Syllabus for
Pre-Ph.D. Coursework

Physics Department,
Gauhati University.

There are four papers, each with 6 credits (30 lectures). Total credit: 6x4=24.

Paper-1: Computer Fundamentals and Programming with Numerical Analysis
Paper-II: Research Methodology and Scientific presentation
Paper-III: Physics (General)
Paper-III: Physics (Optional)

Paper-I

Computer Fundamentals and Programming with Numerical Analysis; Total credit :6

Fundamentals of computers

Computer fundamentals, hardwares and softwares, different operating systems, application programmes, some tips on PC maintenance and servicing of PC. 2L

Common Applications:

Working in a Linux environment, basic Linux commands, writing scientific documents with Latex, graphic and visualization, gnuplot; introduction to other useful software tools e.g. mathematica 4L

computer programming: 10L

Programming language(s) - FORTRAN , C (or C++)

Basic Numerical Methods: 8L

Numerical integration (trapezoidal and Simpson's method), numerical differentiation; Diagonalization and inverse of symmetric and non-symmetric matrices, Eigenvalues and eigenvectors.; Root finding (bisection and Newton-Raphson method); Interpolation techniques; Solution of ordinary differential equations (Euler and Runge-Kutta methods).

Statistics and treatment of experimental data: 4L

Data acquisition system, error propagation, curve fitting, Least square method, Sampling and parameter estimation, the maximum likelihood method. Analysis of a time series and search for periodicity. FFT (Fast Fourier transformation) and power spectrum and any other topics used in physics researches.

Simulation and Monte Carlo Method: 4L

Simulation of Random variables, discrete and continuous. Calculation of integrals. Monte Carlo evaluation of pi. Simulation of simple processes: coin tossing or dice throwing game. Examples and applications.

BOOKS:

1. Numerical methods for Scientific and Engineering Computation: M.K.Jain, S.R.K.Iyengar and R.K.Jain. (Wiley Eastern Limited),
2. Fortran 77 and Numerical Methods: C.Xavier (New Age International Publishers),
3. Techniques for Nuclear and Particle Physics Experiments, A How to approach: W.R.Leo (Narosa Publishing House)
4. Numerical Recipes: W.Press et.al., (Cambridge University Press).
5. Data reduction and error analysis for the Physical Sciences, 3e, Philip R Bevington & D. Keith Robinson . McGraw Hill (2003).

Paper-II

Research Methodology and Scientific presentation

Total credit : 6

Research Aptitude:

- Research: Meaning, characteristics and types;
- Steps of research;
- Research Ethics;
- Paper, article, workshop, seminar, conference and symposium;
- Thesis writing: its characteristics and format.

Data Interpretation

- Sources, acquisition and interpretation of data;
- Quantitative and qualitative data;
- Graphical representation and mapping of data.

Information and Communication Technology (ICT)

- ICT: meaning, advantages, disadvantages and uses;
- General abbreviations and terminology;
- Basics of internet and e-mailing.

Literature survey of the previous works and search for articles in the library

Review of an article in the relevant field and preparation of a short report

Scientific presentation:

One seminar paper- preparation in power point (which includes text, graphs, picture, tables, reference etc.) (oral in power-point/poster); development of communication skills in presentation of scientific seminars- eye to eye contact, facing to audience, question & answer sessions etc.

Art of scientific writing:

Steps to better writing, flow method, organization of material and style, Drawing figures, graphs, tables, footnotes, references etc. in a research paper.

Use of internet in research works

Use of internet networks in research activities in searching material, paper downloading, submission of papers in arXiv, use of SPIRES database, relevant websites for journals and arXives.

Introduction to Patent laws etc.

Patent laws, process of patenting a research finding, Copy right, Cyber laws.

Paper-III (A + B)

Physics (General)

Total credit=6

A. General Physics:

Matrix: Eigenvalues and eigenvectors, square root of a matrix; Lorentz transformations in fully relativistic notations, Structure of the Minkowski spacetime, world-line of a point particle and its equation of motion; covariant formulation of electrodynamics and gauge transformation, classical fields and Euler-Lagrangian equation for fields; salient features of Bose-Einstein statistics and Fermi-Dirac statistics and their applications.

Angular Momentum Formalism: Hydrogen atom problem in spherical coordinates, Angular momentum, addition of angular momentum, Clebsch–Gordon coefficients, Relativistic quantum mechanics, Covariant form of Dirac equation, Dirac gamma-matrices and their properties.

Many body problem in Quantum mechanics: Quasi-particles and collective excitation, Spin wave function and exchange interactions and Heisenberg - Dirac Hamiltonian.

B. Experimental Techniques:

Production and measurements of Low pressure: Rotary, absorption, oil diffusion, Gauges, Pirani, Penning, leak detection; principles and characteristics of LASERS, principle and applications of powder X-ray diffractometer, spectrometer (IR and UV–visible), Fourier transform-infrared (FT-IR) spectrometer SEM,TEM, atomic force microscope, PIXE (Proton-induced X-Ray emission), particle detector and data analysis, wave synthesis and analysis, analog and digital computation.

Paper-IV

Physics: Optional

Total Credit:6

(Only one choice and there is provision to add more optional papers if manpower is available)

1. Astrophysics and Cosmology
2. High Energy Physics
3. Nuclear Physics and Cosmic Rays
4. Condensed Matter Physics
5. Electronics
6. Lasers and spectroscopy
7. Nonlinear Dynamics
8. Plasma physics

I. Astrophysics and Cosmology:

Early Stellar Evolution: Star formation from ISM, Jean's instability, Proto stars, Main sequence, post Main sequence evolution through Helium burning. Low mass stars, High mass stars. Advance stages of evolution. Elements of cosmology, the role of gravity in the cosmology, Newtonian derivation of Friedman equation. Thermal history of the universe, CMBR.

II. **High Energy Physics**:

Introduction to Gauge theory of fundamental interactions, Feynman diagrams in Momentum space and its applications in QED and QCD.

Parton model, Deep-Inelastic Scattering (DIS), QCD-evolution equations.

Standard model of electroweak interaction, Minimal supersymmetric standard model(MSSM), neutrino masses and mixing angles.

GUT and string theory

III. Nuclear Physics and Cosmic Rays

Heavy Ion Physics: Relativistics Kinematics,

Nuclear reaction: Compound nucleus hypothesis. Optical model of elastic scattering, average interaction potential for nucleus, energy dependence of the potential, spin orbit coupling, isospin effect. Nuclear reaction using Radioactive ion Beam.

Nuclear Energy: Nuclear fission: Energy release, mass and energy distribution of fission fragments, cross section for neutron induced fission. Chain reaction.

Cosmic Rays: Review of theories of origin – solar, galactic and extragalactic cosmic rays. Supernovae origin, GZK cutoff. Topdown models of EHE cosmic ray origin.

IV Condensed Matter physics:

Band theory and band structure, Quantum theory of magnetism,

Lattice dynamics, Thin Films, different methods of film preparation, condensation, nucleation and growth, defects, characterization, Size effect on transport properties, thin film semiconducting devices. Magnetic thin films

Nanophysics: Definition of nanoparticles, quantum dots, effect of particle size on band gap energy, method of preparation and characterization of nano materials, electrical, optical and magnetic properties of nanomaterials.

Introduction to soft condensed matter.

V. Electronics

Introduction to the science of Automatic Control System, Servo and Robotics**:** Science of Automatic Control System: Definition, information and energy, process characteristics. Basic building block of a servo system, open loop and close loop configurations with first and second order control, servomotor, servomultiplier.

Role of atmosphere on the propagation of EM wave – a brief introduction.

Insitu and Remote probing system:RADAR: Background science, working principles and basic design. Doppler radar: CW and pulse operations.LIDAR: Doppler, fluorecent, aerosol, Rayleigh and Differential absorption LIDAR and their applications.Signal retrieval and processing techniques.

VI. Lasers and Spectroscopy

Atmospheric opacity: Molecular band absorption, spectroscopic characterization techniques: Infra red, Raman and Fluorescence spectroscopy;

Threshold condition of laser oscillation: variation of laser power around threshold, ultimate line width of lasers, Modern atomic spectroscopy – cold atoms and Doppler free spectroscopy etc; single atom spectroscopy etc.

Nonlinear optics: Susceptibility, harmonic generation- second and third order effects.

VII. Nonlinear Dynamics:

Nonlinear equations in physics: an overview, Non-linear mechanics. Sensitive dependence on initial conditions. Examples of Chaotic systems: nonlinear electrical system and three-body gravitational problem.

Fractal and fractal dimensions, self-similarity and self-affinity. Cantor sets, Sicrpinski gasket, Koch curve.

One dimensional logical map, fixed points, bifuracations and cobwebs. Period doubling route to chaos. Gigenbaurn number. Concept of strange attractor and its fractal nature.

Flow in two-D and limit cycle, bifurcations in a two-D linear system. Nonlinear two-D system and linearization. Van der Pol and Duffing oscillations.

Flow in three-D and chaos. Lorenz attractor. Measures of chaos: Poincare map and Lyapunov exponents.

VIII. Plasma physics

Introduction to plasma, definition, concept of temperature, Debye shielding and different plasma parameters.

Fluid theory in plasma, Fluid equations of motion, introduction to kinetic theory, diffusion and resistivity in plasma.

Gas discharge processes, dc discharge, rf discharge, capacitive and inductively coupled plasma systems, theory and description of different plasma production systems, Dusty plasma.

Fundamentals of plasma processing.

Introduction to controlled thermonuclear fusion, magnetic confinement; Tokamak, Spheromak and ITER.

Nonlinear phenomena in plasma, sheath, Linear and non-linear waves in plasma.

Instability in plasma; streaming instability, ion drag force induced, drift wave instability and parametric instability.

Chaos and time series analysis; Fourier theory, Liapunov exponent, Attractors, self-similarity, Hurst exponent and Fractal dimension.

(Note: Reference books to be supplied at the time of lecture)