Centre for Physical Sciences
Scheme of Programme: Ph.D. in Physics (2016)

S. No.	Paper Code	Course Title	L	T	P	Cr	
1	PHY.701	Research Methodology	4	0	0	4	100
2	PHY.702	Statistics and Computer Applications	3	0	2*	4	100
3	PHY.703	Review Writing and Seminar Presentation	4	0	0	4	100
4	PHY.704	Condensed Matter Physics	4	0	0	4	100
Choose any one of the following#							
5	PHY.705	Thin Film and Vacuum Technology	4	0	0	4	100
6	PHY.706	Nanostructured Materials	4	0	0	4	100
7	PHY.707	Density Functional Theory and Applications	4	0	0	4	100
			19	0	2*	20	500

* 2 practical hours are equivalent to 1 credit hour.
# Elective course will be decided by the guide/supervisor of the student

Course Title: Research Methodology
Paper Code: PHY.701
Total Lectures: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The course Research Methodology has been framed to introduce basic concepts of Research Methods. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism, laboratory safety issues etc. The course also covers important experimental techniques in order to teach the same that will help to doctoral students in carrying out experiments.

Unit I **(18)**

Introduction: Meaning and importance of research, Different types and styles of research, role of serendipity, Critical thinking, Creativity and innovation, Hypothesis formulation and development of research plan, Art of reading and understanding scientific papers, Literature survey, Interpretation of results and discussion. **Library:** Classification systems, e-Library, Reference management, Web-based literature search engines, Intellectual property rights (IPRs).

Unit II **(18)**

Scientific and Technical Writing: Role and importance of communication, Effective oral and written communication, Scientific writing, Research paper writing, Technical report writing, Making R&D proposals, Dissertation/Thesis writing, Letter writing and official correspondence, Oral and poster presentation in meetings, seminars, group discussions, Use of modern aids; Making technical presentations. **Research and academic integrity:** Plagiarism, copyright issues, ethics in research, and case studies. **Laboratory safety issues:** lab, workshop, electrical, health & fire safety, safe disposal of hazardous materials.

Unit III **(14)**

Microscopic and Imaging Techniques: Basics of electron and light microscopy, Polarizing optical microscopy (POM), Fluorescent microscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Bright and dark field imaging, Scanning-probe microscopy (SPM), Atomic force microscopy (AFM), Raman spectroscopy, Ion Beam Techniques in Materials Science.

Unit IV **(10)**

Spectroscopic Techniques: UV-Visible Spectroscopy, Infra red spectroscopy, photoluminescence spectroscopy, Impedance/dielectric spectroscopy.

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical techniques* (Deep and Deep Publications (P) Ltd. New Delhi, India) 2005.
2. C. R. Kothari, *Research Methodology* (New Age International, New Delhi, India) 2008.
3. G. Haugstad, *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications* (John Wiley & Sons, Sussex, U.K) 2012.
4. B.S Murty, P.Shankar, B. Raj, B. B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology* (Springer, New York, USA) 2013.
5. **Web resources:** www.sciencedirect.com for journal references, www.aip.org and www.aps.org for reference styles.
6. **Web resources:** www.nature.com, www.sciencemag.org, www.springer.com, www.pnas.org, www.tandf.co.uk, www.opticsinfobase.org for research updates.

Course Title: Statistics and Computer Applications
Paper Code: PHY.702
Total Lectures: 45
Total Lab Hours: 30

L	T	P	Credits	Marks
3	0	2	4	100

Course Objective: The course **Statistics and Computer Applications** has been designed to introduce basic concepts of data analysis. The course covers errors and uncertainty, various types of distributions, least square fitting etc. The course also contains the basics of MATLAB language to solve the numerical problems.

Unit I **(07)**

Introduction: Measuring errors, Uncertainties, Parent and sample distributions, Mean and standard deviation of distribution.

Unit II **(09)**

Probability Distributions: Binomial distribution, Poission distribution, Gaussian distribution and Lorentzian distribution. **Error Analysis:** Different types of errors: Instrumental, Statistical errors, Propagation of errors, Error formulae, Application of error equation.

Unit III **(12)**

Least Square Fitting: Least-square fitting to a straight line by minimizing χ^2, Error estimation, Least-square fit to a polynomial, Matrix solution, Least-square fit to an arbitrary function, Nonlinear fitting, Grid search method, Gradient search method, Expansion method and Marquardt method.

Testing the Fit: χ^2 test for goodness of fit, Linear-correlation coefficient, Multivariable correlations, Confidence intervals, Monte Carlo tests.

Unit IV **(17)**

Introduction to MATLAB: Standard Matlab windows, Operations with variables: Arrays: Columns and rows: creation and indexing, Size and length, Multiplication, Division, Power, Writing script files: Logical variables and operators, Loop operators; Writing functions: Input/output arguments, Simple graphics: 2D plots, Figures and subplots; Data types: Matrix, string, cell and structure, File input-output, Polynomial fit: 1D and 2D fits; Arbitrary function fit: Error function, Goodness of fit: criteria, Error in parameters; Graphics objects, Differentiation and integration through MATLAB, Solution of system of linear equations using MATLAB.

Recommended Books:

1. P. G. Guest, *Numerical Methods of Curve Fitting* (Cambridge University Press, Cambridge, U. K.) 2012.
2. Z. A. Kotulski and W. Szczepinski, *Error Analysis with Applications in Engineering* (Springer, New York, USA) 2010.
3. J. D. Vore, *Probability and Statistics for Engineering and Sciences* (Cengage Learning India Private Limited, New Delhi, India) 2012.
4. P. R. Bevington and D. K. Robinson, *Data Reduction and Error analysis for the Physical Sciences* (Tata McGraw Hill, Noida, India) 2003.
5. R. Pratap, *Getting Started with MATLAB* (Oxford University Press, Oxford, U. K.) 2010.
6. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, *A Guide to MATLAB: For Beginners and Experienced Users* (Cambridge University Press, Cambridge, U. K.).
7. S. Otto and J. P. Denier, *An Introduction to Programming and Numerical Methods in MATLAB* (Springer, New York, USA) 2005.

Course Title: Review Writing and Seminar Presentation

Paper Code: PHY.703

Total Lectures:120

L	T	P	Credits	Marks
0	0	8	4	100

Objective: The objective of this course would be to ensure that the student learns the aspects of the Review writing and seminar presentation. Herein the student shall have to write a 5000 words review of existing scientific literature with simultaneous identification of knowledge gaps that can be addressed through future work.

The evaluation criteria for "Review Writing and Presentaion" shall be as follows:
Maximum Marks: 200

S.No.	Criteria	Marks
1.	Review of literature	25
2.	Identification of gaps in knowledge	15
3.	References	10
4.	Content of presentation	15
5.	Presentation Skills	20
6.	Handling of queries	15
Total		**100**

Course Title: Condensed Matter Physics

Paper Code: PHY.704

Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: The purpose of this course is to introduce students to the fundamental and advanced concepts of solid materials. The topics include Band gap in semiconductor, Plasmons, Dielectric, optical, ferroelectric properties, Alloys, Magnetism, Magnetic materials and Magnetic resonances.

Unit I **(15)**

Semiconductor Crystals: Band gap, Equation of motion, Effective mass, Intrinsic carrier concentration, Impurity conductivity, Thermoelectric effects.

Fermi Surfaces and Metals: Construction of Fermi surfaces, Electron orbits, Hole orbits and open orbits, Calculation of energy bands, Experimental methods in Fermi surface studies.

Unit II **(15)**

Plasmons, Polaritons, and Polarons: Dielectric function of the electron gas, Plasmons, Electrostatic screening, Plasma oscillations, Transverse optical modes in plasma, application to optical phonon modes in ionic crystals, Interaction of EM waves with optical modes: Polaritons, LST relation, Electron-electron interaction, Electron-phonon interactions: Polarons.

Optical Properties, Color Centers and Excitons: Optical reflectance, Optical properties of metals, Luminescence, Types of luminescent systems, Electroluminescence, Color centers, Production and properties, Types of color centers, Excitons (Frenkel, Mott-Wannier), Experimental studies (alkali halide and molecular crystals), Raman effect in crystals, Energy loss of fast particles in a solid.

Unit III **(15)**

Dielectrics and Ferroelectrics: Polarization, Macroscopic and local electric field, Dielectric constant and polarizability, Pyroelectric and ferroelectric crystals and classification, Polarization catastrophe, Soft modes, Phase transitions, Landau theory of phase transition, Antiferroelectricity, Piezoelectric crystals, Applications.

Noncrystalline solids and Alloys: Diffraction pattern, Glasses, Amorphous ferromagnets, Amorphous semiconductors, Low energy excitations in Amorphous solids, Fiber optics, Substitutional solid solutions Hume-Rother rules, Order-disorder transformation. Phase diagrams, Transition metal alloys, Kondo effect.

Unit IV **(15)**

Magnetism, and Magnetic Resonance: Types and properties of magnetism, Spin waves, Magnons, Magnon dispersion relations, Bloch $T^{3/2}$ Law, Electron spin resonance (ESR), Nuclear magnetic resonance (NMR), Spin relaxation (spin-lattice, spin-spin), Applications of ESR and NMR.

Magnetic Materials: Soft and hard magnetic materials, Hysteresis loop, Magnetic susceptibility, Coercive force, Ferrites, Magnetic anisotropy and Induced magnetic anisotropy, Magneto-striction and effects of stress, Magnetic materials for recording and computers, Magnetic measurements Techniques.

Recommended books:

1. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, Cambridge, U.K.) 2011.
2. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. A.J. Dekker, *Solid State Physics* (Macmillan, London, U.K.) 2012.

Course Title: Thin Film and Vacuum Technology
Paper Code: PHY.705
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Course Objective: To introduce thin film deposition techniques and study of its optical, electrical, magnetic and mechanical properties and applications of thin films. It also aims to introduce basics of vacuum techniques, vacuum measurement systems and leak detection techniques.

Unit I **(15)**

Thin Films: Classification of thin films, Preparation methods: Electrolytic deposition, Thermal evaporation, Spray pyrolysis, Spray pyrolysis, Sputtering Pulse laser deposition, LB, Spin coating, Dip coating solution cast, Tape casting, Sol gel Sputtering, Chemical vapour deposition, Molecular beam epitaxy, Cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques, Thickness measurement and monitoring, Electrical, Mechanical, Optical interference.

Unit II **(15)**

Properties and Applications of Films: Elastic and plastic behavior, Optical properties, Reflectance and transmittance spectra, Anisotropic and gyrotropic films, Electric properties of films: Conductivity in metal, semiconductor and insulating films, Dielectric properties, Micro and optoelectronic devices, data storage, Optical applications, Electric contacts, resistors, Capacitors and inductors, Active electronic elements, Integrated circuits.

Unit III **(15)**

Vacuum Techniques Basics: Basic elements of vacuum science, Viscous and molecular flow, Conductance, Performance measure: Pumping speed, Throughput, Uses of vacuum pumps, Operating pressure range.

Positive Displacement Pumps: Rotary pump, Scroll pump, Momentum transfer or molecular pumps, Diffusion and turbo molecular pump.

Entrapment Pumps: Ion pumps, Sputter pumps, Cryo pumps, Sorption pumps, Design of ultra high vacuum systems.

Unit IV **(15)**

Vacuum Measurement Systems: Vacuum measurement gauges, Hydrostatic gauges, Mechanical or elastic gauges, Thermal conductivity gauges, Ion gauges, Control and interlock systems.

Leak detection techniques: Types of leaks, Bubble test, Pressure decay test, Tracer gas leak testing using helium gas.

Recommended Books:

1. B.S Murty, P. Shankar, B. Raj, B.B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology* (Springer, New York, USA) 2013.
2. A. Kapoor, *An Introduction to Nanophysics and Nanotechnology* (Alpha Science International, New Delhi, India) 2011.
3. K. Seshan, *Handbook of Thin Film Deposition Processes* (Elsevier, London, U. K.) 2012.
4. D. Gall, S. P. Baker and M. Ohring, *Materials Science of Thin Films: Deposition and Structure* (Academic Press, Massachusetts, USA) 2013.
5. A. Roth, *Vacuum Technology* (Elsevier Science Publishers, New York, USA) 1990.
6. J.F. O'Hanlon, *A Users Guide to Vacuum Technology*, (John Wiley & Sons, New

York, USA) 1989.
7. J.M. Lafferty, *Foundations of Vacuum Science and Technology* (John Wiley & Sons, New York, USA) 1998.

Course Title: Nanostructured Materials
Paper Code: PHY.706
Total Lectures: 60

L	T	P	Credits	Marks
4	1	0	4	100

Unit I **(15)**

Synthesis: Introduction to nanotechnology and nanomaterials, Top down and bottom up approaches, Sol-gel, Spin and dip coating, Pulsed Laser Diposition (PLD), Molecular beam epitaxy, Spray pyrolysis, Sputtering, Electron beam lithography, Ion beam lithography, Ball milling, Laser ablation, Thermal and ultrasonic decomposition, Reduction methods, Self-assembly, Focused ion beams, Nanoimprinting, Nanostructuring and modification by swift heavy ions (SHI).

Unit II **(10)**

Nanomaterials: Carbon fullerenes and CNTs, Metal and metal oxides, Self-assembly of nanostructures, Core-shell nanostructures, Nanocomposites, Quantum wires, Quantum dots.

Unit III **(20)**

Characterization: Characterization of nanomaterials for the structure, High resolution X-Ray diffractogram, High resolution transmission electron Microscopy (HRTEM), Fluorescent microscopy, Scanning electron microscopy (SEM), Scanning tunneling microscopy (STM), Bright and dark field imaging, Scanning-probe microscopy (SPM), Field emission scanning electron microscopy (FESEM), Atomic force microscopy (AFM), Impedance spectroscopy, Dielectric spectroscopy, Fourier transform infrared spectroscopy (FT-IR)**,** Raman Spectroscopy, Thermogravimetric Analysis (TGA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis, Universal tensile testing, Transport number, Electron spin resonance, UV spectrophotometer.

Unit IV **(15)**

Physical Properties of Nanomaterials: Dielectric, Magnetic, Optical, Mechanical and photocatalytic properties.

Applications: Electronic devices based on nanostructures, High electron mobility transistors, Nanomagnetism, Surface/interface magnetism, Nanophotonics, Solar cell, Memory devices, Supercapacitors, Lithium ion batteries, Fuel cells, Organic semiconductors, Ferro-fluids.

Recommended Books:

1. G. Haugstad *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications* (John Wiley & Sons, New Jersey, USA) 2012.

2. B.S. Murty, P. Shankar, B. Raj, B.B. Rath and J. Murday, *Textbook of Nanoscience and Nanotechnology* (Springer, Sussex, UK) 2013.
3. K.D. Sattler, *Handbook of Nanophysics* (CRC press, Florida, USA) 2010**.**
4. C.G. Wing, J.L.R. Lpez, O.A. Graeve, and M.M. Navia, *Nanostructured Materials and Nanotechnology* (Cambridge University Press,Cambridge, UK) 2013.

Course Title: Density Functional Theory and Applications
Paper Code: PHY.707
Total Lecture: 60

L	T	P	Credits	Marks
4	0	0	4	100

Course Objective: The objectives of this course are to understand the basics of Density Functional Theory (DFT). With the increasing power of computers, DFT-based calculations are emerging as an useful tool to characterize the materials properties. This course will review the various theories/approximations necessary to understand most popular framework of modern DFT.

Unit-I **(16)**

Many-body Approximations: Schrodinger equation and its solution for one electron and two electron systems, Hamiltonian of many particles system, Born-Oppenheimer approximation, Hartree theory, Idea of self consistency, Exchange energy and interpretation, Identical particles and spin, Hartree-Fock theory, Antisymmetric wavefunctions and Slater determinant, Koopmans' theorem, Failures of Hartree-Fock in solid state, Correlation energy, Variational principle, Connection between Quantum Mechanics,Variational Principle and Classical Mechanics.

Unit-II **(16)**

From Wave Functions to Density Functional: Idea of functional, Functional derivatives, Electron density, Thomos Fermi model, Hohenberg-Kohn theorems, Approximations for exchange-correlation: Local density approximation (LDA) and local spin density approximation (LSDA), Gradient expansion and generalized gradient approximation (GGA), Hybrid functionals and meta-GGA approaches. Self-interaction corrections (SIC).

Unit-III **(14)**

Practical Implementation of Density Functional Theory (DFT): Kohn-Sham formulation: Plane waves and pseudopotentials, Janak's theorem, Ionization potential theorem, Self consistent field (SCF) methods, Understanding why LDA works, Consequence of discontinuous change in chemical potential for exchange-correlation, Strengths and weaknesses of DFT.

Unit-IV **(14)**

Electronic Structure with DFT: Free electron theory, Band theory of solids, Tight-binding method, Semiconductors, Band structure, Density of states. Interpretation of Kohn-Sham eigenvalues in relation with ionization potential, Fermi surface and band gap. Electronic structure of Graphene

Recommended Books:

1. Richard M. Martin, Electronic Structure: Basic Theory and Practical Methods, (Cambridge University Press, 2004)
2. Robert G. Parr and Weitao Yang, *Density Functional Theory of Atoms and Molecules,* (Oxford University Press, 1994).
3. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
4. June Gunn Lee, *Computational Materials Science: An Introduction,* (CRC Press 2011)
5. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007