UNIVERSITY OF THE PUNJAB

NOTIFICATION

It is hereby notified that the Syndicate at its meeting held on 17-12-2022 has approved the recommendations of the Academic Council made at its meetings dated 11-03-2022 and 21-03-2022 respectively, regarding approval of the revised Compulsory Courses and addition of Elective/Optional Courses of MS/Ph.D Physics Program under semester System as per HEC guidelines, w.e.f. the Academic Session, Fall, 2022.

The revised Compulsory Courses and addition of Elective/Optional Courses of MS/Ph.D. Physics are enclosed herewith, vide Annexure-'A'

Sd/-
SHAHID JAVED
Registrar

Admin. Block,
Quaid-i-Azam Campus,
Lahore.
No. D/ 680 /Acad.

Dated: 25 – 01 /2023.

Copy of the above is forwarded to the following for information and further necessary action: -

1. Dean,
   Faculty of Sciences
2. Chairman, Department of Physics
3. Chairperson, DPCC
4. Controller of Examinations.
5. Director, IT for placement at website.
6. Admin. Officer (Statutes)
7. Secretary to the Vice-Chancellor
8. PS to the Registrar.
9. Assistant Syllabus.

Mazhar

Assistant Registrar (Academic)
for Registrar

UNIVERSITY OF THE PUNJAB, LAHORE, PAKISTAN

CURRICULUM OF PHYSICS (2022)

MS/PhD Physics degree program under semester system as per HEC guidelines with effect from Fall 2022

Department of Physics, University of the Punjab, Lahore Pakistan
25/11/2021

MS / PhD PHYSICS DEGREE PROGRAM

Duration of Degree Course	MS (Two years) and PhD (Five years)
Teaching System	Semester System
Credit Hours for Taught Courses	24 (Semesters I, II) for MS / 48 (Semesters I, II, III, IV) for PhD
Session Starts	(Fall) September-October
Eligibility Qualification	BS (Physics) / MS Physics or Equivalent
Number of Student Enrollment	30 for MS / 20 for PhD

MISSION STATEMENT

The mission of the Master of Science/ Doctorate of Philosophy (Physics) program is to equip students with theoretical and applied knowledge of physics for the solutions of complex problems related to understanding of physical world and to enable them to use that knowledge in solving various problems of human world. It is aimed to prepare the students to learn independently and critically in a constantly changing discipline.

OBJECTIVES

The MS/PhD (Physics) degree course is offered by the Department of Physics as a full-time period of teaching and research and introduces students to research skills and specialist knowledge in the subject of Physics. Main objectives of the program are

- to offer students graduate level courses in theoretical and applied physics
- to give students with relevant experience, the opportunity to carry out research in various disciplines of Physics under close supervision
- to give students the opportunity to develop various skills and expertise relevant to their research interests
- to give students the opportunity to engage in rigorous scholarly pursuit, and to contribute in academic and industrial research
- to prepare students with a theoretical physics background and applied research needed to enter a doctorate program in physics.
- to prepare students to join an appropriate and respectable level position in a physics related field, and to maintain their professional skills in rapidly evolving industry and academia.
- to develope research based scientific thinking and to enhance professional skills for teaching, research, managerial positions in wide range of professions in national and international organizations.

Semester-wise breakup and outline of courses for this program are given as under. In addition to compulsory courses, elective courses of graduate level are offered in various specializations in the subject of Physics. The program meets the standards of international graduate programs in the subject of Physics. Taught courses are offered in semesters I and II, while in semester III and IV, studend work towards their thesis projects. Graduate students are offered research projects from various research groups of the Department. Teaching and Examinations are held according to semester rules of University of the Punjab.

SCHEME OF STUDIES

COURSE CODE KEY

For the course code Phys xxxx, the first letter shows the year of degree course in the university (e.g. for first year course, it is written as 1xxx, for third year course it is 3xxx and for fifth year course it is 5xxx (first year of MPhil course), while second letter represents a number assigned to a specific subject area of physics (e.g. in general classification within the subject of Physics, a number is assigned to a set of similar subject titles i.e. for foundation courses, the number is 0 (Phys x0xx), for classical mechanics and related titles, the number is 1 (Phys x1xx), for electrodynamics and related titles it is 2 (Phys x2xx), for quantum mechanics and related titles, it is 3 (Phys x3xx), for solid state physics and related titles, it is 4 (Phys x4xx), for mathematical physics and related titles, it is 5 (Phys x5xx), for experimental physics and labs, it is 6 (Phys x6xx), for electronics and related titles, it is 7 (Phys x7xx), for materials and nanotechnology, it is 8 (Phys x8xx) etc. The last two letters of the course code show the sequence of the course titles in the specific subject and ranges from 01-99 (e.g. for solid state physics-I offered in third year, course code is Phys 3401 and for solid state physics-II offered in third year, it is Phys 3402, and for solid state physics-III offered in fourth year, code is Phys 4403 etc.).

SCHEME OF STUDIES (MS PHYSICS PROGRAM)

	Course Code	Course Title	Credit Hrs.	Course Type
YEAR I	**SEMESTER-I**			
	Phys 5515	Mathematical Techniques in Physics	3	Compulsory
	Phys 5516	Advanced Classical Mechanics	3	Compulsory
	Phys 5318	Advanced Quantum Mechanics	3	Compulsory
	Phys 5213	Topics in Electrodynamics	3	Compulsory
	Credit Hrs.		**12**	
	SEMESTER-II			
	Phys 5416	Techniques in Statistical Physics	3	Compulsory
	Phys	Elective-I	3	Elective
	Phys	Elective-II	3	Elective
	Phys	Elective-III	3	Elective
	Credit Hrs.		**12**	
YEAR II	**SEMESTER III**			
	Phys 6000	Thesis	3	Research
	Credit Hrs.		**3**	
	SEMESTER-IV			
	Phys 6000	Thesis	3	Research
	Credit Hrs.		**3**	

- Elective courses will be offered from the already approved list as well as from the following list of new courses in view of avaialability of instructors and related resources.
- For elective courses, a student has to choose one of the following groups of specializations.

Groups:

1. Theoretical Physics
2. Experimental Physics
3. Computational Physics
4. Multidisciplanary Physics

- Students will be distributed evenly in the above groups.

List of new Elective courses

Along with already approved list of elective courses for MS Physics, the following new courses are being introduced.

Course Code	Course Title	Credit Hrs.
Phys 5611	Experimental Techniques in Physics	3
Phys 5319	Quantum Optics	3
Phys 5813	Physics of Epitaxial Low Dimensional Structures	3
Phys 5814	Laser material processing	3
Phys 5214	Applied Plasma Physics	3
Phys 5815	Fundamental Laser physics	3
Phys 5816	Electrochemical Energy Systems	3
Phys 5817	Introduction To Metamaterials and Nano Photonics	3
Phys 5818	Nano-Sensors: Design, Fabrication & Applications	3
Phys 5819	Fundamentals of transparent conductive oxides	3
Phys 5820	3D printing and Additive Manufacturing Technologies	3
Phys 5320	Astroparticle Physics	3
Phys 5321	Accelerator Physics	3
Phys 5322	Advanced Molecular Physics	3
Phys 5515	Selected topics in Digital Image Processing	
Phys 5516	Selected Topics in Machine Learning	

(More specializations and course titles in each specialization can be added from time to time subject to the approval by relevant academic bodies)

Course Title	**Mathematical Techniques in Physics**
Course Code	**Phys 5515**
Credit Hours	**3**
Prerequisite	**Phys 3501 & Phys 3503**
Learning outcomes	On completion of the course, students will be able to: 1. learn elliptic functions and their identities. 2. understand the fundamentals of nonlinear ordinary differential equations and linear partial differential equations. 3. set up and solve integral equations. 4. understand Fractional calculus. 5. understand integral transforms methods. 6. understand variation techniques that are used by physicists.
Contents	**Review:** Elliptic functions, Weiersrstrass functions, the Jacobian Elliptic functions **Nonlinear Ordinary Differential equations:** Bernoulli's equation, Riccati equation, Lane-Emden equation, Nonlinear Pendulum, Duffing's equation, Pinney's equation, Perturbation theory, Bogoliubov-Krilov method, **Partial Differential Equations:** Linear partial differential equations, orthogonal functions and Fourier series, Boundary-Value Problems in rectangular coordinate systems (separable partial differential equations, classical partial differential equations, Heat equation, Wave equation, Laplace's equation, nonhomogeneous Boundary value problems, Orthogonal series expansions, Fourier Series in two variables, **Integral equations:** Introduction, Some special methods, Neumann series, Hilbert-Schmidt theory Fractional Calculus and its applications: Fractional derivatives and integrals, applications of Fractional Calculus, applications of Fractional differential and integral equations **Integral Transforms:** Hankel transforms and their applications, Operational properties, applications of Hankel transform to partial differential equations, Mellin transforms and their properties, Basic operational properties of Mellin transform, Mellin transforms of the Weyl Fractional Integral and Weyl Fractional derivatives **Calculus of variations:** Euler equation, more general variations, Constraints of Minima/Maxima, Variations with constraints.
Teaching-learning Strategies	1. Lectures 2. Presentation to show applications the methods taught
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%

Text Books	1. Fractional Differential Equations: An Approach via Fractional Derivatives (Applied Mathematical Sciences, 206), Bangti Jin, Springer (2021) 2. Mathematical Methods for Physicists (7th Edition), G. B. Arfken, H. J. Weber and F. E. Harris, Academic Press (2012) 3. Advanced Engineering Mathematics (6th Edition), D. G. Zill, Jones and Bartlett (2018) 4. Integral Transforms and their applications (3rd Edition), L. Debnath and D. Bhatta, CRC Press (2015) 5. A Course of Modern Analysis, E. T. Whittaker and G. N. Watson Cambridge (1996) 6. A Guide to Mathematical Methods for Physicists, M. Petrini, G. Pradisi and A. Zaffaroni,World Scientific (2017) 7. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover (2012)

Course Title	**Advanced Classical Mechanics**
Course Code	**Phys 5516**
Credit Hours	**3**
Prerequisites	**Phys 3101 & Phys 3501**
Learning outcomes	On completion of this course, the students will be able 1. To demonstrate an understanding of basic concepts of evolution equations and symmetry principles 2. To demonstrate systematic understanding of continuum mechanics and field theories.
Contents	**Review:** Lagrangian and Hamiltonian Mechanics, principle of least action, Lagrange equation, Symmetries, Noether's Theorem, Hamilton's equations, Poisson brackets, Symplectic form, phase space and Liouville's theorem, Hamilton-Jacobi equation: Separation of variables, Action-Angle variables, integrable systems. **Motion in rotating frames:** Coriolis and centrifugal forces, effects of coriolis forces. **Motion of rigid bodies:** Eulerian angles, rotational kinetic energy and angular momentum, intertia tensor, Euler's equation, motion of tops. **Small oscillations:** General problems of coupled oscillators, normal coordinates and frequencies. **Continuous systems:** Vibrating string, wave equation, general solution of wave equation, separation of variables, classical fields, field equations
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications the methods taught

Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Modern Classical Mechanics (1th Edition), T. M. Helliwell and V. V. Sahakian, Cambridge (2020) 2. Classical Mechanics, H. Goldstein, C. P. Poole and J. L. Safko, Pearson (2014) 3. Classical Dynamics of Particles and Systems (5th Edition), S. T. Thornton and J. B. Marion, Cengage Learning (2012) 4. Classical Mechanics (2nd Edition), T. L. Chow, CRC Press (2013) 5. Classical Mechanics, D. Strauch, Springer (2009) 6. Classical Mechanics, M. J. Benacquista and J. D. Romano, Springer (2018)

Course Title	**Advanced Quantum Mechanics**
Course Code	**Phys 5318**
Credit Hours	**3**
Prerequisites	**Phys 3501, Phys 3503, Phys 3301 & Phys 4302**
Learning outcomes	On completion of this course, the students will be able 1. To demonstrate an understanding of basic concepts of evolution equations and symmetry principles 2. To demonstrate systematic understanding of continuum mechanics and field theories.
Contents	**Review:** Postulates, operators, Schrodinger wave equation, Wave Packets: Localized wave Packets, wave packets and uncertainty relations, motion of wave packets, Representation in continuous basis: Position representation, Momentum representation. **Symmetries and conservation laws:** Translational invariance, time translational invariance, Parity invariance, time reversal symmetry, Translations in two dimensions, Rotations in two dimensions, Addition of Angular Momenta, Coupling of Orbital and spin angular momentum, Scalar, Vector and Tensor operators: Wigner-Eckart Theorem for Spherical Tensor Operators, Identical Particles, Two-electron systems, Helium atom **Approximate Methods:** The Variational Method, The Wentzel-Krammer-Brillouin (WKB) Method, Time independent perturbation theory (non-degenerate and degenerate cases upto 3rd order), Time-Dependent Perturbation theory (First order and higher orders), Interaction of atoms with electromagnetic radiations, energy shift and decay width The Path Integral Formulation of Quantum Theory: Introduction to path integrals, approximation of time evolution operator for free particle, path integral evaluation

	of the free particle propagator, equivalence of path integral formalism to Schrodinger Equation, Derivation of the path integral, imaginary time formalism, Spin and Fermion path integrals. **Scattering Theory:** General Framework for Scattering Theory, Lippman-Schwinger equation, The Born Approximation, Optical Theorem, Eikonal Approximation, Spherical Waves, Partial Waves Method, Low-energy Scattering, Resonance scattering, Identical particles and scattering, Time-dependent formulation of scattering, inelastic electron-atom scattering, Coulomb Scattering
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%) Final Term Assessment: 40%
Text Books	1. Advanced Topics in Quantum Mechanics New Edition, Marcos Mariño, Cambridge (2021) 2. Introduction to Quantum Mechanics, D. J. Griffiths and D. F. Schroeter (3rd Edition), Cambridge (2018) 3. Introductory Quantum Mechanics, R. Liboff (4^{th} Edition), Addison-Wesley (2002) 4. Quantum Mechanics: Concepts and Applications (2^{nd} Edition), N. Zettili, Wiley (2009) 5. Modern Quantum Mechanics (2^{nd} Edition), J. J. Sakuri and Jim J. Napolitano, Pearson (2010) 6. An Introduction Quantum Mechanics, W. Greiner, Addison Wesley (1980) 7. Principles of Quantum Mechanics, R. Shankar, Springer (2012)

Course Title	**Topics in Classical Electrodynamics**
Course Code	**Phys 5213**
Credit Hours	**3**
Prerequisites	**Phys 4201 & Phys 4202**
Learning outcomes	On completion successful students will be able to: 1. demonstrate an understanding of the use of scalar and vector potentials and of gauge invariance. 2. demonstrate the compatibility of electrodynamics and special relativity. 3. know and use methods of solution of Poisson's equation and the inhomogeneous wave equation. 4. know and use principles of Lorentz covariant formalism and tensor analysis. 5. distinguish between radiation fields and other electromagnetic fields. 6. calculate the radiated power produced by accelerating charges.

Contents	**Linear Algebra:** Revision of vectors and matrices; basis sets and components, index notation and summation convention, rotational invariance and cartesian tensors **Electromagnetic Field Equations:** Maxwell's equations and wave solutions, definition of scalar and vector potential, Poisson's equation and electro- and magnetostatics, multipole expansions, electrodynamics in Lorentz gauge, the inhomogeneous wave equation and the retarded time **Accelerating Charges:** Lienard-Wiechert potentials, power radiated from an arbitrarily moving charge, Larmor's power formula, synchrotron radiation, bremsstrahlung **Harmonically Varying Sources:** Multipole radiation; electric (Hertzian) and magnetic dipole radiation, slow-down of pulsars, Rayleigh and Thomson scattering **Electromagnetism and Relativity:** Four vectors and tensors, Covariant and contravariant formalism of Lorentz transformations; relativistic dynamics, consistency of Maxwell's equations and relativity, electromagnetic field tensor and electrodynamics in covariant form.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. An Introduction to Classical Electrodynamics, Jonathan W. Keohane, Joseph P. Foy, Maricourt Academic Press (2019) 2. Foundation of Electromagnetic Theory (4th Edition), J. R. Reitz, F. J. Milford, and R. W. Christy, Addison-Wesley (2009) 3. Introduction to Electrodynamics (4th Edition), D. J. Griffiths, Prentice Hall (2013) 4. Classical Electrodynamics (3rd Edition), J. D. Jackson, John Wiley (2012) 5. Elements of Electromagnetics(5th Edition), M. N. O. Sadiku, Oxford (2009)

Course Title	**Techniques in Statistical Physics**
Course Code	**Phys 5416**
Credit Hours	**3**
Prerequisites	**Phys 4403**
Learning outcomes	After completion of the course, the student will be able to 1. Apply classical equilibrium statistics to make physical predictions and describe the effects of quantum mechanics on statistical mechanics. 2. Apply statistical mechanics to condensed matter systems and to such examples as the Bose and Fermi gases, and superconductors.

	3. Explain how the order parameter is used in describing phase transitions.
Contents	**Review:** Basic concepts of thermodynamics and statistical mechanics, classical ideal gas, entropy of ideal gas, conditions for equilibrium; **Statistical methods in Physics:** Phase space, distribution function, microcanonical ensemble, the most probable distribution, Lagrange multipliers, Maxwell-Boltzmann distribution, fluctuations, Canonical and grand canonical ensembles, partition function, connection with thermodynamics, fluctuations. minimization of free energy, **Quantum statistics:** Thermal wavelength, Fermi gas, Paramagnets, Ising model, Approximate methods, Thomas Fermi model, Fermi gas at low temperatures, application to electrons in solids, photons, phonons, Debye specific heat, Bose-Einstein condensation, equation of state, liquid helium. The order parameter, broken symmetry, Ising spin model, Ginzburg Landau theory, mean-field theory, critical exponents, Correlation functions, Calculation of Landua free energy and correlation functions, Formulation of two-dimensional Ising model, Results of Ising model in one and two dimensions.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Topics in Statistical Mechanics (2^{nd} Edition) (Advanced Textbooks in Physics), Brian Cowan, World Scientific (2021) 2. Statistical Mechanics, K. Huang, John Wiley (2001). 3. Statistical Mechanics (2^{nd} Edition), R. K. Pathria, World Publishing Company (2000) 4. Fundamentals of Statistical and Thermal Physics, F. Reif, Waveland (2008) 5. Elementary statistical Physics, C. Kittel, Dover Publications (2004) 6. Statistical Physics, L. D. Landau, E. M. Lifshitz, Pergamon Press (1986)

Course Title	**Experimental Techniques in Physics**
Course Code	**Phys 5611**
Credit Hours	**3**
Pre requisites	**Phys 4404**
Learning outcomes	1. To learn working principle and instrumentation of experimental techniques which are being applied by experimentalists to characterize materials 2. To learn basic principles, the operational knowledge, Strength adn limitations of techniques in research

Contents	**Introduction to characterization methods of solid materials:** Solid materials, an overview, growth, bulk characterization, surface characterization, interface characterization, ambient requirements and sample preparation. **Experimental Characterization Techniques**: optical microscopy, scanning electron microscopy, transmission electron microscopy, scanning transmission electron microscopy, instrumentations, applications and limitations. Electron Emission Processes, Theory of secondary electron emission, energy distribution of secondary electrons, secondary electron yield, yields measurement methods. Scanning Probe Microscopy, Atomic force microscopy, scanning tunneling microscopy, magnetic force microscopy, working principle, instrumentation, applications and limitations. **Auger Electron Spectroscopy (AES):** Auger electron emission, instrumentation, depth profiling and interface analysis, applications of AES in material science. X-Ray Photoelectron spectroscopy (XPS) **Ultraviolet Photoelectron Spectroscopy (UPS):** Introduction, principles, instrumentation, applications, surface and chemical analysis. X-Ray **Diffraction:** Properties
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Foundations of Experimental Physics (1st Edition), Shailaja Mahamuni, Deepti Sidhaye, Sulabha Kulkarni, CRC (2020) 2. Materials Characterization: Introduction to microscopic and spectroscopic methods (2nd Edition), Y. Lang, Wiley (2013). 3. Elements of X-ray Diffraction, B. D. Cullity and S. R. Stock, Prentice Hall, (2003). 4. Transmission Electron Microscopy, D. B William and C. B. Carter, Springer (2009). 5. Thin Film Deposition “Principles and Practices” by D. L. Smith, (2009). 6. Methods of Surface Analysis, J. M. Walls, Cambridge, 1988 7. Auger Electron Microscopy, H. Bubert, J. C. Rivière and W. S. M. Werner, Wiley (2011). 8. Essentials of Crystallography, D. Mckie and C. Mckie, Blackwell (1986).

Course Title	**Quantum Optics**
Course Code	**Phys 5319**
Credit Hours	**3**

Prerequisites	Phys3301 & Phys 4201
Learning outcomes	On completion of this course the students will be able to 1. Understand the quantum nature of light 2. Its interaction with quantum optical systems such as atoms, trapped ions and quantum opto-mechanical systems.
Contents	**Introduction:** Why quantum optics? Planck formula, **Semiclassical atom-field interaction:** Einstein's rate equation, Semiclassical approach (two-level atom), Electric dipole approximation, Pauli spin operators and density operator, Optical Bloch equations, Ramsey interferometry, Dark state/STIRAP, Field quantisation: Coulomb gauge, properties of bosonic operators **Quantum states:** Fock state, single photon state, thermal state, coherent state, Beam splitters: homodyne measurements **Two-mode squeezed state:** Multimode entanglement Atom-field interaction: minimal coupling, dipole interaction, Jaynes-Cumming model, Haroche experiments (complementarity test, entanglement generation), Rempe's single photon generation, Parametric down conversion for entanglement generation and quantum state reconstruction, Fluctuations and correlations: Mach-Zehnder interferometry: First-order correlations **Hanbury Brown and Twiss experiment:** Second-order correlations, Antibunching and sub-Poissonian statistics, Hong-Ou-Mandel interference **Quasiprobabilities – statistical properties and reconstruction:** Wigner function (Wigner and Weyl), Characteristic function – expectation value of moments, Properties of the Wigner function, Husimi Q function, Examples of Q function, Generalisation of quasiprobability functions, P function.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Quantum Optics: Taming the Quantum (Graduate Texts in Physics) (1st Edition), Pierre Meystre, Springer (2021) 2. Quantum Optics, D. F. Walls and G. J. Milburn, Springer (1994). 3. Quantum Noise, Crispin Gardiner and Peter Zoller, Springer(2004). 4. Introduction to Quantum Optics, H. M. Moya-Cessa and F. Soto-Eguibar, Rinton Press (2011) 5. Quantum Optics, M. O. Scully and M. S. Zubairy, Cambridge (1997) 6. Quantum Optics in Phase Space, W. P. Schleich Wiley (2001) 7. Semiconductor Quantum Optics, M. Kira, S. W. Koch, Cambridge (2011)

	8. Quantum Optics for Engineers, F. J. Duarte, CRC (2014)

Course Title	**Physics of Epitaxial Low Dimensional Structures**
Course Code	**Phys 5813**
Credit Hours	**3**
Prerequisites	**Phys 3401& Phys 3402**
Learning outcomes	1. To understand fundamentals and advanced applications of molecular beam epitaxial. 2. To study various device designs using molecular beam epitaxy. 3. To reveal impact of epitaxial growth on device performance.
Contents	**Thermodynamic prerequisites for crystal growth:** Chemical potential, Binary phase diagrams, supersaturation, and nucleation. **High vacuum technology:** Pumps, gauges and baking. Surface energies and surface diffusion, Adatom mobility, sticking coefficient, surface reconstructions, and lattice mismatch, and dislocations, growth modes. **Components of molecular beam epitaxial (MBE) system:** Formation of molecular beams, In-situ growth monitoring, in-situ substrate temperature calibrations, Epitaxial strained and lattice-matched structures, epitaxial homo-structures and hetero-structures. **Characterization of epitaxial structures:** Both in- and ex-situ. Impurity doping, band engineering, quantum wells, modulation doping, polarization doping. Superlattices, Self-assembled epitaxial structures, single electron transistor, Coulomb blockade, quantum dots and quantum dot crystals.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem Sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. The Physics of Low-dimensional Semiconductors: An Introduction, John H. Davies, Cambridge University Press (1997) 2. Epitaxy of Semiconductors- Introduction to Physical Principles, Udo W. Pohl, Springer (2013) 3. Molecular Beam Epitaxy; Fundamentals and Current Status (2nd edition), M.A. Herman and H. Sitter, Springer (1996) 4. Quantum transport-Atom to transistor, S. Datta, Cambridge University Press (2005) 5. Transport in nanostructures, D. K. Ferry and S. M. Goodnick, Cambridge University Press, (1997)

Course Title	**Laser Material Processing**

Course Code	**Phys 5814**
Credit Hours	**3**
Prerequisites	**Phys 4201**
Learning outcomes	On completion of this course students wil be able to understand 1. Interaction of laser with material and its applications.
Contents	**Thermal, photophysical, and photochemical processes:** Laser processing, Excitation mechanisms relaxation times, the heat equation, selective excitations of molecules, **Models of Pulsed Laser Ablation, Photo-thermal Ablation**: Photo-physical Ablation, Photo-chemical Ablation, Three Regimes of Laser Ablation, **Primary Mechanisms of Pulsed Laser Sputtering**: Collisional Sputtering, Thermal Sputtering, Electronics Sputtering, Hydrodynamical Sputtering **Experimental aspects of laser processing:** Lasers, Experimental aspects, spatial confinement, CW lasers, Gaussian beams, pulsed and high power CW lasers, micro processing, reaction chamber, confinement of the excitation, the thermal field, gas-liquid and adsorbed phase excitations, plasma formation, material damages. Surface melting, Vaporization**,** **Plasma formation:** Temperature distributions, interface velocities, boundary conditions, temperature dependence of parameters, solidification, process optimization, convection, surface deformation, welding, liquid phase expulsion. Plasma formation, ionization, optical properties of plasmas, laser –supported absorption waves (LSAW), laser supported combustion waves (LSCW), laser supported detonation waves (LSDW), superdetonation, Laser processing techniques. **Nanosecond and Ultrashort Pulse Laser Ablation:** Surface patterning, ablation mechanisms, models, interaction below threshold, the threshold fluence, ablations rates, photothermal volume decomposition, dissociation of polymer chains, defect-related processes, thermo-and photomechanical ablation, biological tissues, material damage, debris, strong absorption, finite absorption, debris. Material patterning and damage, long pulses and short pulses, time resolved dynamics, molecular dynamics simulations, the two-temperature model, damage thresholds, ablation rates, avalanche- and multiphoton ionization, high-aspect-ratio holes, fabrication of cavities in bulk materials, ablation at overcritical temperatures, comparison of nanosecond and ultrashort-pulse laser ablation. **Applications of Laser Matter Interaction:** Processing Systems, Mechanism of Laser Cutting, Forms of Laser Cutting, Fusion Cutting, Sublimation Cutting, Photochemical Ablation, Laser Welding, Laser Drilling, Laser Process Parameters, Effect of Beam Characteristics, Plasma Formation, Gas Shielding, Focal Point Location, beam Absorption, Initial Workpiece Microstructure, Advantage and Disadvantages of Laser Material Processing. **Etching of metals, insulators, and semiconductors**: Structural transformation, laser cleaning, Doping, Cladding, alloying and synthesis, Oxidation, nitradation, reduction, Transformation and decomposition of organic, materials. **Theories and Understanding of physical Mechanisms of laser:** Laser-included Nano scale Periodic Surface Structures (Nano ripples), Nano-Bumps, Nano-cones, Nano-Pores, Nano-Craters, Nanoparticles

	PULSED Laser Deposition Technique, Effects of Processing Parameter, Laser fluence, Laser wavelength, Ambient gas Pressure, Target-to-substrate Distance, and Temperature of the substance. Identification of ultrafast electronic and slow thermal process by Time of Flight Mass Spectrometry and Surface Topography Investigation.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. High Power Laser Matter Interaction, P. Mulser and D. Bauer, Springer (2010) 2. Femtosecond Laser-Matter Interaction: Theory, Experiments and Applications, E. G. Gamaly, Pan Stanford Publishing (2011) 3. Laser Processing and Chemistry, D. Bauerle, Springer Germany (2000) 4. Pulsed Laser Deposition of thin films, D. B. Chrisey and G. K. Hubler, Wiley (1996) 5. Laser Ablation and its Applications, C. Phipps, Springer (2007) 6. Laser Material Processing, W.M. Steen, Springer (2010) 7. Principles Laser Material Processing, Elijah K. Kannatay-Aasibu, Willey (2009)

Course Title	**Applied Plasma Physics**
Course Code	**Phys 5214**
Credit Hours	**3**
Prerequisites	**Phys 4201**
Learning outcomes	On the completion of this course students will be able to understand 1. Introduction of the Plasma Physics theory and plasma-based devices necessary.
Contents	**Introduction:** Basics of plasma, plasma parameters, diffusion of charged particles in plasma, plasma types. Thermal plasma, nonthermal plasma, microplasma. **Plasma Generation:** Glow discharge, Pschen's law, RF discharges, microwave plasma, electron cyclotron resonance plasma, plasma source ion implanation, plasma reactors. **Plasma Focus and Plasma Torches:** Z-pinch device, plasma Focus device, tokamak, plasma Torches and applications. **Plasma Chemistry, plasma processes and plasma polymerization:** Chemical reactions, plasma surface interactions, etching, nitriding, carburizing, and boriding, deposition of organic and inorganic films, diamond and diamond like films, sputtering. **Plasma Diagnostics:**

	Charged particle and neutron diagnostics: Faraday cups and solid-state nuclear track detectors for detection and analysis of charged particles, Time-resolved and time-integrated neutron measurement. Rogowski coil, high voltage probe, magnetic probe, Langmuir probe, voltage loops and Mironov coils. **Laser as a diagnostic tool:** Laser-Induced Plasma, Inverse-Bremsstrahlung or Cascade Iionization, Multiphoton Iionization, Propagation of (optical frequency) electromagnetic wave through plasma both in the absence and presence of magnetic field, shadowgraphy, schrillian imaging, interferometry and determination of plasma density, measurement of magnetic field by Faraday rotation, Thomson and Rayleigh scattering. **X-ray diagnostics of plasmas:** X-ray emission from plasmas, absorption filters and their selection, time-resolved x-ray detectors, pinhole imaging camera, estimate of plasma electron temperature. **Plasma Spectroscopy:** Radiative processes in plasmas, Collisional processes in plasmas, statistical plasma models, plasma optical spectroscopy, and evaluation of plasma parameters. Laser induced fluorescence, absorption spectroscopy, Laser-Induced Breakdown Spectroscopy (LIBS), Working of LIBS System, Elemental Analysis by LIBS, Evaluation of Electron Temperature and Density by using LIBS Technique, Influence of Nature and Pressure of Shield gases, time delay, laser wavelength and fluence on the emission intensity, electron temperature and density of Laser-induced plasma.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Introduction to Plasma Physics and Controlled Fusion (3rd Edition), F. F. Chen, , Springer (2016) 2. The Fourth State of Matter: An Introduction of Plasma Science, S. Eliezer and Y. Eliezer, Institute of Physics UK (2001) 3. Plasma Physics: An Introduction, R. Fitzpatrick, CRC Press (2015) 4. Industrial Plasma Engineering, by J. Reece Roth, Institute of Physics Publishing Bristol (2000). 5. Principles of Plasma Diagnostics, by I. H. Hutchinson, Cambridge University Press New York (1999). 6. Handbook of Radiation Effects, by A. H. Siedle and L. Adams, Oxford University Press (2002). 7. Principles of Plasma Processing, F. F. Chen and J. P. Chang, Kluwer Academic/ Plenum Publishers New York (2003).

Course Title	**Fundamental Laser Physics**
Course Code	**Phys 5815**

Credit Hours	**3**
Prerequisites	**Phys 3301& Phys 4201**
Learning outcomes	On the completion of this course students will be able to understand 1. Basics of laser physics and its applications.
Contents	**Introduction:** Basic concepts, Spontaneous emission, Population Inversion, Stimulated Emission, Pumping Schemes of Lasers, Characteristics of Laser Radiation, Collimation, Monochromatic, Spectral Brightness, Coherence, Evaluation of focused Laser Beam Diameter and Fluence. **Energy levels and radiative properties:** Energy Levels, Molecular Energy Levels & Spectra, Three and four level Lasers Systems, Energy Levels in gases, Solids and dielectric Laser Media, the Einstein relation, rate equation and criteria of lasing, Rate equation analysis, **Laser Resonators:** Laser amplifier, Resonance, Stable Resonators, Unstable Resonators Pumping process: types of pumping, optical pumping, laser pumping, chemical pumping, gas dynamic pumping, electrical pumping, pumping efficiency, physical characteristics of discharges. **Line broadening mechanisms and laser modes:** Feedback mechanism, types of optical cavities, Febry Perot resonator, Line broadening Mechanisms, Longitudinal Laser Cavity Modes, Transverse Cavity Modes, Properties and Detection of Lasers Modes, stability condition, unstable optical cavities, advantages of unstable resonators, hole burning, active medium gain with lasing and without hole burning. **Techniques for Laser pulse shortening:** Q-Switching, Mode Locking, Pulse Compression, Advantages of Femtosecond and Attosecond Laser Pulses over Nanosecond Laser Pulses **Important laser systems:** The structure, excitation mechanism and applications of solid state lasers (Nd:YAG laser system), The structure, excitation mechanism and applications of Gas Lasers (Helium-Neon lasers, Carbon dioxide lasers, Nitrogen Laser, Excimer Laser System), The Structure, excitation mechanism and applications of Femtosecond Lasers (Ti: Sapphire Laser system) **Applications of Lasers:** Laser interaction with tissue, effect on tissue, laser eye treatment, laser in material processing like cutting, welding, drilling, marking and scribing, laser range Finder, laser ablation and deposition, laser target interacion, sputtering, influence of laser parameters, splashing, nanosecond and femtosecod laser ablation, pulsed laser deposition film condensation and different growth processes.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sets 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc.

	Final Term Assessment: 40%
Text Books	1. Laser Spectroscopy Basic Concepts and Instruments, W. Demtroder, Springer (2009) 2. Femmtosecond Laser Pulses: Principles and Experiments (2nd Edition), C. Rulliere, Springer (2005) 3. Laser Fundamentals (2nd Edition), W. T. Silfvast, Cambridge University Press (2004) 4. Laser Principles and Applications, J. Wilson, J. F. D. Hawkes, Prentice Hall (1987) 5. Understanding Lasers: An Entry-Level Guide (4th Edition), J. Hecht, WIELY (2018) 6. Principles of lasers (3rd Edition), O. Svelto, Springer (1989)

Course Title	**Electrochemical Energy Systems**
Course Code	**Phys 5816**
Credit Hours	**3**
Prerequisites	**Phys 3401 & Phys 3402**
Learning outcomes	On completion of this course students will be able to understand 1. Principles and mathematical models of electrochemical energy conversion and storage. 2. Equivalent circuits, thermodynamics, reaction kinetics, transport phenomena, electrostatics, porous media, and phase transformations 3. Applications to batteries, fuel cells, supercapacitors, and electro-kinetics.
Contents	**Basic Concepts:** Basic physics of galvanic cells, Electrochemical energy conversion, Electrochemical energy storage, Equivalent circuit dynamics, Impedance I, Impedance II, Impedance III, Statistical thermodynamics, Regular solution model. **Fuel cells and Batteries:** Fuel cells, Batteries, Metal acid batteries, Lemon battery demo, Li-ion batteries, Pseudocapacitance, Ideal solution model, Linear sweep voltammetry, Phase separation, Reactions in concentrated solutions, Faradaic reactions **Electrochemistry:** Electrocatalysis, Electrochemical phase transformations–constant voltage, Electrochemical phase transformations–constant current, Homogeneous charge transfer, Heterogeneous charge transfer, Charge transfer at metal electrodes, Concentration polarization, Transient diffusion, Warburg impedance, Double layers supercapacitors, Concentrated solutions, bulk electrolytes, Scaling analysis of energy storage, Porous electrodes (overview), Photocatalysis, Photoelectrochemical reactions.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets 4-6

Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Electrochemical Systems: The ECS Series of Texts and Monographs (4^{th} Edition), J. Newman and N. P. Balsara, Wiley (2021) 2. Electrochemical Methods: Fundamentals and Applications (2^{nd} Edition), Wiley (2000) 3. Fuel Cell Fundamentals (3^{rd} Edition), Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, Wiley (2016) . 4. Advanced Batteries: Materials Science Aspects, Robert Huggins, Springer (2009)

Course Title	Introduction to Metamaterials and Nano Photonics
Course Code	**Phys 5817**
Credit Hours	**3**
Prerequisites	**Phys 4201**
Learning outcomes	On completion of this course, the students will be able to understand 1. Basic concept of metamaterial, mathematical treatment and some applications of its emerging types such as the hyperbolic metamaterials, epsilon near zero (ENZ) metamaterials etc. 2. New trends in nanophotonics such as photonic crystals, metasurfaces, and plasmonics
Contents	**Review of optical properties of materials:** constitutive relations and material parameters, Frequency dispersion, electromagnetic waves in materials; **metamaterials:** Basic concept, double and single negative metamaterials, effective medium theory, engineered material parameters, transformation optics, metamaterials for transformation optics, hyperbolic metamaterials, the concept of high-k waves in hyperbolic metamaterials, the diffractin limit and sub-wavelength imaging, the ideas of superlens and hyper lens, metasurfaces, Fermat's principle and the generlized laws of reflections and refractions in Metasurfaces; **photonic crystals:** photonic band structures, isofrequency curves in photonic crystals, Fresenel reflection and diffreaction coefficiens, the transfer matrix approach in photonic crystals, conventional and emerging applications of photonic crystals; **epsilon near zero (ENZ) materials**: exotic properties of ENZ materials and suggested applications; plasmonics, surface plasmon polaritons and plasmonic particles, some properties and applications.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Photonics, R. Menzel, Springer (2007). 2. An Introduction to Metamaterials and Nanophotonics, C. Simovski, S. Tretyakov, Cambridge University Press (2020) 3. Theory and Phenomenon of Metamaterials, F. Capolino, CRC (2009) 4. Fundamentals and Applications of Nanophotonics, J. W. Haus, Elsevier (2016). 5. Optical Metamaterials: Fundamentals and Applications, W. Cai and V. Shalaev, Springer (2009) 6. Plasmonics: Fundamentals and Applications, S. Maier, Springer (2007)

Course Title	Nano-Sensors: Design, Fabrication & Applications
Course Code	**Phys 5818**
Credit Hours	**3**
Prerequisites	**Phys 3401 & Phys 3701**
Learning outcomes	On completion of this course, the students will be able to 1. Understand the basic operating principles 2. Design strategy, fabrication process and 3. Application of nano-sensors.
Contents	**Introduction to nano-sensors**: Materials for nano-sensors, synthesis & characterizations of sensing nanomaterials, configurations of nano-sensors, **Chemiresistors**:Field effect transistors, diodes and Schottky diodes, **Array of nano-sensors**: flexible & wearable nano-sensors, fabrication of nano-sensors, **Types of nano-sensors based on applications:** nano-sensors for environmental monitoring, environmental species, classifications, characteristics, and requirements of gas sensors, conventional gas sensing materials, metal oxides based gas sensors, carbon based gas sensors, nanocomposites based gas sensors, testing & analysis of gas sensors, sensing mechanisms, nano-sensors for photo detection, nano-biosensors
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sheets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Nanofabrication for Smart Nanosensor Applications, K. Pal and F.G. de Souza, Elsevier (2020) 2. Nanosensors: Theory and Applications in Industry, Healthcare and Defense, T. C. Lim, CRC Press (2016) 3. Advanced Nanomaterials for Sensing Applications, Z. Wang, W. Zeng, and Z. Li, Frontiers Media SA (2019) 4. Semiconductor Gas Sensors, Jaaniso, R. and O.K. Tan, Elsevier (2019) 5. Handbook of Gas Sensor Materials: Properties, Advantages and Shortcomings for Applications Volume 1: Conventional Approaches, G. Korotcenkov, Springer (2013)

Course Title	Fundamentals of Transparent Conductive Oxides
Course Code	**Phys 5819**
Credit Hours	**3**
Prerequisites	**Phys 3301 & Phys 3401**
Learning outcomes	1. To understand the basic properties of conventional Transparent eleoctrodes theory and 2. predict new transparent electrode candidates
Contents	**Combining Optical Transparency with Electrical Conductivity:** Introduction, Electronic Properties of Conventional Transparent (semi) conductive oxides Hosts, Carrier Generation, substitutional Doping, Oxygen Reduction, Multicomponent transparent oxides, Electronic Properties of Light Metal Oxides, Multicomponent Oxides with Layered Structures. **Transparent Oxide Semiconductors:** Fundamentals and Recent Progress **N-type Transparent Semiconducting Oxides:** Introduction: Binary and Multicomponent Oxides, Binary Compounds: the Examples of Zinc Oxide and Indium Oxide, Ternary and Quaternary Compounds: the Examples of Indium-Zinc Oxide and Gallium-Indium-Zinc Oxide, Sputtered n-TSOs: Gallium-Indium-Zinc Oxide System, Structural and Morphological Properties, Electrical properties, Optical Properties, Solution-Processed n-TSOs, ZTO by Spray-pyrolysis, ZTO by Sol-gel Spin-coating, GIZO Sol-gel by Spin-coating **P-type Transparent Conductors and Semiconductors:** Introduction to P-type Transparent Conductive Oxides, Thin Film Copper Oxide Semiconductors, Role of Oxygen in the Structure, Electrical and Optical Performance, Thin Film Tin Oxide Semiconductors; Structure, Composition and Morphology of Tin oxide films, Electrical and Optical Properties of Tin oxide films **Gate Dielectrics in Oxide Electronics:** Introduction to High-k Dielectrics: Requirements, High-k Dielectrics Deposition, Sputtered High-k Dielectrics in Oxide TFTs, Hafnium Oxide, Multicomponent Co-sputtered HfO2 Based Dielectrics, Multilayer Dielectrics, High-k Dielectrics/Oxide Semiconductors Interface, zirconium oxide films.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Transparent Electronics: From Synthesis to Applications, A. Facchetti and T. J. Marks, Wiley (2010) 2. Transparent Oxide Electronics From Materials to Devices, P. Barquinha, R. Martins, L. Pereira and E. Fortunato, Wiley (2012) 3. Transparent Electronics, J. F. Wager, D. A. Keszler, and R. E. Presley. Springer (2008)

	4. Handbook of Zinc Oxide and related materials (Editted), Zhe Chuan Feng, CRC Press (2013)

Course Title	**Astroparticle Physics**
Course Code	**Phys 5320**
Credit Hours	**3**
Prerequisites	**Phys 4305 & Phys 4102**
Learning outcomes	On completion of this course, the students will be able to 1. Understand a connection between cosmic rays and particle physics 2. provide an introduction to the phenomenology and theoretical background of this field of particle astrophysics.
Contents	**Cosmic Rays**: Composition of cosmic Rays, Energy Spectra, Energy Density of cosmic rays, cosmic ray measurement methods, Extensive Air Showers, Very high energy cosmic rays, The knee of the spectrum, **Sources of extragalactic cosmic rays**: Neutrino oscillations, **Sources of the highest energy cosmic rays and neutrino**: Hadronic interactions of photons and muons, The Atmosphere, Hadrons in the atmosphere, Atmoshpheric muons and neutrions, Muon charge ratio, Cascade equations, Energy loss by charged particles, Muons and neutrinos underground, passage of muons through matter, seasonal variation of atmospheric muons and neutrinos, Cosmic rays in the galaxy **Models of propagation:** propagation of ultra-high energy cosmic rays in the microwave background extragalactic propagation of cosmic rays Astrophysical gamma rays and neutrinos, Gamma rays from decay of π^0, Acceleration, Supernovae in the Milky way, The compact remnant, High Energy binary systems, Supernova remanants (SNRs), Pulsar wind Nebulae Astrophysical accelerators and beam dumps, Active galactic numclei, Gamma ray bursts.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments, and presentations, homework, attitude and behavior, hands-on activities, short tests, quizzes, etc Final Term Assessment: 40%
Text Books	1. Cosmic Rays and Particle Physics (2nd Edition), T. K. Gaisser, R. Engel, E. Resconi, Cambridge (2016) 2. Extensive Air Showers, P. K. F. Grieder, Springer (2010) 3. The New Cosmic Onion, F. Close, Taylor & Francis (2007) 4. High Energy Cosmic Rays (2nd Edition), T. Stanev, Springer (2004)

Course Title	**Accelerator Physics**
Course Code	**Phys 5321**
Credit Hours	**3**

Prerequisites	Phys 5611, Phys 3101
Learning outcomes	On completion of this course, the students will be able • To demonstrate an understanding of basic concepts of different accelerators and their principles.
Contents	**Historical developments:** Layout and components of accelerators, Accelerator applications, Transverse motion:Hamiltonian for particle motion in accelerators, Linear Betatron motion, Effect of linear magnet imperfections, Offmomentum orbit, Chromatic aberration, Linear coupling, Nonlinear resonances, Collective instabilities and Landau damping, Synchro-Betatron Hamiltonian, **Synchrotron motion:** Longitudinal equation of motion, Adiabatic synchrotron motion, RF phase and voltage modulations, Nonadiabatic and nonlinear synchrotron motion, Beam manipulation in synchrotron phase space, Fundamentals of RF systems, Longitudinal collective instabilities, Introduction to linear accelerators, **Physics of electron storage rings:** Fields of a moving charged particle, Radiation damping and excitation, **Beam dynamics:** Free electron laser (FEL), Beam beam interaction, Emitance in electron storage rings. Classical Mechanics and Analysis: Hamiltonian Dynamics, Stochastic Beam Dynamics, Methods of Data Anlysis in Beam Physics, **Numerical Methods and Physical Constants:** Fourier Transform, Cauchy Theorem and the Dispersion Relation, Useful Handy Formulas, Maxwell's Equations, Physical Properties and Constants
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments, and presentations, homework, attitude and behavior, hands-on activities, short tests, quizzes, etc Final Term Assessment: 40%
Text Books	1. Accelerator Physics (4th Edition), S. Y. Lee, World Scientific (2019) 2. Handbook of Accelerator Physics and Engineering (2nd Edition), Chao, World Scientific (2013) 3. An Introduction to Particle Accelerators (1st Edition), Oxford University Press (2001)

Course Title	**Advanced Molecular Physics**
Course Code	**Phys 5322**
Credit Hours	**3**
Pre- requisites	**Phys 3301, Phys 4303**
Learning outcomes	On completion of this course, the students will be able to 1. Understand thoroughly the advanced methods of quantum mechanics

	2. Apply these methods on atoms, molecules and solids
Contents	**Review:** Spinorbitals, Basis sets, Symmetries of many-particle wave functions, **Separation of nuclear and electronic motion:** Hamiltonian in relative coordinates, Born-Oppenheimer approximation, Adiabatic approximation and nonadiabatic correction. **The independent-particle model:** the Hartree-Fock method, Slater determinant and antisymmetrizer, Slater-Condon rules, Derivation of Hartree-Fock equations, **Density-functional theory (DFT):** Thomas-Fermi-Dirac method, Hohenberg-Kohn theorems, Kohn-Sham method, Local density approximation, Generalized gradient approximations (GGA), Beyond GGA. **Linear response theory:** Response function, Density-density response function, Calculation of properties from response functions. **Nonlocal correlation functionals of DFT:** Van der Waals density functionals, Vydrove and Van Voorhis nonlocal functionals, Damped asymptotic dispersion energy functional. **Many-body perturbation theory (MBPT):** Rayleigh Schrödinger perturbation theory (classical derivation), Hylleraas variation principle, Møller-Plesset perturbation theory, Symmetry-adapted perturbation theory. **Coupled cluster theory (CCT):** Exponential ansatz, Size consistency, Coupled cluster method with double excitations, Equivalence of CCT and MBPT.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. The Theory of Intermolecular Forces (2nd Edition), A. J. Stone, Clarendon Press (2013). 2. Density Functional Theory of Atoms and Molecules, R. G. Parr and W. Yang, Oxford University Press (1989) 3. Density Functional Theory: An Advanced Course, E. Engel, R. M. Dreizler, Springer (2013) 4. Time-Dependent Density Functional Theory: Concepts and Applications, C. A. Ullrich, Oxford University Press (2010) 5. Electronic Density Functional Theory: Recent Progress and New Directions, G. V. J. F. Dobson, M. P. Das, Springer (1998) 6. Many-body Methods in Chemistry and Physics: MBPT and Coupled-Cluster Theory, I. Shavitt, Cambridge University Press (2009)

Course Title	**3D Printing and Additive Manufacturing Technologies**
Course Code	**Phys 5820**
Credit Hours	**3**
Pre- requisites	Phys 3401, Phys 3402
Learning Outcomes	On completion of this course, the students will be able to 1. Comprehensive knowledge of the broad range of Additive manufacturing (AM) processes, devices, 2. Capabilities of availale materials
Contents	**Introduction and Basic Principles:** Why Additive Manufacturing, Evolution of Printing as an Additive, Benefits and Development of AM Technology, Distinction Between AM & CNC Machining, Generic AM Process. **Materials & their Characteristics:** Metals, Polymers, Ceramics & their Composites. Guidelines For Process & Material Selection: Decision Theory, Approaches to Determining Feasibility, Challenges of Selection. **Fabrication & Printing Technologies:** Material Extrusion, Material Jetting, Powder Bed Fusion, Photopolymerization, Direct Energy Deposition, Sheet Lamination & Direct-writing, Process Parameters. **Post-Processing:** Support Material Removel, Surface Texture Improvements, Accuracy Improvements, Aesthetic Improvements, Property Enhancement Using Thermal & Non-Thermal Approaches. Characterizations & Testing, Limitations & Challenges. **Application Areas:** Biomedical, Automotive & Aerospace, Architecture, Surgical Simulations, Future Directions & Scope.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Additive manufacturing technologies (2nd Edition), I. Gibson, D. Rosen, B. Stucker, Springer (2015)

	2. Additive Manufacturing of Metals: The Technology, Materials, Design and Production, Li Yang, K. Shu, B. Baughman, D. Godfrey, F. Madina, M. B. Menon, S. Viener, Springer (2017) 3. 3D Printing: Understanding Additive Manufacturing (2nd Edition), A. Gebhardt, J. Kessler, L. Thurn, Hanser Publications (2018) 4. Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, A. Gebhardt, J. S. Hotter, Hanser Publications (2016)
Course Title	**Selected topics in Digital Image Processing**
Course Code	**Phys 5515**
Credit Hours	**3**
Prerequisites	**Phys 5512**
Learning Outcomes	On completion of this course, the students will be able to 1. Basic mathods of digital image process 2. Implementation of image processing techniques in computer with examples 3. Image processing in medical physics
Contents	**Introduction to image formation and image processing:** What is an image, digital imaging, example of digital images, system of imaging, Noise removal, contrast adjustment, region detection, Histograms and point operations image filters, neighborhood and spatial processing, **Introduction to Edges and Contours**: Detection of Edges and Contours, Corner Detection, Curve detection and Morphological filters, binary images, and regions in binary images, gray images and color image detection and processing, color images. **Introduction to spectral techniques:** Discrete Fourier transform, Geometric operations, comparing images applications of image detection and processing. Implementation of image processing techniques in computer programs with examples. Image processing in medical physics.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments-Types and Number	Problem sheets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments and presentations, homework, attitude and behavior, hands-on-activities, short tests, quizzes etc. Final Term Assessment: 40%
Text Books	1. Digital Image Processing (4th Edition), Rafael C. Gonzalez, Pearson (2018) 2. Digital Image Processing Using MATLAB (3rd Edition), R. C. Gonzalez, R. E. Woods, S. L. Eddins, Gatesmark (2020)

	3. Introduction to Digital Image Processing with MATLAB (2^{nd} Edition), A. McAndrew, Chapman and Hall/CRC (2015) 4. Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab, C. Solomon, T. Breckon, Wiley (2011) 5. Digital Image Processing: An Algorithmic Introduction using Java by Wilhelm Burger and Mark J. Burge, Springer (2016)

Course Title	Selected Topics in Machine Learning
Course Code	**Phys 5516**
Credit Hours	**3**
Pre- requisites	**Phys 5512**
Learning Outcomes	On completion of this course, the students will be able to 1. Understand basic mathods of digital image process 2. Data processing 3. Kernel methods and support vector machines
Contents	**Review:** Introduction to Machine learning and Machine learning Techniques, **Introduction to Data Science:** Data Mining, Data Analysis, Statistical Learning, Knowledge Discovery in Databases, Pattern Discovery, **An overview of fundamental concepts and techniques within machine learning:** Introduction to artificial intelligence and machine learning, Fundamental principles for machine learning, Data preprocessing, feature extraction, and dimensionality reduction. Model selection, generalization, and overfitting Optimization of training models. **Regression:** Nearest neighbor classifiers, Logistic regression, Naïve Bayes, Decision trees, Artificial neural networks. Ensemble methods. Kernel methods and Support vector machines. K-means and hierarchical clustering.
Teaching-learning Strategies	1. Lectures 2. Presentations to show applications of the methods learnt.
Assignments- Types and Number	Problem sets, 4-6
Assessment and Examinations	Mid-Term Assessment: 35% Formative Assessment: (25%): It includes classroom participation, attendance, assignments, and presentations, homework, attitude and behavior, hands-on activities, short tests, quizzes, etc. Final Term Assessment: 40%
Text Books	1. Introduction to Machine Learning: Adaptive Computation and Machine Learning series (4th Edition), E. Alpaydin, The MIT Press (2020) 2. A First Course in Machine Learning (2nd Edition), S. Rogers, M. Girolami, Chapman and Hall/CRC (2016) 3. Introduction to Machine Learning, A. Smola and S. V. N. Vishwanathan, Cambridge University Press (2008). 4. MATLAB Machine Learning, M. Paluszek, S. Thomas, Springer (2017) 5. Fundamentals of Machine Learning for Predictive Data Anayltics: Algorithms, Worked Examples, and Case Studies (1st Edition), J. D. Kelleher, B. M. Namee, A. D'Arcy, The MIT Press (2015)