CENTRAL UNIVERSITY OF PUNJAB, BATHINDA

Ph.D. in Physics

Batch- 2024

Department of Physics

School of Basic Sciences

Learning Outcomes of the Programme:

The students will be equipped with the knowledge and advanced research skills to carry out theoretical and experimental research in the various area of physics. They will use available techniques, methods of analysis of data, interpretations and applications to the research work. This course facilitates the specialized knowledge by inculcating the relevant attitudes and values required for undertaking quality research.

Course Structure

S. No.	Paper Code	Course Title	L	T	P	Cr
1	PHY.701	Research Methodology	2	0	0	2
2	PHY.702	Statistics and Computer Applications	2	0	0	2
3	PHY.751	Research and Publication Ethics	2	0	0	2
4	PHY. 752	Teaching Assistantship	0	0	2	1
5	UNI.753	Curriculum, Pedagogy and Evaluation	1	0	0	1
Choose any TWO of the following courses #						
6	PHY.703	Condensed Matter Physics	4	0	0	4
7	PHY.704	Thin Film and Vacuum Techniques	4	0	0	4
8	PHY.705	Nanostructured Materials	4	0	0	4
9	PHY.706	Density Functional Theory and Applications	4	0	0	4
10	PHY.707	Energetic Materials and Storage Devices	4	0	0	4
11	PHY.708	Accelerator and Plasma	4	0	0	4
12	PHY.709	Data Acquisition and Experiment Automation	4	0	0	4
13	PHY.710	Advanced Spectroscopy and Instrumentation	4	0	0	4
		Total Credits				**16**

L: Lectures; P: Practical; Cr: Credits

Criteria for evaluation of theory exams: EST = 100%

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

L	T	P	Cr
2	0	0	2

Course Learning Outcomes:

On completion of this course, students will be able to:
CLO1: Grasp knowledge about formulating scientific problems
CLO2: Access and appreciate published data basis,

Units/Hours	Contents	Mapping with Course Learning Outcome
I/15	**Principles of research, laboratory practices:** Importance of research and critical thinking, essential parameters of research, citation index, impact factor, handling research engines, Google scholar, Scopus, Web of Science, e-Library etc., literature review, hypothesis making, research plan, laboratory implementations and practices, results and analysis, discussion, data compilation.	CLO1
	Learning Activities: Group discussion, brain storming, case studies	
II/15	**Techno-scientific writing, intellectual property:** Compilation of theses, technical papers, reviews, preparation of poster, presentation and dissertation, etc., plagiarism: regulations, policies, use of allied software, Intellectual Property (IP), tariff, trade, IP protection acts, laboratory ethics.	CLO2 CLO4
	Learning Activities: Implementation based peer thinking, and discussion.	

Suggested Readings:

1. Gupta, S. (2005). *Research Methodology and Statistical techniques.* New Delhi, India: Deep and Deep Publications (P) Ltd.
2. Kothari, C. R. (2008). *Research Methodology.* New Delhi, India: New Age International.

3. Haugstad, G. (2012). *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications:* John Wiley & Sons, Sussex, U.K.
4. Murty B.S, Shankar P., Raj B., Rath B. B., and Murday J., (2013). New York, USA: *Textbook of Nanoscience and Nanotechnology:* Springer.
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.

Transaction Mode: Class room teaching, and practical sessions.

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

L	T	P	Credits
2	0	0	2

Learning Outcomes: The students will be able to

CL01: Explain the basic concepts of data analysis.

CL02: Discuss errors and uncertainty, various types of distributions, least square fitting etc.

CL03: Apply MATLAB language to solve the numerical problems.

Units/Hours	Contents	Mapping with Course Learning Outcome
I/6	**Introduction:** Measuring errors, Uncertainties, Parent and sample distributions, Mean and standard deviation of distribution.	CL01
	Learning Activities: Group discussion and problem solving	
II/7	**Probability Distributions:** Binomial distribution, Poisson distribution, Gaussian distribution and Lorentzian distribution.	CL02
	Error Analysis: Different types of errors: Instrumental, Statistical errors, Propagation of errors, Error formulae, Application of error	

	equation.	
	Learning Activities: Group discussion and problem solving	
III/8	**Least Square Fitting:** Least-square fitting to a straight line by minimizing x^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.	CL02
	Testing the Fit: x^2 test for goodness of fit, Linear-correlation coefficient, Multivariable correlations, Confidence intervals, Monte Carlo tests.	CL02
	Learning Activities: Group discussion and problem solving	
IV/9	**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	CL03
	Learning Activities: Group discussion and problem solving	

Suggested Readings:

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

Transaction Mode: Class room teaching, and practical sessions.

Research and Publication Ethics
Paper Code: PHY.751
Total Lectures: 30

L	T	P	Credits
2	0	0	2

Learning Outcomes: Students will be able to:
CLO1: Familiarize with the ethics of research.
CLO2: Illustrate the good practices to be followed in research and publication.
CLO3: Judge the misconduct, fraud and plagiarism in research.
CLO4: Utilize various online resources and software to analyze their research output.

Unit/ Hours	**Content**	**Mapping with CLO**
I 3 hours	**Philosophy and Ethics** • Introduction to Philosophy: definition, nature and scope, content, branches • Ethics: definition, moral philosophy, nature of moral judgements and reactions	**CLO1**
II	**Scientific Conduct**	**CLO1 &**

5 hours	• Ethics with respect to science and research • Intellectual honesty and research integrity • Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) • Redundant publications: duplicate and overlapping publications, salami slicing • Selective reporting and misrepresentation of data	**CLO2**
III 7 hours	**Publication Ethics** Publication ethics: definition, introduction and importance • Best practices/ standards setting initiatives and guidelines: COPE, WAME, etc. • Conflicts of interest • Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types • Violation of publication ethics, authorship and contributor ship • Identification of publication misconduct, complaints and appeals • Predatory publishers and journals	**CLO2 & CLO3**
IV 4 hours	**Open Access publishing** • Open access publications and initiatives • SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies • Software tool to identify predatory publication developed by SPPU • Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer, Journal Suggester etc.	**CLO2**
V 4 hours	**Publication Misconduct** • Group Discussions: Subject-specific ethical issues, FFP, authorship; conflicts of interest; complaints and appeals: examples and fraud from India and abroad • Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools	**CLO2 & CLO3**
VI	**Databases and Research Metrics**	**CLO4**

7 hours	• Databases: Indexing databases; Citation database: Web of Science, Scopus etc. • Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10 index, almetrics	

Transaction Mode: Class room teaching, guest lectures, group discussions, and practical sessions.

Course Title: Teaching Assistantship

Course Code: PHY.752

Learning Outcomes: **Total Hours: 30**

At the end of this skill development course, the scholars shall be able to

CLO1: familiarize themselves with the pedagogical practices of effective classroom delivery and knowledge evaluation system

CLO2: manage large and small classes using appropriate pedagogical techniques for different types of content

Activities and Evaluation:

- The scholars shall attend Master degree classes of his/her supervisor to observe the various transaction modes that the supervisor follows in the classroom delivery or transaction process one period per week.

- The scholars shall be assigned one period per week under the direct supervision of his/her supervisor to teach the Master degree students adopting appropriate teaching strategy(s).

- The scholars shall be involved in examination and evaluation system of the Master degree students such as preparation of questions, conduct of examination and preparation of results under the direction of the supervisor.

- At the end of the semester, the supervisor shall conduct an examination of teaching skills learned by the scholar as per the

following evaluation criteria:

- The scholars shall be given a topic relevant to the Master degree course of the current semester as his/her specialization to prepare lessons and deliver in the classroom before the master degree students for one hour (45 minutes teaching + 15 minutes' interaction).
- The scholars shall be evaluated for a total of 50 marks comprising *content knowledge* (10 marks), *explanation and demonstration skills* (10 marks), *communication skills* (10 marks), *teaching techniques employed* (10 marks), and classroom interactions (10).

Course Title: Curriculum, Pedagogy and Evaluation

Course Code: **UNI.753**

Total Hours: 18

L	T	P	Credit
1	0	0	1

Learning outcomes:

After completion of the course, scholars shall be able to:
CLO1: analyze the principles and bases of curriculum design and development
CLO2: examine the processes involved in curriculum development
CLO3: develop the skills of adopting innovative pedagogies and conducting students' assessment
CLO4: develop curriculum of a specific course/programme

Unit/ Hours	Content	Mapping with CLO
I 4 hours	**Bases and Principles of Curriculum** 1. Curriculum: Concept and Principles of curriculum development, Foundations of Curriculum Development. 2. Types of Curriculum Designs- Subject centered, learner centered, experience centered and core curriculum. Designing local, national, regional and global specific curriculum. Choice Based Credit System and its implementation.	CLO1

II 4 hours	**Curriculum Development** 1. Process of Curriculum Development: Formulation of graduate attributes, course/learning outcomes, content selection, organization of content and learning experiences, transaction process. 2. Comparison among Interdisciplinary, multidisciplinary and trans-disciplinary approaches to curriculum.	CLO2
III 3 hours	**Curriculum and Pedagogy** 1. Conceptual understanding of Pedagogy. 2. Pedagogies: Peeragogy, Cybergogy and Heutagogy with special emphasis on Blended learning, Flipped learning, Dialogue, cooperative and collaborative learning. 3. Three e- techniques: Moodle, Edmodo, Google classroom.	CLO3
IV 4 hours	**Learners' Assessment** 1. Assessment Preparation: Concept, purpose, and principles of preparing objective and subjective questions. 2. Conducting Assessment: Modes of conducting assessment – offline and online; use of ICT in conducting assessments. 3. Evaluation: Formative and Summative assessments, Outcome based assessment, and scoring criteria. *Activity: Develop curriculum for a course/programme related to the research scholar's discipline.*	CLO3 & CLO4

Transaction Mode

Lecture, dialogue, peer group discussion, workshop

Evaluation criteria

There shall be an end-term evaluation of the course for 50 marks for duration of 2 hours. The course coordinator shall conduct the evaluation.

Suggested Readings

- Allyn, B., Beane, J. A., Conrad, E. P., & Samuel J. A., (1986). *Curriculum Planning and Development*. Boston: Allyn & Bacon.
- Brady, L. (1995). *Curriculum Development*. Prentice Hall: Delhi. National Council of Educational Research and Training.
- Deng, Z. (2007). Knowing the subject matter of science curriculum, *Journal of Curriculum Studies*, 39(5), 503-535.https://doi.org/10.1080/00220270701305362
- Gronlund, N. E. & Linn, R. L. (2003). *Measurement and Assessment in teaching*. Singapore: Pearson Education
- McNeil, J. D. (1990). *Curriculum: A Comprehensive Introduction*, London: Scott, Foreman/Little
- Nehru, R. S. S. (2015). *Principles of Curriculum*. New Delhi: APH Publishing Corporation.
- Oliva, P. F. (2001). *Developing the curriculum* (Fifth Ed.). New York, NY: Longman
- Stein, J. and Graham, C. (2014). *Essentials for Blended Learning: A Standards-Based Guide*. New York, NY: Routledge.

Web Resources

https://www.westernsydney.edu.au/__data/assets/pdf_file/0004/467095/Fundamentals_of_Blended_Learning.pdf

https://www.uhd.edu/academics/university-college/centers-offices/teaching-learning-excellence/Pages/Principles-of-a-Flipped-Classroom.aspx

http://leerwegdialoog.nl/wp-content/uploads/2018/06/180621-Article-The-Basic-Principles-of-Dialogue-by-Renate-van-der-Veen-and-Olga-Plokhooij.pdf

Course Name: Condensed Matter Physics
Course Code: PHY.703
Course type: Elective Course
Total Hours: 45

L	T	P	Credit
4	0	0	4

Course Learning Outcomes:
On completion of this course, students will be able to:
CLO1: Explain the various types of semiconductor, and their theory.
CLO2: Explain Fermi surfaces, their construction, and the experimental methods used for detection of Fermi surfaces.
CLO3: Explain optical properties, colour centres and excitons.
CLO4: Explain plasmons, polaritons, polarons.

CLO5: Develop theories of dielectrics and ferroelectrics.
CLO6: Outline the theory of noncrystalline solids, alloys and analyse diffraction pattern of amorphous solids.
CLO7: Outline the theory of magnetism, and magnetic resonance.
CLO8: Explain theory and applications of magnetic materials.

Units/Hours	Contents	Mapping with Course Learning Outcome
I/12	**Semiconductor Crystals:** Band gap, Equation of motion, Effective mass, Intrinsic carrier concentration, Impurity conductivity, Thermoelectric effects.	CLO1
	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.	CLO2
	Learning Activities: Group discussions, Application based peer thinking	
II/11	**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	CLO3
	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.	CLO4
	Learning Activities: Group discussions, Application based peer thinking	
III/11	**Dielectrics and Ferroelectrics:** Polarization, Macroscopic and local electric field, Dielectric	CLO5

	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.	CLO6
	Learning Activities: Group discussions, Application based peer thinking	
IV/11	**Magnetism, and Magnetic Resonance:** Types and properties of magnetism, Spin waves, Magnons, Magnon dispersion relations, Bloch T3/2 Law, Electron spin resonance (ESR), Nuclear magnetic resonance (NMR), Spin relaxation (spin-lattice, spin-spin), Applications of ESR and NMR.	CLO7
	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.	CLO8
	Learning Activities: Group discussions, Application based peer thinking	

Transaction Mode: Lecture based Class room teaching, case study, blended learning, problem solving, discussion & demonstration, self-study and experimental exposer.

Suggested Readings:

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

Course Name: Thin Film and Vacuum Techniques
Course Code: PHY.704
Course type: Elective Course
Total Hours: 45

L	T	P	Credit
4	0	0	4

Course Learning Outcomes:
CLO1: Outline the thin film deposition techniques.
CLO2: Explain optical, electrical, magnetic and mechanical properties and its applications.
CLO3: Summarise the basics of vacuum techniques.
CLO4: Explain positive displacement pumps.
CLO5: Explain entrapment pumps.
CLO6: Explain vacuum measurement systems.
CLO7: Outline the methods of leak detection.

Units/Hours	Contents	Mapping with Course Learning Outcome
I/12	**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.	CLO1
	Learning Activities: Group discussions, Application based peer thinking	
II/11	**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	CLO2

	elements, Integrated circuits.	
	Learning Activities: Group discussions, Application based peer thinking	
III/11	**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.	CLO3
	Positive Displacement Pumps: Rotary pump, Scroll pump, Momentum transfer or molecular pumps, Diffusion and turbo molecular pump.	CLO4
	Entrapment Pumps: Ion pumps, Sputter pumps, Cryo pumps, Sorption pumps, Design of ultra high vacuum systems.	CLO5
	Learning Activities: Group discussions, Application based peer thinking	
IV/11	**Vacuum Measurement Systems:** Vacuum measurement gauges, Hydrostatic gauges, Mechanical or elastic gauges, Thermal conductivity gauges, Ion gauges, Control and interlock systems.	CLO6
	Leak detection techniques: Types of leaks, Bubble test, Pressure decay test, Tracer gas leak testing using helium gas.	CLO7
	Learning Activities: Group discussions, Application based peer thinking	

Transaction Mode: Lecture based Class room teaching, case study, blended learning, problem solving, discussion & demonstration, self-study and experimental exposer.

Suggested Readings:

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

6. J.F. O'Hanlon, (1989). A Users Guide to Vacuum Technology. New York, USA: John Wiley & Sons.
7. J.M. Lafferty, (1998). Foundations of Vacuum Science and Technology. New York, USA: John Wiley & Sons.

Course Title: Nanostructured Materials
Paper Code: PHY.705
Total Lectures: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: After completion of this course students would be able to

CL01: Explain important role in the growing field of materials research.
CL02: Discover innovative/smart modern materials.
CL03: Explain Nano materials and their properties.
CL04: Explain synthesis via different methods/rout.
CL05: Analyze different characterization tools that are used to probe the nanomaterials application/devices.

Units/Hours	Contents	Mapping with Course Learning Outcome
I/15	**Synthesis:** Introduction to nanotechnology and nanomaterials, Top down and bottom up approaches, Sol-gel, Spin and dip coating, Pulsed Laser Deposition (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, Nano structuring and modification by swift heavy ions (SHI).	CL01
	Learning Activities: Group discussions, Application based peer thinking	
II/10	**Nanomaterials:** Carbon fullerenes and CNTs, Metal and metal oxides, Self-	CL02

	assembly of nanostructures, Core-shell nanostructures, Nanocomposites, Quantum wires, Quantum dots.	
	Learning Activities: Group discussions, Application based peer thinking	
III/20	**Characterization:** Characterization of nanomaterials for the structure, High resolution X-Ray diffract gram, 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.	CL04
	Learning Activities: Group discussions, Application based peer thinking	
IV/15	**Physical Properties of Nanomaterials:** Dielectric, Magnetic, Optical, Mechanical and photocatalytic properties.	CL03
	Applications: Electronic devices based on nanostructures, High electron mobility transistors, Nano magnetism, Surface/interface magnetism, Nano photonics, Solar cell, Memory devices, Super capacitors, Lithium ion batteries, Fuel cells, Organic semiconductors, Ferro-fluids.	CL05
	Learning Activities: Group discussions, Application based peer thinking	

Suggested Readings:

1. Haugstad G. (2012). *Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications.* New Jersey, USA: John Wiley & Sons,
2. Murty B.S., Shankar P., B. Raj, Rath B.B. and Murday J., (2013) *Textbook of Nanoscience and Nano technology* Sussex, UK; Springer.
3. Sattler K.D. (2010).*Handbook of Nanophysics* Florida, USA :CRC press.
4. Wing C.G., Lpez J.L.R., Graeve O.A., and Navia M.M., (2013). *Nanostructured Materials and Nanotechnology* Cambridge, UK: Cambridge University Press.

Transaction Mode: Class room teaching, group discussions, and practical sessions.

Course Name: Density Functional Theory and Applications

L	T	P	Credit
4	0	0	4

Course Code: PHY.706

Course type: Core Course

Total Hours: 45

Course Learning Outcomes:

On completion of this course, students will be able to:

CLO1: Explains the nuts and bolts of many-body approximations.

CLO2: Apply the laws of quantum physics to understand of density functional theory.

CLO3: Apply the concepts of solid state physics for practical implementation of density functional theory.

CLO4: Explain the details of density functional theory for electronic structure problems.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12 Hours	**Many-body Approximations:** Schrodinger equation and its solution for one electron and two electron systems, Hamiltonian of many particles system, Born-Oppenheimer approximation, Hartree	CLO1

	theory, Idea of self-consistency, Exchange energy and interpretation, Identical particles and spin, Hartree-Fock theory, Anti symmetric wave functions 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.	
	Learning Activities: Brain-storming	
II 11 Hours	**From Wave Functions to Density Functional:** Idea of functional, Functional derivatives, Electron density, Thomas 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 functional and meta-GGA approaches. Self-interaction corrections (SIC).	CLO2
	Learning Activities: Group discussion	
III 11 Hours	**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.	CLO3
	Learning Activities: Brain-storming	
IV 11 Hours	**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	CLO4

	in relation with ionization potential, Fermi surface and band gap. Electronic structure of Graphene	
	Learning Activities: Group discussion and problem solving	

Transaction Mode: Lecture, problem solving, group discussion, self-study.

Suggested Readings:

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

Course Tile: Energetic Materials and Storage Devices

Paper Code: 707

Total Lectures: 60

L	T	P	Credits
4	0	0	4

Learning Outcomes: At the end of the course students would be able to

CL01: Explain different materials use in development of solar cell
CL02: Explain different materials use in development of Fuel Cell
CL03: Explain different materials use in development of solar cell LED and Photovoltaic devices
CL04: Explain different materials use in development of solar cell different Primary and Secondary Batteries

- Explain different materials use in development of super/ultra capacitors

Units/Hours	Contents	Mapping with Course Learning Outcome
I/15	**Materials for Energy Conversion and Storage Devices:** Nanomaterials, Mesoporous materials, Biomaterials, Carbon based materials, Best absorbing materials, electron transport materials, hole transport materials, Perovskites and oxides	CL01
	Learning Activities: Group discussions, Application based peer thinking	
II/15	**Material Synthesis:** Physicochemical method, Electrochemical method, Spin coating, Dip coating, Sol-gel, Spray pyrolysis, Doctor blade, Hydrothermal, Chemical bath deposition, Chemical vapor deposition, Physical vapor deposition (DC/RF Magnetron sputtering, Electron beam evaporation, LASER ablation etc.).	CL02
	Learning Activities: Group discussions, Application based peer thinking	
III/15	**Band Engineering:** Electron in a crystal, Intrinsic semiconductor, Extrinsic semiconductor, Alignment of Fermi levels, Drift of electrons in an electric field, Mobility, Drift current, Diffusion current, Generation/Recombination Phenomena, Origin of bands, Band theory, Models of band engineering, Schottky diode, Ohmic contact	CL03
	Learning Activities: Group discussions, Application based peer thinking	
IV/15	**Energy Conversion Devices:** Solid state devices, Solid state mesoscopic solar cells, Silicon based solar cells, Dye sensitized solar cells, Organic solar cells, Dark current measurement, Calculation of efficiency, Super capacitors, Batteries.	CL04
	Learning Activities: Group discussions, Application based peer thinking	

Suggested Readings:

1. Sulabha K. Kulkarni Nanotechnology: Principles and Practices: Springer.
2. Murty B.S., Shankar P., Baldev Raj, Rath B B, James Murday. Textbook of Nanoscience and Nanotechnology: Springer
3. David B., Mitzi. Synthesis, Structure, and Properties of Organic-Inorganic Perovskites and Related Materials. Progress in Inorganic. Chemistry Vol. 48
4. Colinge J P and Colinge C. A. Physics of Semiconductor Devices: Kluwer Academic Publishers.
5. Francois B´ eguin. Super capacitors: Materials, Systems, and Applications, Wiley-VCH Verlag GmbH & Co.

Transaction Mode: Class room teaching, group discussions, and practical sessions.

Course Title: Accelerator and Plasma
Paper Code: PHY.708

L	T	P	Credits
4	0	0	4

Total Lectures: 60

- **Learning Outcomes:**

  CL01: Students will design the electron/ion accelerators, Cyclotron, Microtone etc.

  CL02: Students will design the radiation detectors

  CL03Students will explain the Plasma, plasma parameters such as electron/ion density and temperature, ion velocity, Debye length etc.

  CL04: Students will find the importance of Plasma wake field acceleration

Units/Hours	Contents	Mapping with Course Learning Outcome
I/15	**Accelerators:** Motion of charged particles in electric and magnetic fields, axial and radial magnetic field distributions in dipole, quadrupole and hex pole arrangement, Equipotential lines in different electrodes arrangement, Particle trajectory in electric and	CL01

	magnetic field, Electron sources, ion sources, Van de Graaf generator, DC linear accelerator, RF linear accelerator, Cyclotron, Microtone, introduction to advance accelerator (LHC)	
	Learning Activities: Group discussions, Application based peer thinking	
II/15	**Detectors:** Relation detectors Gaseous ionization, ionization and transport phenomena in gases, proportional counters, organic and inorganic scintillators, detection efficiency for various types of radiation, photomultiplier gain, semiconductor detectors, surface barrier detector, Si(Li), Gel(Li) and HPGe detectors.	CL02
	Learning Activities: Group discussions, Application based peer thinking	
III/15	**Plasma:** Introduction to Plasma, Properties of low and high temperature plasma, plasma parameters (electron density, ion density, electron temperature, ion temperature, ion velocity, Debye length etc.), Types of Plasma, Radio-frequency (RF) discharges: Capacitive RF discharge, Inductive RF discharge, Electron-cyclotron resonance (ECR) discharge, Dielectric barrier discharges, Atmospheric pressure plasmas, Magnetron discharge, Matching circuits and Applications.	CL03
	Learning Activities: Group discussions, Application based peer thinking	
IV/15	**Electron/Laser Beam Interaction with Plasma:** Plasma wake field acceleration, Drive beam, Tailor Beam, Plasma density, Plasma length, Plasma frequency, linear regime, blowout regime, Laser wake field acceleration	CL04
	Learning Activities: Group discussions, Application based peer thinking	

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Suggested Readings:

1. Helmut Wiedemann, (1994). *"Particle Accelerator Physics" Springer* Publications
2. Rudolf Bock, Angela Vasilescu. (1998). *The Particle Detector Accelerator Physics.*
3. Goldstone, Robert J. and Paul Harding Rutherford. (1995). *Introduction to plasma physics:* CRC Press,

4. Bittencourt, José A. (2013). *Fundamentals of plasma physics*. : Springer Science & Business Media,
5. Bellan, Paul M. (2008)**.** *Fundamentals of plasma physics:* Cambridge University Press.

Transaction Mode: Class room teaching, group discussions, and practical sessions.

Course Title: Data Acquisition and Experiment Automation
Paper Code: PHY.709

L	T	P	Credits
4	0	0	4

Total Lectures: 45

Learning Outcomes: At the end of the course, students will able to:

CLO1**:** Measure temperature, resistivity, etc. and design constant current sources and other instruments.

CLO2: Interface instruments with a computer and acquire measurement data using various methods e.g., DAQ cards, Arduino, etc.

CLO3: Automate experiments by writing programs to control data acquisition over GPIB or DAQ.

CLO4: Build a completely automated experiment with a low-cost computer Raspberry Pi and a low cost DAQ Arduino.

Course Contents:

Unit/Hours	Content	Mapping
1/12	**Measurement, Sensors and Error Analysis:** Temperature measurement, Four probe resistivity measurement, Van der pauw resistivity measurement, Hall measurement, Current-voltage characteristics measurement, RTD, Thermocouples, Low temperature sensors, Photodetectors, Thermistors, Photoresistors, Errors and calibration, Fabrication of constant current sources using op-Amp, signal and power amplifiers using bipolar junction transistors, Measuring resistance of calibrated RTD sensor for temperature measurement.	CLO1

2/11	**Data Acquisition and Interfacing with Computers:** Analog to digital conversion, Digital to analog conversion, Aliasing, Signal processing, RS232 communication, GPIB interfacing, Introduction to various data acquisition systems; NI-DAQ cards, Lab Jack, Arduino, Reading and writing data to computers.	CLO2
3/11	**Control and Experiment Automation:** Temperature control, PID control algorithm, implementation of control using programming languages like Lab View, Python, Arduino programming language, Setting up a completely automated resistivity versus temperature measurement.	CLO3
4/11	**Single Board Computers:** Introduction to single board computers, cheap data acquisition systems, Raspberry Pi, setting up of an automated experiment using Arduino for AD conversion and Raspberry Pi for computer control.	CLO4

Suggested Readings:

1) J.P. Bentley (1995): Principles of Measurement Systems (*Third edition)*, Longman, U.K.
2) S. Sen and S. Mukhopadhyay: Industrial and automation control, NPTEL, IIT Kharagpur.
3) E.O. Doeblin (1990), Measurement System Application and Design (*Fourth Edition*), Mcgraw-Hill, Singapore.
4) D.R. Coughanowr (1991), Process systems analysis and control *(Second edition)*, McGraw-Hill, NY.
5) Gareth Halfacree (2019), The official Raspberry Pi beginners guide *(Third edition)*; Raspberry Pi Press.

Transaction Mode: Class room teaching, group discussions, and practical sessions.

L	T	P	Credit
4	0	0	4

Course Name: Advanced Spectroscopy and Instrumentation

Course Code: PHY.710
Course type: Elective Course
Total Hours: 60
Course Learning Outcomes:
On completion of this course, students will be able to:
CLO1: Designed to impart advanced knowledge on the principles and instrumentation of MR spectroscopy.
CLO2: Spectroscopy and Instrumentation with the introduction of advanced topics such as QCLs, UC, etc. and application in different fields.
CLO3: To understand Physics of Functional Magnetic Resonance Imaging (fMRI) for practical implementation in Interdisciplinary research (Cognitive science, Neuroimaging, Clinical, etc.).
CLO4: Explains the details of Mass Spectrometry and technique.

Units/Hours	Contents	Mapping with Course Learning Outcome
I/15	**Magnetic Resonance Spectroscopy:** ^{1}H NMR Spectroscopy, Carbon -13 NMR Spectroscopy, 2D NMR Spectroscopy, Magic-angle spinning (MAS), FT-NMR spectrum (Time and Frequency Domain Spectra), Nuclear Magnetic Resonance Quantum Computing (NMRQC).	CLO1
	Learning Activities: Brain-storming	
II/15	**Emission Spectroscopy**: Fluorescence, Delayed fluorescence, Cross-relaxation, Energy transfer, Quantum yield and life time, Förster resonance energy transfer (FRET).	CLO2

	Spectroscopy techniques: Quantum Cascade Laser Spectroscopy (QCLs), Photon Upconversion (UC) Spectroscopy, Multiphoton Absorption Spectroscopy, Spectroscopic sensors, Spectroscopy in Forensic, Defense and medical applications.	
	Learning Activities: Group discussion	
III/15	**Functional Magnetic Resonance Imaging (fMRI)**: Basics, MRI Scanner, M*ulti-channel coils*, Gradient, T1 and T2* weighted, Free Induction Decay (FID), MR signals and BOLD effect, Spin echo, TR and TE, Diffusion Weighted Imaging (DWI), *Apparent Diffusion Coefficient* (ADC), Diffusion Tensor Imaging (DTI), *Hemodynamic Response Function* (HRF), Physiology of fMRI and Brain Physics, Image analysis.	CLO3
	Learning Activities: Brain-storming	
IV/15	**Mass Spectrometry:** Principles, Fragmentation, Ionization techniques (Electron ionization method, Chemical ionization method, Fast Atom Bombardment Technique), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Inductively coupled plasma atomic emission Spectroscopy (ICP-AES), Atomic Absorption Spectroscopy (AAS) and Accelerator Mass Spectrometry (AMS).	CLO4
	Learning Activities: Group discussion and problem solving	

Transaction Mode: Lecture, problem solving, PPT, group discussion, self-study.

Suggested Readings:

1. Introduction to spectroscopy by- Donald L. Pavia, Gary M. Lampman and George S. Vyvyan.

2. Instrumental Methods of Chemical Analysis by B.K Sharma.
3. Electrospray Ionization Mass Spectrometry: A Powerful Platform for Noble-Metal Nanocluster Analysis Dr.TiankaiChen,Dr. QiaofengYao,Dr. RiccaRahmanNasaruddin,Prof. JianpingXie ,1,2019.
4. Vogel's Text book of quantitative_chemical_analysis_5th_ed, John Wiley & Sons. Inc., New York.
5. Handbook of Functional MRI Data Analysis, by Russell A. Poldrack, *Stanford University, California*, Jeanette A. Mumford, *Stanford University, California*, Thomas E. Nichols, *University of Oxford*, Cambridge University Press, 2011.
6. Dass, C. Introduction to mass spectrometry S. K. Aggarwal and H. C. Jain, Eds.. J Am Soc Mass Spectrom 9, 345–346 (1998).