Proposed Scheme and Syllabi of M.Sc. Physics 2nd Year for A.Y. 2024-25

Semester-III:

S. No.	Course Code	Course Title	L	T	P	Credits
1.	PHPC515	Advanced Electronics	3	0	0	3
2.	PHPC517	Condensed Matter Physics	3	0	0	3
3.	PHPE5##	Programme Elective - I	3	0	0	3
4.	PHPE5##	Programme Elective -II	3	0	0	3
5.	PHOE###	Open Elective - I	3	0	0	3
6.	PHPC519	Advanced Physics Lab	0	0	6	3
7.	PHPC521	Seminar	0	0	1	1
8.	PHPC523	Preparatory Research Project	0	0	4	2
			Total Credit			**21**

Semester-IV:

S. No.	Course Code	Course Title	L	T	P	Credits
1.	PHPE5##	Programme Elective – III	3	0	0	3
2.	PHPE5##	Programme Elective - IV*	3	0	0	3
3.	PHOE###	Open Electives-II*	3	0	0	3
4.	PHPC522	Research Project (Dissertation)	0	0	20	10
			Total Credit			**19**

Course Code PHPC 515	Advanced Electronics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about advanced electronic devices and their applications.
COE2	To develop understanding of design Digital circuits and interfacing simple systems using Microcontrollers.
COE3	To develop understanding of Communication systems.

UNIT-1 **9 L**

Semiconductor Devices: Drift and diffusion of carriers, Generation and recombination of charges, Direct and indirect semiconductors. P-N junction, diode equation, barrier width and Capacitance of PN junctions,Varactor, switching diode, FET as switch and amplifier, Optoelectronic Devices: LEDs, Diodes Lasers, Photodetectors and Solar Cells.

UNIT-2 **9 L**

Advanced Electronic Devices: Metal Oxide Field Effect Transistors (MOSFET), Short Channel Effects in MOSFET, Fin Field-Effect Transistors (FinFETs), Ferroelectric field effect devices and 2D nanosheet devices; Emerging Memory devices: DRAM, ReRAM, FeRAM and Phase Change memory (PCM) and universal memory devices.

UNIT-3 **10 L**

Analog Systems: Phase-lock loop and its applications frequency multiplication; Analog multiplier and its applications; log and antilog amplifiers; Instrumentation amplifiers;
Sensors: Temperature, Magnetic field, Displacement, Light intensity and Force sensors
Design of combinational circuits: Programming logic devices and gate arrays, 7- segment and LCD display system, digital gain control, analog multiplexers, PC based measurement system;
Design of Sequential circuits: Different types of A/D and D/A conversion techniques, TTL, ECL, MOS & CMOS operation and specifications.

UNIT-4 **9 L**

Communication Systems: Concepts of communication systems, role of electromagnetic spectrum, elementary ideas about terminology of communication systems, Need for modulation, amplitude, frequency, pulse amplitude, pulse position, pulse code modulation, Information in communication system, Coding, Types of Pulse modulation, Pulse width modulation (PWM), Pulse position Modulation (PPM), Principle of Pulse code modulation (PCM); Introduction to digital communication.

Reference Books:

1. **S. M. Sze**, Physics of semiconductor devices, Wiley, 2021.
2. **J. Millman & Grable**, Microelectronics, McGraw Hill, 2017.
3. **Santosh K. Kurinec**, Nanoscale Semiconductor Memories.
4. **Malvino and Leach**, Digital Principles & Applications, II edition, McGraw Hill, 2017.
5. **Fraser**, Telecommunications, CBS Publisher, 2019.
6. **J. D. Ryder**, Electronic fundamental and applications, Prentice Hall India, 1975.

Course Outcomes: Students will be able to:

CO1	Illustrate the basic concepts and applications of different Analog systems.
CO2	Design different digital electronic circuits such as 7 segment and LCD display systems.
CO3	Illustrate the basic concepts of Communication systems.

Course Code PHPC 517	Condensed Matter Physics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about the fundamentals of Semiconductor Physics and its applications.
COE2	To develop understanding of dielectric behavior of materials in electro- magnetic fields.
COE3	To develop understanding of magnetic and superconducting behavior of various condensed matter systems.

UNIT-1 **9 L**

Semiconductors: Semiconductor materials, Elemental and compound semiconductors, Energy bands, Direct and indirect Band gap semiconductors, Density of states, effective mass, donors and acceptors, Degenerate and Non-degenerate Semiconductors, Equilibrium and extrinsic carrier concentration, carrier transport, Drift and Diffusion current, mobility, Einstein relation, Excess carrier generation and recombination.

UNIT-2 **9 L**

Dielectrics: Polarization, Bound Charges, Electric displacement, susceptibility, dielectric coefficient, and permittivity, Dielectrics in AC fields, Clausius- Mossotti equation, polarizability- classical theory of electronic polarizability, dipolar polarizability, Effect of temperature and frequency on dielectric constant and dielectrics loss factor, Piezo-, Pyro- and ferroelectric solids, ferroelectric domains, ferroelectricity, anti-ferroelectricity and ferrielectricity, Applications of dielectrics.

UNIT-3 **8 L**

Magnetism: Classification of magnetic materials, origin of permanent magnetic moments, Langevin's classical theory of diamagnetism, Magnetic susceptibility, Quantum theory of paramagnetism, ferromagnetism, Weiss theory, ferromagnetic domains, Ferromagnetic order, Hysteresis, anti-ferromagnetism, Curie temperature and Neel temperature, ferrimagnetism and anti-ferrimagnetism, Susceptibility measurements- Guoy Balance; Quincke's method.

UNIT-4 **8 L**

Superconductors: Zero resistivity, Critical temperature, Meissner effect, London equation, Type I and II superconductors, thermodynamics, superconducting band gap, Cooper pairs, flux quantization, BCS theory, Josephson Effect, SQUIDS, High temperature superconductors, Applications of superconductivity.

Reference Books:

1. **Kittel C.**, Introduction to Solid State Physics, Wiley, 2007.
2. **Ben G. Streetman**, Prentice-Hall of India, Solid State Electronic Devices, 2012
3. **Jaspreet Singh**, John Wiley, Semiconductor Devices-Basic Principles, publication, 2008
4. **M A Wahab**, Solid State Physics-Structure and Properties of Materials, Narosa, 2005.

Course Outcomes: Students will be able to:

CO1	Understand the Semiconductor Physics and strategies for realizing its various applications.
CO2	Disseminate their understanding on behaviour of dielectric materials in electro- magnetic fields.
CO3	Understand the concept of superconductivity and magnetism.

Programme Elective – I (Semester-III):

S. No.	Course Code	Course Title
1.	PHPE 551	Quantum Field Theory
2.	PHPE 553	Lasers and Spectroscopy
3.	PHPE 555	Functional Materials and Characterization

Programme Elective – II (Semester-III):

S. No.	Course Code	Course Title
1.	PHPE 557	Radiation Physics and Nuclear Fragmentation
2.	PHPE 559	Nonlinear Spectroscopy
3.	PHPE 561	Materials Science

Programme Elective – III (Semester-IV):

S. No.	Course Code	Course Title
1.	PHPE 552	High Energy Physics
2.	PHPE 554	Photonics
3.	PHPE 556	Thin Film Physics and Applications

Programme Elective – IV (Semester-IV):

S. No.	Course Code	Course Title
1.	PHPE 558	Nuclear Technology
2.	PHPE 560	Physics of Optoelectronics Devices
3.	PHPE ###	NPTEL/SWAYAM/edX

Programme Elective NPTEL/SWAYAM/edX Courses:

S.No.	Course Code	Course Title
1.	PHPE ###	Accelerator Physics
2.	PHPE ###	Neutron Scattering for Condensed Matter Studies
3.	PHPE ###	Scientific Computing Using Python
4.	PHPE ###	Numerical Methods and Simulation Techniques for Scientists and Engineers
5.	PHPE ###	Computational Physics
6.	PHPE ###	A Brief Course On Superconductivity
7.	PHPE ###	Physics Of Linear And Nonlinear Optical Waveguides
8.	PHPE ###	Solar Photovoltaics Fundamentals, Technology and applications

Course Code PHPE 551	**Quantum Field Theory**	**Credits 3-0-0: 3**

Course Educational Objectives :

COE1	To familiarize the students about interaction among fundamental entities of the universe.
COE2	To develop understanding of perturbation theory and Feynman Rules to apply in high energy scattering measurements.
COE3	To develop understanding of bound state structure.

UNIT-1 **10 L**

Relativistic Electrodynamics: Maxwell's Equations in Relativistic Form, four-current, four-potential, The Field Strength Tensor, Maxwell's inhomogeneous and Homogeneous equations, Transformation Law for Electric and Magnetic Fields.

The Klein-Gordon Field: Elements of Classical Field Theory, The Klein-Gordon field as Harmonic Oscillator, The Klein-Gordon field in Space-time, Classical Propagator and particle creation by a classical source.

UNIT-2 **8 L**

The Dirac Field: Lorentz invariance in Wave Equations. The Dirac equations and Weyl spinors, Free particle solutions of the Dirac Equations and Spin sum rule, Dirac Matrices and Dirac Field Bilinears, Quantization of the Dirac Field, The Dirac Propagator, Discrete symmetries of the Dirac Theory, Parity, Time Reversal, Charge Conjugation.

UNIT-3 **8 L**

Quantum Electrodynamics and Feynman diagrams: Perturbation Theory and expansion of Correlation functions. Wick's Theorem, Feynman Diagrams, Cross-sections and the S-matrix calculation from Feynman diagrams, Feynman Rules for Fermions, Yukawa Theory, Feynman Rules for Quantum Electrodynamics, The Coulomb Potential.

UNIT-4 **10 L**

Applications to Elementary process: Electron Muon High Energy Scattering, Trace technology, Unpolarized Cross-Sections, Helicity Structure, Crossing Symmetry, Mandelstam Variables, Compton Scattering, Photon Polarization Sum, Klein-Nishina Formula, Pair annihilation into photons.

Reference Books:

1. **F. Halzen and A. Martin**, Quarks and Leptons: An Introductory Course in Modern Particle Physics**,** John Wiley & Sons, 1993.
2. **D. J. Griffiths**, Introduction to elementary Particles, John Wiley & Sons, 2006.
3. **Richard P. Feynman,** The strange Theory of Light and Matter, Prinston University Press, 1983.
4. **W. Greiner, J. Reinhart**, Quantum Electrodynamics, Springer, 2003.
5. **C. Cohen-Tannoudji, J. D. Roc, G. Grynberg,** Photons and Atoms: Introduction to quantum electrodynamics, WILEY VCH Verlag GmbH & Co. KGaA, 1997.
6. A. Lahiri, P. B. Pal, A first Book of Quantum Field Theory, Narosa Publication, 2007.

Course Outcomes: Students will be able to:

CO1	Estimate the interaction strength among fundamental constituent of the universe.
CO2	Apply Feynman rules technique to the high energy scattering process measured in experiments like LHC, COMPASS, HERA, LEP etc.
CO3	Cultivate critical thinking on symmetries and conservation laws involved in cutting edge research.

Course Code PHPE 553	Lasers and Spectroscopy	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To develop the understanding of Laser technology and Laser based devices.
COE2	To learn Vibrational spectroscopy and related technologies.
COE3	To understand various laser based detection techniques and instrumentation.

UNIT-1 **9 L**

Laser fundamentals: Einstein coefficients, Population inversion, Line shape function, Line broadening, Three level system, Four level system, Optical resonators, Laser cavity design; cavity modes, laser spiking, gain saturation, Laser properties, Pulse amplification techniques (Q-Switch, Mode-locking), Coherence properties of light, optimization of laser output.

UNIT-2 **9 L**

Laser devices: Solid State Lasers: Concept, design and applications, Nd:YAG Laser, Semiconductor lasers, Gas laser systems: He:Ne, CO_2 laser, Excimer laser; Dye laser; Fiber laser.

UNIT-3 **9 L**

Infrared and Raman Spectroscopy: Vibrational Degree of freedom, Normal coordinates, Normal vibrations and mathematical formulations, Degenerate vibrations, Infrared spectra: Active and inactive vibrations, Overtone and combination vibrations, Vibrational Raman Spectra: concept, Mathematical Formulations, Polarizability ellipsoid, Overtone and combination vibrations, Polarization of Rayleigh and Raman Scattering.

UNIT-4 **9 L**

Spectroscopic techniques: Spectroscopic processes, Absorption and fluorescence spectroscopy, Steady-state and time-resolved emission spectroscopy, Raman Spectroscopy, Stand-off Laser Spectroscopy, Cavity ring-down laser absorption spectroscopy, Laser Induced Breakdown Spectroscopy, Photoacoustic Spectroscopy.

Reference Books:

1. **William T. Silfvast**, Laser Fundamentals, Cambridge University Press, 2003.
2. **John F**. **Ready**, Industrial Applications of Lasers, Acedamic Press, 1997.
3. **John Ion**, Laser Processing of Engineering Materials: Principles, Procedure and Industrial Applications, Elsevier, 2005.
4. **Colin N.** Banwell & Elaine M. McCash, Fundamentals of molecular spectroscopy, McGraw Hill, 2017.
5. **G. Aruldhas**, Molecular structure and Spectroscopy, Prentice - Hall of India, 2007.

Course Outcomes: Students will be able to:

CO1	Learn the concept of lasers, its instrumentation and will be able to design and develop lab scale lasers.
CO2	Use vibrational spectroscopy for various applications related to molecular analysis.
CO3	Develop new spectroscopic technique and perform experiments.

Course Code PHPE 555	Functional Materials and Characterization	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To provide an overview of functional materials' design, composition, processing processes, structure, and physical properties.
COE2	To familiarize the students with different techniques associated with the fabrication and physical property testing of functional materials.
COE3	To impart knowledge and develop the understanding of applications of a range of advanced functional materials.

UNIT-1 **9 L**

Functional Materials And Nanotechnology: Introduction to functional materials (magnetism, ferroelectricity, piezoelectricity, semiconductors, polymers, and storage) and nanotechnology: definitions and background, a brief history, scales and sizes, size effects, elegant examples from nature and materials science, nanotechnology, environmental and health impact.

UNIT-2 **9 L**

Functional Materials Synthesis: Top-down and Bottom-up approaches for synthesis of functional materials; Ball milling, Electron Beam Lithography, Atomic Layer Deposition, Pulse Laser Deposition, Spray pyrolysis, Chemical Vapor Deposition (CVD), Sol-gels, Hydrothermal methods, Microwave, Spin and Dip coating techniques.

UNIT-3 **9 L**

Functional Materials Characterization: XRD, Raman, UV-VIS-Spectroscopy, Microscopy (SPM, TEM, SEM), Vibrating sample magnetometer (VSM), PE-loop tracer, Electrochemical workstation.

UNIT-4 **9 L**

Functional Materials Applications: Applications of functional materials in electronics, optics and photovoltaic cells, sensors, fuel cells, batteries, supercapacitors H_2 storage and waste water treatment.

Reference Books:

1. Principle of Nanoscience & Nanotechnology: **M.A. Shah and T. Ahmad**, Narosa, 2010.
2. Nanoscale Multifunctional Materials**: S. M. Mukhopadhyay**, Wiley, 2012.
3. Elements of X-ray Diffraction, **B. D. Cullity**, 4th Edition, Addison Wiley, 1978.
4. Physics of Functional Materials, **HasseFredriksson& Ulla Akerlind**, Wiley, 2015.
5. Functional Materials; Electrical, Dielectric, Electromagnetic, Optical, and Magnetic Applications, **Deborah DL Chung**, World Scientific, 2010.
6. Functional Materials: Preparation, Processing and Applications, **S. Banerjee, AK Tyagi**, Elsevier, 2011.
7. Functional Molecular Materials: An Introductory Textbook, **Matteo Atzori, F. Artizzu**, CRC Press, 2018.

Course Outcomes: Students will be able to:

CO1	Understand functional materials behaviour to the design of new materials with novel properties.
CO2	Utilize lithographic methods to fabricate functional materials.
CO3	Use relationships between composition, processing route, microstructure, properties and applications of advanced functional materials.

Course Code PHPE 557	Radiation Physics and Nuclear Fragmentation	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To give understanding of different types of radiations and their interaction of with matter.
CEO2	To gain knowledge about design and working of gas filled and semiconductor radiation detectors.
CEO3	To develop the understanding of Solid state nuclear track detectors working and their application for measurement of environmental radioactivity.

UNIT-1 **9 L**

Biological Effects of Radiation: Types of Radiation, Radiation Doses- Exposure dose, Absorbed dose, Effective dose, special parameter, Weighting factor, Tissue Factor, background levels, LET and Radiation Biological Effectiveness.

Health effects: Schostic effects, Delayed Effect. Recomdation doses. Induction of chromosomal aberrations and its application in biological dosimetry of absorbed radiation. Cell killing and induction of mutations.

Radiation protection standards: Need for protection, ALARA principle. Radiation Shielding, Time, distance, shielding. External and internal exposure. ICRP and AERB recommendations.

UNIT-2 **9 L**

Environmental Radiation Detection Devices: Track etch generation mechanisms, conditions for tracks formation, etching and counting of tracks, properties and applications of SSNTD, detection thresholds, restricted energy loss, Active measurement techniques for environmental radioactivity; beta/gamma radiation survey meter, Scintillation Radon Monitor (SRM), Scintillation Thoron Monitor (STM).

UNIT-3 **8 L**

Nuclear Fragmentation: High energy heavy ions, heavy ions interactions in matter, Energy loss in matter by heavy particles, odd-even effect in fragmentation, fragmentation cross sections of heavy ions in various targets, total fragmentation, charge-changing nuclear reactions of relativistic ions during the passage of matter, charge-changing cross sections, partial-charge changing cross-section, fragmentation of ultra-relativistic heavy ions, electromagnetic dissociation.

UNIT-4 **10 L**

Radiation therapy: Photon therapy, electron therapy, charge particle therapy, hadrontherapy, systematics of heavy ion therapy, Bragg's peak analysis.

Special techniques in radiation therapy: Total Body Irradiation, Total Skin Electron Therapy, Stereotactic Radiosurgery (SRS); SRS Delivery Systems, Linac based, Gamma Knife, Robotic
LINAC.

Reference Books:

1. Radiation Detection and Measurement, T. Lewellen, Wiley, 2008**.**
2. Nuclear Instrumentation: **W. J. Price,** Johnes and Bartlett, 2012.
3. Solid State Nuclear Track Detectors-Principal and Applications: **R. L. Fleischer**, **P. B. Price**& R. M. Walker, Springer, 1948.
4. Techniques for nuclear and particle physics experiments: **W. R. Leo,** Springer, 1948.

Course Outcomes: Students will be able to:

CO1	Understand different types of radiations and their interaction of with matter.
CO2	Understand design and working of gas filled and semiconductor radiation detectors with associated electronics.
CO3	Understand solid state nuclear track detectors and their application for measurement of environmental radioactivity.

Course Code PHPE 559	Nonlinear Spectroscopy	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of nonlinear spectroscopy and various processes therein.
CEO2	To learn various nonlinear experimental methods.
CEO3	To understand multiphoton absorption process and instrumentation

UNIT-1 **9 L**

Fundamental: Wave Propagation in Nonlinear Medium, Nonlinear Polarization Density and Nonlinear Susceptibility, nonlinear optical coefficient, Saturable absorber, Phase Matching conditions, types of phase matching.

UNIT-2 **9L**

Second order Nonlinear process: Second Harmonic Generation (SHG), Sum and difference frequency generation, Parametric oscillation, Optical parametric oscillator, Singly and Doubly resonant oscillator, Examples of SHG in KDP and LiNbO3 crystals.

UNIT-3 **9L**

Third order Nonlinear process: Third Harmonic Generation, Self focusing, Photo-thermal spectroscopy; Optical Kerr effect, Self phase modulation, Four wave mixing concept and measurements, Multiphoton absorption process, Upconversion process, Z-scan technique.

UNIT-4 **9L**

Raman Spectroscopy: Raman Spectroscopy, Stimulated Raman scattering (SRS), Quantum theory, Coupled wave concept of SRS, Inverse Raman Effect, Coherent anti-stokes Raman Spectroscopy, Hyper-Raman effect, Stimulated Raman Gain and Loss Spectroscopy.

Reference Books:

1. Laser Fundamentals, **William T. Silfvast**, Cambridge University Press, 2003.
2. Industrial Applications of Lasers, **John F. Ready**, Academic Press, 2012.

Course Outcomes: Students will be able to:

CO1	learn laser technology and its advancement for defence.
CO2	Design and develop lab scale lasers and 3D objects.
CO3	Develop various laser detection techniques and perform experiments.

Course Code PHPE 561	Materials Science	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To impart knowledge in the field of material and their applications in engineering.
CEO2	To understand the origin of mechanical and thermal properties of materials.
CEO3	To prepare the students to take up the future challenges related to advanced materials for developing futuristic devices.

UNIT-1 **7 L**

Introduction: Historical perspective of Materials Science, Classification of materials, Structure property relationship in material, multiphase materials, Advance materials- polymers, ceramics and composites, Crystallinity and its effect on physical properties, metal, ceramic, polymers, Future materials, Materials and environment, Applications of materials.

UNIT-2 **7 L**

Diffusion in Solids: Introduction, Mechanisms of diffusion, Types of diffusion, Fick's law of diffusion, Concept of different types of diffusion coefficients, Factors affecting diffusion coefficient, Temperature dependence of diffusion coefficient, The Kirkendall effect, Darken analysis, Applications of diffusion.

UNIT-3 **7 L**

Mechanical Properties: Introduction, elastic deformation- Stress-strain response of materials; yield and tensile strength, modulus of elasticity, toughness, Elastic Properties of Materials; plastic deformation- fatigue, creep and fracture; Tensile Properties, True Stress and Strain, Elastic recovery after plastic deformation, Compressive, Shear, and Torsional deformation, Hardness, Variability of material properties.

UNIT-4 **7 L**

Thermal Properties: Introduction, specific heat, thermal conductivity, Thermal expansion, thermal stress, thermal stability, Thermal radiation, emissivity, Relationship between structure and thermal properties of materials, Phase Transition, Experimental methods for thermal analysis of materials, Thermoelectric properties.

Reference Books:

1. Material Science and Engineering, 6th edition, **V. Raghavan**, 2014.
2. Materials Science and Engineering, **William D. Callister, Jr. D. G. Rethwisch**, 2014.
3. Introduction to Materials Science for Engineers, **James F. Shackelford**, 2014.
4. Diffusion in Solids, **P. Shewmon**, 2016.

Course Outcomes: Students will be able to:

CO1	Understand different types of materials for various applications.
CO2	Understand thermal properties of materials.
CO3	Develop futuristic devices.

Open Elective – I (Semester-III):

S.No.	Course Code	Course Title
1.	PHOE581	Energy Materials and Devices
2.	PHOE583	Polymers, Ceramics and Composite Materials
3.	PHOE585	Semiconductor Devices

Open Elective – II (Semester-IV):

S.No.	Course Code	Course Title
1.	PHOE582	Fiber Optics and Optical Communication Systems
2.	PHOE584	Biomedical Instrumentation
3.	PHOE###	NPTEL/SWAYAM/edX

Open Elective NPTEL/SWAYAM/edX Courses:

S.No.	Course Code	Course Title
1.	PHOE###	Fundamentals of Artificial Intelligence
2.	PHOE###	Cyber Security and privacy
3.	PHOE###	Educational Leadership
4.	PHOE###	Artificial Intelligence: Search methods for problem solving
5.	PHOE###	Entrepreneurship
6.	PHOE###	Machine Learning and Deep Learning—Fundamentals and Applications
7.	PHOE###	Learning Analytics Tools

Course Code PHOE 581	Energy materials and devices	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To make graduates understand the use of nanomaterials in energy generation and storage.
CEO2	To exhibit understanding of the sources of energy and the methods of energy conversion in Nanotechnology.
CEO3	To gain the knowledge solar energy, electrochemical storage of energy and fuel cells.

UNIT-1 **7 L**

Introduction: Energy challenges, Energy consummation, Current sources of energy, Status of energy map, Energy policies, Conservation of energy, Alternative energy sources, Development and implementation of renewable energy technologies, role of renewable energy sources, Energy transport, conversion and storage, Sustainable Energy.

UNIT-2 **7 L**

Solar Energy: Fundamentals of solar cells, Types of solar cells, Photovoltaic effect, Semiconducting materials bandgap theory, Band gap engineering, Solar cell properties and design, p-n junction, Photodiodes, electron and hole transports, charge carrier generation, recombination, I-V characteristics, Tandem structure, Single junction and triple-junction, solar panels, thin film solar cells, solar cell applications, solar cell manufacturing process.

UNIT-3 **7 L**

Electrochemical Energy Storage Devices: Thermodynamics of electrochemical reaction Li- ion batteries, Nanostructured materials for Li-ion batteries, Principle of supercapacitor, Advanced supercapacitor technology,. Basics of Fuel cells - working principle of fuel cells and related thermodynamics, Fuel cell electrochemistry, Fuel cell types ; SOFC, MCFC, PAFC, PEFC, Water management in PEFCs-Current issues in PEFCs.

UNIT-4 **7 L**

Thermoelectric and Piezoelectric Energy: Thermoelectric and Pizoelectric materials, Fabrication and characterization of thermoelectric devices, Bulk thermoelectric materials performance, Thermoelectric modules, Piezoelectric harvester design, Micro and nanoscale energy harvesting, Fabrication and characterization of piezoelectric devices, Strategies for optimizing efficiency, Future directions.

Reference Books:

1. Energy for a sustainable world by **L. Freris, D. Infield**, Wiley, 2008.
2. Nanomaterials for Sustainable Energy by **Quan** (Ed.), Springer, 2016.
3. Nanomaterials in Energy Devices by **Jun HiengKait** CRC Press, 2017.
4. Advanced nanomaterials and their applications in renewable energy by **J. Louise**, **L. S. Bashir**, 2015.

Course Outcomes: Students will be able to:

CO1	Technically skilled to comprehend the principles behind energy storage mechanism.
CO2	To gain a broad understanding of concepts and applications of batteries and super capacitors.
CO3	Design and fabricate solar cells, electrochemical storage devices and fuel cells.

Course Code PHOE 583	Polymers, Ceramics And Composite Materials	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To impart fundamental knowledge about polymer, ceramic and composite materials.
CEO2	To understand processing techniques of polymer and ceramics.
CEO3	To prepare the students to develop the advanced materials through composite materials.

UNIT-1 **7 L**

Polymers and Chemical Bonding: Polymerization mechanism, Addition and Condensation polymerization, Molecular weights and their distribution, Simple and hindered rotation, Crystallinity and melting, Glass transition, Thermosetting and Thermoplastic Polymers, Conducting polymers and their types, Doping and De-doping of conjugated polymers, Solatron and polaron formation in conducting polymers.

UNIT-2 **7 L**

Composite Materials: Introduction and overview, Types of Composite Materials, Carbon based Reinforcements, Matrix materials, Factors affecting mechanical and electronic properties, Property Enhancement, case studies of composite materials for defense applications.

UNIT-3 **7 L**

Ceramics and Polymers Matrix Composites: Bonding and crystal structure; Defects in Ceramics, Diffusion and Electrical conductivity of ceramic materials. Synthesis of ceramic powder and nanoparticles and their consolidation; Processing of ceramics and polymers matrix composites, Interfaces and properties of ceramics matrix composites, Thermal shock resistance, Biodegradable Polymer Composites, Applications.

UNIT-4 **7 L**

Metal-Matrix Composites: Aluminium and Magnesium based Matrix Composites; Titanium based Matrix Composites, Fabrication and Applications.

Reference Books:

1. Polymer Science, **V.R. Gowariker, N.V. Viswanathan and JayadevSreedhar**, Halsted Press, John Wiley & Sons, New York, 1986.
2. Principles of Polymerization, **George Odian**, John Wiley & Sons, 2004.
3. Introduction to Ceramics, **W.D. Kingery, H.K. Bowen and D.R. Uhlmann,** Wiley, 1960.
4. Fundamentals of ceramics, **W.M. Barsoum,** CRC Press, 2002.
5. Composite Materials Science and Engineering, **Krishnan K. Chawla**, Springer, 2012.

Course Outcomes: Students will be able to:

CO1	Understand different types of materials for various applications.
CO2	Understanding will improve regarding mechanical properties of materials.
CO3	Understand the properties of new materials useful for developing futuristic devices.

Course Code PHOE 585	Semiconductor Devices	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of Physics essential for Electronics Engineering students.
CEO2	To gain knowledge of electronic and semiconducting properties of materials.
CEO3	To understand theories relevant to the engineering principles of Semiconductor devices.

UNIT-1 **4 L**

Review of Band theory of solids: Metal, Insulator, and Semiconductors; Periodic structures, Origin of Energy Bands- Bloch Theorem, Kronig-Penney Model (qualitative), E-K diagram, Brillouin Zones-extended, reduced and periodic zone schemes, Concept of Fermi energy Electrons and Holes, Concept of effective mass, Material classification, Direct and Indirect Band gap semiconductors. Effect of temperature and electric field on the band structure.

UNIT-2 **10 L**

Semiconductor Physics: Crystal properties, Elemental and compound semiconductors, Density of states, Doping- donors and acceptors, Equilibrium and extrinsic carrier concentration, Carrier transport, Drift and Diffusion current, Mobility, Einstein relation, Excess carrier generation and recombination, Hall-Shockley-Reed theory of recombination, Equilibrium and non-equilibrium processes, Charge transport equation;
Electrical conductivity and mobility of charge carriers, mechanisms of scattering; Four probe and Hall effect for the measurement of conductivity, carrier concentration and mobility; Measurement of bandgap- optical absorption spectroscopy and Effective mass- Cyclotron resonance experiment.

UNIT-3 **10 L**

Junctions and Devices: Types of junctions, Ohmic and Schottky contacts, Schottky barrier and barrier lowering effects, Theory of p-n junction, the concept of depletion later, resistance and capacitance across the depletion layer Charge transport in a p-n junction; Practical junctions and Ideality factor; Space charge and diffusion capacitances. Impurity profiling through capacitance measurements.
Typical Single layer and multilayer devices and their characteristics: PN diode; Light Emitting Diodes; Solar cells; Photodetectors; Tunnel diode, Transistors; Field Effect Transistors.

UNIT-4 **8 L**

Fabrication Tools and Techniques: Importance of Vacuum in fabrication- methods of achieving vacuum, Crystal growth techniques, Wafer cleaning techniques, Surface conditioning and modification techniques, Concept of Photolithography, Doping techniques (Diffusion and Ion implantation), Metallization (Physical Vapor Deposition), semiconductor device sealing and packaging.

Reference Books:

1. **S. M. Sze**, Semiconductor Devices: Physics and Technology, John Wiley publication, 2013.
2. **Donald A**. Neamen, Semiconductor Physics and Devices: Basic Principles, McGraw-Hill publication, 2012.
3. **Ben G. Streetman**, Solid State Electronic Devices, Prentice-Hall of India, 2012.
4. **Jaspreet Singh**, Semiconductor Devices-Basic Principles,John Wiley publication, 2008.
5. **Charles Kittel**, Introduction to Solid State Physics, John Wiley publication, 2013.

Course Outcomes: Students will be able to:

CO1	Solve and realize Electronics Engineering problems and challenges.
CO2	Understand fundamentals of semiconducting properties of materials for technological applications.
CO3	Realize the operation mechanism of various electrical and electronic devices.

Course Code PHPE 552	High Energy Physics	Credits 3-0-0: 3

Course Educational Objectives :	
CEO1	To familiarize the students about fundamental entities of the universe and their interactions and how the universe is made off!
CEO2	To develop understanding of perturbation theory and Feynman Rules to apply in high energy scattering measurements.
CEO3	To develop understanding of Standard model of particle Physics and the formation of bound states.

UNIT-1 **8 L**

Elementary Particles: Introduction to Four Fundamental Forces and the interactions-- EM force, Gravitational force, Strong force and Week forces; Fundamental entities—quarks, leptons, mediators, Quarks and colors; Basics of Quantum Chromodynamics, Strong coupling and Asymptotic freedom.

UNIT-2 **10 L**

Symmetries and Quarks: Symmetries, Conservation laws and Groups. The Group SU(2), SU(2) of Isospin for particles and antiparticles, The Group SU(3)—Isospin and strangeness, Quark structures of Mesons and Baryons. Construction of wave function for bound states. Magnetic moments of proton and Neutron. Color factors.

UNIT-3 **10L**

Standard Model (SM) of Particle Physics: Local gauge transformation, Global gauge transformation, Symmetry, Noether's theorem, spontaneous symmetry breaking, Higgs Mechanism, The Higgs Boson, Standard Model of Particle Physics.

UNIT-4 **8 L**

Applications in High Energy Scattering Experiments: Photon self-energy correction, Radiative corrections, Soft Bremsstrahlung--Classical Computation, Quantum computation. The electron vertex function in formal structure and evaluation through Feynman Parameterization.

Reference Books:

1. Quarks and Leptons: An Introductory Course in Modern Particle Physics, **F. Halzen and A. Martin**, John Wiley & Sons, 1993.
2. Introduction to elementary Particles, **D. J. Griffiths**, John Wiley & Sons, 2006.
3. The strange Theory of Light and Matter, **Richard P. Feynman**, Prinston University Press, 1983.
4. Quantum Electrodynamics, **W. Greiner, J. Reinhar**t, Springer, 2003.
5. Photons and Atoms: Introduction to quantum electrodynamics, **C. Cohen-Tannoudji**, **J. D. Roc**, **G. Grynberg**, WILEY-VCH Verlag GmbH & Co. KGaA, 1997.
6. A first Book of Quantum Field Theory, **A. Lahiri**, **P. B. Pal**, Narosa Publication, 2007.

Course Outcomes: Students will be able to:	
CO1	Illustrate the fundamental constituent of the universe.
CO2	Apply Feynman rules technique to the high energy scattering process measured in experiments like LHC, COMPASS, HERA, LEP etc.
CO3	Cultivate critical thinking on symmetries and conservation laws involved in cutting edge research.

Course Code PHPE 554	Photonics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To impart the fundamental knowledge about the light matter interaction.
CEO2	To give the proper understanding of novel developments in the area of photonics.
CEO3	To provide understanding of the principles of photon generation, propagation and manipulation.

UNIT-1 **9 L**

Introduction: Dual nature of light, Photon energy, Photon position, Photon, momentum, Photon Polarization, Mean photon flux, Photon number statistics, Quantum states of light: Coherent-state light and Squeezed-state light; Propagation of EM waves in anisotropic materials, Uniaxial and biaxial materials.

UNIT-2 **9 L**

Fiber Optics Losses and Dispersion: Linear and nonlinear losses, Signal degradation in optical fibers due to dispersion and attenuation; Pulse dispersion in graded index optical fibers, Material dispersion, Waveguide dispersion and design considerations.

UNIT-3 **9 L**

Photonic Crystal: Basic Concepts, Photonic Bandgap Structures, Features of Photonic Crystals, Photonic Crystal Fibers, Photonic crystal Sensors, Method of Fabrication.

UNIT-4 **9 L**

Fabrication of photonic structures: Fabrication techniques of photonic structures: Fabrication steps, Coating techniques, etching processes: wet and dry; types of masks, Basic idea of photolithography and electron beam lithography, Applications of photonic devices.

Reference Books:

1. Fundamental of Photonics by **Baha E.A.**, Saleh and M.C. Teich: John Wiley and Sons 2010.
2. Photonics by **Ralf Menzel**: Springer Verilog 2001.
3. Nonlinear Optics by **Boyd**: Academic Press 2010.
4. Nonlinear Fiber Optics by **G. P. Aggarwal**: Elsevier 2013.

Course Outcomes: At the end of the course students will be able to:

CO1	Understand the concept of the photons, their generation and manipulation.
CO2	Apply the relevant concepts of the photonics for the development of novel photonic technologies.
CO3	Solve technical and strategic problems related to the light-matter interaction.

Course Code PHPE 556	Thin Film Physics And Applications	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	Student will gain fundamental knowledge of thin film growth processes and techniques.
CEO2	Student will be able to understand basic physics behind various thin film growth techniques.
CEO3	Student will learn the hybrid thin film growth approaches and design thin film based devices.

UNIT-1 **8 L**

Introduction: Technological status, Physics of solidification, cooling curve, Thermodynamics and kinetics of Nucleation and growth mechanisms, Critical radius of nuclei, Grain formation, Defects in thin films, Adsorption and desorption, Surface conditioning and modification methods: Cleaning methods, Thermal annealing, Surface Ozonisation, Plasma processing.

UNIT-2 **8 L**

Fabrication Techniques: Film thickness uniformity and purity, Evaporation hardware and techniques, Resistance heating and electron beam evaporation, Fundamentals of Chemical Vapor Deposition, Sputtering, Pulsed laser deposition, Langmuir Blodgett technique, Spin and Dip coating techniques, Doctor blade technique, Film patterning techniques: wet and dry etching.

UNIT-3 **10 L**

Characterization Techniques: Film Thickness measurement- Optical techniques: Interferometry and Ellipsometry, Mechanical techniques: Stylus Profilometry, Structural studies: Energy Dispersive Studies by X-Rays, Surface studies: Surface topography and thin film morphological studies by SEM and AFM, Film composition and depth profiling techniques: Photoelectron spectroscopy- XPS, UPS, Auger Electron Spectroscopy (AES).

UNIT-4 **8 L**

Thin Film Properties And Applications: Multilayer Optical Film Applications: reflecting and anti-reflecting optical coating, Photo-thermal Coatings, Optical Filters, single layer and multilayer Organic Light Emitting Diodes (OLEDs), single layer and multilayer Polymeric Light Emitting Diodes (PLEDs), Thin film solar cells, Thin Film Transistors, Thin film battery.

Reference Books:

1. Solid State Electronic Devices, **Ben G. Streetman**, Prentice-Hall of India, 2012.
2. Semiconductor Devices-Basic Principles, **Jaspreet Singh**, John Wiley publication, 2008.
3. Physical vapour deposition of thin films, **John E. Mahan**, John Wiley & Sons, 2000.
4. Materials science of thin films: Deposition and structure, **Milton Ohring**, Elsevier, Inc., 2002.
5. Thin film Phenomena, **K. L. Chopra**, McGraw-Hill, New York, 1969.

Course Outcomes: Students will be able to:

CO1	Have knowledge of the physics of various thin film growth approaches.
CO2	Analyze practical problems on various thin film growth techniques.
CO3	Design thin film based devices.

Course Code PHPE 558	Nuclear Technology	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To give understanding of different types of radiations and their interaction of with matter.
CEO2	To gain knowledge about design and working of gas filled and semiconductor radiation detectors.
CEO3	To develop the understanding of Solid state nuclear track detectors working and their application for measurement of environmental radioactivity.

UNIT-1 **6 L**

Interaction of Nuclear Radiations: Interaction of Radiations with Matter: Charge Particles (Heavy & Light), Electromagnetic Radiations (Photoelectric effect, Compton scattering, Pair production) and Neutrons.
Nuclear Radiation Detectors, Various Types of Radiation Detectors: Gas ionization based detectors, ionization chambers, Proportional counters, G.M. detectors, & their design considerations.

UNIT-2 **10 L**

Radiation Detectors: Split Anode detector, Multi-wire detectors, Particle by Particle identification, Time of flight spectroscopy, Bubble chamber, Cloud chamber, Scintilation detector.
Semiconductor radiation detectors: Mechanism of Electron-Hole Pair generation, Fano Factor, Energy Resolution and recombination, Characteristics of Homogeneous and Junction type detectors fabrication and design considerations, Signal Generation and Frequency Response.

UNIT-3 **8 L**

Nuclear Reactors: Nuclear reaction and their type, Conservation laws, Direct and compound nucleus reaction, Nuclear fission, fission products, Mass and energy distribution of fission products, nuclear fission reactors, Fast Breeder reactor, Nuclear Fuel, Control rods, nuclear fusion–controlled thermonuclear reactions.

UNIT-4 **12 L**

Amplifiers and Instrumentation Circuits: Photomultiplier tube, Noise Considerations in PMT, Preamplifiers- Voltage, Current and Charge sensitive preamplifiers, Signal Transport and design considerations of signal cables, Fast pulse amplifiers, Pulse Shaping circuits- Delay Line, CR-RC Semi-Gaussian and semi-triangular, Filtering circuit, discriminator module, Pulse height analyzers- Single and multi-channel Analyzers, Analog to Digital Conversion, Various Electronics Noises, Noise in Amplifiers and ADCs.

Reference Books:

1. Radiation Detection and Measurement, T. Lewellen, Wiley, 2008**.**
2. Nuclear Instrumentation: **W. J. Price,** Johnes and Bartlett, 2012.
3. Solid State Nuclear Track Detectors-Principal and Applications: **R. L. Fleischer**, **P. B. Price**& R. M. Walker, Springer, 1948.
4. Techniques for nuclear and particle physics experiments: **W. R. Leo,** Springer, 1948.

Course Outcomes: Students will be able to:

CO1	Understand different types of radiations and their interaction of with matter.
CO2	Understand design and working of gas filled and semiconductor radiation detectors with associated electronics.
CO3	Understand solid state nuclear track detectors and their application for measurement of environmental radioactivity.

Course Code PHPE 560	Physics of Optoelectronic Devices	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of physical process for designing Optoelectronic Instruments.
CEO2	To understand the optoelectronic mechanisms in various optical detectors working in different range.
CEO3	To utilize the optical sources and devices for research and industrial application.

UNIT-1	8 L
Optical Sources And Detectors: Sources and Detectors for IR, Visible, UV radiations, Constant illumination sources, Optical Fiber Sensors: Active and passive optical fiber sensor, intensity modulated, displacement type sensors.	
UNIT-2	**10 L**
LASERS: Characteristics of laser radiation, Einstein Coefficients and Laser Amplification, Q-switching, Mode-locking, Types of lasers (solid state lasers, Gas lasers, Molecular Laser, Dye lasers) Diode laser array, Applications of Lasers**.**	
UNIT-3	**10L**
Optoelectronic Process And Spectrophotometers: Optoelectronics process and systems, Photoconductive devices, LDR; Photoemissive devices, Photomultiplier tube; Photovoltaic Devices, Tandem solar cell, and DSSC Solar cell; Photoinduced voltage; Solar Concentrators, Quantum dot solar cells, Construction of solar cell; factors affecting the solar cell; Monochromators: Prism, Grating and Filter; Dual beam Spectrophotometers.	
UNIT-4	**8 L**
Optoelectronic Devices: Laser range finder, Laser Interferometers, Colorimeters, Flame-Photometers, Turbidity meters, LED: Mechanism, Design and Fabrication; Laser Diodes, Charge Couple Detector, Opto-isolator.	

Reference Books:

1. Optoelectronics: An introduction, John Wilson**, J. F. B. Hawkes**, Prentice Hall Europe, 1998
2. Photoelectronic Devices by **J. B. Danoe**, 1991
3. Lasers and optical engineering by **P. Das,** Springer, 2011.
4. Lasers by **Ghatak & Thyagrajan,** Laxmi Publication, 2019.

Course Outcomes: Students will be able to:

CO1	Design optoelectronic Instruments.
CO2	Imply the mechanisms of various optical detectors.
CO3	Utilise optical sources and devices for research and industries.

Course Code PHOE 582	Fiber Optics and Optical Communication Systems	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To provide essential knowledge about fiber optic technology.
CEO2	To convey the idea of the principles of light guidance inside the optical fibers.
CEO3	To provide understanding of various potential applications of the optical fibers in optical communication systems and other fields.

UNIT-1 **9 L**

Introduction: Basic elements of the fiber optic communication system; Single and multimode optical fibers; Ray analysis of optical fiber: Propagation mechanism of rays in an optical fiber; Meridional rays, Skew rays, Fiber numerical aperture; Electromagnetic mode theory for optical propagation.

UNIT-2 **9 L**

Propagation Mechanics: Electromagnetic mode theory for optical propagation. Mode theory for circular waveguides: step index optical fibers; Propagation characteristics of step index optical fibers; graded index optical fibers.

UNIT-3 **9 L**

Fiber Optics Losses and Dispersion: Linear and nonlinear losses, Signal degradation in optical fibers due to dispersion and attenuation; Pulse dispersion in graded index optical fibers, Material dispersion, Waveguide dispersion and design considerations.

UNIT-4 **9 L**

Fiber Devices, Applications, and Sustainability: Conventional applications of optical fibers, Optical fiber amplifiers: EDFA, Gain spectrum and gain band width, EDFAs for WDM transmission, Various potential applications of the optical fibers other than the telecommunication industry.

Reference Books:

1. **Keiser**, “Fiber optic communication” McGraw Hill, 2009.
2. **F. C. Allard**, “Fiber Optics Handbook for engineers and scientists”, McGraw Hill, 2009.
3. **J. Gowar**, “Optical communication system”, Prentice Hall, 1993.
4. **T. Tamir**, “Integrated optics”, Academic Press, 2010.
5. **S.E. Miller & A. G. Chynoweth**, “Optical Fibers Telecommunication”, Academic Press, 1979.

Course Outcomes: At the end of the course students will be able to:

CO1	Apply the concept of optical fiber technology, their applications, and the relevant physics concepts for realizing and solving light guidance in different structures.
CO2	Solve technical and strategic problems related to the fabrication of optical fibers.
CO3	Realize the various potential applications of the optical fibers in telecommunication and other industries.

Course Code PHOE 584	Biomedical Instrumentation	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To understand the utilization of different types of Biomedical Instruments for diagnosticpurposes.
CEO2	To gain comprehensive knowledge of various processes related to human body and its organs.
CEO3	To apply the diagnostics and therapeutic tools in medical field.

UNIT-1 **10 L**

Bio-Potentials and Electrodes: Introduction to the main biomedical instrumentation system and its components, problems encountered in the design of biomedical instrumentation system. Origin of Bioelectric potentials; The electrode-electrolyte system, Polarization, polarizable and non- polarizable electrodes, skin contact impedance, electrodes for ECG, EEG & EMG, microelectrodes, Biomedical Recorders: Electrocardiograph, electroencephalograph and electromyograph. Blood pressure measurement: Direct and indirect methods.

UNIT-2 **8 L**

Blood Flowmeters: Electromagnetic, Ultrasonic, NMR and Laser Doppler Blood flowmeters. Pulmonary Function Analysers: Respiratory volumes, wedge and ultrasonic spirometers, Fleischpneumo-tachometer.

UNIT-3 **8 L**

Biomedical Imaging Techniques: X-ray machine, Image intensifiers & image noise. Principles and theory of Tomographic Imaging, parallel and fan beam illumination, X-ray computed tomography, Emission computed tomography. Nuclear imaging techniques: PET, SPECT. Optical imaging and microscopy. Molecular and Cellular imaging, Contrast agents.

Nuclear Magnetic Resonance imaging and its application in the field of diagnostics, MRI, Benefits and limitations of MRI.

UNIT-4 **10 L**

Ultrasound Imaging and Therapy: Ultrasound, Ultrasonic scanning: A-scanners & B-scanners, Real time ultrasonic imaging systems, Therapy with ultrasonic waves, Biological effects of ultrasonic waves, Radiotherpy: Radiobiology and radiation physics treatment planning, radiation therapy, Particle beam therapy (hadrontherapy), biological effects of radiations, instrumentation for the medical use of radioisotopes, Dosimetry in modern radiation therapy, Dose measurement.

Reference Books:

1. **A handbook of Biomedical Instrumentation**, R S Khandpur, McGraw-Hill Education (India) Pvt Limited, 2003.
2. **Biomedical Instrumentation & Measurement**, Leslie Cromwell, Fred J Weibell & ErichAPfeiffer. Prentice-Hall, 1990.
3. **Medical Instrumentation: Application and Design**. John G. Webster, John Wiley & Sons, 2009.
4. **Medicine &Clinical Engineering,** Bertil Jacobson & John G Webster, Prentice- Hall. 1977.

Course Outcomes: At the end of the course students will be able to:

CO1	Graduates will develop the understanding of utilization of different types of Biomedical Instruments.
CO2	Graduates will have comprehensive knowledge of various processes related to human body and its organs.
CO3	Graduates will be able to apply the diagnostics and therapeutic tools in medical field.