, screening of field, plasma oscillations.

QCD: quarks and gluons, asymptotic freedom, perturbative evaluation, instantons, deconfinement phase transition, ultra-relativistic nucleus-nucleus collisions, strange matter.

Weak Interactions: Standard model, symmetry breaking, early universe and effects of temperature and density.

Recommended Books/References:

i. Finite Temperature Field Theory by A. Das (World Scientific, 1997).

ii. Finite Temperature Field Theory by Joseph I. Kapusta (Cambridge Univ. Press, 2006).

iii. Relativistic Quantum Field Theory at Finite Temperature: Applications in Elementary Particle Physics and Cosmology by Anders E. I. Johansson (Institute of Theoretical Physics: Chalmers University of Technology: University of Göteborg, 1986).

iv. Quantum field theory at finite temperature: renormalization and radiative corrections by Anders E. I. Johansson, Giorgio Peressutti, Bo-Sture Skagerstam, (Institute of Theoretical Physics: Chalmers University of Technology: University of Göteborg, 1985).

v. Field theory at finite temperature and phase transitions by Mariano Quiros, http://xxx.lanl.gov/abs/hep-ph/9901312.

vi. Real and Imaginary Time Field Theory at Finite Temperature and Density, N. P. Landsman and Ch G. Weert, (Phys. Rep. **145**, 141, 1987).

vii. Current research papers.

PHY734

QUANTUM CHROMODYNAMICS (QCD)

The course aims to develop understanding on the theory of string interactions and its applications. This is one of the hot areas of research in particle physics and ultra-relativistic heavy ion collisions from the theoretical as well as experimental perspective.

Introduction: Quarks and color, asymptotic freedom, quark confinement.

Elements of QCD: Gauge Principle, Quantization, Feynman rules, regularization, renormalization.

Renormalization group method: renormalization group, renormalization group equations, their solutions.

Operator product expansion and QCD sum rules, Infrared Divergences in QCD, QCD at finite temperature and density.

Applications of QCD in astrophysics, compact stars and early universe.

Recommended Books and Literature:

i. Foundations of Quantum Chromodynamics by T. Muta, (World Scientific, 1998).

ii. Quantum Chromodynamics by Walter Greiner and Andreas Schaefer, (Springer-Verlag, 1995).

iii. The Theory of Quark and Gluon Interactions by J. F. Yandurain, (Springer-Verlag, 2006).

iv. QCD: Renormalization for the Practitioner by P. Pascual and R. Tarrach, (Springer-Verlag, 1984).

v. Gauge Theories in Particle Physics by A. J. R. Aitchison and A. J. G. Hey, (Taylor and Francis, 2004).

vi. Gauge Theory of Elementary Particle Physics by Ta-Pei Cheng and Ling-Fong Li, (Oxford University Press, 2000).

vii. Current literature.

PHY743

QUARK GLUON PLASMA (QGP)

The theoretical aspects of one of the thoroughly being probed state of matter –the quark gluon plasma, are to be studied in this course. The phase transitions, the parameters involved and the factors that can lead to its detection will be thoroughly discussed.

A new phase of matter: micro bang and big bang, vacuum as physical medium, statistical properties of hadronic matter.

Phase transitions: critical phenomena, 1st and 2nd order phase transitions, phase transitions in QCD.

Experiments and analysis: nuclei in collision, collision dynamics, entropy and heavy ion collisions.

Particle production: particle spectra, centrality, incoming stopping, transverse energy, strangeness production, charm suppression.

Hot hadronic matter: hadronic states in hot environment, field theory at finite temperature, relativistic gas, hadronic gas, Hagedron gas.

QGP and lattice gauge theory: QCD on lattice, Lattice gauge approach to QCD phase transitions

Recommended Books/References:

i. Hadrons and Quark Gluon Plasma by Jean Letessier and Johann Rafelski, (Cambridge Univ. Press, 2002).

ii. Physics of Quark Gluon Plasma by Berndt Muller, (Springer, 1985).

iii. The Phases of Quantum Chromodynamics by John B. Kogut and Mikhail A. Stephanov, (Cambridge Univ. Press, 2004).

iv. Quark-Gluon Plasma: From Big Bang to Little Bang by Kohsuke Yagi, Tetsuo Hatsuda, and Yasuo Miake, (Cambridge University Press, 2008).

v. Quark-Gluon Plasma: Theoretical Foundations: An Annotated Reprint Collection by J. Kapusta, B. Muller and J. Rafelski, (Elsevier Science, 2003).

vi. The Physics of the Quark Gluon Plasma: Lecture Notes in Physics, Vol. 785, Sourav Sarkar, Helmut Satz and Bikash Sinha, Eds., (Springer, 2010).

vii. Current research papers.

PHY744

KINEMATICS OF NUCLEAR REACTIONS AT HIGH ENERGIES

The course aims to cover the theoretical details involved in the detection and study of physical parameters required in the study of heavy ion colliders. The focus will be also to train students on computer simulations involved to verify theoretical predictions at relativistic energies and be able to derive further detailed analysis of the ongoing experimental predictions.

Overview of practical aspects of High-Energy Physics in particle colliders and detectors.

Understanding Big Bang and evolution in early universe through accelerators, experimental nuclear collision physics, experimentation for quark gluon plasma, nuclear matter created at relativistic and ultra-relativistic energies and its relation to observations.

Study of deconfined nuclear medium: theory of the heavy quark production; chiral symmetry restoration; transformation of experimental data from one frame to the other, presentation of data in Lorentz invariant form; transformation of kinematic variables; use of the modern generators for simulation of events at high energy.

Primary scattering events, kinematics of elastic and inelastic collisions in relativistic framework, quasi elastic collisions, deep inelastic scatterings, phase space integrations, relativistic lab frame and center-of-mass frame, rapidity, particle decays, particle collisions, hadron spectroscopy.

Event Generators: HIJING, CASCADE; UrQMD; GEANT and ROOT pockets.

Recommended Books/References:

i. Particle Kinematics by E. Byckling and K. Kajantie, (Wiley, New York, 2007).

ii. Relativistic Kinematics of Particle Interactions by W von Schlippe, **www**.phys.spbu.ru/content/File/Library/studentlectures/**schlippe**/kin_rel.pdf

iii. Current research papers.

PHY753

ADVANCE CONDENSED MATTER PHYSICS AND THIN FILMS

Introduction, Response of substance to magnetic field, Atomic theory of magnetism, Classifications of magnetic materials; Paramagnetism, Diamagnetism, Ferromagnetism, Antiferromagnetism, Ferromagnetic domains, Ferrimagnetism and Ferrites; Optical properties, Photoconductivity, Photoluminescence, Colour centres, types of colour centres, generation of colour centres; Superconductivity, Sources of superconductivity, Meissner effect, Isotope effect, Thermodynamics of the superconducting transition, London equations, London penetration depth, BCS theory of superconductivity, Ginsburg Landau theory, High-T_c superconductivity; Dielectrics, Dipole moment, Polarization, Types of polarizations, Polarization mechanisms, Dielectric properties; Ferroelectricity, anti-ferroelectricity, ferrielectricity, Piezoelectricity, and pyroelectricity, Techniques and processes encountered in growth and characterization of thin films, Chemical vapor deposition, Characterization of Thin Film, Issues involved in thin film growth

Recommended Books

1. C. Kittel, "Quantum Theory of Solids" (John-Wiley and Sons).
2. T. Landsberg, "Solid State Theory" (John-Wiley and Sons).
3. H. Craft, "The Elements of Solid State Physics"
4. C. Kittle, "Introduction to Solid State Physics" 7th edition 1996, (John-Wiley).

PHY 754

ADVANCED MATERIALS

The nature of materials science: MATERIALS, Metals, Ceramics, polymers, composites, SHAPES, Flat and dished sheet, prismatic, 3-D. PROCESSES, Casting, molding, powder methods, machining.

Phase Diagrams: Construction of a Phase Diagram, Binary and Ternary Phase Diagram, Applications of Phase Diagram**.**

Advanced Ceramic Materials: Definition of Advanced Ceramics, General Improvements in Mechanical Properties, Aluminum Oxide, Silicon Nitride, Silicon Carbide, Transformation-Toughened Zirconia, Other Monolithic Advanced Ceramics, Self-Reinforced Ceramic Composites, Particle-Reinforced Ceramic Composites.

Metal Matrix Composites: Introduction, Applications, Processing, Damage Tolerance, Fatigue Damage in µMMCs, Damage-Tolerant Design, Initial Cracks, Threshold Stress Intensity Factor, Final Crack Length, Crack Growth Rate.

Biomaterials: Introduction to biomaterials, materials selection, biopolymers, structural polysaccharides, hard materials, biomedical materials.

Nano Materials: Quantum dots, nano wires, nano photonics, magnetic nano structures, nano thermal devices, Nano fluidic devices, biomimetic materials.

Recommended Books:

1. The Hand Book of Advanced Materials by James K. Wessel.

2. Materials Science and Engineering by William D. Callister, Jr. and David G. Rethwisch.

3. The Principles of Engineering Materials, C.R. Barrett, W.D. Nix, A.S. Tetelman, Prentice Hall, Upper Saddle River 1973.

4. Introduction to Nano science and Nanotechnology by C. Binns, (Wiley Survival Guides in Engineering and Science), Wiley, 2010.

PHY-755 Thermodynamics of Materials 03 Cr.hrs

Basic thermodynamics, Experimental Determination of Thermodynamic Quantities, Calorimetric Methods, Measurement of Enthalpy and Heat Capacity, Measurement of Enthalpies of Transformation, Gas Phase Equilibria Techniques, Static Methods for Measurement of Vapor Pressures, The Dew-point and Non-isothermal Isopiestic Methods, The Knudsen Effusion and Langmuir Free-Evaporation Methods, Electromotive Force Measurements, Experimental Determination of Phase Diagrams, Non-isothermal Techniques, Isothermal Techniques, Metallography, X-rays, Quantitative Determination of Phase Compositions in

Multi-Phase Fields, thermodynamic models for solution and compounds models, Stoichiometric Compounds, Random Substitutional Models, Simple Mixtures, Sub lattice Models, The Generalized Multiple Sub lattice Model, Ionic Liquid Models, Phase Stabilities, Thermo chemical Estimations, General Procedure for Allotropic Elements, General Procedure for Non-Allotropic Elements,

Calculation of Phase Equilibria, Binary and Ternary Phase Equilibria, Calculation Methods for Multi-Component Systems, Thermodynamic Optimization of Phase Diagrams.

Recommended Books:

1. N.Sunders and A. P. Miodownik "CALPHAD Calculation of Phase Diagrams" Pergamon materials series : v. 1. Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 IGB.

2. David R. Gaskell "Introduction to the Thermodynamics of Materials". Taylor and Frances, 29 West 35th Street New York, NY 10001.

3. Qing Jiang and Zi Wen, "Thermodynamics of Materials" Springer Heidelberg Dordrecht London New York, 2010.