Department of Physics,

Jamia Millia Islamia

Pre-Ph.D. Course Work Syllabus

The following are the courses offered for candidates who are admitted for PhD in the Department of Physics, as approved by the Board of Studies of the Department. “Research Methodology” and “Bibliography” papers are common to all of them. For the remaining courses, candidates are to opt for any two, with the consent of their supervisors.

- Research Methodology
- Preparation of Materials
- Characterization of Materials
- Physics of Ultra-relativistic Nuclear Collisions
- Photonics
- Review of Optical Sciences
- Advanced Condensed Matter Physics
- Selected Topics in Mathematical Physics
- Bibliography

Research Methodology in Physics

UNIT 1 : BRIEF HISTORY OF PHYSICS 16 LECTURES

1. Early views on nature of the universe, matter and forces.
2. Contributions of Copernicus, Kepler, Galileo.
3. The rise of the Mechanics (17-18th centuries) : Newton Huygens, Hooke, Bernoullis, Euler, Lagrange, Laplace.
4. The development of the field concept and space geometry (19th century) : Ampere, Faraday, Maxwell, Lorentz, Gauss Riemann.
5. The evolution of the concepts of energy, entropy and Statistical Mechanics(19th) : Carnot, Clausius, Kelvin, Boltzmann, Gibbs.
6. Experimental discoveries at the end of 19th century : cathode rays, x-rays, electron, radioactivity, blackbody radiation, Photoelectric effect, Michelson-Morley experiment.
7. Twentieth Century : Relativity, Bohr- Sommerfield quantum theory upto 1922, Quantum Mechanics. Discovery of positron, neutron and mesons. Nuclear model. Discovery of Weak and Strong (nuclear) forces. Application of quantum theory to crystalline solids. Quantum Electrodynamics and gauge theories.
8. Role of physics in advance in technology: semiconductors, laser etc.

UNIT 2 : METHODOLOGY OF PHYSICAL SCIENCES 6 LECTURES

1. Introduction to symbolic logic. Propositions and truth-tables. Inference.
2. Hypothesis and axiomatic-deductive systems.
3. Falsifiability. The logic of scientific discovery.

UNIT 3: MEASUREMENTS AND STATISTICAL ANALYSIS 6 LECTURES

1. Errors and analysis of errors.
2. Introductory probability and stochastic processes.
3. Descriptive statistics and correlations.

UNIT 4: MISCELLENEOUS RESEARCH SKILLS 12 LECTURES

1. The world of scientific literature : journals and internet sources
2. Preparing scientific reports : introduction to latex,GnuPlot and Sage/Mathematica/Matlab
3. Scientific ethics, copyrights and plagiarism

LITERATURE AND SUGGESTED READING

1. J. Bronowiski: Ascent of Man
2. A. Einestien and L. Infeld: Evolution of physics
3. E.T.Whittaker: History of theories of Aether and Electricity vol. 1 and II
4. M. Jammer: Conceptual development of Quantum Mechanics
5. R.P.Feynman: The character of Physical Laws

Preparation of Materials

Unit 1. Methods of crystal growth

Solution methods, Melt methods, Homogeneous nucleation and heterogeneous nucleation, Energy of formation of a nucleus

Unit 2. Preparation of Amorphous Materials:

Introduction to amorphous materials & conducting mechanism, Melt Quenching technique, Thermal Evaporation method, Ball milling, Electrodeposition, Sputtering, Glow-discharge decomposition. Shear amorphization.

Unit 3. Thin film and epitaxial growth:

Thermal Evaporation method, Sputtering, CVD, LPCVD, Spin Coating, Molecular beam epitaxy.

Unit 4. Ceramic material preparation:

Introduction to ceramic materials, properties, preparation; Recrystalization and Grain Growth, solid state sintering, sintering with reactive liquid, pressure sintering.Synthesis of Nano-Scale ceramics powder.

Unit 5. Preparation of Nanomaterials:

Sol gel technique, Chemical Vapor Deposition, LPCVD, plasma arc discharge, sputtering, evaporation, Pulsed laser deposition, electrodeposition.

Unit 6. Preparation of Conducting Polymers:

Conducting polymer, Properties, Conduction mechanism, Preparation; Chemical Oxidation polymerization, Plasma polymerisation.

References:

1. *Essentials of Crystallography*, M. A. Wahab, Narosa, New Delhi
2. *Introduction to Ceramics*, 2nd Ed. W. D. Kingery, H. K. Bowen and D. R. Uhlmann John Wiley & Sons, Singapore, 1991.
3. *Ceramic Processing*, M. N. Rahaman, CRC Press, 2007.
4. *Introduction to the Principles of Ceramic Processing*, J. S. Reed 2nd Ed., John Wiley & Sons, 1995.
5. *Non-Crystalline Semiconductors*, Device and Mott.
6. *Amorphous Semiconductors* , Richard and Zallen.
7. *Handbook of Conducting Polymers*, T.A Skotheim and J.R. Reynolds
8. *Nanomaterials: Synthesis; properties and applications*, A.S. Edelstein and R.C. Commarata

Characterization of Materials

Unit 1: Diffraction phenomena as applied to Solid State problems, Scattering and Absorption of X-rays, neutrons and electrons, X-ray methods for orienting crystals, applications of XRD, Diffraction from regular and faulted closed packed structures, Broadening of diffraction spots due to defects, Line profile analysis, crystal structure analysis, measurement of intensities of X-ray reflection

Unit 2: Raman Spectroscopy, Photoluminescence, Scanning Electron Microscopy (SEM)

Unit 3: Auger Electron Spectroscopy, X-Ray Photoelectron Spectroscopy, SIMS, Rutherford Backscattering Spectroscopy

Unit 4: AFM, ESR, Electron Diffraction, LEED, RHEED, TEM, STM

References:

1. Woodruff and Delchar : Experimental Techniques of Surface Science
2. Ashcroft and Mermin : Solid State Physics
3. S. R. Elliot : Amorphous Materials
4. L.C. Feldman and J.W. Mayer : Fundamentals of Surfaces and Thin Films Analysis
5. M.M. Woolfson : An Introduction of X-ray Crystallography
6. W.K. Chu : Rutherford Backscattering Spectrometry

Physics of Ultra-relativistic Nucleus-Nucleus Collisions

Code : PPH – 108

Unit 1 : QED Lagrangian, QCD Lagrangian, Feynman diagrams and running coupling constants in QED and QCD, ultra-violet freedom (or asymptotic freedom) and infra-red slavery (confinement) in QCD.

Unit 2 : Importance of ultra-relativistic heavy-ion collisions, collision scenarios and formation of dense hadronic matter, possibility of the formation of a novel state of matter called quark gluon plasma (QGP), conditions for the formation of QGP, conditions for the application of thermal models and Resume of thermodynamics, state of thermo-chemical equilibrium in nucleus-nucleus reactions, Grand canonical treatment, phase transition theory for hadron to quark transition, application in ideal gas of quarks and gluons within M.I.T Bag model, criteria for a first order quark-hadron phase transition, phase transition at zero temperature, phase transition at finite temperature, phase boundary of quark-hadron phase transition.

Unit 3 : Evolution of quark-gluon plasma and light quark-antiquark pair and heavy (strange) quark-antiquark production, influence of Pauli blocking of final states, results for static quark-gluon plasma, strange particle production in baryon rich plasma. strangeness abundance in hadronic gas in chemical equilibrium, influence of volume (or hydrodynamic) expansion, hadronization scenarios,

Unit 4 : Signals of quark gluon plasma : strangeness abundances, dilepton and hard photon production, J/Ψ formation.

Unit 5 : Relativistic kinematics : rapidity and pseudo rapidity variables, transverse mass, invariant cross-section, invariance of particle's rapidity and invariant spectra under Lorentz transformation.

Books :

1. “Quark Gluon and Hadron Physics”, Eds. P.K. Sahu, S.C. Phatak, Y.P. Viyogi, Narosa Publishing House.
2. “The Physics of the Quark-Gluon Plasma”, Lecture Notes in Physics by Berndt Muller, Springer-Verlag
3. “Quark-Gluon Plasma”, Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology by K. Yagi, T. Hatsuda and Y. Miake, Cambridge University Press.
4. “Finite-Temperature Field Theory Principles and Applications” by Joseph I. Kapusta and Charles Gale, Cambridge Monographs on Mathematical Physics, Cambridge University Press.
5. “Quarks and Gluons at High Temperatures and Densities” by J. Cleymans, R.V. Gavai and E. Suhonen, Physics Reports, Vol. 130, No. 4, pp 217 – 292.
6. “Strangeness in Relativistic Heavy Ion Collisions”, by P. Koch, B. Muller and J. Rafelski, Physics Reports, Vol. 142, No. 4, pp 167 – 262.

Photonics

Unit 1: Fourier Optics: Propagation of light in free space- transfer function of free space, Optical Fourier Transform, Fourier transform using a lens, image formation and spatial frequency filtering. Fourier Transform Holography.

Unit 2: Polarization Optics: Polarization of Light, Optics of anisotropic media: The index ellipsoid. Optical activity and Faraday effect. Polarization devices: Wave retarders, rotators and optical isolators.

Unit 3: Statistical Optics: Statistical properties of Light, Temporal Coherence and Spectrum, Degree of Coherence, Spatial coherence, Mutual coherence function, longitudinal coherence. Interference and Transmission of Partially Coherent Light.

Unit 4: Non-linear Optics: Pockels and Kerr Effect- Electro-optics of Anisotropic media, Phase and amplitude modulators. Non-linear optical media, second order non-linear optics- SHG, Three wave mixing. Third order non-linear optics, THG and self phase modulation. Four wave mixing and Optical Phase conjugation. Frequency conversion, Parametric Amplification and Oscillation. Self focusing of light.

REFERENCES:

1. A. Ghatak & K. Thyagarajan : Optical Electronics (Cambridge University Press)
2. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich
3. A. Yariv : Quantum Electronics (Wiley, New York)
4. M. Young : Optics and Lasers (Springer Verlag)

Review of Optical Science

Unit 1- Ray optics-General properties of rays-The differential equation of light rays, The laws of refraction and reflection, Lagrange's integral invariant, The principle of Fermat theorem of Malus and Dupin

Unit2-Wave optics- Interference of two monochromatic light-Division of Wave front, Young's experiment, Frencel's mirror, Use of slit sources; visibility of fringes Standing wave,

Interference of two monochromatic light-Division of amplitude-Fringes with a plane parallel plate, localization of fringes, Multiple-beam interference, Fabry-Perot interferometer, The Huygens-Frenel Principle, Kirchhoff's Diffraction theory- the integral of Kirchhoff, Fraunhofer and Fresnel diffraction.

Unit3-Particle Nature of light-Photoelectric effect. Compton effect, Spontaneous and stimulated emission, Einstein A & B coefficients; Lasers, optical pumping, inversion, rate equation; Modes of resonators and coherence length.

Unit 4-Electromagnetic Theory Electrostatics; Gauss' Law and its application; Laplace and Poisson equations, boundary value problems; Magneto statics: Biot-Savart Law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interface; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel Law, interference, coherence, and diffraction; Dispersion relation in plasma; Lorentz invariance of Maxwell's equations; Transmission lines and wave guide; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles and retarded potentials.

Advanced Condensed Matter Physics

Unit 1: The electron gas without interaction; Electrons in a periodic potential.

Unit 2: The interacting electron gas; The Hartree-Fock approximation; Quasi-electrons, plasmons; The Dielectric constant of the electron gas.

Unit 3: Ion-ion interactions; Phonons; Spin-spin interactions; Magnons; Dia-magnetism; Paramagnetism.

Unit 4: Superfluidity; Landau's criteria; Superconductivity; BCS Theory; High Tc superconductivity.

References

[1] Introduction to Solid State Theory; Otfried Madelung; Springer.
[2] Quantum Theory of Solids; C. Kittel; John Wiley and sons.
[3] Solid State Physics; N. W. Ashcroft and N. D. Mermin.

Selected Topics in Mathematical Physics

Unit 1: Elements of computational techniques: root finding, interpolation, extrapolation, integration, solution of differential equation using

RK4, simulation techniques (molecular dynamics, monte carlo etc)
Unit 2: Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals

Unit 3: Linear ordinary differential equations of first & second order, Sturm-Liouville Theory, special functions (Hermite, Bessel, Laguerre and Legendre functions); Fourier series, Fourier and Laplace transforms.

Unit 4: Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions)

Unit 5: Introduction to Group theory, Generators of continuous group, Lorentz group, discrete groups, SU(2), O(3), differential forms

References

1. Mathematical Methods for Physicists, Arfken & Weber.
2. Mathematical Physics, S Hassani
3. Group Theory and its Applications to Physical Problems, Morton Hammermesh
4. Advanced Engineering Mathematics, Erwin Kreyszig
5. Monte Carlo Methods in Statistical Physics, G T Barkema & Newmann
6. Monte Carlo Simulation in Statistical Physics, K Binder & Heermann.