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University of Kalyani

Syllabus

Pre-Ph.D. Course in Physics
(2014 onwards)

Department of Physics
Kalyani-741235

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Syllabus of the pre-Ph.D. Course in Physics

Duration: **One Semester**

Total Marks: **200 Credit Points: 08**

1) Literature Review: (Marks: 50, Credit: 02)

(consisting of a final report followed by an *oral presentation*)

2) Research Methodology including Computer Applications: (Marks: 100, Credit: 04)

a) *Theoretical Methodology*: Path Integral Formalism in quantum mechanics; Density Funtional
Theory (preliminary ideas); Ising Model in one and two dimensions; Mean field theory; ANNNI
Model; Group theory and its applications. Numerical methods.
Programming languages (Fortran)
Application package – Mathematica/Matlab

b) *Experimental Methodology*: Material preparation and different characterization techniques;
Basic instruments (XRD, Electron & Atomic microscopes, Spectroscopic techniques; Astronomical instruments); Experimental data analysis technique.

3) Subject Up-gradation: (students have to choose any two units)
(Marks: 2 x 25 =50, Credit: 02)

Unit 1: Crystal Field Theory

a) Hydrogen atom problem, *s*-, *p*-, *d*-orbital wave functions, wave-mechanical picture of covalent
and ionic bonding, Valence Bond and Molecular Orbital theory, ***sp***
n hybridization, Ligand-Field

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theory for 3*d*-group of elements, weak and strong field cases, application to d_n-orbitals for
octahedral and tetrahedral symmetry- Orgel model, Jahn-Teller distortion. Crystal-field theory

for rare-earth elements, Van Vleck Susceptibility, Schottky Specific heat, Nuclear quadrupolar
and hyperfine properties.
b) Molecular Symmetry: Reflection, inversion, rotational-reflection symmetry; Symmetry
elements, Point Groups, Space Groups, Classes, and representation, Character Tables; Direct
Product, Double Groups, idea of Kramers' degeneracy.

Unit 2: Properties of Polymer Materials and Composites

a) Classification, structure and synthesis- The classification of polymers, 'Classical' polymerisation processes, newer polymers and polymerisation processes, properties and applications, Polymer processing, additives (cross-linking, plasticizers, and fillers) and composites. Amorphous and crystalline polymer state and their structure, structural relaxations
for amorphous and crystalline polymers; theories of glass transition, determination of glasstransition
temperature of amorphous and crystalline Polymer.
b) Electrical and optical properties **-** Electrical polarization, dielectric constant and refractive
index, Molecular polarisability, Dielectric relaxation. Conducting polymers, electronic conductivity in conducting polymer. Polymer electrolytes, Ionic conduction in polymer electrolytes. Optical properties of polymers, transparency and colorlessness, Light-emitting
polymers and electroactive Materials.

Unit 3: Statistical Mechanics and Strongly Correlated Systems

a) Thermodynamics and Statistical Mechanics: Partition function, Free energy, internal energy
and entropy, Fluctuations
b) Phase Transitions: Liquid-gas, order-disorder, order parameter; correlation function; continuous and discontinuous transitions; Landau's theory of continuous transitions; continuity
of entropy; discontinuity of specific heat; singularities of order parameter and partition function;
mean-field theory, Critical exponents, scaling and fluctuations of order-parameter.
c) Mixed Valent Systems: Definition, characteristics, electronic structure of the materials, electronic, thermal and magnetic properties of the system; theoretical approach to the explanation of the experimental observations.
d) Non-conventional superconducting materials: Definition, characteristics, experimental observations; Theoretical review, possible mechanism of non-conventional superconductivity.

Unit 4: Semiconductor Physics

a) Semiconductors in equilibrium and under non-equilibrium conditions, ionization coefficient
for impurities, Fermi level and IMREF, recombination and generation of carriers, concept of

lifetime, Schokley-Read-Hall theory, surface recombination.
b) Vapour phase epitaxy, molecular beam epitaxy, impurity, impurity diffusion, ion implantation
technique.
c) Silicon solar cells, short-circuit current, open circuit voltage, fill factor, efficiency, factors
limiting the performance of solar cells.
d) Hetero-junctions, ideal low dimensional systems, density of states for an ideal electron gas in
one, two and three dimensions, quantum wells, quantum wires and quantum dots, superlattices.

Unit 5: Cosmology

a) Qualitative ideas of the large scale structure of the universe.
b) Standard Cosmology, Friedmann metric, Hubble law.
c) Observational Parameters: deceleration parameter, equation of state parameter, red-shift
parameter, etc; temporal history for different curvatures, abundance of lighter elements, cosmic
microwave radiation, cosmological singularity.
d) Problem with standard cosmology. Dark energy and Dark matter, observational evidence,
models with cosmological constant, dynamical origin of cosmological constant, Inflationary
models, structure formation (qualitative), Late time accelerating universe, ΛCDM model.

Unit 6: Radio Wave Propagation

a) Antenna: Parabolic reflector antenna, Horn Antenna, Lens Antenna, Log Periodic Dipole
Array, Jovian Antenna.
b) Radio Signal Transmission and Reception: Different theories of radio wave propagation,
Signal transmission and reception techniques from satellites, Indian satellites, Observing techniques of astronomical objects.
c) Solar, Jovian and Extraterrestrial signal receiving methods.

Unit 7: Nuclear Physics

a) General form of wave function in terms of scattering matrix, scattering cross section.
b) Conservation and reciprocity theory of nuclear reactions.

c) Angular distribution of reaction products, reaction amplitudes and the conservation of parity,
limitations due to the complexity of the incident beam and formation of the compound nucleus.
d) Heavy ion induced nuclear reactions.
e) Accelerators of charged particles.

Unit 8: Advanced Particle Physics

a) Calculation of 2-->2 cross-sections and 1-->2 and 1-->3 decay widths. Pion and muon decays.

b) The Glashow-Salam-Weinberg theory of electroweak interactions, local non-abelian gauge invariance,
spontaneous symmetry breaking and Higgs mechanism, properties of the Higgs boson .
c) Introduction to deep inelastic scattering, parton model and quantum chromodynamics .