DEPARTMENT OF PHYSICS
UNIVERSITY OF PUNE
PUNE - 411007

SYLLABUS for the M.Phil. (Physics) Course

Each Student will be required to do 3 courses, out of which two are common courses. The third course syllabus is designed and conducted by the research guide for each student.

Two common courses are: 1) Fundamentals of Physics revisited.
2)Methods of Experimental Physics.

1. Fundamentals of Physics revisited

Students will be provided reading material of the portion to be covered by the teacher. The Teacher will discuss only the gist/ important principles etc. in the class. More emphasis will be on application in solving problems, improve the understanding of students (Discussing multiple-choice questions, objective and descriptive questions etc.)The total syllabus for the course is divided into 8 compulsory units each of 10 lectures.

i. **Mathematical Methods:**

Application of vector calculas in classical mechanics and electrodynamics. Vector spaces and operator algebra, matrices and their application in quantum mechanics, Linear first order and second order differential equations in physics, Fourier series, Fourier and Laplace transforms, Complex analysis its applications in evaluating intergrals.

[10]

ii. **Classical Mechanics:**

Lagrange's and Hamiltonian Formalisms, Conservation theorems and symmetry properties, Two- body central force problem- reduction to one body problem, scattering in a central force field. Small oscillations, orthogonal transformations,. Eulerian angles, Rigid body motion.

[10]

iii. **Electrodynamics:**

Laplace and Poisson equations, boundary value problems, method of images, Electrostatics in dielectric media, Ampere's theorem. Bio-Savart law, electromagnetic induction, Maxwell's equations in free space and in linear isotropic media, Boundary conditions on fields at interfaces, scalar and vector potentials. Gauge invariance. Electromagnetic waves - reflection and refractions, dispersion, interference, coherence, diffraction, polarization, electrodynamics of charged particles in electric and magnetic fields. Time varying fields, plane electromagnetic waves in non-conducting media. Radiation from moving charges and from a dipole, retarded potentials and fields.

[10]

iv. **Quantum Mechanics:**

One dimensional problems, Harmonic oscillator, hydrogen atom , spherically symmetric potential: bound states and scattering states, angular momentum algebra, time independent and time dependent perturbation theories, WKB approximation, identical particles and symmetry, quantization of electromagnetic field (Coulomb gauge), Kramers-Heisenberg formula, Thomson, Raleigh and Raman scattering

[10]

v. **Statistical Mechanics:**

Probability theory, statistical description of macroscopic systems, phase space, ensembles, partition function, laws of thermodynamics, thermodynamic potentials and Maxwell's relations. Chemical potential, free energy and connection with thermodynamic quantities. Ideal gas, Classical and quantum statistics, degenerate electron gas, Bose-Einstein condensation, realization of Bose-Einstein condensate in the laboratory.

vi. **Atoms and Molecules:**

Electrons in atoms, exchange symmetry of wavefunctions, atomic and molecular spectra and their explanations including spin-orbit coupling, fine structure, relativistic corrections, spectroscopic terms and selection rules, hyperfine structure, Zeeman, Paschen-Back and Stark effects, principles of ESR and NMR bondings in molecules, rotation and vibration spectra, Raman spectra. Bindings in molecules, rotation and vibration spectra, Raman spectra. Thomas-Fermi Theory, Hartree and Hartree-Fock methods, self-consistent fields. [10]

vii. **Condensed Matter Physics:**

Crystal classes and systems, lattice vibration, free electron theory, energy bands in solids, electronic structure of quantum confined structures, impurity levels in doped semi conductor structures. Electron transport, dielectrics, Clausius-Mosstti equation, ferroelectricity, dia-, para, ferro-,antiferro- and ferri-magnetism, superconductivity, Messiner effect, Type 1 and Type 2 superconductors, high T_c super conductors.

[10]

viii. **Nuclear and Particle physics:**

Basic nuclear properties, liquid drop model, nuclear forces, nuclear shell structure, interaction of charged particles and electromagnetic radiation with matter, basic principles of particle detectors, radio-active decays, nuclear reactions, fundamental forces, Gellmann-Nishijima formula Quark model, CPT invariance in different interactions, parity non-conservation in weak interactions. [10]

2. Methods of Experimental Physics

Unit I : Data Analysis

1. Line Shapes in Spectroscopy

   Lorenzian and Gaussian, Fitting of the spectras. (curve fitting)
   Deconvolution of spectrum, Derivative peak shapes
   Some examples of generating spectra and analysis of spectra by
   Taking examples of X-ray photo-electron spectra.

   Software/analysis using Origin and Easy plot. [10]

2. Noise and Signal handling

   Signal to noise ratio, Johnson Noise and Nyquist theorem, Shot noise,
   Means of reducing noise. Grounding – shielding, pre amplifier,
   Considerations sampling theorem, filters – ADCs/DACs Foamier
   Transform, Laplace and Fast Fourier Transforms. [10]

3. Resolution of spectrometer/ instrument (general),Resolving power and
   influence of different experimental parameters on it. Sensitivity of
   Measurement. Accuracy of measurements. Instrumental errors and
   measurement errors.(static & dynamic)
   Examples of UV-vis-NIR, IR, XRD, XPS, MassSpectrometer spectra, vis-a-
   vis Instrumental parameter like slit width, relaxation time, scan speed etc.
   Ligand Fields, Crystal fields, their effects. [10]

Unit II : Interaction of radiation and energetic particles with matter

1. Basic phenomena in case of low energy and high energy
   interactions (KeV and MeV energies) of photons, **γ**-rays,
   electrons, protons, neutrons, ions etc. [10]
2. Applications of these processes in synthesis of thin films, coatings,
   evaporation, sputtering (like plasma, processing, ion-beam processing,
   LASER processing).

Unit III. Compositional analysis

Atomic absorption, emission spectroscopy - fundamental of optical atomic spectrometry, Atomic emission spectroscopy. Atomic fluorescence spectrometry. Comparison of Atomic spectroscopies.

UV-vis-NIR absorption spectroscopy, Electronic transition in solids, Transmission reflection and absorption coefficient Infrared spectroscopy, Molecular vibration spectroscopy, Rotational spectroscopy, Bond analysis. Raman spectroscopy.

Special Analysis: Tutorials on each of the above spectroscopies.

[10]

Unit IV. **Crystal structural and microstructure analysis**

X-ray diffraction principles, Type of the cameras.
Intensity dependence. Rietveld analysis
For powder diffraction.Particle size determination using Scherrer formula
Analysis Microstructure analysis.
Scanning electron and Transmission electron microscopy, Field emission microscopy, scanning Tunneling microscopy, Atomic force microscopy.

Analisis of experimental results

[10]

Unit V. Resonance Spectroscopy

Angular momentum, Magnetic moments and energy levels,
Magnetic resonance, Nuclear Magnetic Resonance, Chemical shifts
Fine structure and Intensity variations. Mossbauer spectroscopy
Analysis of the spectra.

Reference Books

1. *Characterization of Materials*
   John B. watchman
   (Butlerworth - Heinemann
   Manning Greenwich)
2. *Quantitative Analysis - Day Underwood*
3. *Fundamentals of Analytical Chemistry*
   Skoog, West Holler
4. *Modern Methods for trace element determination*
   C. Vandecasteele,
   (C. B. block - John Wiley and sons (NY).)