Name of the Programme: Ph.D. (Physics)
Course Code: PHY-700
Title of the Course: Research Methodology
Number of Credits: 04
Effective from AY: 2022-23

Pre-requisites for the Course:	M.Sc. in Physics	
Course Objectives:	The aim of course is to orient Pre-PhD students towards research by introducing them to research methodology and data analysis in Physics. The basic principles of different experimental methods and characterization techniques will be covered along with computer programming and numerical methods..	
Content:	**UNIT I** Research methods and research methodology in Physics, Basic and applied research, Experimental and Theoretical research, Presenting a scientific seminar-oral report, Art of writing a research paper and thesis, Outline of a report, Layout of a research report/ PhD thesis, Quality of research	5 hours
	Documentation using Latex,	10 hours
	UNIT II Uncertainties in measurements: Measuring errors, Uncertainties, Parent and sample distributions, Mean and standard deviation of distributions, Binomial distributions, Poisson distribution, Gaussian or normal Error distribution, Lorentzian distribution; Approximation and errors in computing: Significant digits, Numerical errors, Modelling errors, Conditioning and stability, Convergence of iterative processes. Error analysis: Instrumental and statistical uncertainties, Propagation of errors, Application of error equations, Method of least squares, Statistical fluctuations, Probability tests, χ^2 test of a distribution. Curve fitting (Regression analysis); Least square fit to a straight line, Error estimation of the fitted parameters, Limitations of the least square method, Least squares fit to a polynomial, matrix solution, Goodness of a fit, Linear correlation coefficient, Multivariable correlations.	15 hours
	UNIT III (For Experimental students) **1. Methods of Material Preparation:** Crystal growth, Single crystal, Zone melting, Epitaxy, Compaction and solid state sintering, melting, annealing, methods of quenching, combustion, microwave, sol-gel synthesis process, deposition techniques, chemical analysis. **2. Vacuum Techniques:** Production and measurement of vacuum, Different types of vacuum systems and gauges, their working and limitations, Leak detection **3. Methods of Characterization:** X-ray diffraction, Raman Spectroscopy, IR Spectroscopy, UV-Visible spectroscopy, Mossbauer spectroscopy, Electrical transport and magnetic measurement techniques, Scanning and transmission electron microscopy, Differential scanning calorimetry – Principles,	30 hours

	instrumentation and applications. **UNIT III (For Theory students)** **1. Computer Programming and Numerical Techniques:** C/Fortran/Python programming, Finite differential calculus, Interpolation and extrapolation, Roots of equations, Solution of simultaneous Linear algebraic equation, Linear and non-linear least squares, Curve fitting, Numerical differentiation and integration, Fourier transform techniques, Numerical solution of ordinary differential equations, Matrix Eigen value problem, Monte Carlo and Maximum entropy method.	30 hours
Pedagogy:	Test paper/Assignments/Presentations/Self-study	
References/ Readings:	1. Research Methods for Science, M. P. Marder, Cambridge University Press, 2011. 2. Research Methodology Techniques and Trends Khanzode, V, APH Publishing Corporation House, 1995. 3. Research Methodology, S. Rajasekar, P. Philominathan, V. Chinnathambi, arXiv: physics /0609001v3 (2006) 4. Data Reduction and Error Analysis for the Physical Sciences 3rd Ed. by Philip R Bevington and D Keith Robinson, McGraw – Hill (2003) 5. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, 2nd Ed. John R. Taylor, University Science Books (1997) 6. Preparative Solid State Chemistry, P. Haggenmuller, Academic Press, London (1972) 7. Crystal Growth, C. H. L. Goodman, Plenum Press, New York 8. Elements of X-ray Diffraction, B. D. Cullitty, Stock S. R. Prentice Hall, New Jersey (2001) 9. Fundamentals of Vacuum Technology, A. Pipko, V. Pliskovsky, B. N. Korolev, Mir Publishers, Moscow (1984) 10. Thin Film Technology and Applications, K. L. Chopra, Tata McGraw-Hill, New Delhi (1985) 11. An Introduction to Electron Microscopy Instrumentation, Imaging and Preparation, Andres Kaech (reading material) 12. Fundamentals of Molecular Spectroscopy, C. Banwell and E. M. McCash, Tata McGraw-Hill, New Delhi, (2000) 13. Numerical Recipes in C, C. W. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, Cambridge University Press (2008) 14. Introduction to numerical programming: a practical guide for scientists and engineers using Python and C/C++, Beu, Titus A., CRC Press (2015) 15. Fortran 90/95 for Scientists and Engineers, Stephen J. Chapman, McGraw-Hill Higher Education, (2004) 16. Computer Programming in Fortran 90 and 95, V. Rajaraman, PHI Learning Pvt. Ltd. (1997)	
Course Outcomes:	The students will 1. get familiarized with research methodology and data analysis techniques. 2. be able to adopt the data analysis, fitting, and error calculations in their research work. 3. gain knowledge in different experimental characterization techniques and theoretical methods. 4. be able to better plan, execute their research and present it.	