Pre-Ph.D. COURSE WORK

Post Graduate Diploma in Research (PGDR)

in

PHYSICS

(Effective from the session 2024-2025)

Department of Physics

DDU Gorakhpur University, Gorakhpur

Pre-Ph.D. Course Work in Physics

Every student admitted in Physics for the Pre-Ph.D. course work is required to complete a minimum of 12 credits course, in order to register for the Ph.D. program. The division of this 12 credits Courses is spanned in three Courses. Courses I and II are *compulsory* for all aspiring Ph. D. students. Course III is Open Elective. A student has to choose one course amongst the Courses offered under Open Elective.

Course Nature	**Course Code**	**Core Courses**	**Credit**
(Courses I & II)			
Compulsory Courses	RPE-600	Research and Publication Ethics	1+1
	PHY-601	Research Methodology	5+0
			07 Credits
	Course III – Innovative Research Approaches in Physics		
Open Elective (Any one)	PHY-602	Astrophysics	5+0
	PHY-603	Biophysics	5+0
	PHY-604	Condensed Matter Physics	5+0
	PHY-605	Electronic Structure and Spectroscopic Studies	5+0
	PHY-606	Nano Science and Gas Sensors	5+0
	PHY-607	Photonic Quantum Information Processing and Quantum Optics	5+0
			05 Credits
		Total	**12 Credits**

Course I: RPE-600 – Research and Publication Ethics Credits: 1+1

Unit 1: (Theory) Philosophy and Ethics, Introduction to Philosophy: definition, nature, scope, concept, branches Ethics: definition, moral philosophy, nature of moral judgment and reactions. Scientific Conduct, Research ethics, research Intellectual honesty and research integrity, copyright, Scientific misconduct: falsification, fabrication, and Plagiarism (FFP), Redundant Publication: duplication and overlapping publication salami slicing, Selective reporting, and misrepresentation of data

Unit 2: (Theory): Publication Ethics: definition, introduction, and importance Best practice/standard setting initiative and guidelines: COPE, WAME, etc. Conflict and interest, Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, Violation of publication ethics, authorship and contributor-ship, Predatory publisher and journals, Avoiding Plagiarism. Preparing documents for MoUs, Confidentiality Agreements

Unit 3: (Practice) Open access publication and initiatives SHERPA/RoMEO online resource to check publisher copyright and 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. Publication Misconduct, Subject Specific Ethical Issues FFP, authorship Complaints and appeals: examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund, and other open-source softwaretools.

Unit 4: (Practice): Database and research metrics. Indexing database, 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, i-10 index, altmetrics.

Suggested Readings:

(1) Bird, A (2006). Philosophy of Science. Routledge.
(2) Maclntyre, Alasdair (1967) A short history of Ethics, London
(3) P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not getplagiarized, ISBN:978-9387480865
(4) National Academy of Sciences, national Academy of Engineering and Institute of Medicine (2009) On Being A Scientist: A guide to Responsible conduct in Research.Third Edition. National Academics Press.
(5) Resnik, D. B. (2011). What is ethics in research & why is it important? National Instituteof Environmental Health Sciences, 1-10. Retrieved from http://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
(6) Bcall, J. (2012. Predatory publishers are corrupting open access. Nature, 489 (7415), 179.https://doi.org/10.1038/489179a
(7) Indian National Science Academy (INSA), Ethics in Science Education, Research andGovernance (2019),ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf

Course II: PHY-601 - Research Methodology Credit 5+0

Unit 1: Intellectual Property Rights (IPR): an introduction; IP as a global indicator of innovations, Role of IPR in economic and cultural developments, Types of IPR, Patents, Copyrights, Trademarks, Geographical Indications, Trade Secrets, Semiconductor Intigrated Circuits and Layout Designs, Protection of Plant Varieties and Farmers, Rights (PPV & RF), Industrial Designs.

Unit 2: Spectroscopic Techniques:
Microstructural characterization using X-ray Diffraction and neutron diffraction spectroscopy, UV and Visible absorption spectroscopy, IR and Raman spectroscopy, Basics of nuclear magnetic resonance (NMR) and electron spin resonance (ESR) spectroscopy.

Unit 3: Microscopic Characterization Techniques:
Basics and applications of Scanning electron microscopy (SEM), Scanning tunnelling microscopy (STM), Atomic Force Microscopy (AFM), Focussed ion beam (FIB) system, Transmission Electron Microscopy (TEM).

Unit 4: Basics of Molecular Modelling
Introduction to coordinate systems, potential energy surfaces, model building and computer simulation; introduction to quantum mechanics – postulates –Schrodinger wave equation – operators – eigen function – eigen values – expectation values – hydrogen molecule – Born-Oppenheimer approximation.

Unit 5: Molecular mechanics, Energy minimization and MD Simulation:
Empirical force field models – Bond stretching – angle bending – torsional term –nonbonding interactions – thermodynamics properties using a force field; boundary conditions, searching configuration space and generating ensemble; Derived and non-derive denergy minimization methods – steepest descent and conjugate gradient methods; Molecular dynamics simulation – integration algorithms.

Reference Books:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International, 418p.
3. Day, R.A., 1992. How to write and publish a Scientific paper, Cambridge UniversityPress.
4. Fink, A.,2009. Conducting Research Literature Reviews: From the internet to paper.Sage Publications.
5. Satarkar, S.V.,2000. Intellectual property rights and copyright. EssEss Publications.
6. Saxena, V.P.,2013. Lecture Notes on Research Methodology. Indra Publishing House.
7. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
8. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrived from http://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
9. Indian National Science Academy (INSA), Ethics in Science Education, Reasearch and Governance(2019),ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf
10. Bird, A. (2006)- Philosophy of Science.
11. Maclntyre, Alasdair (1967)- A short History of Ethics.

12. National Academy of Science, National Academy of Engineering and institute of Medicine (2009) On being a Scientist: A Guide of Responsible Conduct in Research.
13. Beall, J. (2012) – Predatory publishers are corrupting open access. Nature, 489(7415).
14. Introduction to Information Technology, ITL Education Solutions, Pearson Education.
15. Introduction to Computer Science, ITL Education Solutions, Pearson Education.
16. Computer Fundamentals by P.K.Sinha & Priti Sinha, BPB Publications.
17. Spectroscopy Volume 1, 2 and 3: B.P. Straughan and S. Walker.
18. Modern Spectroscopy: J.M. Hollas.
19. Transmission Electron Microscopy of Metals: Gareth Thomas
20. Elements of X-ray Diffraction: Bernard Dennis Cullity.
21. Atomic Force Microscopy/Scanning Tunneling Microscopy: M.T. Bray, Samuel H. Cohen and Marcia, L. Lightbody.
22. A. R. Leach - Molecular Modelling Principles and Application, 2nd edition, Longman Publications, 1996.
23. F. Jensen – Introduction to Computational Chemistry, 2nd edition, John Wiley & Sons Ltd.,2007.
24. T. K. Attwood, D. J. parry-Smith, Introduction to Bioinformatics, Pearson Education, 1st Edition, 11th Reprint 2005

Course Outcomes:

• Foundation for basic research methodology, research and publication ethics will be laid.

• Basic understanding of MS word, MS excel, Power point, Latex and endnote etc will be taught, which will help students writing their research articles and PhD thesis.

Course III: Innovative Research Approaches in Physics

PHY-602 - Astrophysics Credit 5+0

Course Objectives: Developing concept for observation of stars and galaxies and understanding the Physics of various astrophysical objects.

Unit 1: Celestial Sphere: Coordinate systems, Right Ascension and Declination, Trigonometric Parallax, Radial velocities and proper motions of stars.

Unit 2: Properties of stars: Apparent and Absolute magnitude, Distance, Colour index, Bolometric magnitude and Luminosity, Stellar Classification, HR diagram, Stellar energy and evolution.

Unit 3: Radiation Mechanisms: Synchrotron, Black body, Bremsstrahlung, Compton and Inverse Compton scattering, Examples of Astronomical objects exhibiting these processes.

Unit 4: Stellar structure: Hydrostatic equilibrium, Lane-Emden equation, Radiative equilibrium, Mass-Luminosity relation, The Solar system: Origin, Planets, Planetary rings and satellites, The Sun: Surface features, granules, sunspots, Chromosphere, Corona.

Unit 5: Star Clusters and Variability: Open and Globular clusters, Binary stars, Stellar pulsation, Cepheid variables, Nova, Supernova.

References:

1. Text book on Spherical Astronomy by W. M. Smart (Cambridge University Press)
2. Principles of Astronomy by S. P. Wyatt (Allen and bacyon, Inc.)
3. An Introduction to Astrophysics by B. N. Basu , T. Chattopadhyay, S. N. Biswas (Prientice Hall of India)
4. The Physical Universe by F. Shu (University Science Books, California, U.S.A.)
5. Principles of Astronomy by S. P. Wyatt (Allen and Bacyon, Inc.)
6. An Introduction to Astrophysics by B. N. Basu , T. Chattopadhyay, S. N. Biswas (Prentice Hall of India)
7. Astrophysics and Stellar Astronomy by T. L. Swihart
8. Astrophysics: Stars and Galaxies by K. D. Abhyankar
9. Essentials of Astronomy by Lloyd Motz (Columbia University Press)

Course Outcomes:

- Learning astronomical terms and prepare for observational research.
- Learning basic astrophysics and prepare for research in observation and theory.

PHY-603 - Biophysics **Credit 5+0**

Course Objectives: To understand basics of Biophysics, molecular basis of life and fundamental process at molecular level and to understand molecular forces and their time dependent behavior and techniques to study them.

Unit 1: The central dogma, structure of nucleic acids, nucleotides, nucleosides, backbone, conformation of nucleic acid, sugar pucker, primary, secondary and tertiary structure of DNA and RNA, Watson-Crick model, Transcription, replication and translation

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Unit 2: Amino acids, peptide bonds, primary, secondary and tertiary structure of proteins, alpha-helix and beta-sheet, Ramachandran plot, Disulphide Bridge. Structure of Haemoglobin and myoglobin, Dynamics of protein folding.

Unit 3: Structure of lipids and membranes, passive and active membrane transports, transporters and ion channels. Donnan equilibrium and Hodgkin- Katz formula, elementary idea of molecular reception.

Unit 4: General features of Molecular Mechanics: Force Field, Bond Stretching, Angle Bending, Torsional terms, Non-bonded interactions: electrostatic interactions, van der Waals interactions, Many body effects in empirical potentials, effective pair potentials, Hydrogen bonding in Molecular Mechanics, Force field models, Thermodynamical properties using force field, force field parameterization.

Unit 5: Molecular dynamics simulation: Derived and non-derived energy minimization methods – steepest descent and conjugate gradient methods; Molecular dynamics simulation – integration algorithms – temperature and pressure control during MD simulation – equilibration – analysis of simulation.

Books recommended:

1. Molecular Biology of the Genes by J. D. Watson (Benjamin Inc, California)
2. Principles of Nucleic Acid Structure by W. Saenger (Springer Verlag, New York)
3. Biophysics; Ed. W. Hoppe et. al. , (Springer Verlag, New York)
4. Introduction to Biophysics by P.S. Narayanan
5. Biophysics by M. V. Volkenstein (MIR publishers)
6. Molecular Modeling Principles and Application, 2nd edition by A. R. Leach-Longman Publications, 1996.
7. Introduction to Computational Chemistry, 2nd edition, by F. Jensen –, John Wiley & Sons Ltd. , 2007.
8. Introduction to Biophysics by PS. Narayanan
9. Biophysics by M. V. Volkenstein (MIR publishers)
10. Physical Biochemistry by K. E van Holde, (Prentice Hall, NJ)

Course outcomes:

1. Learn the genetic materials and their structure, and properties
2. Learn the role of different amino acids in the synthesis of proteins.
3. Learn the process of transportation of metabolites and ions through the membrane.
4. Learn long and short range forces and theories for their treatment.
5. Learn various biophysical techniques used in the advanced study of biophysical phenomena.

PHY-604 - Condensed Matter Physics Credit 5+0

Course Objective: To enhance the knowledge about recent research in Condensed Matter Physics.

Unit 1: Elements of crystal structure: space lattice, basis, unit cell, lattice parameter, seven crystal systems and fourteen bravis lattices, crystal system structures, Packing factor (cube, body and face), crystal structure of sodium chloride and diamond, Lattice planes, miller indices, Reciprocal lattices.

Unit 2: Superconductivity: Persistent currents, effect of magnetic fields, flux exclusion, the Meissner effect, Type I and Type II super conductors, Intermediate states, Entropy and heat capacity, energy gap, thermal conductivity, Isotope effect, Cooper pairs, BCS theory.

Unit 3: Electrical transport: Boltzmann transport equation, collision operator, Lorentz solution, Somerfield theory of electrical conductivity, Relaxation time, thermal conductivity, criterion of Somerfield theory, mean free paths, solid electrolytes and structure, types of ionic bonds, proton conductors and application of solid electrolytes.

Unit 4: Free-electron theory of metals: Sommerfield quantum theory, free electron gas in one dimensional box, free electron gas in three dimensional box, filling up of the energy levels, density of electron states, parameters of free electron gas at absolute zero, Fermi energy, average kinetic energy of an electron.

Unit 5: Magnetic resonance: Nuclear magnetic resonance, nature of phenomenon, analysis of phenomenon, experimental methods, some applications, determination of nuclear magnetic moments, structural studies, diffusion in solids, electron spin resonance(ESR); Method of observation, structure of resonance line and their uses.

References:

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London)
2. Theoretical Solid State Physics Vol.1 and Vol.11 by W. Jones and N.H. March (John Wiley and Sons, London)
3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London)
4. Quantum Theory of Solids by R.E. Peirls (Oxford University Press, London)
5. Superionic Solids: Principle and Applications by S. Chandra (North-Holland Publishing Company, Oxford)

Course Outcome:

- Tendency to develop different types of materials and their applications in novel technologies and instruments.

PHY-605- Electronic Structure and Spectroscopic Studies Credit 5+0

Objective: Spectroscopic and electronic structure studies of the molecules and solids.

Unit 1: Born-Oppenheimer approximation and its application, Hydrogen molecule, Valence bond methods, Diatomic molecule, Slater Determinant, LCAO approximation.

Unit 2: Self-consistent field (SCF) theory, basis sets, Hartree-Fock-Roothaan's equation, *ab initio* methods,

Unit 3: Density functional theory (DFT): Electron correlation, local density approximation (LDA), hybrid functionals (such as B3LYP), Kohn-Sham equations, Hohenberg-Kohn's Theorem, exchange correlation hole, exchange interaction, functional derivative.

Unit 4: Charge density distribution in molecules, dipole moment, molecular electrostatic potential, intermolecular interactions, energy partitioning into different types of interactions, Hellman-Feynman theorem and concept of force, hybrid atomic orbitals, lone pairs, conformations, calculation of electronic spectra of molecules.

Unit 5: Vibration spectra of polyatomic molecules. Classical and quantum mechanical treatment of normal modes of vibration, vibrational selection rules, Fermi resonance, Microwave spectra of ammonia. Raman spectra for vibration and Rotation.

References:

1. J. C. Slater, *Quantum Theory of Molecule and Solids*, vol. I, MacGraw-Hill, 1963.
2. N. Levine, *Quantum Chemistry*, Fifth Edition, Pearson Education, Singapore, 2003.
3. H. F. Schaefer, *The electronic Structure of Atom and Molecules*, Addison-Wesley, 1972.
4. Molecular Spectra and Molecular Structure by G. Herzberg (Dover Publication).
5. Introduction to Molecular Spectroscopy by G.M. Barrow (McGraw-Hill)
6. Modern Spectroscopy by M.J. Hollas (Wiley Inter Science)

Course Outcomes:

1. Learn various methods and techniques for electronic structure of molecules.
2. Learn valence bond and semi-empirical approaches for the molecules
3. Learn wave function and density functional theories.
4. Learn Spectroscopic behavior of molecules.

PHY-606 - Nano Science and Gas Sensors Credit 5+0

Course objective: Understanding of nano science, nano materials and its applications
Design and fabrication of gas sensors.

Unit 1: Liquid crystals: Definition, Classification, Characteristic features; Thermotropic and Lyotropic Liquid Crystals, FLCs, Basic principle of LCDs.

Unit 2: Polymers: Structure, properties and methods of Polymerization, Degradation of Polymers, Viscoelastic state, Glass transition temperature.

Unit 3: Nano-materials: Nano Materials: Introduction, Definition and Scopes, Density of States, Quantum size effect, General methods of preparation and synthesis, Comparison of Mechanical, Electrical and Optical properties with Bulk Material, Mono-dispersed Nanoparticles. Nanocomposites: Dye- inorganic, Organic-inorganic, Magnetic-fluorescent Nano composites.

Unit 4: Sensors: Sensor architecture, figure of merit, sensor design, selection of transducer material, growth and synthesis of nanostructured thin films: Physical vapor deposition (PVD), Chemical vapor deposition (CVD) and spin coating, sol-gel, glancing angle deposition (GLAD) methods.

Unit 5: Types of sensors: Physical sensor, Chemical sensors, Adsorption of gases in solids, MOS gas sensors, MOS capacitors; C-V characteristics, fixed oxide charge, Interface trapped charge, Flat-band voltage, Threshold voltage.

Course Outcome:

- The students will understand how to control matter at Nano scale and its importance.
- To learn various aspects of Nano technology for gas sensors.

PHY-607 - Photonic Quantum information processing and Quantum Optics Credit 5+0

Course Objective: The students will learn one of the exciting fields of 21st century, that is, convergence of quantum mechanics, Computer science and Communication Technology.

Unit 1: Ingredients of Quantum Mechanics and Generalized Measurement: Superposition Principle, Hermitian operator, Density operator, Pure and Mixed states, Unitary operators, Qubit and it's representation on Bloch-sphere, No-cloning Theorem and Prohibition of Quantum Copying. Generalized measurements : von Neumann (ideal) measurement, Non-ideal measurements, Probability operator measures (POM), Optimal POM, Post-measurement State.

Unit 2: Entanglement: Historical background, EPR paradox and Non-locality, Indirect measurements; The Schmidt decomposition and Entangled states, Peres-Horodecki and Simon Criterion. Ebits and shared entanglement, Quantum Teleportation Protocol (Local Operation and Classical Communication), Fidelity and it's Phtonic realization.

Unit 3: Quantum Computation and Quantum Communication: Quantum gates : Single qubit, Multiple qubits, Quantum circuits and Universality. Principles of quantum computation: The quantum Fourier transform, Shor's factoring algorithm, Grover's search algorithm. Quantum Communication : The von Neumann entropy, Composite systems and Quantitative state Comparison; Information security: RSA cryptosystemand Quantum Cryptography, Optical polarization and Quantum key distribution (BB84), Entanglement-based Quantum cryptography (Ekert Protocol).

Unit 4: Optical Coherence and Photon Statistics : Quantized Electromagnetic Field; Second- and Higher-order Coherence Function : Classical (Wolf) and Quantum (Glauber); Optical Field States: Fock states, Thermal States and Coherent states; Sudarshan-Glauber P-representation; Photoelectric detection and Poissonian and sub-Poissonian statistics.

Unit 5: Quasi-distribution Function and Measuring Quantum state: Wigner, P- and Q-Quasi-distributionFunction of Fock states, Thermal States, Coherent states and squeezed vacuum; Quadrature Distributions and Optical homodyne detection; Quantum state tomography.

References :

1. A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers, Dordrecht, 1995.
2. M.A. Nielsen and I.L.Chuang, Quantum computation and Quantum information, Cambridge University Press, Cambridge, 2000.
3. V. Vetal, Introduction to Quantum information science, Oxford University Press Oxford, 2006.
4. Stephen M. Barnett, Quantum Information, Oxford University Press Oxford, 2009.
5. Emmanuel Desurvire, Classical and Quantum Information Theory, Cambridge University Press, Cambridge, 2009.
6. E.Wolf and L. Mandel, Optical Coherence and Quantum Optics, Cambridge University Press, Cambridge, 1995.

7. Ulf Leonhardt, Measuring Quantum State of Light, Cambridge University Press, Cambridge, 1997.
8. R. Loudon, The Quantum theory of light, 3rd Edition, New York, Oxford University Press, 2000.
9. W. P. Schleich, Quantum Optics in Phase Space, Berlin, Wiley-VCH, 2001.
10. G. S. Agarwal, Quantum Optics, Cambridge University Press, Cambridge, 2013.

Course Outcome:

- The Students willacquirebasic Principles, Techniques and protocols involved in quantum computation and communication and characterization of Optical Quantum fileds and it's Detection, Quasi-probability Distribution formalism of Quantum-Optics and Optical Field states-measurement.