Course Structure and Scheme of the Programme

Ph.D Physics

S.No.	Course Code	Course Title	Teaching Schedule			Duration of Exam. (hr.)	No. of Credit
			Lecture	Tutorial	Practical		
1.	PH –601	Advanced Quantum Mechanics	3	-	-	3	3
2.	PH - 602	Advanced Particle Physics	3	-	-	3	3
3.	PH - 603	Advanced Nuclear Physics	3	-	-	3	3
4.	PH-604	MHD AND Plasma Physics	3	-	-	3	3
5.	PH –605	Physics of Laser Plasma Interactions	3	-	-	3	3
6.	PH- 608	Advanced Computational Techniques	3	-	-	3	3
7.	PH- 609	Digital Signal Processing	3	-	-	3	3
8.	PH- 610	Voice over Internet Protocol (VoIP)	3	-	-	3	3
9.	PH- 611	Advanced Radiation Physics – I	3	-	-	3	3
10.	PH- 612	Advanced Radiation Physics – II	3	-	-	3	3
11.	PH- 613	Experimental Techniques	3	-	-	3	3
12.	PH- 614	Liquid Crystals	3	-	-	3	3
13.	PH- 615	Dispersed Liquid Crystals	3	-	-	3	3
14.	PH-616	Properties of Oxides	3	-	-	3	3
15.	PH-617	Thin Film Technology	3	-	-	3	3
16.	PH-618	Carbon Nanotechnology – I	3	-	-	3	3
17.	PH-619	Carbon Nanotechnology – II	3	-	-	3	3
18.	PH- 505	Electrical and Magnetic Properties of Materials	3	-	-	3	3
19.	PH-556	Nano Materials	3	-	-	3	3

PH – 601 Advanced Quantum Mechanics

Preliminaries to a Quantum Field Theory: Relativistic wave equations (Klein Gorden Equation and Dirac Equation) ; Covariant form of Dirac Equation, Spin and Magnetic moments of Dirac Particles, Solution of Dirac Equation, Normalisation of the Dirac Equation, Orthogonality condition for the Dirac Spinors, Dirac Equation for a Particle of zero mass, Lorentz Transformation and the Dirac Equation, Parity and the Dirac Wavefunction, Dirac Bilinear Covariants, Development of Classical Field Equations : Equation for a Classical Relativistic field, Energy and momentum of a field, Noether's Theorem and its applications.

Quantum Theory of Non interacting Fields: Types of quantised field Theories, Klein Gorden (Scalar) Field and its quantization, Total energy and momentum operators for the Scalar Fields, Quantisation of scalar field and its physical interpretation and its Plane Wave representation, The Classical Electromagnetic (Vector) Field , Quantisation of Electromagnetic Field and its physical interpretation , The plane wave representation of the Dirac (Spinor) Field, Hamiltonian Operator for the Dirac Field, Quantisation of Dirac Field, Charge and Current operators for the Dirac Field, Covariant Commutation Relations.

The Interaction of Fields : S matrix, Transition Amplitude, The Transition Probability, photon – electron interaction, Properties of Transition Amplitude, Specific forms of S Matrix, Covariant Perturbation Theory, Ordering Theorems, Feynman Graphs, Graphs in Momentum Space, Evaluation of some S Matrix elements.

Books Recommended:

1. J.J. Sakurai, "Modern Quantum Mechanics", Pearson Publication.
2. J.J. Sakurai, "Advanced Quantum Mechanics', Pearson Publication.
3. F. Mandl and G. Shaw, "Quantum Field Theory", John Wiley Publication.
4. H.Muirhead, "The Physics of Elementary Particles", Pergamon Press Publication.

PH - 602 Advanced Particle Physics

Unitary Symmetries: Introduction to Symmetries, Lie-algebra and fundamental representations of the Symmetry groups SU(2), SU(3) and SU(N). Applications of symmetry groups to hadron spectroscopy.

Quark Model of Hadrons: Quark Statistics and Color, Octet and Decuplet of Baryons, Mesons, Applications of Quark Model.

Heavy Flavor Quarks and Quarkonium: Charm and Charmed States, Charm particle Decays, *b*-Quark, Quarkonium, Leptonic and Hadronic Decay width.

Color, Non-Abelian Gauge Field and QCD: Introduction to gauge field theories, Abelian transformations: U(1) Gauge symmetry, Spontaneous symmetry breaking, Non-Abelian gauge field, Elements of QCD.

Weak Hadronic Currents and Chiral Symmetry: Four-Fermion Weak Coupling, Strangeness non-changing Decays: V-A law, Strangeness changing Decays, CVC and PCAC, Current Algebra and Chiral Symmetry.

Unification Schemes: Glashow-Weinberg-Salam model, Electroweak model, Standard model, GUTS, Supersymmetry. Recent developments.

Books Recommended:

1. Litchtenberg, “Introduction to Unitary Symmetry”, Addison Wesley, Reading.
2. F.E. Close, “Introduction to Quarks and Partons”, Academic Press, London.
3. M.P. Khanna, “Introduction to Particle Physics”, Prentice-Hall of India, New Delhi.
4. C. Quigg, “Gauge Theories of Weak, Strong and Electromagnetic Interactions”, Gorden & Breach, New York.
5. T.P Cheng and L.F. Li, “Gauge Theory of Elementary Particle Physics”, Oxford University Press, Oxford.
6. F. Halzen and A.D. Martin, “Quarks and Leptons: An Introductory Course in Modern Particle Physics”, John Wiley and Sons, USA.

PH - 603 Advanced Nuclear Physics

Nuclear Interactions: Nuclear force: Two nucleon system, deuteron problem, nuclear potential well, pp and pn scattering experiments at low energy, meson theory of nuclear force, e.g. Bartlett, Heisenberg, Majorana forces and potentials, exchange forces and tensor forces, effective range theory-spin dependence of nuclear force, Charge independence and charge symmetry of nuclear forces-Isospin formalism, Yukawa interaction.

Nuclear Models: Liquid drop model, Bohr-Wheeler theory of fission, Experimental evidence for shell effects, Shell Model, Spin-Orbit coupling, Magic numbers, Applications for Shell model like Angular moment and parities of nuclear ground states, Quantitative discussion and estimates of transition rates, magnetic moment and Schmidt lines, Collective model-nuclear vibrations spectra and rotational spectra, Nilson Model, Shape Fluctuation Model, Asymmetric Rotor Model, Interacting Boson Model.

Nuclear Decay: Beta decay, Fermi theory of beta decay, shape of the beta spectrum, Total decay rate, Comparative half-lives, allowed and forbidden transitions, selection rules, parity violation, Two component of neutrino decay, Detection and properties of neutrino, Gamma decay, Multipole transitions in nuclei, angular momentum, Internal conversion, Nuclear isomerism.

Nuclear Reactions: Conservation laws of nuclear reactions, Energetics of nuclear reactions, Direct and compound nuclear reactions mechanism, Breit-Wigner Formula, Nuclear reactions induced by heavy ions, Mechanisms of photo-nuclear reactions, scattering matrix.

Books Recommended:

1. Bohr A and Mottelson B R, “Nuclear Structure”, Vol. 1 (1969) and Vol. 2 (1975), Bengamin, Readings, A.
2. Krane K S, “Introductory Nuclear Physics”, Wiley Eastern, New York, 1988.
3. Roy R R & Nigam B P, “Nuclear Physics”, New Age International, New Delhi.
4. Irving Kaplan, “Nuclear Physics”, Addison Wesley, New Delhi.
5. Pal M K, “Theory of Nuclear Structure”, East West Press Pvt. Ltd., New Delhi.
6. Hans H S, “Nuclear Physics: Experimental and Theory”, New Age International, New Delhi, 2001.
7. Iachallo F and Arima A “The Interacting Boson Model”, Cambridge University Press, Cambridge, 1987.

PH-604 MHD AND PLASMA PHYSICS

Plasmas As Fluids: Introduction, Relation of Plasma Physics to Ordinary Electromagnetics, The fluid equation of motion, Fluid drifts perpendicular to B, Fluid drifts parallel to B, The plasma approximation.

Diffusion and Resistivity: Diffusion and mobility in weakly ionized gases, Decay of a 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 β, 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 f(v), Equations of kinetic theory, Derivation of the fluid equations, Plasmas Oscillations and landau damping, The meaning of landau damping, A physical derivation of landau damping, BGK and van kampen modes, Experimental verification, Ion landau damping, Kinetic effects in a magnetic field.

Books Recommended:

1. Francis F Chen, "Plasma Physics and Controlled Fusion", Springer.
2. Bittencourt J A, "Plasma Physics", Springer.
3. Richard Dendy, "Plasma Physics An Introductory Course", Cambridge University Press.

PH – 605 Physics of Laser Plasma Interactions

Basics Concepts and Two-Fluid Description of Plasmas: Basics plasma concepts, The vlasov equation, The moment equations, The two-fluid description of plasma, Plasma waves, Debye shielding.

Electromagnetic Wave Propagation in Plasmas: Wave equation for light waves in a plasma, WKB solution for wave propagation in an inhomogeneous plasma, analytic solution for plasma with a constant density gradient.

Parametric Excitation of Electron and Ion Waves: Coupling via ion density fluctuations, The ponderomotive force, Instabilities – A physical picture, Instability analysis, Dispersion relation, Instability threshold due to spatial inhomogeneity, Effect of incoherence in the pump wave.

Stimulated Raman Scattering: Instability analysis, Dispersion relation, Instability thresholds, The $2\omega_{p2}$ instability.

Stimulated Brillouin Scattering: Instability analysis, Dispersion relation, Instability thresholds, The filamentation instability.

Books Recommended:

1. William L Kruer, “The Physics of Laser Plasma Interaction”, Addison Wesley Publishing Company.
2. Shalom Eliezer, “Interaction of High Power Lasers with Plasmas”, Taylor & Francis, Dec. 2001.

PH- 608 Advanced Computational Techniques

Solution of non-linear equations: Linear Interpolation Methods, Newton's Method, Muller's Method, Fixed-Point Iteration: *x=g(x)* Method, Newton's Method for Polynomials, Bairstow's Method for Quadratic Factors, system of non-linear equations

Matrix algebra and simultaneous equations: Matrix Notation, The Elimination Method, The Gaussian Elimination and Gauss-Jordan Methods, Pathlogy in Linear Systems-Singular Matrices, Determinants and Matrix Inversion, Norms, Condition Numbers and Errors in Solutions, Iterative Methods, The Relaxation Method, Systems of Nonlinear Equations, Applications of Sets of Equations: Finding the Steady State Temperatures in a Plate, Computing the Forces in a Planar Truss.

Numerical integration and numerical differentiation: Derivatives from Difference Tables, Higher-Order Derivatives, Extrapolation Techniques, Newton-Cotes Integration Formulas, The Trapezoidal Rule, Simpson's Rules, Gaussian Quadrature, Monte carlo Integration, Adaptive Integration, Multiple Integrals, Multiple Integration with Variable Limits, Applications of Cubic Splines, An Applications of Numerical Integration – Fourier Transforms.

Numerical solution of ordinary differential equations: The Taylor-Series Method, Euler and Modified Euler Methods, Runge-Kutta Methods, Multistep Methods, Milne's Method, The Adams-Moulton Method, Convergence Criteria, Systems of Equations and Higher-Order Equations, Comparison of Methods/Stiff Equations.

Numerical solution of Partial Differential Equations: Numerical solution of Elliptic (Laplace and Poisson equation), parabolic (convection-diffusion equation) and hyperbolic (wave equations) partial differential equations using finite difference method, finite element method, Numerical solution of Schrodinger equation: Numerov method

- Students have to develop the programs for above numerical methods using the programming language which they will use for their research work

Books Recommended:

1. Curtis F. G. and Patrick O. W. "Applied Numerical Analysis", Pearson Education (Singapore) Pvt. Ltd.**,** Delhi, 2002.
2. Hamming R.W. "Numerical Methods for Scientists and Engineers", McGraw-Hill, New York, 1973.
3. Hoffman J. D., "Numerical Methods for Engineers and Scientists", Marcel Dekker, Inc., 2001
4. Steven C Chapra, Raymond P Canale "Numerical Methods for Engineers", Tata McGraw- Hill Education

PH - 609 Digital Signal Processing

An introduction to signals and systems, and representation of signals in time domain; Linear, time-invariant systems, impulse response and convolution sum; Linear constant-coefficient difference equation, Fourier transform and frequency response; z- transform and its properties; Discrete Fourier transform (DFT); Signal analysis and synthesis based on DFT; Matrix representation of digital network.

Books Recommended:

1. A.V. Oppenheim and R.W., Schafer Digital Signal Processing, Prentice Hall, 1986
2. J.G. Proakis and D.G. Manolakis, Digital Signal Processing -- Principles, Algorithms, and Applications, Prentice Hall, 1996
3. C.S. Burrus and et al, Computer-Based Exercises for Signal Processing Using MATLAB, Prentice Hall, 1994.

PH-610 Voice over Internet Protocol (VoIP)

Classes of speech, sampling, quantization, Coding - P~M, DPCM, ADPCM, CVCD modulation, Vocoding, Hybrid coding, Digital speech interpolation, Telephony-signaling, components of phone system, Numbering plans, VoIP and VoIP phone

Introduction to networking - ISOIOSI network model, *TCP/IP* network model, Routing & Switching - Address Resolution Protocol CARP), IP, TCP, UDP & ICMP packets, Call and Session Control Protocols - SIP, MGCP

VoIP security protocols - SIP Security, confidentiality of media data in SIP, MGCP security considerations, Voice Transport Protocols - RTP, TCP & UDP, RTCP, SCTP, TFTP VoIP Processing - Voice packetization, compression, Jitter, timing latency, VoIP call setup protocols, Voice streaming protocols, VoIP gateways, Routers & Switches VoIP implementation

Books Recommended:

1. Jonathan Davidson, Voice over IP Fundamentals, Cisco Press, 2006
2. Walker, J. & Hicks J., Taking Charge of Your VoIP Project, Cisco Press, 2004. -
3. Keagy Scott, Integrating Voice and Data Networks, Cisco Press, 2000.

PH-611: Advanced Radiation Physics - I (3-0-0)

Radioactive Spectroscopy with Scintillators: General Consideration in Gamma Ray Spectroscopy, Gamma ray Interaction, Predicted Response Functions, Properties of Scintillation Gamma Ray Spectrometers, Response of Scintillation Detectors to Neutrons, Electron Spectroscope with Scintillators, Specialized Detector Configuration Based on Scintillation, Germanium Gamma Ray Detectors, General Considerations, Configurations of Germanium Detectors, Germanium Detector Operational Characteristics, Gamma-Ray Spectroscopy with Germanium Detectors

Dosimetry: Quantities describing radiation beam, kerma and absorbed dose, charged particle equilibrium, Bragg-Gray and Spencer-Attix cavity theory, AAPM protocols for dose measurements.

External radiation protection: Shielding of Alpha, Beta particles and photon sources, dose equivalent and structural shielding design.

Suggested Books:

1. A Primer In Applied Radiation Physics by F. A. Smith, World Scientific Publishing Company, ISBN-13: 978-9810237127.

2. Radiation Detection and Measurement *by Glenn Frederick Knoll.* Publisher: Wiley, John & Sons, ISBN-13: 9780471073383.

3. Natural Radiation Environment by John Adams. Publisher: University of Chicago Pr (Tx) ISBN-10: 0226005968, ISBN-13: 978-0226005966

4. Solid State Nuclear Track Detectors (Journal of Nuclear Tracks, Methods, Instruments & Applications, Supplement) By Peter H. Fowler And V. M. Clapham . Publisher: Pergamon, ISBN-10: 008026509X, ISBN-13: 978-0080265094

5. Modern Physics by G. Aruldhas and P. Rajgopal, Publisher: PHI. ISBN-81-203-2597-4.

6. Modern Physics by Kenneth Krane, Publisher: Wileyindia Pvt. Ltd., ISBN-81-265-0826-4.

PH-612:- Advanced Radiation Physics - II (3-0-0)

Counting statistics: statistical distributions, counting radioactive samples, critical levels of detection.

Measurement of Radon in Air, water and soil: Working Level Month (WLM), Life Time Fatality Risk, Dose, DSAABC Method, Alpha Guard, RAD 7, SSNTD, Radon Exhalation Rate.

Measurement of Uranium, Radium, Thorium and Potassium in soils: Gamma Ray Spectroscopy, HPGe detector, NaI detector, Fission Track Registration technique.

Measurement of Uranium content in water.

Effects of Ionising Radiations, Induction of cancers, Risk Assessments, Risk factors for cancers, Hereditary disease, Communal risk, Other late effects, Irradiation in pregnancy, System of Radiological Protection, Central principles, Scope of application, Justification of practices, Optimisation of protection, Limitations of doses, Constraints, Comparing risks, Legal controls.

Medical uses of ionizing radiation, Diagnostic radiology, Nuclear medicine, Radiotherapy, Reference doses, Total doses, Occupational exposure to ionizing radiation, Artificial sources, Natural sources, Total doses, Environmental pollution, Weapons tests, Chernobyl accidents, Radioactive discharge, Total doses.

Suggested Books:

1. Radon Measurements by Etched Track Detectors. Edited By Saeed A Durrani & Radomir Ilic . Publisher: World Scientific, ISBN: 981-02-2666-7.

2. A Primer In Applied Radiation Physics By F. A. Smith, World Scientific Publishing Company, ISBN-13: 978-9810237127.

3. ICRP Publication 65: Protection Against Radon-222 At Home And At Work, 65, Annals Of The ICRP Volume 23/2 By International Commission On Radiological Protection. ISBN-13: 978-0-08-042475-0, ISBN-10: 0-08-042475-9.

4. Radiation Detection and Measurement *by Glenn Frederick Knoll.* Publisher: Wiley, John & Sons, ISBN-13: 9780471073383.

5. Natural Radiation Environment by John Adams. Publisher: University of Chicago Pr (Tx) ISBN-10: 0226005968, ISBN-13: 978-0226005966.

PH-613 Experimental Techniques

Light/Optical Microscopy:
Optical Microscope – basic principles & components, different examination modes (bright field illumination, oblique illumination, dark field illumination, phase contrast, polarized light, hot stage, interference techniques), stereomicroscopy, photo-microscopy.

Surface Analysis:
Atomic force microscopy, Scanning, Tunneling microscopy, Secondary ion mass spectrometry, Auger electron spectroscopy, X-ray photoelectron spectroscopy, image analysis.

Thermal Analysis:
Differential thermal analysis, Differential scanning calorimetry and Thermo-grayimetric analysis. Fourier transform infrared spectroscopy. Ultraviolet visible spectrophotometer.

Electron Microscopy:
Interaction of electrons with solids, Scanning Electron Microscopy and specimen preparation techniques, Wavelength dispersive spectroscopy.

Diffraction Methods:

Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, X-ray methods of analysis including powder diffraction, Wavelength and energy dispersive X-ray fluorescence (XRF).

Radiation analysis: Raman analysis and spectroscopy, Photo luminance, Photo multiplier tube, LINAC.

Recommended Books:

1. Materials Characterisation, Metals Hand Book, 9th edition, Vol 10.
2. Cullity, B.D., “Elements of X-ray Diffraction”, Addision Wesley Publishingh Co., Massachusetts, 1968.
3. Phillips, V.A., “Modern metallographic techniques and their applications”, Wiley Interscience, 1971.
4. Cherepin and Malik, “Experimental Techniques in Physical Metallurgy:, Asia Publishing Co. Bombay, 1968.
5. Brandon D.G., “Modern Techniques in Metallography”, VonNostrand Inc. NJ. USA, 1986.
6. Thomas G., “Transmission electron microscopy of metals”, John Wiley, 1996.
7. Weinberg F., “Tools and Techniques in Physical Metallurgy”, Volume I & II, Marcel and Decker.

PH-614 Liquid Crystals

Ferroelectrics and Dielectrics:

Introduction, Polarization mechanism, Structure, Experimental criteria of ferro-electricity, Ferro-electricity and order and disorder theory, Thermodynamic theory, Relaxation mechanism, Relaxation in electrical circuits, Relaxation in dielectric material. Method of evaluation of dielectric measurements, dielectric parameters measurement and their interpretation.

Liquid Crystal:

Classification of liquid crystals (LC), Thermotropic, Lyotropic, LC phases: Nematic, Smectic, cholestric, Ferroelectric liquid crystal, Chiral nematic LC, Molecular structure and engineering. Physical and chemical properties of liquid crystal. Electric & Magnetic effects, Optical properties of liquid crystal, Liquid crystal displays, various displays organic LED plasma, LC addressing, Application.

Sample fabrication:

Fabrication of liquid crystal cells, Alignment methods, Homogenous and homotropic technique materials for LC cell fabricatons, LC material requirements.

Structure and physical properties:

Polarizing microscopy, Scanning electron microscopy and transmission electron microscopy, Atomic force microscopy, Thermal Studies: Temperature controller, Differential scanning calorimetry, Fourier transform infrared spectroscopy, Ultra-violet visible spectrophotometer. Electro-optic properties: Spontaneous polarization, Switching time, Threshold voltage measurement, Dielectric studies: permittivity, Relaxation modes and Frequency, Optical properties, Contrast ration, rise time, fall time.

Recommended Books:

1. Introduction to Liquid crystal Chemistry and Physics: Peter J. Cooling and M. Hird, Taylor and Francis, (1997).
2. The physics of Liquid Crystals, P.G. De. Gennes, Oxford University Press, (1993).
3. Liquid Crystals, 2nd edition, S. Chandrasekhar, Cambridge University Press, (1992).
4. Dielectric relaxation , V.V. Daniel, Academic Press London (1967).

PH-615 Dispersed Liquid Crystals

Polymer Dispersed Liquid Crystals:

Preparation methods: Polimerization induced phase separation. Thermally induced phase separation. Solvent induced phase separation. Polymers physical properties. Nematic and Ferroelectric and antiferroelectric PDEC films, choletric PDEC. Polymer stabilized liquid crystal, Droplet configuration: Bipolar, Maltese. Torodial, radial: Droplets orientation, Electroclinic-effects, Surface anchoring, Structure property relations.

Dyes-Liquid Crystal Composite:

Dichroic dyes, chemical and physical properties. Guest Host Displays, nematic dye doped IC films, ferroelectric dye dopes LC films. Scattering phenomenia, principle of dichroic displays, Field and temperature effects.

Nanomaterial-Liquid Crystal Composite Films:

Nanomaterial, classification of nanomaterial, Carbon nanotubes, synthesis routes, physical mechanical, electrical and thermal properties, synthesis of CNT liquid crystal films, preparation methods, polarizing microscopy, electrical, optical, thermal studies.

Recommended Books:

1. Liquid Crystal Dispersion, P.S. Drazic, World Scientific, Singapore, (1995).
2. Non Linear Optical, Properties of LC & PDLCs, F. Simoni, World Scientific, Singapore, (1997).
3. Liquid Crystal Displays, B.Bahadur, Gorden and Breach Science Publishers, Volume 109, No. 1 (1994).
4. Carbon Nanotube Properties and Application, Michael J.O. Chonnell, Taylor and Francis, (2006).

PH-616 Properties of Oxides [3-0-0]

1. **Electronic Structure:** Crystal field theory, orbital degeneracy and Jahn-Teller Effect, charge transfer and band gaps. Cluster models: molecular orbital method and configuration interaction model. Band structure, conduction electron properties, magnetic band structure, Peierls instabilities Fermi surface nesting. Intermediate models: Hubbard model, excitons, impurity states, Anderson localization and Polarons.
2. **Insulating Oxides:** Spectroscopic transitions, dielectric and non-linear properties, Closed shell oxides, transition metal impurities, their spectroscopic properties, charge transfer and impurity-state energies, interaction between impurities. Magnetic insulators: their properties, band gap, magnetic ordering, exchange interactions, GKA rules, orbital ordering.
3. **Defects in semiconductors:** Donor/acceptor ionization energy, transport properties, activation energy, thermal properties, point-defect model, law of mass action, defect mobility and diffusion. Carrier binding energies and spectroscopy. Metal-insulator transition, heavily doped oxides, models of the transition.
4. **Metallic oxides:** Band structure and Fermi surface, transport properties, optical and spectroscopic properties. Band magnetism, mixed valency and double exchange. Mott transition and chemical trends, Fermi surface instabilities, metal-metal bonding, charge ordering and disproportionation.

Books

1. "Transition Metal Oxides", P. A. Cox, Clerendon Press, Oxford (1995).
2. "Spin Electronics", Michael Ziese Martin J. Thornton (Eds.), Springer-Verlag Berlin (2001).
3. "Spintronics: From GMR to Quantum Information", Stefan Blügel, Daniel Bürgler, Markus Morgenstern, Claus M. Schneider, Rainer Waser (Eds.), 40^{th} Spring School, Jülich (2009).

PH-617 Thin Film Science and Technology [3-0-0]

High Vacuum Production

Fundamentals of vacuum, Mechanical pumps, Diffusion pump, measurement of vacuum, gauges, production of ultra high vacuum, thin film vacuum coating unit, substrate cleaning

Evaporation Theory

Hertz-Knudsen equation, Free evaporation and effusion, evaporation mechanism for liquids and crystalline solids. Directionality of evaporation molecules, Cosine law of emission. Emission from a point source. Mass of material condensing on the substrate.

Preparation of Thin Films

Chemical methods: Qualitative study of preparation of thin films by Electroplating, vapor phase growth and anodization. Physical methods: Vacuum evaporation, study of thin film vacuum coating unit, construction and uses of vapor sources-wire, sublimation, crucible and electron bombardment heated sources. Arc and laser evaporation. Sputtering, study of glow discharge, physical nature of sputtering, sputtering yield, experimental set up for DC sputtering, AC sputtering and RF sputtering.

Thickness Measurement and Monitoring

Multiple beam interference, quartz crystal, ellipsometric, stylus technique. Characterization: X-ray diffraction, electron microscopy, high and low energy electron diffraction, ESCA, EPMA, Auger emission spectroscopy.

Growth and Structure of Films

General features, nucleation theories, post-nucleation growth, thin film structures, structural defects.

Recommended Books:

1. Ohring M “Materials Science of Thin Films”, Academic Press, 2001.
2. Seshan K “Handbook of Thin-Film Deposition Processes and Techniques”, Noyes Publications, 2002.

PH-618 Carbon Nanotechnology-I [3-0-0]

Introduction:- From conventional technology to Carbon nanotechnology, Polymorphism and structure of Carbon, Thermodynamic stability and associated phase diagram, New predicted phases, New carbon structures; Carbon clusters, discovery of C60, structure of C60, Fullerenes, Graphene, Carbon Nanotubes, Electronic structure of Carbon Nanotubes :- Vector notation, Unit cell, Nanotube capping, Classification of CNTs, Bonding in carbon materials, Physical stability of carbon nanotubes.

Physics of carbon nanotubes: - Electronic properties of graphite, carbon fiber and carbon nanotubes, Dependence of electronic properties of CNTs on their structure, Magnetic properties of carbon nanotubes, Vibrational properties of nanotubes.

Synthesis, Growth Mechanisms and Processing of Carbon Nanotubes: - Synthesis techniques for Single Walled CNTs and Multi Walled CNTs: Arc Discharge, Laser Ablation, Chemical Vapor Deposition and Flame Synthesis Techniques. Growth Mechanisms: Bottom Up and Top Down approaches, Purification and Separation of CNTs and related aspects.

Structural analysis of Carbon Nanotubes using different imaging and spectroscopic techniques: - XRD, SEM, TEM, AFM, Raman spectroscopy.

Carbon Nanotubes: Surface, Porosity and related applications:- Adsorption in carbon nanotubes, Porous structure of CNTs, Surface characterization of CNTs, Capillarity and Filling in carbon nanotubes, Related applications- Hydrogen storage, Lithium storage in carbon nanotubes, CNT based electrodes for super capacitors.

Books:-

1. Carbon Nanotechnology: Liming Dai, Elsevier
2. Carbon Nanotubes and Related Structures: Peter F Harris, Cambridge University Press
3. Understanding Carbon Nanotubes: From Basics to Applications, Springer

PH-619 Carbon Nanotechnology-II [3-0-0]

Functionalization and based applications of Carbon nanotubes:- Introduction, Covalent Functionalization, Functionalization of CNT outer wall and inner wall, Non Covalent Functionalization of carbon nanotubes, Functionalization of CNTs with other physical and chemical methods, Effect of functionalization on electronic properties, Potential applications of modified carbon nanotubes.

Electrochemical properties of Carbon Nanotubes: - Carbon nanotubes based electrodes, Sensors, Energy storage, Batteries, Electro Mechanical actuators.

Carbon Nanotubes as Nanoelectromechanical Systems:- Nanoelectromechanical Systems, Mechanical properties of CNTs, Carbon nanotubes in tension and compression, Plastic responses and failure of CNTs, Deformation of carbon nanotubes, Carbon nanotubes junctions, Relation between electronic and mechanical properties of carbon nanotubes, Carbon nanotube based electronic devises.

Thermal Properties of Carbon nanotubes: - Specific heat, Thermal conductivity, its variation with temperature, length, chirality and diameter. Effect of physical and chemical modifications.

Carbon nanotubes and Epoxy composites:- CNT/ Epoxy composites, Structure-Property relation, Nanocomposite stiffness and strength, hardness, fracture toughness, Enhanced properties of Nanocomposites- electrical, thermal, mechanical, Military applications- Multifunctional smart materials, Coatings, adhesives, Polymer and carbon nanotube composite for space applications.

Books:-

1. Carbon Nanotechnology: Liming Dai, Elsevier
2. Carbon Nanotubes and Related Structures: Peter F Harris, Cambridge University Press
3. Understanding Carbon Nanotubes: From Basics to Applications, Springer

PH- 505 ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS [3-0-0]

Electrical conduction: Conductivity - Classical and quantum mechanical considerations, experimental results and their inter-pretation; Pure metals, Alloys, Ordering, Thermoelectric phenomena, Distribution Functions, Free electron theory, Fermi Energy, Metallic conduction, Band Theory-Konig-Penney Model, Brillouin zones, Temperature dependence of metallic conductivity, Impurity contributions, Semiconductor materials, p-n junctions, Electrical resistivity and Hall effect measurements, Semiconductor technology, Diffusion phenomena, Ionic conduction, Super ionic conductors and devices.

Dielectric properties: Dielectric polarization, Polarization mechanisms, Complex dielectric coefficient, Frequency dependence of electronic polarizability. Dielectric loss, Dielectric parameters and their measurements, Electrets and their applications. Dielectric breakdown, Mechanisms of dielectric breakdown. Experimental determination of dielectric strength.

Magnetic properties of materials: Foundation of magnetism, Basic concepts in magnetism, Magnetic phenomena and their interpretation, Dia, para-ferro-, ferri-and antiferro magnetism, Molecular field theory, Magnetostriction effect, Measurement of magnetic properties, Soft and hard magnetic materials and their technology, Nuclear magnetic moments, Determination of nuclear magnetic moments.

Books Recommended:

1. Hummel R. E. “Electronic Properties of Materials”, Narosa Publishing House, New Delhi, 1997.
2. Jastrzebski Z.D. ”The Nature and Properties of Engineering Materials”, John Wiley and Sons, 1976.
3. Cullity B.D. “Introduction to Magnetic Materials”, Addision-Weslay MA, 1972
4. Azaroff L.V. “Introduction to Solids”, Tata McGraw Hill, New Delhi, 1992.

PH-556 NANO MATERIALS [3-0-0]

Synthesis and processing: Nano particles from low- pressure, Low temperature plasmas and its applications, Low temperature compaction of nanosize powders, Nanofabrications with atom optics, Processing of nanocrystalline materials. Vapour processing of nanostructured materials.

Electrical properties: Quantized states in low-dimensional systems, Self-consistent treatment of one- and two- dimensional problems, Quantum wires- magnetosize effects and weak localization; magnetophonon reaonances; vertical tunneling, Quantum dots-fabricated quantum dots; impurity dot system; energy states, Current-voltage characteristics, Vertical transport through quantum dots.

Magnetic properties: Magnetic field profile, quantum motion in nonhomogeneous magnetic fields, Diffusive transport of electrons through magnetic barriers, One- and two- dimensional magnetic modulation, Hall effect devices, Nanoscale magnets.

Optical properties: Photo refractive quantum well structures and its optical properties, electronic transport and grating formation, Diffraction - Raman-Nath diffraction; nondegenerate four-wave mixing; two- wave mixing, Photorefractive effects and applications, Non-linear optical properties, Non-linear phenomenon – theoretical treatment of optical nonlinearities.

Books Recommended:

1. Nalwa, H.S. “Handbook of Nanostructured Materials and Nanotechnology”, Vol.1, 3 and 4, Academic Press 2000.
2. Ying.J.Y. “ Nanostructured materials”, Academic Press, U.S.A., 2001.