SYLLABUS

Ph. D. (PHYSICS)

(COURSE WORK)

DEPARTMENT OF PHYSICS

INSTITUTE OF SCIENCE

BANARAS HINDU UNIVERSITY

(Last Updated in BoS Meeting dated 26-May-2018)

Ph.D. Course Work in Physics

DISTRIBUTION OF DIFFERENT COURSES AND CREDITS

Common Courses		
Course Code	**Name of Course**	**Credits**
FSPC01	a. Ethics in Science	01
FSPC02	b. Science Communication	01
FSPC03	c. Research Methods & Good Lab Practices	01
	Total	**03**
	Discipline Specific Core Courses	
PHPC-01	Research Methodology: Theoretical Techniques Based Course	04
PHPC-02	Research Methodology: Experimental Techniques Based Course	03
	Total	**07**
	Research Theme Specific Courses	
PHPR-01	Structural and Microstructural Characterization of Materials	03
PHPR -02	Synthesis and Physical Property Measurement Techniques of Materials	03
PHPR -03	Condensed Matter Theory-I	03
PHPR -04	Condensed Matter Theory- II	03
PHPR -05	Experimental Spectroscopy – I	03
PHPR -06	Experimental Spectroscopy – II	03
PHPR -07	Theoretical Spectroscopy – I	03
PHPR -08	Theoretical Spectroscopy – II	03
PHPR -09	Emerging Electronic, Ionic and Magnetic Material-I	03
PHPR -10	Emerging Electronic, Ionic and Magnetic Material-II	03
PHPR -11	Computational Methods in Electronics-I	03
PHPR -12	Computational Methods in Electronics-II	03
PHPR -13	Theoretical Nuclear Physics	03
PHPR -14	Experimental Nuclear Physics	03
PHPR -15	Theoretical High Energy Physics	03
PHPR -16	Experimental High Energy Physics	03
PHPR -17	Preparations and Presentation of the Research Plan Proposal	
PHPR-18	Review, Report and Seminar	04

Note: Each student has to study a common course of 3 credits offered at the Faculty level, two core courses of 7 credits, two RPC based courses of 3 credits each from the Research Theme Specific Courses. Each student has to make a survey of research work done in his/her field and submit a review report and give a seminar based on his/her research area of 4 credits.

PHPC-01: RESEARCH METHODOLOGY: THEORETICAL TECHNIQUES BASED COURSE

Credits 04

Classical Mechanics

Lagrangian and Hamiltonian methods, small oscillations, Hamilton -Jacobi theory, rigid body motion, rotation matrices, relativistic kinematics

Quantum Mechanics

Schrodinger wave equation, operator methods, symmetry and angular momentum. approximate methods, quantum mechanics for a system of particles, Dirac equation.

Electrodynamics

Maxwells equations, potential formulation, energy and momentum, electromagnetic waves and radiation

Statistical Physics

Ensemble theory, partition function, quantum statistics, Bose einstein condensation, quantum fluids, superconductivity. Non equilibrium statistical mechanics, renormalization group theory, Kinetics of phase transitions.

Computational Physics

Matrix diagonalization, numerical integration, solving differential equation, Euler, Runge –Kutta and Verlet schemes. Monte-Carlo and molecular dynamics methods and algorithms.

Suggested reading:

1. H. Goldstein, (1965), Classical Mechanics, Addison-Wisley
2. H. Goldstein, C.P. Poole, J.L. Safko, (2001), Classical Mechanics, Addison-Wisley
3. D.J. Griffiths, (2001), Introduction to Quantum Mechanics, Springer Link
4. L.H. Ryder, (1996), Quantum field theory, Camb. Univ. Press
5. R.K. Patharia, Statistical Mechanics
6. L.E. Reichl, (1998), A Modern Course in Statistical Physics, John Wiley & Sons
7. Landau & Lifshitz, (1980), Classical Theory of Fields, Butterworth-Heinermann

PHPC - 02: RESEARCH METHODOLOGY: EXPERIMENTAL TECHNIQUES BASED COURSE

Credits 03

Vacuum Techniques:

Simple description and working principle of vacuum pumps (Rotary, Diffusion and Turbo-molecular), Penning and Pirani gauges, leak detection techniques.

Structural Characterization and Imaging Techniques:

X-ray diffraction ((XRD), electron and neutron diffraction, elementary ideas of photoelectron spectroscopy (PES), basic principal of atomic resolution electron microscopy, scanning electron microscopy (SEM), scanning tunneling and atomic force microscopy (STM, AFM) techniques.

Optical Characterization and Spectroscopic Techniques:

Infrared and ultraviolet / visible (IR, UV/Vis) absorption spectroscopy, Raman and Fluorescence spectroscopy, elementary idea of laser-based non-linear techniques.

Accelerator-based Techniques:

Accelerators, Rutherford back scattering (RBS), particle induced x-ray emission (PIXE) and particle induced g-ray emission (PIGE)

Physical Property Measurements:

Intensive and extensive properties, physical property measurements (DSC, DTA, TGA,), transport properties (R-T, I-V), low conductivity measurement (Dielectric Spectroscopy), magnetic properties of bulk and nano phases of material (VSM & SQUID).   .

Detection Techniques:

Particle and radiation interaction with material, detectors: thermal, photon and electron detectors, Soild State and scintillation detectors, multi-channel analyzers (MCA).

Suggested reading:

1. J.M. Hollas, (1986), Modern Spectroscopy, John Wiley & Sons
2. G.M. Barrow, (1984), Introduction to Molecular Spectroscopy, McGraw-Hill Book Co.
3. Gareth Thomas and Michael J. Goringe, (1979), Transmission Electron Microscopy of Materials, John Wiley
4. B. D. Cullity, (1978), Elements of X-ray Diffraction, Addison-Wesley
5. M.T. Bray, Samuel H. Cohen and Marcia L. Lightbody,(1993), Atomic Force Microscopy/Scanning Tunneling Microscopy, Plenum Press

PHPR-01: Structural and Microstructural Characterization of Materials

Credits: 03

X-ray diffraction: Fundamental of material characterization using x-ray technique, intensity data collection, data reduction profile fitting and refinement (Lebail & Rictveld). Small angle x-ray scattering (SAXS) to study shape and size distributions.

Transmission Electron Microscopy: Working principle of transmission electron microscope (TEM). High resolution electron microscope. Electron optics kinematical theory. Bright field and dark field imagings. Phase contrast and diffraction contrast. Indexing and analysis of selected area diffraction. Elementary idea of abervation from electron microscopy. Sample preparation for TEM (Jet polishing and Ion beam milling)

Scanning Electron Microscopy:- Basic of scanning electron microscopy (secondary electron and their detections). Evaluation of surface images from (SEM). Elemental analysis through energy dispersive x-ray analysis (EDX).

Suggested reading:

1. B.D. Cullity, (1956), Elements of X-ray diffraction, Addison-Wesley Publishing Company.
2. R.A. Young, (1996),The Rietveld Method: Edited by International Union of Crystallography, Oxford, New York.
3. Gareth Thomas, Michael John, A Wiley, (1987), Transmission Electron Microscope of Materials: Interscience Publication (John Wiley & Sons).
4. J. Goldstein, D. Newbury, D. Joy, C.Lyman, P. Echlin, E.Lifshin, L. Sawyer and J. Michael, (2003), Scanning Electron Microscope and X-ray Microanalysis, Springer Science.
5. H. Singh Nalva, Vol.-02 (2004) Specification of Microstructure and Characterization by scattering Techniques

PHPR-02: Synthesis and Physical Property measurement techniques of Materials

Credits: 03

Synthesis:- Principal of radio frequency induction furnace, melt quenching method to produce glassy materials, elementary concepts of pulsed laser deposition, chemical vapour deposition, spray pyrolysis and colloidal technique to synthesis of nano-particles, High Energy ball milling, Methods for synthesis of Low dimensional (2-D) materials.

Physical Property Measurement:-

PPMS:- Its use to measure magnetic and transport properties such as AC & DC magnetization, classical and Quantam Hall coefficient, I-V characteristics, specific heat thermo power, Thermal constant analysis using transient plane source method and its application to measure various thermal properties (thermal conductivity and thermal diffusivity).

DSC & DTA:- Principal of DSC & DTA techniques in isothermal and non isothermal modes. Some applications in the study of solid state phase transition. Impedance analysis to determine dielectric properties of materials

Suggested reading:

1. Charles P. Poole Jr and Frank J. Owens, (2007), Introduction to Nanotechnology,
2. John Wiley & Sons (Asia) Pvt. Ltd.
3. J. Goldstein, D. Newbury, D.Joy, C.Lyman, P. Echlin, E.Lifshin, L.Sawyer and J. Michael, Springer, (1996), Different Scanning Calorimetry, Berlin Heidelberg New York
4. Sulbha K. Kulkarni, (2007), Nanotechnology: Principles and practices, Capital Publishing Company, New Delhi
5. C. Suryanarayana, Bibliography on Mechanical Alloying and Milling, Cambridge Interscience Publ., Cambridge UK, (1995)

PHPR -03 : Condensed Matter Theory-I

Credit: 03

Symmetry and Structures

Density operator and its correlation functions, one-and two-dimensional order in 3D materials, liquids and liquid crystals, Incommensurate structures, magnetic order, fourier transforms.

Thermodynamics and Statistical Physics

Basics of thermodynamics, review of statistical methods, spatial correlations in classical systems, ordered systems, symmetry and order parameters, functional derivatives

Mean-Field Theory

The ising and n-vector model, Landau theory, extension to first - order transitions, applications to magnetism, liquid crystals and multiferroics, variational mean- field theory, density functional theory and its applications to ordered systems

Models and methods for Polymeric Systems

Continuous models, lattice models, renormalization group approach and its application to polymeric systems

Suggested reading:

1. P.M. Chaikin and T.C. Lubensky, (1998) Principle of Condensed Matter Physics, Cam.Univ.Press
2. J.P. Hansen and I.R. McDonell, (2006), Theory of Simple Liquids, Elsevier Inc.
3. P.G. de Gennes, (1979), Scaling Concept in Polymer Physics, Cornell Univ. Press
4. J.D. Cloizeanx and G. Jannink, (1990), Polymer in Solutions: Their modelling and structure, Oxford Univ. Press
5. S. Singh, (2002), Liquid Crystals: Fundamentals, World Scientific
6. G.D. Mahan, Many, (1990), Particle Physics, Springer
7. Nigel Goldennfeld, (1992), Lectures on Phase Transitions and the renormalization group, Addison-Wisley
8. S.Puri and V.K. Wadhawan, (2010), Kinetics of Phase Transitions, World Scientific

PHPR -04: Condensed Matter Theory- II

Credit: 03

Field Theories, Critical Phenomena and renormalization group

Breakdown to mean-field theory, mean-field transitions revisited, self-consistent field approximation, critical exponents, universality and scaling, Kadnoff construction, Momentum shell renormalization group

Dynamics

Correlation functions, response functions, applications to simple problems, Kinetics of phase transitions

Green Function and its Applications to Superconductivity

Introduction to green function, free fermi gas, calculation of density of states and other physical quantities, BCS theory of superconductivity

Suggested reading:

1. P.M. Chaikin and T.C. Lubensky, (1998) Principle of Condensed Matter Physics, Cam.Univ.Press
2. J.P. Hansen and I.R. McDonell, (2006), Theory of Simple Liquids, Elsevier Inc.
3. P.G. de Gennes, (1979), Scaling Concept in Polymer Physics, Cornell Univ. Press
4. J.D. Cloizeanx and G. Jannink, (1990), Polymer in Solutions: Their modelling and structure, Oxford Univ. Press
5. S. Singh, (2002), Liquid Crystals: Fundamentals, World Scientific
6. G.D. Mahan, Many, (1990), Particle Physics, Springer
7. Nigel Goldennfeld, (1992), Lectures on Phase Transitions and the renormalization group, Addison-Wisley
8. S.Puri and V.K. Wadhawan, (2010), Kinetics of Phase Transitions, World Scientific

PHPR -05 : Experimental Spectroscopy – I

Credits: 03

Spectroscopy of Atoms and Molecules: Designation of Atomic and Molecular States, Electronic, vibrational and rotational spectra, concept of allowed and forbidden Transitions, Elements of Microwave Spectroscopy.

Vibrational Spectroscopy: Principle of Fourier transform (FT) spectroscopy, FT-IR and FT- Raman spectrometers, advantages of Fourier transform technique over the conventional methods, fast Fourier transform (FFT), applications of IR and Raman spectroscopy, surface enhanced Raman spectroscopy (SERS) and its applications, Resonance Raman spectroscopy and CARS.

Electronic Spectroscopy: UV/Vis absorption spectroscopy & flourescence spectroscopy of materials.

Collision-Based Spectroscopic Techniques: Collision cross section, inner shell excitation / Ionization, molecular beam spectroscopy.

Suggested reading:

1. W. Demtroder, (2004) Laser Spectroscopy, Basic concept and Instrumentation, Springer
2. J. M. Hollas, (1998), High Resolution Spectroscopy, John Wiley & Sons
3. J.M. Hollas, (1986), Modern Spectroscopy, John Wiley & Sons
4. A. Thorpe,(1999), Spectrophysics, Springer
5. B. Schrader, (1993), Infrared and Raman Spectroscopy, John Wiley & Sons

PHPR -06 : Experimental Spectroscopy – II

Credits: 03

Electronic Spectroscopy: Electronic spectra of linear molecules, classification of electronic states in polyatomic molecules and their spectra, vibrational analysis of diatomic and polyatomic molecules, dissociation energy and its determination.

Non-Conventional Spectroscopic Techniques:

Basic idea of circular dichroism, optogalvanic spectroscopy, principle and applications of photoacoustic spectroscopy, laser fluorescence and single vibronic level (SVL) spectroscopy, saturation spectroscopy, multiphoton spectroscopy, time-resolved spectroscopy and measurement of life time, time of flight mass spectroscopy and its applications, laser-Induced breakdown spectroscopy (LIBS).

Laser Cooling:

Laser cooling, spectroscopy of ultracold atoms and molecules, formation of Bose-Einstein condensate.

Suggested reading:

1. W. Demtroder, (2004) Laser Spectroscopy, Basic concept and Instrumentation, Springer
2. J. M. Hollas, (1998), High Resolution Spectroscopy, John Wiley & Sons
3. J.M. Hollas, (1986), Modern Spectroscopy, John Wiley & Sons
4. A. Thorpe,(1999), Spectrophysics, Springer
5. B. Schrader, (1993), Infrared and Raman Spectroscopy, John Wiley & Sons
6. S.N. Thakur and D.K.Rai, (2010), Atom Laser and Spectroscopy, PHI, Learning Pvt. N.D.

PHPR -07: Theoretical Spectroscopy – I

Credits: 03

Group theory and its application to molecular vibrations: Symmetry operations and their matrix representations, reducible and irreducible representations, Great Orthogonality Theorem and its corollaries, character tables, irreduciable representations of $C_{2v,}$ C_{3v} and D_2h point groups, normal modes of vibration and their distribution into symmetry species of point groups of molecules, infrared and Raman selection rules, overtone and combination bands, Normal coordinate analysis using Wilson's GF matrix method, G-matrix, force fields and F-matrix, Determination of consistent force fields for molecules of $C_{2v,}$ C_{3v} and D_2h point groups.

Quantum Optics

Non-linear optics: Non-linear susceptibilities, symmetries, phase matching, second harmonic and sum frequency generation.

Optical coherence: The mutual coherence function, Van Cittert-Zernike theorem, Hanbury Brown-Twiss effect, Second order coherence for thermal and coherent light.

Quantum electromagnetic field: Quantization of the electromagnetic field, Fock basis expansion, coherent state expansion, diagonal representation, Phase-space probability densities (P-, W-, and Q-representations). Ordering of operators, Non-classical states of radiation with examples. Photon antibunching. Beam splitter and single-photon interference, The Mach-Zehnder interferometer, Two-photon interference and the Hong-Ou-Mandel effect. Squeezing and generation of squeezed states. Elementary concept of entanglement.

Suggested reading:

1. F.A. Cotton, (1990), Cgemical Applications of Group Theory, John Wiley & Sons
2. E.P. Wigner, (1959), Group Theory and its Application to the Quantum Mechanics of Atomic Spectra, Academic Press
3. R.W. Boyd, Non-linear optics
4. M. O. Scully, M. S. Zubairy, Quantum Optics
5. L. Mandel and E. Wolf, Optical coherence and quantum optics
6. C. C. Gerry, P. L. Knight, Introductory Quantum Optics
7. G. S. Agarwal, Quantum Optics

PHPR -08: Theoretical Spectroscopy – II

Credits: 03

Electronic structure theory of molecules: Quantum theoretical methods, concepts of atomic and molecular orbitals, Hartree-Fock theory, introductory details of ab-initio methods, density functional theory, Slater orbitals, Gaussian basis sets, application of molecular orbital theory to diatomic and polyatomic molecules, charge density distribution in molecules, dipole moment, molecular electrostatic potential, intermolecular interactions, Hellman-Feynman theorem and concept of force, hybrid atomic orbitals, lone pairs, conformations, calculation of electronic spectra of molecules, geometry optimization, chemical reactions, transition state theory, Treatment of excited states and determination of excited state molecular geometry, molecular mechanical methods.

Spectroscopy of Astrophysical objects: Luminosity and brightness, Magnitudes, Stellar spectra and classification of stars, Color-Magnitude plot, Hertzsprung - Russel (H-R) diagram, Star formation and stellar evolution, Temperature and density structure of Sun and Solar atmosphere.

Introduction to the interstellar medium(ISM), emission and absorption lines,objects and environments of the ISM and physical processes

Suggested reading:

1. I.N. Levine, (1994), Quantum Chemistry, 4th Edition: Prentice-Hall of India, Pvt. Ltd.
2. W.J. Hehre, L.Radom, P.V.R. Schleyer, J.A. Pople, John Wiley, (1986), Ab Initio Molecular Orbital Theory, Wiley- Interscience
3. A. Szabo and N.S. Ostlund, (1996), Modern Quantum Chemistry, Mc-Graw Hill
4. R. McWeeny, Coulsons's Valence, (1979), Oxfort University Press
5. The Physical Universe; an introduction to Astronomy, Frank Shu
6. Astrophysics: Stars and Galaxies, KD Abhyankar
7. Introduction to Stellar Astrophysics (Volumes 1, 2 and 3), Erika Bohm-Vitense
8. Physics of the Interstellar and the Intergalactic medium, BT Draine

PHPR -09: EMERGING ELECTRONIC, IONIC AND MAGNETIC MATERIALS-I

Credit: 03

Electronic Materials: Crystalline semiconductors, compound semiconductors, interface properties, M-S interface and its relationship with semiconductor parameters, traps and defects in semiconductors. Organic semiconductors, photovoltaic devices. Material preparation by vacuum deposition and sputtering, substrate cleaning by glow discharge by low pressure. Experimental methods for characterizing semiconductors: (I-V, C-V, optical absorption and band gap).

Ionic and Polymeric Materials: Basics of ion conduction in solids, superionic solids/solid electrolytes, crystalline, gel, polymer and glassy solid electrolytes, polymer-ceramic nanocomposites and bio-polymers. Types of ion conducting polymers. Polymer complexes with salt/acid/fillers/plasticizers. Method of preparation of polymeric films.

Magnetic Materials: Magnetic materials and layered magnetism, half metals, DMS, spontaneous magnetization, GMR materials and measurements of magnetic susceptibility by vibration magnetometer, SQUID, spin-polarized transport, magnetism of nano-phase magnetic materials, MFM/AFM.

Suggested reading:

1. S.M. Sze, (2003), Semiconductor Devices Physics and Technology, John Wiley & Sons, Inc
2. K.L. Chopra, (2008), Thin Film Phenomenon, Krieger Pub. Co.
3. F.M. Grey, (1991), Solid Polymer Electrolytes Fundamentals and Technological Application VCH Publishers, Inc
4. Farzad Nasipouri and Alain Nogaret (2010), Nanomagnetsim and Spintronics (Fabrication, Materials, Characteization and Applications), World Scientific Company

PHPR -10: EMERGING ELECTRONIC, IONIC AND MAGNETIC MATERIALS-II

Credit: 03

Ionic and Conducting Polymeric Materials, Characterization and Applications: Simple models for ionic conduction, dielectric relaxation (α, β, γ) in ionic materials, polarisation, complex permittivity and loss factor, frequency and temperature dependence of dielectric parameters, scaling of frequency dependent conductivity (Jonschers law).Viscoelastic relaxation. Electrodeposition. Solid state ionic devices with special reference to fuel cells, dye sensitized solar cell, batteries, supercapacitors and electrochromic display devices, ionic liquids and ionogels. Experimental methods for characterizing solid electrolytes, impedence spectroscopy, cyclic voltametry. Ion dynamics by dielectric relaxation and NMR, ionic transference number and mobility measurement, optical properties and determination of band gap, thermal characterization of ionic materials.

Semiconductor ceramics, method of preparation of ceramics (solid-state and sol-gel route) use of ceramics as temperature sensors. Electroactive polymers, organic semiconductor, organic semiconductor electronic devices, nanoelectronics.

Suggested reading:

1. S.M. Sze, (2003), Semiconductor Devices Physics and Technology, John Wiley & Sons, Inc
2. K.L. Chopra, (2008), Thin Film Phenomenon, Krieger Pub. Co.
3. F.M. Grey, (1991), Solid Polymer Electrolytes Fundamentals and Technological Application VCH Publishers, Inc
4. C. Pratt, Application of Conducting Polymers
5. J. Przyluski and S. Roth, (1993), Conducting Polymers-Transport Phenomena, Trans. Tech. Pub.

PHPR - 11 : COMPUTATIONAL METHODS IN ELECTRONICS — I

Credits: 03

Data Acquisition Fundamentals:

Introduction to signal and system, signal conditioning, sampling, digitization and data acquisition. DAQ hardware and software perspectives with respect to applications.

Digital Signal Processing and Application Algorithms:

Continuous and discrete integral transforms, discrete Fourier transform, Laplace transform, Z-transform, Hilbert transform, wavelets and wavelet transform, convolution and correlation, autocorrelation, crosscorrelation, power spectral analysis, discrete wavelet decomposition and transient analysis, digital filtering, window function method, denoising, Kalman filtering.

Problem Solving in MATLAB

1. Digital filter design
2. Time-series analysis by FFT
3. Transient analysis by wavelet decomposition

Suggested reading:

1. Bateman, I. P. Stephens,(2002), The DSP Handbook— Algorithms, Applications and Design Techniques, Prentice-Hall
2. E. O. Brigham, (1988), The Fast Fourier Transform and Its Applications, Prentice Hall
3. J. G. Proakis, D. G. Manolakis, (2004), Digital Signal Processing, Pearson
4. S. Burrus, R. A. Gopinath, H. Guo, (1998), Introduction to Wavelets and Wavelet
5. Transforms, Prentice-Hall

PHPR -12 COMPUTATIONAL METHODS IN ELECTRONICS — II

Credit: 03

Data Analysis Methods

Multivariate statistical analysis, averaging, smoothing, parametric and nonparametric data modeling and estimation, principal component analysis, genetic algorithm, and some examples of specific applications.

System Modeling and Solution Methods

Linear and nonlinear oscillators, equations of motion, fixed points, linear stability analysis, bifurcation and chaos.

Modal propagation in waveguides and periodic media, coupled wave analysis by matrix method, finite element method.

Problem Solving in MATLAB

1. Principal component analysis
2. Wave propagation in multilayer structures
3. Finite element method

Suggested reading:

1. T. W. Anderson, (2003), An Introduction to Multivariate Statistical Analysis, Wiley
2. M. Lakshmanan, S. Rajasekar, (2003) Nonlinear Dynamics— Integrability, Chaos And Patterns, Springer
3. M.S. Gockenbach, (2006), Understanding and Implementing the Finit Element Methods, SIAM
4. P. Yeh, (2005), Optical wave in Layered Media, Wiley

PHPR-13: Theoretical Nuclear Physics

Credits: 03

General Properties of the Nuclei: Parameterization of nuclear masses, Properties of nuclear matter; Nuclear stability, Alpha, beta and gamma decays; Nuclear fission and fusion processes, Production of nuclear energy and working of a reactor.

Nuclear Structure: General nature of nuclear force, Fermi gas model, Shell model; Collective rotational and Vibrational modes of excitations; Microscopic description of nuclei; Physics of high spin states, Backbending phenomenon.

Nuclear Reactions : General features of nuclear reactions, stripping and pick up reactions, Heavy-ion reactions, Resonant and non-resonant reactions; Energy production and nuclear reactions in stars viz. Hydrogen burning, Helium burning, r-, s- and p-processes.

Suggested reading:

1. M. A. Preston and R. K. Bhaduri, (1982), Structure of the Nucleus, Addison wesley,
2. M. K. Pal, (1982), Theory of Nuclear Structure, East-west Press.
3. W. E. Burcham and M. Jobes, (1998), Nuclear and Particle Physics, Addison-Wesley,
4. B. Povh, K. Rith, C. Scholz, F. Zetsche, (1995) Particles and Nuclei, Springer,
5. Rolfs and Rodney, Cauldrons in Cosmos: Nuclear Astrophysics, Chicago University Press

PHPR 14 : EXPERIMENTAL NUCLEAR PHYSICS

Credits: 03

Nuclear Techniques and Applications:

Particle Induced X-ray Emission (PIXE), Rutherford Back Scattering (RBS), Neutron Activation Analysis (NAA) and their applications, Gamma-ray Spectroscopy: Energy, Intensity, Angular correlation and Coincidence measurements, development of nuclear level scheme, Lifetime measurements using Doppler Shift Attenuation and Plunger techniques, Charged particles spectroscopy, Time of flight (ToF) technique, Positron Annihilation and Mossbauer Spectroscopy.

Instrumentation:

Production of beam of charged particles using Linear Accelerator and Tandetron Accelerator; Production of neutron using accelerator, Radiation detection using Si(Li), HPGe, Si-Surface Barrier, MCP and Scintillator detectors; Energy and timing signal processing using Pre-Amplifier, Amplifiers, CFD and TAC; Data Acquisition using SCA, MCA , CAMAC based systems.

Suggested reading:

1. S N Ghoshal (1998) Atomic and Nuclear Physics Vol. II, S Chand & Company Ltd.
2. H. Ejiri and M. J. A. de Voigt (1989), Gamma-ray and Electron Spectroscopy in Nuclear Physics,Oxford Studies in Nuclear Physics, Clarendon Press.
3. Glenn F. Knoll (1979), Radiation Detection and Measurements, John Wiley & Sons.
4. K. Siegbahn (1965) Alpha-, Beta- and Gamma-Ray Spectroscopy Vol. 2, North-Holland Publ. Company.
5. S E Johansson, J L Compbell, K G Malmquist (1923), Particle Induced X-Ray Emission Spectroscopy, Vol 133, John Wiley & Sons.
6. W. R. LEO (1987) Techniques for Nuclear and Particle Physics Experiments, Springer Verlag.

PHPR -15 : THEORETICAL HIGH ENERGY PHYSICS

Credit: 03

Introduction to Quantum Field theory: Introduction to Klein-Gordon and Dirac equations, solutions and antiparticles, γ-matrices, bilinear covariants, spin and helicity, two component theory of neutrinos.

Canonical quantization of scalar, electromagnetic and Dirac fields; interacting fields: $\lambda\phi^4$ theory.

Introduction to quantum electrodynamics (QED), Feynman diagrams and Feynman rules.

Introduction to Particle Physics: Parton model of hadrons, Bjorken scaling, quark confinement, colour and quark-gluon interactions, quantum chromodynamics (QCD), asymptotic freedom.

V-A theory of weak interactions, weak interactions of quarks, neutral weak interactions; massive neutrinos and neutrino oscillations; Introduction to Electroweak unification.

Suggested reading:

1. D.J. Griffiths, (1987), Introduction to Elementary Particles, John Wiley & Sons
2. F. Halzen and A D Martin, (1984), Quarks and Leptons, John Wiley & Sons
3. A. Lahiri and P B Pal, (2001), A first book of Quantum Field Theory, Norosa
4. A. Das, (2008), Lectures on Quantum Field Theory, World Scientific
5. M E Peskin and D V Schroeder (2005), An Introduction to Quantum Field Theory, West view Press
6. I J R Aitchison and A J G Hey, (1982), Gauge Theories in Particle Physics (Vol. I), Adam Hidger
7. D H Perkins,(1987), Introduction to High Energy Physics, Addition Wesley

PHPR 16 : EXPERIMENTAL HIGH ENERGY PHYSICS

Credit: 03

High Energy Physics Accelerators:

Classification of accelerators, principle and design of ion-sources, Linear accelerators, Large Hadron Collider (LHC), Relativistic Heavy Ion Collider (RHIC), Tevatron, storage rings.

Detectors for ionization and track measurements:

Detection of charged particles, ionization chambers, proportional counters, muti-wire proportional counters (MWPC), drift chambers, Particle measurements in liquids.

Particle Identification: Cherenkov radiation in anisotropic and optically active media, Cherenkov radiation and bremsstrahlung, Cherenkov detectors, Classification of Cherenkov detectors (focusing and non-focusing type), transition radiation detectors; Choice of photomultiplier, Comparison of particle identification methods.

Data Analysis: Input from detectors for data analysis, Pattern recognition and track reconstruction, Event reconstruction, Event generators, Detector simulation.

Suggested reading:

1. T Ferbal, (1991), Experimental Techniques in High Energy Nuclear and particle Physics:World Scientific, Singapore.
2. F. Sauli, (1992), Instrumentation in High Energy Physics, World Scientific, Singapore.
3. G.F. Knoll, (1979), Radiation detection and measurement, John Wiley & Sons Inc, New York
4. D.M. Ritson, (1961), Techniques of High Energy Physics, Interscience Publishers Inc., New York.