Department of Physics
Presidency University, Kolkata

Ph D Coursework Structure and Syllabus (w.e.f. Feb. 2019)

(Number of Semester 1, the semester in which the student has taken admission is considered)

Course Code	Course Title	Course Type	Credit	Marks
PHYC1	Research Methodology	Taught	4	50
PHYSE2	Elective 1	Taught	4	50
PHYSE3	Elective 2	Taught	4	50
PHYSC4	Literature Review and Presentation	Sessional	4	50

Pool for Elective Papers: (Any two for choice of PHYSE2 and PHYSE3)

Course Title	Course Type	Credit	Marks
A. Advanced Experimental Techniques	Taught	4	50
B. Advanced Techniques of Theoretical Physics	Taught	4	50
C. Advanced Computational Techniques	Taught	4	50
D. Quantum field theories: Standard model and beyond	Taught	4	50

Compulsory PHYSC4 (Literature Review and Presentation): Depends on choice of research topic and Supervisor

Detailed Syllabus

(Number of lectures allotted is indicated in brackets)

PHYSC1: Research Methodology (Compulsory)

<u>Principles of Statistical Inference</u> [10]

Formal mathematical basis of statistical inference is used in scientific data analysis and hypothesis testing including testing hypotheses, regression, distribution functions and multivariate data analysis, Order of magnitude calculations

<u>Monte-Carlo methods</u> [4]

<u>Self-study and Bibliography</u> [7]

Bibliographic and database search. Assessing the significance of published work. Writing and Presentational skills: Use of TeX/LaTex to write a report, Scientific language skills, presenting talks of various lengths

<u>Research Ethics:</u> Laboratory ethics, working in collaboration. Plagiarism [4]

Advanced Numerical Methods [10]

Theoretical basis of advanced numerical methods for solving Ordinary and Partial Differential equations. Matrix Analysis, FFT

<u>Laboratory Skills</u> [5]

Basic skills common to Physics labs. Specific skills for sub-fields. Familiarity with major instruments in the field. Recording experimental research. Time Management

Computational Skills [10]

Hands-on advanced computational physics laboratory, to familiarize with statistical data analysis package *R* and the basics of scientific programming in *PYTHON*

Advanced Experimental Techniques (Elective)

Fabrication Techniques for Nanostructures and Devices [10]

Synthesis of nanoparticles, nanowires and thin films- Physical Vapour Deposition, Chemical Vapour Deposition, wet chemical technique. Micro and nanofabrication – Lithography, E-beam nanofabrication.

Material Characterization Techniques [12]

Microstructural Characterizations- X-ray diffraction techniques

Electron microscopy techniques- Scanning electron microscopy, Transmission electron microscopy.

Scanning probe microscopy- Scanning tunnelling microscopy, Atomic force microscopy.

Spectroscopic techniques- Infrared and Raman spectroscopy, Photoluminescence, X-ray photoelectron spectroscopy.

Characterization of optoelectronics and energy devices [12]

Optical and electrical characterizations of Photo-detectors, solar cells, super- capacitors, nano-generators.

Ultrafast Measurement Techniques [8]

Ultrafast lasers, Pump-probe spectroscopic technique, Transient photoconductivity, Time-resolved spectroscopy-Photoluminescence and Raman, Time-resolved magneto optical kerr effect

Image Processing [8]

Physical principles of remote sensing, satellite images of visible, infrared and microwave wavelength ranges, panchromatic, multispectral and hyperspectral images, extraction of spatial and spectral information from the image: stretching, classification and filtering techniques

Advanced Techniques of Theoretical Physics (Elective)

Topics in mathematical physics [16]

Complex Analysis – Analytic continuation, Method of steepest descent, Asymptotic expansion; Application of Lie algebraic methods to solving differential equations; Introduction to differential forms - applications to physics.

Topics in statistical mechanics [17]

Cluster mean field calculation, Series expansion, High and Low temperature expansion of partition function, Scaling hypothesis, Renormalization group method, Non-equilibrium phenomena, Solution of stochastic differential equations, exactly solvable models, elementary idea of quantum phase transitions, Solution of stochastic differential equation. Calculation of correlation function in exactly solvable models; Introduction to quantum phase transitions; Introduction to statistical field theory; modelling through cellular automata.

Topics in classical and quantum mechanics [17]

Path integral formalism in quantum mechanics; Green's functions : source points and boundary points; Green's function for steady wave equation, scalar wave equation; Integral equations and Green's functions, Sturm-Liouville system, Green's function for scattering problems; propagator and Green's function, applications in classical electrodynamics, quantum mechanics and in condensed matter physics.

Advanced computational techniques (Elective)

Solutions of Ordinary and Partial Differential Equations [20]

Classical equations of motion: Verlet and leapfrog algorithm (Possible application to: solar system)

Methods of solving stochastic differential equations (Possible application to: Brownian motion).

Methods of solving partial differential equations: Finite difference method, Finite element analysis, Spectral method (Possible application to: Poisson's equation, Schrodinger's equation, Diffusion equation, Navier-Stokes equation, Reaction-Diffusion type equations, time dependent Schrodinger equation. Nonlinear Schrodinger equation, Solitonic excitations)

Exact Diagonalization [5]

Methods of calculating the eigenvalues and eigenvectors of Hermitian matrices (Possible application to: Density of quantum states, Other problems in quantum mechanics, Coupled oscillators, Rigid Body Dynamics)

Introduction to Computer Simulations [10]

Basic philosophy, Models in physics, Idea of an algorithm, Discretisation, Monte Carlo methods, Quantum Monte Carlo methods, Suzuki-Trotter formalism (Possible application to: Cellular automata, Molecular dynamics, Brownian dynamics, Collective dynamics, Glauber dynamics, Kawasaki dynamics, Stellar clusters, Cosmological simulation)

Specialized Numerical Packages for Solving Physics Problems [10]

Using specialized modules in XMAXIMA, MATHEMATICA, MATLAB, MAPLE, IDL, Numerical Python, Scientific Python, or similar to carry out numerical integration, differentiation, differential equation, fast Fourier transform, data fitting, statistical inference, likelihood analysis, model selection, spectral analysis, random matrix theory, level spacing distributions. Application to classical and quantum problems

Techniques of Interfacing and Data Acquisition [5]

General idea of computer interfacing in experimental and observational data acquisition

Quantum field theories: Standard model and beyond (Elective)

Group Theory [10]

SU(2), SU(3) and rotation group, SL(2,C) and Lorentz group, Poincare group, Little group; Representation theory of Lie groups and algebras, Young tableux, Dynkin diagram.

Abelian gauge theory [20]

Covariant quantization of Klein-Gordon and Dirac field; Electromagnetic field – Gauge fixing, Kallen Lehmann Spectral representation, Cluster Decomposition principle, LSZ reduction, Optical Theorem, Path Integral quantization and Feynman Rules, Generating functionals and 1PI effective action; Regularization and Renormalization of QED, Cancellation of divergences and local counterterms, Dimensional regularization, Ward-Takahashi identity, Rnormalization group

– relevant, marginal and irrelevant couplings, Asymptotic behaviour of beta functions, Callane-Symanzik equations.

Non-Abelian gauge theory [10]

Yang-Mills field, Path integral quantization, Faddev-Popov lagrangian, Ghosts and unitarity, Slavnov-Taylor identities, BRST symmetry, Renormalization of spontaneously broken Non-abelian gauge theories, BPHZ formalism, Higgs mechanism and the Glashow-Weinberg-Salam model, QCD and the Standard model, Renormalization group and Operator product expansion, Wilson coefficients; Grand unified theories.

Introductory string theory [10]

Historical origins, Nambu-Goto string action, Free bosonic strings, Covariant quantization, Virasoro algebra, Light cone quantization.