School of Physics

Devi Ahilya Vishwavidyalaya

Vigyan Bhawan, Khandwa Road Campus, Indore, M.P, India – 452001

M.Sc. (Physics) Syllabus

1-Year Program

Session: 2026-27

Scheme of Examination for M. Sc. programme

First Semester from July to December				
	COURSE CODE	**COURSE TITLE**	**Category**	**CREDITS**
	PHY-501	Solid State Physics	CC-31	5
	PHY-503	Atomic, Molecular and Laser Physics	CC-32	5
	PHY-505	Quantum Mechanics and Nuclear Physics	CC-33	5
	PHY-507	Physics Laboratory-II / Computational Physics	PC-31	5
	PHY-509	Seminar / Internship / Apprenticeship	Seminar/Internship	2
Second from January to June				
	COURSE CODE	**COURSE TITLE**	**Category**	**CREDITS**
	PHY-510	Digital Electronics and Computational Methods	CC-41	5
	PHY-512	Materials Physics and Nanoscience	CC-42	5
	PHY-514	Plasma Physics	CC-43	5
	PHY-516	Advanced Physics Laboratory / Microprocessor Lab	PC-41	5
	PHY-518	Numerical Methods using Python	VAC/EESC	2

Year	Credits	Remark
Year-I	44	Eligible exit point: PG diploma in Physics after successful completion of Year I

PHY-501 SOLID STATE PHYSICS 05 credits

Electron theory: Drude Model, Electrical and thermal conductivity, Wiedemann–Franz Law, Scattering Processes, Relaxation-time approximation, Peltier Coefficient. Thermoelectric power.
Electrons in a periodic lattice: Nearly free electron model, Bloch theorem, Kronig Penney model, Metals–Semimetals–Semiconductors–Insulators, Tight binding approach, Fermi surface, de Haas Van Alfen effect, Magnetoresistance.
Superconductivity: Zero resistance, perfect diamagnetism, theory of superconductivity, Thermal properties, Isotope effect, Manifestations of energy gap, London theory, tunneling, *dc* and *ac* Josephson effect, High temperature superconductors.

Introduction to nanomaterials: Synthesis, characterization and applications.

Suggested References

1. Introduction to Solid State Physics – Charles Kittel
2. Solid State Physics – Neil W. Ashcroft and N. David Mermin
3. Solid State Physics – A. J. Dekker
4. Introduction to Solid State Physics – Harald Ibach and Hans Lüth
5. Solid State Physics – S. O. Pillai
6. Introduction to Nanotechnology, Charles P. Poole Jr. and Frank J. Owens, Wiley.
7. Nanomaterials: An Introduction to Synthesis, Properties and Applications, Dieter Vollath, Wiley-VCH.
8. Transmission Electron Microscopy: A Textbook for Materials Science, David B. Williams and C. Barry Carter, Springer.
9. Scanning Electron Microscopy and X-Ray Microanalysis, Joseph I. Goldstein et al., Springer.
10. X-Ray Diffraction Procedures for Polycrystalline and Amorphous Materials, H. P. Klug and L. E. Alexander, Wiley.

Course Outcomes (COs)	Description
CO1	Students will be able to explain classical electron theory using the Drude model and analyze electrical and thermal conductivity, including concepts like Wiedemann–Franz law, scattering processes, relaxation time, and thermoelectric effects.
CO2	Students will be able to describe electron behavior in periodic potentials using Bloch theorem, nearly free electron model, and Kronig–Penney model, and classify materials as metals, semiconductors, and insulators based on band theory.
CO3	Students will be able to interpret concepts such as Fermi surfaces, tight-binding approximation, magnetoresistance, and quantum oscillatory phenomena like the de Haas–van Alphen effect.
CO4	Students will be able to describe the fundamental properties of superconductors, including zero resistance and Meissner effect, and explain theoretical models such as London theory, Josephson effects, and characteristics of high-temperature superconductors.
CO5	Students will be able to explain synthesis techniques, characterization methods, and practical applications of nanomaterials in modern technology.

PHY-503 ATOMIC, MOLECULAR AND LASER PHYSICS 05 credits

Atomic Structure and Hydrogen-like Systems: Quantum states of hydrogen-like atoms; energy levels and wave functions of hydrogen-like systems. Fine structure: relativistic correction, spin-orbit coupling, and Darwin term. Spectroscopic terms and selection rules. Zeeman effect and Paschen–Back effect. Hyperfine structure and Lamb shift.

Multi-electron Atoms and Atomic Spectra: Identical particles and exchange symmetry; spectra of two-electron atomic systems; independent particle model and exchange effects. Pauli exclusion principle and periodic table. Central field approximation; Hartree self-consistent field method and Hartree–Fock method. Coupling schemes for many-electron atoms: L-S coupling and j-j coupling; equivalent electrons and atomic term symbols.

Molecular Structure and Molecular Spectroscopy: Hydrogen molecular ion H_2^+ ; Heitler–London theory of the hydrogen molecule; covalent and ionic bonding. Rotational spectra of molecules; vibrational spectra; rotation-vibration spectra; Raman spectra; electronic spectra of molecules; Franck–Condon principle and its applications.

Fundamentals of Laser Physics: Characteristics of laser radiation; spontaneous and stimulated emission; Einstein A and B coefficients; population inversion; optical pumping; coherence; laser amplification and threshold condition. Line-broadening mechanisms: homogeneous and inhomogeneous broadening. Gain saturation, gain clamping, spatial and spectral hole burning. Rate equations for three-level and four-level laser systems.

Laser Resonators and Laser Systems: Optical resonators; cavity modes; stability criterion; Gaussian beams and their propagation; quality factor and resonant frequencies of optical cavities. Q-switching and mode-locking techniques. Specific laser systems: He-Ne laser, CO_2 laser, argon-ion laser, ruby laser, Nd:YAG laser, Nd:glass laser, and dye laser. Applications of lasers in spectroscopy, material processing, communication, medicine, and research.

Suggested Books

1. B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules.*
2. G. Aruldhas, *Molecular Structure and Spectroscopy*.
3. W. Demtröder, *Atoms, Molecules and Photons.*
4. P. W. Milonni and J. H. Eberly, *Lasers.*
5. O. Svelto, *Principles of Lasers.*
6. A. Yariv, *Introduction to Quantum Electronics.*
7. K. Thyagarajan and A. Ghatak, *Lasers: Theory and Applications.*

Course Outcomes (COs)	Description
CO1	Analyze the quantum mechanical description of hydrogen-like atoms, including atomic energy levels, fine and hyperfine structures, spectroscopic terms, selection rules, and the effects of external magnetic fields on atomic spectra.
CO2	Explain the electronic structure and spectra of multi-electron atoms using exchange symmetry, central field approximation, Hartree–Fock theory, and angular momentum coupling schemes, and interpret atomic term symbols.
CO3	Evaluate the structure, bonding, and spectroscopic properties of molecules by applying quantum mechanical models and interpreting rotational, vibrational, Raman, and electronic spectra using the Franck–Condon principle.
CO4	Apply the fundamental principles of laser physics to explain the generation, amplification, and characteristics of laser radiation, including population inversion, line broadening, gain mechanisms, and rate equations for laser systems.
CO5	Analyze the design and operation of optical resonators and different laser systems, and assess the applications of lasers in spectroscopy, communication, material processing, medicine, and scientific research.

PHY-505 QUANTUM MECHANICS AND NUCLEAR PHYSICS 05 credits

Linear operators, eigen functions and values, Dirac bra and ket notation and vectors, postulates of quantum mechanics, Hilbert Space, Hermitian Operators, properties of Hermitian Operators, position and momentum representation, time varying expectations, Ladder operators, the eigen values of ladder operators, the eigen functions of the orbital angular momentum operator.

Nuclear sizes and shapes. Experimental methods of determining nuclear radius. Two-nucleon problem: Deuteron problem. Central and non-central forces. Tensor forces. Nuclear models: Semi empirical mass formula and isobaric stability. Nuclear shell structure. Magic numbers. Single particle model. Spin orbit coupling. Schmidt lines. Rotational and vibrational spectra and elementary idea of unified model. Nuclear reactions: Q value. Compound nuclear reaction and direct reactions. Single level Breit-Wigner formula. Nuclear fission: Liquid drop model.

Time independent and Time dependent Perturbation Theories: The interaction pictures. Time dependent two state problems. Nuclear magnetic resonance. Rabi's molecular beam method, Ammonia molecule and maser. Time dependent perturbation theory, harmonic perturbation. Interaction of an atom with electromagnetic radiation. Absorption and stimulated emission. Electric dipole approximation. Sum rule. Photoelectric effect. Passage of charged particle through matter.

Scattering Theory: Scattering amplitude and cross section, Born approximation and its application to various potentials, Electron scattering from nuclei, form factor and nuclear radius, Validity of Born approximation, Partial wave analysis, Scattering by a rigid sphere and square well. Low energy nucleon-nucleon scattering.

Relativistic Quantum Mechanics: Klein-Gordon Equation and its non-relativistic reduction. Dirac equation for a free particle and its solution. Interpretation of negative energy states. Nonrelativistic approximation to the Dirac equation. Existence of spin. Fine structure effects. Solutions of Dirac equation for hydrogen atom.

Books recommended:

1. Principles of Quantum Mechanics, R. Shankar, Springer.
2. Quantum Mechanics, Claude Cohen-Tannoudji, Bernard Diu and Franck Laloë, Wiley.
3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press.
4. Quantum Mechanics, Eugen Merzbacher, Wiley.
5. Introduction to Quantum Mechanics, David J. Griffiths and Darrell F. Schroeter, Cambridge University Press.
6. Quantum Mechanics, Leonard I. Schiff, McGraw-Hill.
7. Introductory Nuclear Physics, Kenneth S. Krane, Wiley.
8. Theoretical Nuclear Physics, John M. Blatt and Victor F. Weisskopf, Springer.
9. Introductory Nuclear Physics, Harald A. Enge, Addison-Wesley.
10. Nuclear Physics: Principles and Applications, John Lilley, Wiley.
11. Concepts of Nuclear Physics, Bernard L. Cohen, McGraw-Hill.
12. Nuclear Physics, Irving Kaplan, Narosa Publishing House.
13. Quantum Mechanics: B. H. Bransden and C.J. Joachain, Prentice Hall.

Course Outcomes (COs)	Description
CO1	Apply the formalism of quantum mechanics, including linear operators, Dirac notation, Hilbert space, and angular momentum algebra, to analyze the quantum states and dynamics of microscopic systems.
CO2	Explain the fundamental properties of atomic nuclei and apply nuclear models to interpret nuclear structure, stability, magnetic moments, energy spectra, nuclear reactions, and fission phenomena.
CO3	Analyze quantum systems using time-independent and time-dependent perturbation theories, and evaluate the interaction of atoms with electromagnetic radiation and its applications in spectroscopy and magnetic resonance.
CO4	Apply scattering theory, including Born approximation and partial wave analysis, to determine scattering amplitudes, cross sections, and the properties of nuclear interactions.
CO5	Analyze relativistic quantum systems using the Klein–Gordon and Dirac equations, and explain relativistic effects such as spin, fine structure, and the hydrogen atom spectrum.

PHY-507 PHYSICS LABORATORY-II/COMPUTATIONAL PHYSICS 05 credits

Physics Laboratory-II

Course Objective

The objective of this laboratory course is to strengthen advanced experimental skills in optics, electronics, nuclear physics, instrumentation, solid-state physics, and modern physics. Emphasis shall be placed on careful observation, calibration, data analysis, error estimation, graphical representation, and interpretation of experimental results.

List of Experiments

1. Determination of the wavelength of laser light using a diffraction grating.
2. Determination of the numerical aperture of an optical fibre.
3. Determination of attenuation loss in an optical fibre.
4. Study of the Michelson interferometer and determination of wavelength separation / refractive index.
5. Study of Fabry–Perot interferometer and determination of finesse/wavelength separation.
6. Determination of Planck's constant using the photoelectric effect.
7. Determination of Planck's constant using LEDs.
8. Study of solar cell characteristics and determination of fill factor and efficiency.
9. Determination of the dielectric constant of a material.
10. Determination of magnetic susceptibility by Gouy's method or Quincke's method.
11. Study of electron spin resonance and determination of the g-factor.
12. Study of the Zeeman effect and determination of specific charge or magnetic moment-related parameters.
13. Study of operational amplifier circuits: adder, subtractor, integrator, and differentiator.
14. Study of active low-pass and high-pass filters using an operational amplifier.
15. Study of comparator and Schmitt trigger circuits using an operational amplifier.
16. Construction and analysis of an RC phase-shift oscillator or Wien bridge oscillator.
17. Study of a 555 timer in astable and monostable modes.
18. Verification of truth tables of basic logic gates using ICs.
19. Study of flip-flops, counters, or shift registers.
20. Measurement of voltage, frequency, and phase using CRO/DSO.
21. Study of Lissajous figures using CRO/DSO.
22. Study of GM counter characteristics and determination of operating voltage.
23. Study of counting statistics and verification of Poisson/Gaussian distribution.
24. Study of gamma-ray absorption and determination of the absorption coefficient.
25. Determination of the resolving power of a grating or spectrometer.
26. Study of polarisation of light using a polarizer and analyzer.
27. Study of the magnetoresistance of a material.
28. Study and calibration of temperature sensors such as RTD, thermistor or thermocouple.
29. Study and calibration of LVDT or any displacement transducer.
30. Design of a signal-conditioning circuit for a sensor using operational amplifier.

Laboratory Requirements

Students shall perform a minimum prescribed number of experiments, as decided by the department, from the above list or equivalent experiments depending on the availability of apparatus. Each experiment should include proper observation, tabulation, graphical analysis, error estimation and physical interpretation of the result.

Suggested Books

1. B. L. Worsnop and H. T. Flint, *Advanced Practical Physics*.
2. D. Chattopadhyay, P. C. Rakshit and B. Saha, *An Advanced Course in Practical Physics*.
3. S. L. Gupta and V. Kumar, *Practical Physics.*
4. C. L. Arora, *Practical Physics*.
5. A. K. Sawhney, *A Course in Electrical and Electronic Measurements and Instrumentation*.
6. H. S. Kalsi, *Electronic Instrumentation.*

Computational Physics

Scientific Computing and Programming: Introduction to computational physics and scientific computing; algorithms and flowcharts. Fundamentals of programming using C++/Python or equivalent language: data types, variables, operators, control statements, functions, arrays, strings, file handling and modular programming. Basic concepts of object-oriented programming: classes, objects, constructors, inheritance and polymorphism. Introduction to scientific libraries and plotting tools.

Error Analysis, Data Handling and Numerical Calculus: Computer arithmetic; floating-point representation; precision and accuracy; truncation and round-off errors; propagation of errors; stability of numerical algorithms. Data analysis and visualization. Least-squares fitting; linear and polynomial regression. Interpolation using Newton forward, Newton backward and Lagrange methods; spline interpolation. Numerical differentiation. Numerical integration using Trapezoidal rule, Simpson's 1/3 and 3/8 rules, Gaussian quadrature and Monte Carlo integration.

Algebraic Equations, Matrices and Differential Equations: Solution of nonlinear equations using Bisection, Regula-Falsi, Newton–Raphson and Secant methods. Solution of simultaneous linear equations using Gaussian elimination, Gauss–Jordan method, LU decomposition and iterative methods such as Jacobi and Gauss–Seidel methods. Eigenvalue problems and matrix diagonalization. Numerical solution of ordinary differential equations using Euler method, Modified Euler method, Taylor series method, Runge–Kutta methods and predictor-corrector methods. Introduction to finite-difference methods for heat, wave and Laplace equations.

Computational Methods in Physics: Root-finding problems in physics; Fourier series and Fast Fourier Transform. Random number generation and pseudo-random numbers. Monte Carlo methods and their applications. Numerical simulation of physical systems: projectile motion with air resistance, radioactive decay, harmonic oscillator, damped oscillator, coupled oscillators, diffusion, random walk, and simple quantum mechanical problems such as particle in a box and tunnelling.

Scientific Data Analysis and Computational Applications: Graphical representation of scientific data; curve fitting and parameter estimation. Computational treatment of experimental data. Smoothing and filtering of data; basics of signal processing. Introduction to optimization methods. Applications of computational methods in quantum mechanics, statistical physics, electromagnetism, nuclear physics, condensed matter physics and astrophysics. Introduction to scientific software environments such as MATLAB, Python with NumPy, SciPy and Matplotlib, or equivalent open-source platforms. Elementary introduction to parallel computing, high-performance computing and GPU computing.

Suggested Computational Exercises

1. Write programs for basic numerical operations, plotting and file handling.
2. Find roots of algebraic and transcendental equations by Bisection, Newton–Raphson and Secant methods.
3. Perform interpolation using Newton and Lagrange methods.
4. Evaluate definite integrals using Trapezoidal, Simpson and Gaussian quadrature methods.
5. Solve systems of linear equations using Gaussian elimination and Gauss–Seidel methods.
6. Find eigenvalues and eigenvectors of simple matrices.
7. Solve first-order and second-order ordinary differential equations using Euler and Runge–Kutta methods.
8. Simulate projectile motion with and without air resistance.
9. Simulate simple harmonic, damped and driven oscillators.
10. Simulate radioactive decay and compare with analytical results.
11. Simulate one-dimensional random walk and diffusion.
12. Use Monte Carlo method to estimate \pi and evaluate integrals.
13. Perform Fourier analysis of a given signal using FFT.
14. Solve the one-dimensional heat equation using finite-difference method.
15. Solve simple quantum mechanical problems such as particle in a box or tunnelling through a barrier.

Suggested Books

1. Nicholas J. Giordano and Hisao Nakanishi, *Computational Physics*.
2. Tao Pang, *An Introduction to Computational Physics*.
3. Jos Thijssen, *Computational Physics*.
4. William H. Press, Saul A. Teukolsky, William T. Vetterling and Brian P. Flannery, *Numerical Recipes: The Art of Scientific Computing*.
5. Steven C. Chapra, *Applied Numerical Methods with MATLAB for Engineers and Scientists*.
6. Richard Hamming, *Numerical Methods for Scientists and Engineers*.
7. Joel Franklin, *Computational Methods for Physics*.
8. Qiang Ye, *Python Programming and Numerical Methods: A Guide for Engineers and Scientists*.
9. David Pine, *Introduction to Python for Science and Engineering*.
10. James Scarborough, *Numerical Mathematical Analysis*.
11. E. Balagurusamy, *Computer Programming with C++*.

PHY-509 SEMINAR / INTERNSHIP / APPRENTICESHIP 02 credits

Each student shall complete one of the following components under the supervision of a faculty mentor:

1. Seminar, or
2. Internship, or
3. Apprenticeship / Training

The activity may be carried out within the department, university, research laboratory, industry, academic institution, scientific organization, technical facility, or any other approved organization. The topic or training area shall be finalized in consultation with the faculty mentor and approved by the department.

A. Seminar Component

A student opting for a seminar shall select a topic from Physics or allied interdisciplinary areas. The topic may be based on advanced concepts, recent developments, experimental techniques, computational methods, instrumentation, applications, or a review of scientific literature.

The seminar work shall include:

- selection of a suitable topic in consultation with the faculty mentor;
- literature survey using textbooks, review articles, research papers, reports, and other academic sources;
- study of the basic theory, methodology, applications, and recent progress related to the topic;
- preparation of a written seminar report;
- oral presentation before faculty members and students;
- participation in discussion and viva-voce.

Suggested Areas for Seminar

Condensed Matter Physics, Electronics, Photonics, Laser Physics, Nuclear Physics, Particle Physics, Plasma Physics, Computational Physics, Materials Science, Nanoscience, Renewable Energy, Environmental Physics, Astrophysics, Instrumentation, Quantum Technologies, Semiconductor Devices, Radiation Physics, Medical Physics, or any other relevant interdisciplinary area.

B. Internship Component

A student opting for an internship shall undertake short-term academic, research, technical, industrial, or laboratory-based work in an approved institution or organization. The internship should provide exposure to practical methods, data analysis, instrumentation, experimental procedures, computational tools, research methodology, or professional work culture.

The internship work may include:

- orientation to the host institution or laboratory;
- learning of relevant experimental, computational, or technical procedures;
- participation in assigned academic, research, laboratory, or industrial tasks;
- maintenance of a daily/weekly work diary or logbook;
- preparation of an internship report;
- Presentation of the internship experience before the department.

Suggested Areas for Internship

Research laboratories, universities, industries, instrumentation facilities, computational laboratories, material characterization laboratories, or other approved scientific/technical organizations.

C. Apprenticeship / Training Component

A student opting for apprenticeship or training shall undergo supervised skill-based learning in an academic, laboratory, technical, industrial, or field environment. The emphasis shall be on hands-on learning, professional discipline, technical skill development, and application of knowledge.

The apprenticeship/training may include:

- learning of laboratory practices and safety procedures;
- operation and handling of instruments;
- fabrication, testing, calibration, or measurement techniques;
- computational or data-processing work;
- technical documentation;
- participation in assigned practical or professional tasks;
- preparation of a training report;
- Oral presentation and viva voce.

M.Sc. (PHYSICS): SEMESTER-II

PHY-510: DIGITAL ELECTRONICS AND COMPUTATIONAL METHODS 05 Credits

Number Systems, Codes and Boolean Algebra: Binary, decimal, octal and hexadecimal number systems and interconversion. Binary arithmetic, signed and unsigned numbers, 1's and 2's complement representation. Boolean laws and theorems, logic gates, truth tables, positive and negative logic. Karnaugh map simplification, pairs, quads, octets and don't-care conditions. Digital codes: BCD, ASCII, Excess-3 and Gray code.

Combinational Logic Circuits: Half and full adders, half and full subtractors, parallel adder and subtractor. Multiplexers, demultiplexers, encoders and decoders. BCD-to-decimal decoder, 7-segment decoder, Exclusive-OR gates, parity generators and checkers. Applications of combinational circuits in arithmetic, display and control systems.

Logic Families, Sequential Circuits and Memories: TTL and CMOS logic families, 7400 and 74C00 series devices, logic levels, fan-in, fan-out, noise margin, propagation delay and power dissipation. Flip-flops, registers, shift registers and counters. Semiconductor memories: RAM, ROM, EPROM, EEPROM and flash memory. Basic memory organization and applications.

Data Converters, Microprocessors and Microcontrollers: A/D and D/A converters: principles, types, resolution, accuracy, conversion time and applications. Digital measurement and data acquisition systems. Basic architecture and instruction set of 8085 microprocessor. Introduction to microcontrollers: Arduino platform based on ATmega microcontroller, 8051 microcontroller, or equivalent microcontroller. Digital I/O, timers, counters, interrupts, serial communication and PWM. Interfacing of sensors, transducers, displays, ADC, DAC, keypad and stepper motor. Applications in embedded systems and experimental physics.

Computational Methods for Electronics and Experimental Physics: Algorithms, flowcharts, and structured programming. Computer representation of numbers, floating-point arithmetic, round-off and truncation errors, quantization error, and numerical stability. Statistical analysis of experimental data: mean, variance, standard deviation, uncertainty, error bars, and least-squares fitting. Numerical solution of linear and nonlinear equations, interpolation, numerical differentiation, and integration. Computational analysis of RC, RL, and RLC circuits. Introduction to sampling, filtering, noise reduction, Fourier analysis, data logging, and computer-based measurements.

Suggested Computational Exercises

Programming exercises may include number-system conversion, truth-table generation, binary arithmetic, least-squares fitting, error analysis, numerical solution of circuit equations, RC/RLC circuit simulation, filtering of noisy data, Fourier analysis of sampled signals, and simple data acquisition using a microcontroller.

Suggested Books

1. Malvino and Leach, Digital Principles and Applications.
2. R. P. Jain, Modern Digital Electronics.
3. Morris Mano, Digital Logic and Computer Design.
4. R. S. Gaonkar, Microprocessor Architecture, Programming and Applications with the 8085.
5. Mazidi, Mazidi and McKinlay, The 8051 Microcontroller and Embedded Systems.
6. V. Rajaraman, Computer Oriented Numerical Methods.
7. S. S. Sastry, Introductory Methods of Numerical Analysis.
8. Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers.

Course Outcomes (COs)	Description
CO1	Apply the principles of Boolean algebra, number systems, logic gates, Karnaugh maps, and digital codes to analyze and design basic combinational and sequential digital circuits.
CO2	Analyze and explain the working principles of digital building blocks including adders, subtractors, multiplexers, demultiplexers, encoders, decoders, parity generators, flip-flops, registers, counters, and semiconductor memory devices.
CO3	Describe the architecture and operation of microprocessors and microcontrollers, and apply programming and interfacing concepts for developing digital instrumentation and embedded systems used in physics experiments.
CO4	Analyze data acquisition systems, ADC/DAC techniques, sensor interfacing, and digital measurement systems by evaluating parameters such as accuracy, resolution, errors, and performance characteristics.
CO5	Apply computational techniques for digital systems and instrumentation, including numerical methods, statistical data analysis, error estimation, curve fitting, and computational approaches for solving electronic circuit-related problems.

PHY-512 MATERIALS PHYSICS AND NANOSCIENCE 05 credits

Binary alloys: Interstitial and substitutional solid solution, Factors governing solid solubility, Statistical stability of alloys, Temperature dependence of solubility, phase diagrams, Superlattices, Equilibrium between two phases. Two component systems containing two phases. The phase rule. Binary phase diagrams: Isomorphous alloy systems, The Lever rule, Eutectic systems, The equilibrium microstructure of eutectic systems, applications, Peritectic transformation, Iron-Carbon phase diagram.

Polymers and Ceramics: Classification of polymers, homo- and co-polymers, Linear, branched and crosslinked polymers, Organic, Elemento-organic and Inorganic polymers, Synthesis of polymers, chain polymerization, step polymerization, thermodynamics of the process, Effect of various factors on polymerization rate, Synthesis of graft and block copolymers, Crosslinking reactions, Vulcanization of rubbers, Hardening of plastics, Degradation of polymers, effect of high temperatures, Light and ionizing radiation, Chemical degradation. Ceramics: Short range order, Coordinated polyhedron and ionic radius, crystalline and glassy states, Glasses, Whitewears and refractories, Cement and Concrete.

Magnetic materials: Magnetocrystalline anisotropy, Induced magnetic anisotropy, Magnetostrction, Magnetoelastic energy, Magnetoelastic coupling, Volume changes in magnetostriction, Villari effect, Wiedemann effect, Inverse Wiedemann effect, Matteucci effect, effect, Barkhausen effect, Magnetization process, Technical magnetization, Magnetic after effect, Soft and hard magnetic materials, Ferrites their structure and uses.Type equation here.

Fundamental of Nanoscience and Nanomaterials: Introduction to nanoscience and nanotechnology, historical development and significance of nanoscale materials. Classification of nanomaterials based on dimensionality: zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanostructures. Size-dependent properties of nanomaterials: surface-to-volume ratio, quantum confinement effects, optical, electrical, magnetic, thermal and mechanical properties. General applications of nanomaterials.

Synthesis, Characterization and Applications of Nanomaterials: Synthesis techniques of nanomaterials: top-down and bottom-up approaches. Mechanical milling, lithography, laser ablation, sputtering, chemical vapour deposition (CVD), physical vapour deposition (PVD), sol-gel method, hydrothermal synthesis, self-assembly and biological synthesis of nanomaterials.

Characterization techniques: X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), scanning tunneling microscopy (STM), UV-Visible spectroscopy, Fourier transform infrared spectroscopy (FTIR) and thermal analysis techniques.

Books recommended:

Materials Science and Metallurgy

1. Physical Metallurgy, R. E. Reed-Hill and R. Abbaschian, Cengage Learning.
2. Introduction to Properties of Materials, Resenthal and Asimow, Prentice Hall.
3. Elements of Materials Science and Engineering, Lawrence H. Van Vlack, Addison-Wesley.
4. Science of Engineering Materials, C. M. Srivastava, New Age International Publishers.
5. Physical Metallurgy, V. Raghavan, Prentice Hall India.
6. Materials Science and Engineering: An Introduction, William D. Callister Jr. and David G. Rethwisch, Wiley.
7. Introduction to Materials Science for Engineers, James F. Shackelford, Pearson Education.
8. Phase Transformations in Metals and Alloys, D. A. Porter, K. E. Easterling and M. Y. Sherif, CRC Press.

Polymer Science

9. Physical Chemistry of Polymers, A. Tager, Mir Publishers.
10. Polymer Science and Technology, Joel R. Fried, Prentice Hall.
11. Textbook of Polymer Science, Fred W. Billmeyer Jr., Wiley.

Magnetic Materials

12. Physics of Magnetism, S. Chikazumi, Oxford University Press.
13. Introduction to Magnetic Materials, B. D. Cullity and C. D. Graham, Wiley-IEEE Press.
14. Magnetism and Magnetic Materials, J. M. D. Coey, Cambridge University Press.

Nanoscience and Nanotechnology

15. Nanotechnology: Principles and Applications, Sulabha K. Kulkarni, Capital Publishing Company.
16. Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Guozhong Cao and Ying Wang, World Scientific Publishing.
17. Introduction to Nanotechnology, Charles P. Poole Jr. and Frank J. Owens, Wiley.
18. Nanomaterials: An Introduction to Synthesis, Properties and Applications, Dieter Vollath, Wiley-VCH.
19. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. Wolf, Wiley-VCH.

Characterization Techniques

20. Transmission Electron Microscopy: A Textbook for Materials Science, David B. Williams and C. Barry Carter, Springer.
21. Scanning Electron Microscopy and X-Ray Microanalysis, Joseph I. Goldstein et al., Springer.
22. X-Ray Diffraction Procedures for Polycrystalline and Amorphous Materials, H. P. Klug and L. E. Alexander, Wiley.

Course Outcomes (COs)	Description
CO1	Explain the principles of alloy formation, phase equilibria, phase diagrams, phase transformations, and heat treatment processes to understand the structure and properties of engineering materials.
CO2	Analyze the structural, mechanical, thermal, chemical, and functional properties of polymers, ceramics, and composite materials, and relate their properties to technological applications.
CO3	Describe the origin of magnetic properties in materials and evaluate the behavior, applications, and performance of soft magnetic, hard magnetic, and ferrite materials.
CO4	Explain the fundamental concepts of nanoscience, including size-dependent properties, quantum confinement effects, surface phenomena, and different classes of nanomaterials such as nanoparticles, nanotubes, quantum dots, graphene, and nanocomposites.
CO5	Analyze various synthesis and characterization techniques of nanomaterials and evaluate their applications in electronics, energy, sensors, catalysis, biomedical fields, and advanced functional materials.

PHY-514 PLASMA PHYSICS 05 credits

Basic Plasma Concepts and Single-Particle Motion: Occurrence of plasma in nature and laboratory; plasma criteria; Debye shielding; plasma frequency; plasma parameter; quasineutrality and validity of plasma approximation. Motion of charged particles in uniform electric and magnetic fields; crossed electric and magnetic fields; motion in non-uniform fields; gradient drift, curvature drift, and polarization drift. Adiabatic invariants and magnetic mirrors.

Fluid Description and Plasma Transport: Fluid description of plasma; continuity equation, equation of motion, and pressure equation. Plasma as a conducting fluid; electron and ion fluid motion. Fluid drifts parallel and perpendicular to the magnetic field. Plasma oscillations; electron plasma waves; ion acoustic waves. Diffusion in weakly ionized and fully ionized plasmas; ambipolar diffusion; decay of plasma by diffusion.

Waves in Plasma and Wave Propagation: Electrostatic waves and electromagnetic waves in plasmas. Wave propagation in unmagnetized plasma; dispersion relation, cutoff, and plasma refractive index. Wave propagation in magnetized plasma for propagation vector parallel and perpendicular to the magnetic field. Ordinary and extraordinary waves; Alfvén waves and magnetosonic waves. Phase velocity, group velocity, energy flow, and basic waveguide/resonator concepts relevant to plasma devices.

Kinetic Theory and Plasma Instabilities: Distribution functions and velocity space; Boltzmann equation and Vlasov equation; derivation of fluid equations from kinetic theory. Landau damping. Two-stream instability; Weibel instability; gravitational instability. Ion acoustic shock waves. Ponderomotive force; parametric instabilities; frequency matching condition; instability threshold; oscillating two-stream instability and plasma echoes.

Controlled Fusion and Plasma Applications: The problem of controlled thermonuclear fusion; Lawson criterion; magnetic confinement: torus, mirrors, and pinches. Plasma heating methods. Laser-induced fusion and inertial confinement fusion. Introduction to plasma applications: space and astrophysical plasmas, plasma processing, plasma diagnostics, microwave-plasma interaction, and high-power microwave/plasma devices.

Suggested Books

1. F. F. Chen, *Introduction to Plasma Physics and Controlled Fusion.*
2. D. R. Nicholson, *Introduction to Plasma Theory*.
3. J. A. Bittencourt, *Fundamentals of Plasma Physics*.
4. T. H. Stix, *Waves in Plasmas.*
5. R. J. Goldston and P. H. Rutherford, *Introduction to Plasma Physics*.

Course Outcomes (COs)	Description
CO1	Explain the fundamental concepts of plasma, including plasma criteria, Debye shielding, plasma frequency, quasineutrality, and analyze the motion of charged particles in electric and magnetic fields, including particle drifts and magnetic confinement.
CO2	Apply the fluid description of plasmas to derive and analyze the governing equations of plasma dynamics, transport processes, plasma oscillations, wave phenomena, and diffusion mechanisms in weakly and fully ionized plasmas.
CO3	Analyze the propagation of electrostatic and electromagnetic waves in magnetized and unmagnetized plasmas by interpreting dispersion relations, wave modes, cutoff conditions, refractive index, and wave energy transport.
CO4	Evaluate plasma behavior using kinetic theory by interpreting distribution functions, Vlasov and Boltzmann equations, Landau damping, plasma instabilities, shock waves, and nonlinear wave–particle interaction phenomena.
CO5	Assess the principles of controlled thermonuclear fusion, plasma heating, magnetic and inertial confinement techniques, and examine the applications of plasma in space science, industry, diagnostics, and high-power microwave technologies.

PHY-516 ADVANCED PHYSICS LABORATORY/MICROPROCESSOR LAB 05 credits

Part A: Microprocessor Laboratory

8085 Microprocessor Programming and Interfacing

1. Study of 8085 microprocessor architecture, instruction set, addressing modes, assembly language programming, and use of microprocessor trainer kit.
2. Programs for arithmetic and logical operations using 8085 microprocessor.
3. Programs for data transfer, sorting, searching, delay generation, and code conversion using 8085 microprocessor.
4. Interfacing of 8085 microprocessor with elevator simulator module.
5. Interfacing of 8085 microprocessor with traffic light controller module.
6. Interfacing of 8085 microprocessor with ADC 0809 module.
7. Interfacing of 8085 microprocessor with DAC 0800 module.
8. Interfacing of 8085 microprocessor with stepper motor controller module.
9. Interfacing of seven-segment display and matrix keyboard module.
10. Interfacing of 16 × 1 LCD display module.
11. Interfacing of 16 × 1 LCD display with matrix keyboard module.
12. Interfacing of 5 × 4 matrix keyboard module.
13. Temperature measurement using microprocessor-based interfacing module.
14. Microprocessor-based data acquisition and display of sensor output.
15. Simple control application using microprocessor and external interfacing module.

Part B: Advanced Physics Laboratory

The following experiments may be included depending on the availability of apparatus:

1. Study of electron spin resonance and determination of g-factor.
2. Study of Zeeman effect.
3. Study of Michelson interferometer or Fabry–Perot interferometer.
4. Study of optical fibre characteristics: numerical aperture and attenuation.
5. Study of laser diffraction and determination of wavelength.
6. Study of GM counter characteristics and counting statistics.
7. Study of gamma-ray absorption and determination of absorption coefficient.
8. Study of solar cell characteristics and determination of efficiency and fill factor.
9. Study of dielectric constant of a material.
10. Study of magnetic susceptibility by Gouy's method or Quincke's method.
11. Study of magnetoresistance of a material.
12. Calibration and study of temperature sensors such as RTD, thermistor or thermocouple.
13. Study of LVDT or displacement transducer.
14. Design and testing of signal-conditioning circuit for a sensor.
15. Study of data acquisition using computer / microprocessor / microcontroller interface.

Suggested Books

1. Ramesh S. Gaonkar, *Microprocessor Architecture, Programming, and Applications with the 8085*.
2. B. Ram, *Fundamentals of Microprocessors and Microcomputers.*
3. A. P. Mathur, *Introduction to Microprocessors*.
4. Douglas V. Hall, *Microprocessors and Interfacing*.

5. B. L. Worsnop and H. T. Flint, *Advanced Practical Physics.*
6. D. Chattopadhyay, P. C. Rakshit and B. Saha, *An Advanced Course in Practical Physics.*
7. H. S. Kalsi, *Electronic Instrumentation.*
8. A. K. Sawhney, *A Course in Electrical and Electronic Measurements and Instrumentation.*

PHY-518 NUMERICAL METHODS USING PYTHON 02 credits

Introduction to Python for Scientific Computing

Introduction to Python programming environment and Jupyter Notebook. Python basics: variables, data types, operators, conditional statements, loops, functions, modules and packages. Introduction to scientific computing libraries: NumPy, SciPy, Matplotlib and Pandas. Arrays and matrix operations, data handling and visualization. Reading, processing and plotting experimental data. Writing efficient and structured computational programs.

Numerical Methods and Data Analysis using Python

Representation of numbers in computers, floating-point arithmetic, precision and accuracy, truncation and round-off errors, error propagation and numerical stability. Solution of algebraic equations using Bisection method, Newton-Raphson method and Secant method. Numerical solution of simultaneous linear equations using matrix methods. Interpolation techniques: Newton and Lagrange interpolation. Curve fitting, least-square fitting, linear and polynomial regression. Numerical differentiation and integration using trapezoidal rule, Simpson's rule and Gaussian quadrature.

Computational Methods for Physical Problems

Numerical solution of ordinary differential equations using Euler method, Modified Euler method and Runge-Kutta methods. Introduction to finite difference methods for partial differential equations. Numerical simulation of physical systems: harmonic oscillator, projectile motion, radioactive decay, population dynamics and coupled oscillators. Random number generation, Monte Carlo methods and applications. Fourier analysis and Fast Fourier Transform (FFT). Introduction to computational modeling in quantum mechanics, electromagnetism and statistical physics.

Students may perform computational assignments such as:

1. Implementation of numerical integration and differentiation algorithms.
2. Curve fitting and analysis of experimental data.
3. Solution of ordinary differential equations using Runge-Kutta methods.
4. Simulation of harmonic oscillator and coupled oscillator systems.
5. Monte Carlo simulation of random walk and physical systems.
6. Fourier analysis of experimentally generated signals.
7. Numerical solution of simple quantum mechanical problems.

Recommended Books

1. Computational Physics, Nicholas J. Giordano and Hisao Nakanishi, Pearson Education.
2. An Introduction to Computational Physics, Tao Pang, Cambridge University Press.
3. Computational Physics, Jos Thijssen, Cambridge University Press.
4. Numerical Recipes: The Art of Scientific Computing, W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, Cambridge University Press.
5. Python Programming and Numerical Methods: A Guide for Engineers and Scientists, Qiang Ye, Springer.
6. A Student's Guide to Python for Physical Modeling, Princeton University Press.
7. Effective Computation in Physics: Field Guide to Research with Python, O'Reilly Media.
8. Python for Data Analysis, O'Reilly Media.

Course Outcomes (COs)	Description
CO1	Develop Python programs using scientific computing libraries for numerical calculations, data processing, and visualization of physical data.
CO2	Analyze numerical errors and apply appropriate numerical methods for solving algebraic equations, matrix problems, interpolation, regression, differentiation, and integration.
CO3	Implement computational algorithms for solving ordinary and partial differential equations and simulate physical systems using Python.
CO4	Apply computational techniques such as Monte Carlo methods and Fourier analysis to analyze and model physical phenomena.
CO5	Develop computational approaches for solving research-oriented problems in physics using Python-based numerical tools.