Integral University, Lucknow

Effective from Session: 2024-25							
Course Code	**PY601**	**Title of the Course**	**Material Synthesis, Characterization and Applications**	**L**	**T**	**P**	**C**
Year	**First**	**Semester**	**First**	**3**	**1**	**0**	**4**
Pre-Requisite	M. Sc. with Physics	**Co-requisite**					
Course Objectives	To provide the students with basic knowledge of materials science, so that they would be able to understand and distinguish between the varieties of materials based on their structure and properties.						

Course Outcomes	
CO1	To learn about the different types of functional materials
CO2	To understand the electrical, thermal, magnetic and superconducting properties of the nanomaterials.
CO3	To learn about the different types of synthesis methods of nanomaterials
CO4	To develop an understanding of characterization techniques of nanomaterials.
CO5	To learn about the applications of nanomaterials in different types of fields.

Unit No.	Title of the Unit	Content of Unit	Contact Hrs.	Mapped CO
1	**Liquid Crystals, Modern Functional Materials and Nanomaterials**	**Liquid crystals:** Phases of matter and liquid crystal phase transitions, Types of liquid crystals: nematic, smectic, cholesteric, Landau-de Gennes theory, Dynamics of liquid crystal molecules, Electro-optical effects in Liquid Crystals. Polymers and composites, Advanced ceramic materials, Biomaterials, Magnetic materials, Dielectric materials **Nanomaterials:** Surface to Volume ratio, Energy Levels & Density of States, Quantum confinement effects, Bandgap engineering in nanostructures, Physical, Chemical & Magnetic properties, Quantum Wells, Wires & Dots, Landauer Formula, Coulomb Blockade, Fullerene, CNT, Graphene, MXenes.	8	CO1
2	**Properties of Nanomaterials**	Size-dependent electronic and optical properties, Quantum interference effects in nanodevices, Role of defects and grain boundaries in nanocrystalline materials, Surface energy and surface tension at the nanoscale, Mechanical properties of nanostructured materials (Strength, hardness, and elasticity), Thermal conductivity, Size-induced phase transitions, Dielectric Properties, Magnetic Properties, Superconductivity.	8	CO2
3	**Synthesis Methods of Nanomaterials**	**Top-Down Approach:** Lithography techniques: photolithography, electron beam lithography, Ion and plasma etching methods, Challenges, and breakthroughs in top-down nanofabrication **Bottom-up Approaches:** Chemical vapor deposition (CVD), Solution-phase methods: sol-gel, hydrothermal synthesis, and co-precipitation, atomic layer deposition (ALD) and chemical bath deposition (CBD), Vapor-phase techniques: physical vapor deposition (PVD), chemical vapor synthesis (CVS), Green synthesis methods and sustainability considerations in nanomaterial production.	8	CO3
4	**Characterization Techniques of Nanomaterials**	Fundamental of material characterization using x-ray technique, intensity data collection, data reduction profile fitting and refinement (Le-bail & Rietveld), UV-Visible and Diffused Reflectance Spectroscopy, Fourier Transform Infrared Spectroscopy, Raman Spectroscopy, Photoelectron Spectroscopy, Imaging Techniques (Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy), Thermogravimetric analysis, Differential Scanning Calorimetry, Vibrating Sample Magnetometer, SQUID, Impedance Analyzer, Electrochemical Characterization (CV, GCD).	8	CO4
5	**Nanomaterials in Applications**	Nanoscale electronic Components, Quantum dots in transistors and diodes, memory devices, magnetic and resistive switching devices, Spintronics and spin-based devices, Energy conversion and harvesting, Energy storage (batteries and supercapacitors), fuel cells, hydrogen storage, Nano catalysis and Photodegradation (waste water treatment), Sensing Applications, Bio-medical Applications of nanomaterials.	8	CO5

Reference Books:

1. "Introduction to Solid State Physics" by Charles Kittel
2. "Solid State Physics" by Neil W. Ashcroft and N. David Mermin
3. "Materials Science and Engineering: An Introduction" by William D. Callister Jr. and David G. Rethwisch
4. "Introduction to Liquid Crystals" by Peter J. Collings and Michael Hird
5. "Nanomaterials: Synthesis, Properties, and Applications" by A. S. Edelstein and R. C. Cammarata
6. "Nanomedicine and Nanobiotechnology" by N. Saravanan
7. "Nanoelectronics: Principles and Devices" by Sergey Edward Lyshevski

e-Learning Source:

1. Physics of Solids (https://ocw.mit.edu/courses/8-231-physics-of-solids-i-fall-2006/)
2. Fundamentals of Materials Science (https://ocw.mit.edu/courses/3-012-fundamentals-of-materials-science-fall-2005/)
3. Introduction to Nanoelectronics (https://ocw.mit.edu/courses/6-701-introduction-to-nanoelectronics-spring-2010/)

Course Articulation Matrix: (Mapping of COs with POs and PSOs)

PO-PSO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3	PSO4
CO1	3	1	---	1	2	3	---	---	1	1	3	1	1	2
CO2	2	2	---	2	3	3	---	---	1	3	3	3	1	2
CO3	3	1	---	2	2	3	---	---	1	3	3	3	2	2
CO4	2	3	---	3	3	3	---	---	2	3	3	3	3	3
CO5	3	2	---	3	3	3	---	---	3	3	3	1	3	3

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

Name & Sign of Program Coordinator	**Sign & Seal of HoD**

Integral University, Lucknow

Effective from Session: 2024-25							
Course Code	**PY602**	**Title of the Course**	**Computational Physics**	**L**	**T**	**P**	**C**
Year	**First**	**Semester**	**First**	**3**	**1**	**0**	**4**
Pre-Requisite	M. Sc. with Physics	**Co-requisite**					
Course Objectives	To provide basic knowledge of computational research to the students and to equip them with the necessary computational tools to carry out the research.						

Course Outcomes	
CO1	To learn the basics of Computational Physics
CO2	To learn the basics of DFT method and to apply it to different types of systems
CO3	To learn the basics of MATLAB and its application to different types of system
CO4	To learn the LINUX operating system and perform various tasks through it
CO5	To learn the advance techniques of computational research

Unit No.	**Title of the Unit**	**Content of Unit**	**Contact Hrs.**	**Mapped CO**
1	**Introduction to Computational Physics**	Introduction to Computational Physics, Basic Concepts of Numerical Analysis, Error Analysis and Round-off Errors, Numerical Methods for Solving Algebraic Equations, Numerical Methods for Solving Ordinary Differential Equations, Numerical Methods for Solving Partial Differential Equations, Monte Carlo Methods, Molecular Dynamics Simulations	8	CO1
2	**Density Functional Theory (DFT) Methods**	Introduction to DFT, Hohenberg-Kohn Theorems, Kohn-Sham Equations, Exchange-Correlation Functionals, Plane-Wave Basis Sets, Pseudopotentials, Implementation of DFT Calculations, Applications of DFT	8	CO2
3	**MATLAB**	Introduction to MATLAB, MATLAB Basics, Data Types and Operators, Control Structures, Functions and Scripts, Plotting and Graphics, Numerical Methods in MATLAB, Applications of MATLAB in Computational Physics	8	CO3
4	**LINUX**	Introduction to LINUX, LINUX Basics, The Command Line Interface, File System and Permissions, Process Management, Software Installation and Management, Networking and Security, Applications of LINUX in Computational Physics	8	CO4
5	**Advanced Topics in Computational Physics**	Quantum Monte Carlo Methods, Time-Dependent Density Functional Theory, Many-Body Perturbation Theory, Green's Function Methods, Renormalization Group Theory, Monte Carlo Methods for Statistical Physics, Molecular Dynamics Simulations of Biological Systems, Applications of Computational Physics in Materials Science	8	CO5

Reference Books:

1. Computational Physics by Mark E. Tuckerman (Unit-1)
2. Physics for Scientists and Engineers with Modern Physics by Serway and Jewett (Unit-1)
3. Numerical Recipes in C++ by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery (Unit-1)
4. Density Functional Theory by Robert G. Parr and Weitao Yang. (Unit -2)
5. Fundamentals of Time-Dependent Density Functional Theory by Miguel A.L. Marques and Neepa T. Maitra (Unit-2)
6. Practical Density Functional Theory by Reinhard M. Martin (Unit-2)
7. MATLAB Programming for Engineers and Scientists by Steven J. Chapman (Unit-3)
8. Mastering MATLAB by Duane Hanselman and Bruce Littlefield (Unit-3)
9. MATLAB for Computational Physics by Emil Simiu and Bogdan Grigorenko (Unit-3)
10. The Linux Command Line by William E. Shotts (Unit-4)
11. The Linux Bible by Christopher Negus (Unit-4)
12. Linux for Dummies by Richard Blum (Unit-4)
13. Quantum Monte Carlo Methods by W.M.C. Foulkes, L. Mitas, R.J. Needs, and G. Rajagopal (Unit-5)
14. Time-Dependent Density Functional Theory by Miguel A.L. Marques and Neepa T. Maitra (Unit-5)
15. Many-Body Perturbation Theory in Condensed Matter Physics by H. Bruus and E. Flensberg (Unit-5)
16. Green's Function Methods in Physics by Elihu Abrahams and Stephen D. Sarma (Unit-5)
17. Renormalization Group Theory by John Cardy (Unit-5)

e-Learning Source:

1. MIT Open Course Ware: Computational Physics
2. Stanford Online: Computational Physics
3. University of California, Berkeley: Computational Physics
4. MIT Open Course Ware: Density Functional Theory
5. Stanford Online: Density Functional Theory
6. University of California, Berkeley: Density Functional Theory
7. MATLAB Tutorial, MATLAB Online Documentation, MATLAB Central
8. Linux Tutorial, Linux Online Documentation, Linux Foundation Training
9. MIT Open Course Ware: Advanced Topics in Computational Physics
10. Stanford Online: Advanced Topics in Computational Physics
11. University of California, Berkeley: Advanced Topics in Computational Physics

	Course Articulation Matrix: (Mapping of COs with POs and PSOs)													
PO-PSO / CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PSO1**	**PSO2**	**PSO3**	**PSO4**
CO1	3	1	---	1	2	3	---	---	1	1	3	1	1	2
CO2	2	2	---	2	3	3	---	---	1	3	3	3	1	2
CO3	3	1	---	2	2	3	---	---	1	3	3	3	2	2
CO4	2	3	---	3	3	3	---	---	2	3	3	3	3	3
CO5	3	2	---	3	3	3	---	---	3	3	3	1	3	3

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

Name & Sign of Program Coordinator	**Sign & Seal of HoD**

Integral University, Lucknow

Effective from Session: 2024-25							
Course Code	**PY603**	**Title of the Course**	**General Theory of Relativity and Cosmology**	**L**	**T**	**P**	**C**
Year	**First**	**Semester**	**First**	**3**	**1**	**0**	**4**
Pre-Requisite	M. Sc. with Physics	**Co-requisite**					
Course Objectives	To provide the students with basic knowledge of general theory of relativity and cosmology and to equip them with the necessary tools to carry out research in this field.						

Course Outcomes	
CO1	To make students aware of Special Theory of Relativity
CO2	To learn about the Riemannian Geometry
CO3	To learn about Einstein Field Equations
CO4	To learn about the different applications of General Theory of Relativity
CO5	To learn about the basics of Cosmology

Unit No.	**Title of the Unit**	**Content of Unit**	**Contact Hrs.**	**Mapped CO**
1	**Special Theory of Relativity**	Historical Perspective, Theory of Relativity and Applications, The spacetime of special relativity, Theoretical and Observational formulation, Postulates for the special theory of relativity, Lorentz and generalized Lorentz transformations, Length contraction, Time dilation, Relativistic Mechanics, Classical field theory, symmetries and conservation laws	8	CO1
2	**Mathematical Formulation**	The Equivalence principle and spacetime curvature, Manifolds and coordinates, Tensors, Symmetric and antisymmetric tensors, Metric Tensor, Covariant and Contravariant derivatives, Ricci scalar, Riemann curvature tensor, Ricci curvature tensor. Stress-energy–momentum tensor, Derivation of the Geodesic equation and Defining Christoffel Symbols	8	CO2
3	**Einstein Field Equations**	Einstein-Hilbert Action, Derivation of Einstein field Equations, Cosmological constant, Lagrangian formulation of General Theory of Relativity, Symmetries and conservation laws in General Theory of Relativity, The *Friedmann–Lemaître–Robertson–Walker* Model	8	CO3
4	**Applications of General Relativity**	Solar System tests, bending of light, mercury perihelion advance, geodetic precession, trajectories – time-like, light-like and space-like, Linearization and Newtonian Approximation, Gravitational Waves, Gravitational Red shift, Cosmology, Miscellaneous Applications; Frame dragging and General Positioning System (GPS)	8	CO4
5	**Introduction to Cosmology**	Hubble Expansion, $H_0 t_0$, Angular Diameter Test, Type Ia Supernova, Inflation, Quantum Fluctuations from Inflation, Radiation and Matter Era, Nucleosynthesis, Cosmic Microwave Background Radiation Physics, Structure Formation, Current Status for Cosmology	8	CO5

Reference Books:

1. The Classical Theory of Fields by L. D. Landau & E. M. Lifshitz, Imprint: Butterworth-Heinemann, ISBN: 9780750627689
2. Gravitation and Cosmology: Principles and Applications of The General Theory of Relativity by Steven Weinberg (MIT), Publisher: John Wiley & Sons, Inc. ISBN: 0-471-92567-5
3. A First Course in General Relativity by Bernard F. Schutz, Publisher: Cambridge University Press, ISBN: 0521277035
4. Gravity: An Introduction to Einstein's General Relativity by James B. Hartle, Publisher: Pearson, ISBN: 0805386629
5. Cosmological Physics by John A. Peacock, Publisher: Cambridge University Press, ISBN: 9780511804533
6. Cosmology by Daniel Baumann, Publisher: Cambridge University Press, ISBN: 1108838073

e-Learning Source:

1. Lecture notes on General Relativity by Sean M. Carroll, University of California, USA
2. Lecture notes: Cosmology by Luca Amendola, University of Heidelberg, Germany
3. MIT Open Course Ware: Cosmology

Course Articulation Matrix: (Mapping of COs with POs and PSOs)

PO-PSO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3	PSO4
CO1	3	1	---	1	2	3	---	---	1	1	3	1	1	2
CO2	2	2	---	2	3	3	---	---	1	3	3	3	1	2
CO3	3	1	---	2	2	3	---	---	1	3	3	3	2	2
CO4	2	3	---	3	3	3	---	---	2	3	3	3	3	3
CO5	3	2	---	3	3	3	---	---	3	3	3	1	3	3

1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation

Name & Sign of Program Coordinator	**Sign & Seal of HoD**