# Pre-Ph.D. Course (Physics) Contents
**One Semester (2021-2022)**

**Note:** A minimum of 75 % attendance is an essential in all the subjects and academic activities

## 1. Research Methodology & Computational Techniques — 150 marks

### A. Research Methodology — (30 Lectures) 75 marks

**(Prof. D. Mehta)** S17

***(Schedule: Tuesday (15 hrs-16 hrs) & Thursday (16 hrs-17 hrs); Room w.e.f. Feb 24, 2022)***

**Note:** The work load for the (RM) teacher will be taken into account in his/her total teaching load.

***Evaluation:*** Written examination of three hours duration (75 Marks)

Descriptive Statistics – Accuracy, Precision, Systematic and Statistical errors, Propagation of uncertainties,

Measures of Central tendency, Dispersion, Skewness, Kurtosis, Unweighted and Weighted, Correlation, Regression Analysis, Factor Analysis.
Sampling, sampling distribution, Statistical Inference, Testing of Hypothesis, Hypothesis testing for mean, proportion and Variance, Chi-Square Tests,

Journal searching key words, citations, impact factor, various citation and indexing sites, PACS numbers of APS, letters/articles/reviews, writing research paper for journal and conference, referencing, figures, style etc, Authorship, patents, plagiarism

### B. Computational Techniques: — (30 Lectures) 75 marks

**(Dr Ashok Kumar)** S17

***(Schedule: Tuesday (12-13 hrs) & Friday (12-13 hrs); Room w.e.f. Feb 24, 2022)***

**Note:** The work load for the (CT) teacher will be taken into account in his/her total teaching load.

***Evaluation:*** Written examination of three hours duration (75 Marks)

Resume of Practical approach of learning operating systems (DOS, UNIX, Windows), Graphical packages, Calculations using Spreadsheet programming and Latex, Internet use.

Programming using Fortran 90/ $C^{++}$ to handle various numerical techniques.

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Mathematica software: Numerical calculations, Mathematical operations, in-built functions, Equation solving, matrices, differentiation, integration, series, limits, Graphics including 3D plots.
Matrices: Matrix inversion using iterative methods and accuracy, Numerical Linear Algebra: Solution of systems of linear equations, direct methods, error analysis.

Numerical integration methods: Quadrature formula and Monte Carlo methods, Numerical methods for Ordinary and partial differential equations.

Linear and non-linear least squares fitting methods, Interpolation methods including splines, Fourier Series Analysis, Fast Fourier Transform, Convolution and Correlation.

Simulations using Monte Carlo methods: Geometrical simulations, absorption of gamma rays in matter, Molecular dynamics.

Teachers should provide the hands on experience to the students in programming using $C^{++}$ and FORTRAN.

Teachers shall choose relevant / useful topics from the above for students.

## 2. Advanced Theoretical & Experimental courses in Physics

***Note:*** The question paper for the semester examination will consist of seven questions of equal marks. The first question will be compulsory and will consist of several short questions/problems covering the entire syllabus. The candidates will attempt five questions in all including the compulsory question. The work load for the teacher will be taken into account in his/her total teaching load.

**Examination**: Written examination of three hours duration of each paper separately i.e. Papers A and B (75 marks each)

**The students shall select according to the field one paper from each i.e. Papers A and Papers B where he/she is pursuing the Ph.D..**

**A. TECHNIQUES IN THEORETICAL PHYSICS** 75 marks

**(i) Theoretical Techniques in Particle Physics, Solitons and Chaos:**
**(Prof. C.N. Kumar and Dr Gulsheen Ahuja)** **(22-23 Lectures)**
***(Schedule: Thursday (15 hrs-16 hrs) & Tuesday (14-15 hrs); Room w.e.f. Feb 24, 2022)*** S17

Review of characteristics, classification and interactions of fundamental particles, Symmetries in particle physics-discrete and continuous , Interaction to Flavor Physics- quark and lepton masses and mixing, phenomenology of neutrino oscillations.

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Discovery of solitary waves and soliton interactions, Importance of solitons, KdV equation and its elementary solutions. Solitons in field theories. Chaos and its examples, parameters, one dimensional maps.

(ii) **Theoretical Techniques in Nuclear Physics:**
**(Dr Sakshi Gautam)** **(22-23Lectures)**
***(Schedule: Monday (14-15 hrs); Room (w.e.f. Feb 24, 2022)***

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Review of static properties, binding energy, density, nuclear forces, and potentials, shell model, collective models and energy levels, Hartree-Fock theory of nuclear shape and states with good J Quantum number and applications, correlations in nuclear matter and exclusive principle correlations, Bethe-Goldstone equation and G-matrix, heavy-ion physics at low and intermediate energies, simulations and QMD model, hot and dense matter and multi fragmentation.

(iii) **Theoretical Techniques in Condensed Matter Physics**:
**(Dr Ranber Singh)** **(22-23 Lectures)**
***(Schedule: Tuesday (11-12 hrs); Room w.e.f. Feb 24, 2022)***

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Theory of NMR & ESR techniques, Theory of Anharmonic solids, Theory of Liquid state. Ising model, ferromagnetism, Phase transition, BCS theory, superconductivity, superfludity. DFT: Many body Schrödinger equation, density functional theory, equilibrium structure of materials, elastic properties of materials, vibrations of molecules and solids, Band structure and dielectric function.

**B. TECHNIQUES IN EXPERIMENTAL PHYSICS** (3 credits) 75 marks

(i) **Particle physics, Collider Physics & Accelerator:**
**(Prof. Vipin Bhatnagar)** **(22-23 Lectures)**
***(Schedule: Friday (14-15 hrs); Room (w.e.f. Feb 24, 2022)***

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Relativistic kinematics, Four vectors & invariants, some practical examples for use of invariants. Accelerator Physics: Ion optics including solutions of differential equations dealing with motion of ions through magnets, electrostatic fields, electrostatic analyzers, etc. Transformation of differential cross-section. Monte Carlo calculations and its applications, typical uses of Monte Carlo techniques to High Energy particle physics. Collisions in colliders: Reconstruction of events-examples, LHC collider, CMS detector, ALICE detector, Belle detector (brief), Extraction of signal – top Higgs, QGP, CP violation.

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**(ii)Experimental methods for probing nuclear structure:**

**(Prof. B.R. Behera)** **(22-23 Lectures)**

***(Schedule: Wednesday (15 hrs-16 hrs); Room w.e.f. Feb 24, 2022)***

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Experimental methods for gamma-ray, conversion-electron and charged-particle spectroscopy associated with nuclear reactions and Coulomb excitation, Compton-suppressed Ge detectors, multiplicity filter, Neutron detectors, Sector field electron spectrometer, mini-range spectrometer, Recoil mass-separator, Advanced detector arrays-GAMMASPHERE and EUROBALL. Lifetime measurements – DSAM and RDM techniques, coincidence method, pulsed beam method. Hyperfine interactions – Static magnetic and quadrupole Interactions, Time differential orientation measurements. Photon – atom Interactions – interaction processes in X-ray energy region, inner-shell photoionisation and subsequent processes, Elastic and inelastic scattering.

**(iii) Experimental Techniques in Solid State Physics:**

**(Prof. S.K. Tripathi))** **(22-23 Lectures)**

***(Schedule: Monday (11-12 hrs); Room w.e.f. Feb 24, 2022)***

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High Vacuum: Diffusion Pump, Turbo Molecular Pump, Gauges for measuring high vacuum. Preparation of Materials: Crystal Growth, Amorphous materials, Nano materials, Polymers by different techniques. Device Fabrication: Oxidation Diffusion, Ion Implantation, Metallization, Lithography and Etching, Bipolar and MOS device fabrication. Characterization Techniques: Impedance, TEP, AFM, TEM, SIMS, micro-Raman, Luminescence, Ellipsometry.

**Recommended Books:**

(***Additional references can be provided by the concerned teachers***):


1. Data Reduction and Error Analysis for the Physical Sciences by P.R. Bavington and D. Keith Robinson (McGraw Hill, 2003).
2. Numerical Mathematical Analysis by James B. Scarborough (Oxford University Press 1930)
3. Statistics and data Analysis in geology by John C. Davis (John Wiley, 2002)
4. Bussiness Statistics by J.K. Sharma (Pearson Education India, 2012)
5. Statistics for Nuclear and Particle Physicists by Louis Lyons. 500726
6. Computer based Numerical Methods by V. Rajaraman 3rd Ed. Prentice Hall India 1980,
7. The C++ Programming Language/Addison Wesely
8. Mathematica, S. Wolfram, Addison. Wesely
9. Application of the Monte Carlo Method, K. Binder, Springer Veriag
10. Numerical Recipes in Fortran: The Art of Scientific Computing, W.H. Press et al., Cambridge Press.
11. Numerical Recipes in Fortran: the Art of Scientific Computing, W.H. Press et. al, Cambridge Press


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12. An Introduction to Computer Simulation Methods, H.Gould and J. Toobochnlik, Addison Wesley, 1996.
13. Computational Physics by S.E. Koonin
14. Solitons an Introduction by P.G. Drazin and R.S. Johan (Cambridge Univ. Press, 1989)
15. Chaos in Dynamical Systems by E. Ott (Cambridge Univ., Press, 1993)
16. Solitons and Instantons by R. Rajaraman (North Polland. 1989)
17. Gauge theory of Elementary Particles by T.P. Cheng and Li (Oxford)2000
18. Structure of the Nucleus by M.A. Preston and R.K. Bhadhuri.
19. Quantum Theory of Solids by C.Kittel
20. Liquid State Physics by N.H. March and M.P. Tosi
21. Liquid State Physics by Engelsta
22. Quantum field theory by Lahiri and Pal
23. The chemical evolution of the galaxy by F. Matteucci
24. Planetary Science by I. Pater and J.J. Lissauer
25. Solar system evolution: A new perspective by S.R. Taylor
26. Relativistic Kinematics by R. Hagedon.
27. CMS – Technical Proposal
28. ALICE – Technical
29. In beam gamma-ray spectroscopy by II, Morinaga and T. Yamazaki.
30. Nuclear spectroscopy and reactions (part A & C) edited by Joseph Cerny.
31. Radiation detection and measurements by Glenn. F. Knoll.
32. Gamma-ray and electron spectroscopy in Nuclear Physics by H. Ejiri and M.J.A. de Voigt.
33. The electromagnetic interaction in Nuclear Spectroscopy, Edited by W.D. Hamliton.
34. Alpha, Beta-and Gamma-ray Spectroscopy, Vol 1 and 2, Edited by Kal Siegbahn.
35. X-rays in Atomic and Nuclear Physics by N.A. Dyson
36. Elastic scattering of gamma-rays and X-rays by atoms – Phys, Reports 140 (1986-75 by P.P. Kane, L. Kissel, R.H. Pratt and S.C. Roy.
37. Inelastic scattering of X-rays and gamma-rays by Inner shell electrons-Phys. Reports 218 (1992) 67 by P.P. Kane, L. Kissel, R.H. Pratt and S.C. Roy.
38. Thin Films Phenomena by K.L. Chopra
39. Science of Engineering Materials by C.M. Srivastava and C. Srinivasan, Wiley East. Ltd.
40. Nanoparticles and Nanostructured Films-Preparation, Characterization and Applications: J.H. Fender (Wiley).
41. Microelectronic Processing by W. Scot Ruska, McGraw-Hill.
42. Characterization of Semiconductor Materials by Philips F. Kare and Greydon B. Lausbee, Mc Graw Hill.
43. Physical methods for Materials Characterization by P.E.J. Fiewitt & R.K. Wild.
44. Optical Properties of Solids by M. Fox, Oxford University Press. Fortran Programming – V. Rajaraman
45. Numerical Methods: A Computer Oriented Approach, BPB Publ. 1996 R.S. Salaria

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46. Materials modelling using density functional theory, by Feliciano Giustino, Oxford Press