भौतिकी विभाग
मोतीलाल नेहरू राष्ट्रीय प्रौद्योगिकी संस्थान इलाहाबाद
प्रयागराज - 211004 (उ०प्र०), भारत
Department of Physics
Motilal Nehru National Institute of Technology Allahabad
Prayagraj - 211004 (U.P.), India

Ph.D. coursework offered by the Department of Physics and their syllabi

List of courses

1 Advanced Characterization Techniques

Course Code: PH70111 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Need of characterization. Physical parameters for characterization. Basic principles, and description of such techniques as diffraction (X-ray, electron, and neutron), spectroscopy (UV, VIS, IR, and Raman), thermal (DTA, TGA, DSC), electronic (resistivity, Hall effect and TEP), resonance (NMR, EPR and Massbauer), and electron and ion spectroscopy (AES, ESCA, SIMS and RBS). Electron microscopy - SEM and TEM.

References

[1] P.R.Vaya, ed., Semiconductor Materials: Characterization Techniques, Narosa Publishing House

[2] J. B. Wachtman, Zwi H. Kalman, Characterization of Materials, Boston : Butterworth-Heinemann

[3] Elton N. Kaufmann, Characterization of Materials, Wiley-Interscience

[4] W. R. Runyan, Semiconductor Measurements and Instrumentation, McGraw-Hill Kogakusha, Ltd. Tokyo

[5] S. C. Kashyap, ed., Advanced Techniques for Characterization of Materials, IIT Delhi.

2 Science and Technology of Thin Films

Course Code: PH70112 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Nucleation, growth, kinetics and thermodynamics of materials; Physical vapor deposition, Chemical vapor deposition, Plasma / Ion beam deposition, Epitaxial thin films: LPE, MBE, MOCVD; Film formation, Thin film characterization, Inter-diffusion and reaction in thin films, Film formation, structural and physical properties: thickness, composition, morphology, mechanical properties, uniformity, grain size etc., Electrical, Optical and Magnetic properties of thin films, Electrical conduction in thin films- size effects, interface properties.

References

[1] L.I.Maissel and R.Glang, eds., Handbook of Thin Film Technology, Mc Graw-Hill, New York.

[2] K.L.Chopra, Thin Film Phenomena, Mc Graw-Hill, New York

[3] J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York.

[4] A.Goswami, Thin Film fundamentals, New Age International Publishers, New Delhi.

[5] S.M.Sze, VLSI Technology, Mc Graw-Hill, New York.

3 Gas-Sensor Materials

Course Code: PH70113 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Gas sensor materials: Criteria for the choice of materials, Experimental aspects – materials, properties, measurement of gas sensing property, sensitivity and selectivity, response time, LEL and UEL; Gas sensors based on semiconductor devices, thin films and sintered pellets, Gas sensors for detection of hydrogen, hydrocarbon, nitrogen oxides, carbon monoxide, oxygen and carbon dioxide in a variety of ambient gas conditions and temperatures.

References

[1] C.N.R.Rao, A.R.Raju and K.Vijaymohan, "Gas-Sensor Materials", in New Materials, (eds.) S.K.Joshi, T.Tsurute, C.N.R.Rao and S.Nagakura, Narosa Publishing House

[2] M.J.Madou and S.Roy Morrison, Chemical Sensing with Solid state Devices, Academic Press, Inc.

[3] D.Patranabis, Sensors and Transducers, Prentice Hall of India.

[4] P.T.Moseley and A.J.Krocker, Sensor Materials, CRC Press.

4 Non-linear Dynamics and Chaos

Course Code: PH70114 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Dynamical systems: Linear and nonlinear forces; Mathematical implications of Nonlinearity, Linear oscillators and predictability; nonlinear oscillations and bifurcations. Autonomous and nonautonomous systems; dynamical systems a s coupled first-order differential equations: equilibrium points; phase space/ phase plane and phase trajectories: stability, attractors and repellers; limit cycle motion-periodic attractors: Poincare-Bendison theorem; Higher dimensional systems: dissipative and conservative systems: Hamiltonian systems; Bifurcation and Chaos; onset of chaos: sensitive dependence on initial conditions- Lyapunov exponent, Henon map. Chaos in Nonlinear Electronic Circuits: Chaotic Dynamics of the simplest dissipative nonautonomous circuit; Murali-Lakshmanan-Chua (MLC) circuit: Experimental realization, stability analysis, explicit analytical solutions, experimental and numerical studies.

References

[1] S. Strogatz, *Nonlinear dynamics and Chaos* (CRC Press, New York, 2015).

[2] H. Goldstein, *Classical Mechanics* (Narosa, New Delhi, 1990).

[3] E. A. Jackson, *Perspectives of nonlinear Dynamics: Vol. I and II* (Cambridge University Press, UK, 1990).

[4] M. Lakshmanan, and S. Rajasekar, *Nonlinear Dynamics: Integrability, Chaos and Patterns* (Speringer-Verlag, New York 2003).

[5] M. Lakshmanan, and K. Murali, *Chaos in Nonlinear Oscillators: Controlling and Synchronization* (World Scientific, Singapore, 1996).

[6] N. Minorsky, *Nonlinear Oscillations* (Van Nostrand, New Jersey, 1962).

[7] A. H. Nayfeh, and D. T. Mook, *Nonlinear Oscillations* (Wiley, New York, 1979).

[8] J. Gleick, *Chaos: Making a new science* (Viking, New York, 1987).

[9] R. J. Field, and L. Gyorgyi (Eds.), *Chaos in Chemistry and Biochemistry* (World Scientific, Singapore, 1993).

[10] P. Hagedorn, *Nonlinear Oscillations* (Oxford University Press, Oxford, 1988).

[11] P. Gladdening, *Stability, Instability and Chaos* (Cambridge University Press, Cambridge 1994).

[12] M. Tabor, *Chaos and Integrability in Nonlinear Dynamical Systems: An Introduction*, (John-Wiley, New York, 1989).

5 General Relativity and Black Hole Physics

Course Code: PH70115 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Brief review of Special Relativity, manifolds and analysis on manifolds, affine conection, curvature and torsion, Cartan's structure equations, Levi-Civita connection, principle of equivalence, gravitation as spacetime curvature, physics in curved spacetime, Einstein equations, Einstein-Hilbert action, Lie derivatives, isometries and Killing vectors, vierbeins, coupling of fermion to gravitational field, Palatini form, Post-Newtonian formalism, Schwarzschild solution and Black holes, Birkoff theorem, charged black holes(Reissner-Nordstrom), rotating black holes(Kerr solution), ADM energy, Black hole thermodynamics, Hawking Radiation, Black holes in higher dimensional spacetime.

References

[1] S. Carroll, *Lecture Notes on General Relativity* (arXiv:gr-qc/9712019).

[2] S. Weinberg, *General Relativity and Cosmology: Principles and applications* (John Wiley & Sons, 1972).

[3] S. Carroll, *Spacetime and Geometry: An introduction to General Relativity* (Addison- Wesley, 2004).

[4] P. K. Townsend, *Black Holes: Lecture notes* (arXiv:gr-qc/9707012).

[5] L. Susskind and J. Lindesay, *An Introduction to Black Holes, Information And The String Theory Revolution: The Holographic Universe* (World Scientific Publishing Company, 2005).

6 Physics of the Early Universe

Course Code: PH70116 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** PH70115

Expanding Universe, large scale isotropy and homogeneity, cosmic microwave background radiation, matter density, dark matter, dark energy, Robertson-Walker metric, Friedmann equation, horizons, phase transitions in Early Universe, Big-bang nucleosynthesis, problem with standard hot big-bang cosmology, inflationary paradigm, inflation and scalar fields, modeling the inflaton field, the amount of inflation, observational tests of inflation. Cosmological perturbation theory and large scale structure formation.

References

[1] E. W. Kolb and M. S. Turner, *The Early Universe* (Westview Press, 1994).

[2] A. R. Liddle and D. H. Lyth, *Cosmological Inflation and Large Scale Structure* (Cambridge University Press, 2009).

[3] J. A. Peacock, *Cosmological Physics* (Cambridge University Press, 1999).

[4] P. Coles and F. Lucchin, *Cosmology: The Origin and Evolution of Cosmic Structure* (John Wiley & Sons Ltd., 2002).

7 Introduction to Quantum Field Theory

Course Code: PH70117 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Quantum mechanics of many particle systems, necessity of the concept of fields, classical field theory, principle of least action, symmetries and conservation laws, energy-momentum tensor, internal symmetries, Noethers's theorem, Poincare group and its irreducible representation, spin zero particle and Klein-Gordon equation, Green function. Free scalar fields and canonical quantization, propagators. Interacting fields and perturbation theory, interaction picture, time-evolution operator, S-matrix, Wick's theorem, Dyson's formula, Feynman rules and Feynman diagrams, Feynman Rules for Phi4 theory and scattering amplitudes. Path-integral quantization : application to QED and non-Abelian gauge theory. Sample Feynman diagram calculation in gauge theory.

References

[1] M. Peskin and D. Schroeder, *An Introduction to Quantum Field Theory* (Perseus Books Publishing, 1995).

[2] P. Ramond, *Field Theory: A Modern Primer*, (The Benjamin/Cummings Publishing Company, 1981).

[3] L. Ryder, *Quantum Field Theory* (Cambridge University Press, 1985).

[4] W. Greiner and J. Reinhardt, *Field Quantization* (Springer-Verlag, 1993).

8 Introduction to String Theory

Course Code: PH70118 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** PH70117

Basic ideas, types of strings, bosonic strings, worldsheet, string interactions, critical dimension. Quantization of closed bosonic string, Nambu-Goto and Polyakov action, Light-cone quantization and string spectra. Light-cone quantization of open string, Neumann and Dirichlet boundary conditions, string spectra. D-branes , perturbative description of D-branes in terms of open string, Chan-Paton factors. Path-integral quantization of bosonic strings. Strings in presence of background fields and quantization. Conformal field theory(CFT), commutators in CFT and radial ordering, operator product expansion, correlation functions, Wick's theorem, operator-state correspondence. String interaction, topology of string worldsheets, Riemann surfaces. Tree level bosonic string interaction and computation of the simplest string scattering amplitudes. Superstring theory : Type I, IIA, IIB, Heterotic SO(32) and E8xE8. Superstring interactions. String theory in curved spaces, idea of compactification, simplest compactification : Orbifolds. Calabi-Yau manifolds and compactification. Low-energy theory, Supergravity in various dimensions, overview of string theory beyond perturbation theory, non-perturbative states, p-branes. String dualities.

References

[1] J. Polchisnki, String Theory, Vol. 1 and 2, Cambridge University Press(Paperback, 2005).

[2] M.B. Green, J. Schwarz and E. Witten, String Theory, Vol. 1 & 2, Cambridge University Press(1988).

[3] E. Kiritsis, String Theory in a Nut-shell, Princeton University Press(March 19, 2007).[Also the free lecture notes by the same author, available online at http://arxiv.org/ abs/hep-th/9709062]

[4] D. Lust and S. Theisen, Lectures on String Theory, Springer(December 1989).

[5] A. Sen, An Introduction to Non-perturbative String Theory. Available online free of cost at http://arxiv.org/abs/hep-th/9802051.

9 Nonlinear Fiber Optics

Course Code: PH70119 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

1. Linear and Nonlinear Dispersive Waves; Nonlinear Dispersive Systems: An Illustration of the Wave of Permanence, John Scott Russel's Great Wave of Translation, Cnoidal and Solitary Waves. Pulse Propagation in Fibers: Nonlinear Pulse Propagation; Higher-Order Nonlinear Effects; Numerical Methods: Split-Step Fourier Method, Finite-Difference Methods.; Group-Velocity Dispersion; Fibre Grating: Bragg Diffraction, Photosensitivity; Fabrication Techniques: Single-Beam Internal technique, Dual-beam holographic technique, Phase mask technique, Point-by-point fabrication technique; Grating Characteristics: Coupled-Mode Equations, CW Solution in the Linear Case, Photonic Band gap or Stop band, Grating as an optical filter; Experimental verification.

References

[1] M. Lakshmanan and S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer-Verlag, New York 2003.

[2] Govind P. Agrawal, Nonlinear Fiber Optics, Third Edition, Academic Press, California 2001.

[3] Govind P. Agrawal, Fiber-Optic Communication Systems, Second Edition, Wiley, New York 1987.

[4] P. Diamet, Wave Transmission and Fiber Optics, Macmillan, New York 1990.

[5] S. A. Akhmanov, V. A. Vysloukh and A. S. Chirkin, Optics of Femptosecond Laser Pulses, American Institute of Physics, New York 1992.

10 Synthesis and Optical Properties of Nano Structures

Course Code: PH70120 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Electron Band Structure and Its Modification due to change in dimensionality. Phonon absorption in Nanomaterials. Physical, Chemical and Bio-routes for Synthesis of Nanomaterials, Experimental Techniques for Characterization of Nanomaterials, Metal Nanoparticles, Some applications of Nano Materials, Bulk to Nano Transitions. Nature of Carbon Clusters, Discovery of C60 Structures of C 60. Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties. Preparation of Quantum Nanostructures, Size Effects, Conduction Electrons and Dimensionality, Properties Dependent on Density States. Scanning Probe Microscopes (SPM), Diffraction Techniques, Spectroscopic Techniques.

References

[1] Poole and Owens , Introduction to Nanotechnology: Wiley-Interscience (May 30, 2003).

[2] Jacak, Hawrylak and Wojs , Quantum Dots, Springer; 1 edition (March 20, 1998).

[3] Nalva (Ed.), Handbook of Nanostrcture Materials and Nanotechnology, Academic Press, 2002 .

[4] S.K. Kulkarni, Nano Technology: Principles and Practices, ISBN: 81-85589-29-1 / 8185589291, Delhi, 2006.

[5] C. Kittel, Introduction to Solid State Physics, Wiley; 8th. edition (November 11, 2004).

[6] C.M. Niemeyer and C.A. Mikin(Eds.), Nanobiotechnology : Concepts, Applications and Perspectives, John Wiley & Sons, 2004.

11 Biophysics and Quantum Chemistry

Course Code: PH70121 **Credit (L-T-P):** 4 (4-0-0) **Prerequisite:** None

Elementary ideas about the DNA structure, sugar-phosphate backbone, nucleosides and nucleotides, three-dimensional DNA structure, RNA. Proteins: primary, secondary, tertiary and quaternary structures, enzymes and their catalytic activity, DNA and protein folding, DNA denaturation, replication, mutation, intercalation, neurotransmitters, membranes. Forces stabilizing DNA and protein structure, Theoretical quantum chemical and molecular mechanical methods, Treatment of intermolecular interactions, conformations, hydrogen bonding, stacking and hydrophobic interactions, importance of electrostatic interactions, biomolecular recognition, drug design. Application of experimental techniques of light scattering, absorption and fluorescence spectroscopy, Nuclear magnetic resonance, Interaction of UV radiation with DNA, Photodimerization, Photodynamic action.

References

[1] P. Narayanan , Essentials of Biophysics, New Age Publishers(2003).

[2] Price, Basic Molecular Biology, John Wiley & Sons Inc (April 1979).

[3] Pullman (Ed.), Quantum Mechanics of Molecular Conformations, John Wiley and Sons Ltd (January 1, 1976).

[4] Yakushevich , Non-linear Physics of DNA, Wiley (February 25, 1998).

[5] Nelson, Biological Physics, W. H. Freeman; First Edition (June 15, 2007).