Curriculum

BS in Physics with Specialization

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Department of Physics
IIT Jodhpur

1. Introduction

The vision of the Department of Physics is to become a globally renowned Academic Hub of Physics for Quality Education, excellence in Scientific Research and Technology Innovation with High Societal and Strategic Impact by excelling in fundamental knowledge and applications of Physics blended with Engineering through curricular and co-curricular activities. In line with this vision, the Department offers an undergraduate program in Physics to attract highly motivated students interested in basic science and cutting-edge technologies in the broad discipline of physics blended with engineering and wish for a flexible program to consider a variety of challenging career paths through capability-linked specializations in Energy, Photonics and Quantum Technologies.

The program provides strong fundamentals in basic sciences and mathematics that are critical in developing analytical thinking and form the basis of the diverse tools used in fundamental and applied physics linked with engineering problems to innovate, design, and develop future technologies. The engineering design component is integrated throughout the curriculum, motivating and familiarizing students with real-world engineering challenges and equipping them with the essential technical skills for problem-solving. Strong theoretical foundations and hands-on exposure at the early stage of the BS Physics program are supplemented by a spectrum of fundamental and applied physics concepts ranging from statistical physics with emphasis on data-driven analysis, modern physics including quantum technologies targeting future communication, computational physics with a focus on current trends in machine learning and artificial intelligence, condensed matter physics with emphasis on next-generation materials and devices for future electronics, energy materials and devices, terahertz physics and photonics, fundamental and applied plasma for various applications. Further, the program’s design projects, and laboratory experiments develop additional problem-solving skills and practical experience.

One of the key salient features of the BS Physics program at the IIT Jodhpur is that the curriculum offers enormous flexibility to students for pursuing capability-linked specializations of their choice. The Department’s core specializations are designed to enable students to lead future technological innovations addressing the emerging industrial and societal challenges in various domains of Energy, Photonics and Quantum Technologies. The students can choose any of the specializations mentioned above depending on their interests. The in-depth understanding of the concepts and technical skills acquired through these program specializations will enable graduates to play a vital role in advancing the technologies such as Flexible Electronics, Green Energy, Terahertz Technology/Communications, Quantum Communications, Smart Energy for smart cities/distributed applications in rural/remote areas, and Smart Healthcare, etc.

Another distinct feature of the program is the provision for minors in Entrepreneurship. This unique feature will allow students to pursue diverse and challenging career options. The curriculum also offers numerous options that enable students to gain industrial experience through collaborative industrial projects at industries and entrepreneurship experience at the Institute's Incubation Center.

2. Objectives of the Program

The program aims at imparting theoretical foundations and practical skills in fundamental and applied physics blended with engineering applications. It prepares graduates for the following potential career options:

- An academic path to enter the graduate program, conduct basic and application-oriented advanced scientific research with a broad range of applications, and eventually pursue research or academic profession.
- An industrial path to take up the role of a technical leader through lifelong learning.
- An entrepreneurial path to apply the acquired knowledge to develop new products and initiate a Deep Tech Start-up Company.

3. Expected graduate attributes

The Graduates of the UG program in Physics are expected to have the following attributes:

- Strong foundations of fundamental as well as applied concepts of physics enabling to excel in physics-driven technologies.
- Ability to acquire new knowledge of physics and integrate with engineering concepts to create new and innovative technologies for current and future applications.
- Ability to apply critical scientific thinking and engineering skills to identify, formulate, and solve complex problems encountered in applied areas blended with engineering practices.
- Ability to apply principles of physics in the domain of Energy materials and devices with a focus on generation, storage, and management.
- Ability to engage and actively participate in the upcoming areas of Quantum Information and related research domains of Quantum Technologies.
- Preparedness to participate in future technological developments in photonics and optical communications beyond 5G including Terahertz technology.
- Ability to compete effectively in a world of rapid technological advancements and assume leadership roles within academic, industrial, or entrepreneurial environments in the broad context of fundamental and applied physics blended with engineering skills.
- They will be aware of ethical issues, societal needs, and problems and conduct themselves as responsible professionals.

4. Learning outcomes

The Graduates of the UG program in Physics will be able:

- To acquire knowledge of fundamental and applied physics principles along with the required understanding of computing, mathematics, and engineering.
- To create, select, and apply appropriate techniques, resources, and fundamental physics tools to solve complex engineering problems with an understanding of the limitations through laboratory exercises and design projects.
- To apply the concepts of mathematics, physics including Quantum technologies and advanced computing tools, to design complex engineering systems containing hardware and software (including Quantum algorithms) modules.
- To acquire knowledge of fundamental and advanced concepts of Photonics and Terahertz technologies for communications, devices towards medical applications, sensing, quantum technologies, spectroscopy, and imaging.
- To gain an in-depth understanding of concepts of materials and devices for energy generation and storage, integration of energy sub-systems and next generation communications.
- To perform a critical literature review and patent landscaping for innovative research.
- To understand professional ethics and social responsibilities.
- To develop technical presentation skills and communicate effectively.
- To develop an attitude for product design and entrepreneurial activities.

5. New skill sets targeted

Physics BS students explore subjects critical to advancement in today's needs-from everyday common know-how to critical problems in different inter/multi-disciplinary domains using the fundamental and applied physics knowledge blended for present and future complex issues/challenges. The acquired knowledge will be helpful in future technologies, including:

- Quantum technologies for future Quantum communication and computation
- Terahertz optics, optical fiber communication, and photonics for 5G and beyond communications
- Next-generation energy materials and devices.

6. Proposed Specialization Areas

1. **Advanced Energy Materials**
2. **Photonics**
3. **Quantum Technologies**
4. **Entrepreneurship**

7. Program Structures

<table>
<tr><th>S. No.</th><th>Course Type</th><th>Course Category</th><th colspan="2">Credits</th></tr>
<tr><td rowspan="3">1.</td><td rowspan="3">Institute Core (I)</td><td>Engineering (IE)</td><td>29</td><td rowspan="4">69</td></tr>
<tr><td>Science (IS)</td><td>18</td></tr>
<tr><td>Humanities (IH)</td><td>12</td></tr>
<tr><td>2.</td><td>Programme Linked (L)</td><td>Engineering and Science</td><td>10</td></tr>
<tr><td>3.</td><td>Programme Core (P)</td><td>Programme Compulsory (PC) + BS project</td><td>58+3</td><td>61</td></tr>
<tr><td rowspan="2">4.</td><td rowspan="2">Specialization (E)</td><td>Specialization Core (SC)</td><td>12</td><td rowspan="2">30</td></tr>
<tr><td>Specialization Elective (SE)</td><td>18</td></tr>
<tr><td rowspan="3">5.</td><td rowspan="3">Non-Graded (N)</td><td>Humanities (NH)</td><td>6</td><td rowspan="3">15</td></tr>
<tr><td>Engineering (NE)</td><td>3</td></tr>
<tr><td>Design/Practical Experience (ND)</td><td>6</td></tr>
<tr><td colspan="4" align="right">Total</td><td>175</td></tr>
</table>

Note: Students opting for specialization in Entrepreneurship will be required to earn 10 credits through relevant core/electives courses offered from one of the specializations offered from the department.

8. Programme Core (PC) Courses

S. No.	Course Name	LTP	Contact Hours	Credit
1.	Mechanics - I	3-0-0	3	3
2.	Mechanics - II	3-0-0	3	3
3.	Mathematical Methods for Physicists	3-0-0	3	3
4.	Basic Computational Lab	0-0-3	3	1.5
5.	Applied Computational Lab	0-0-3	3	1.5
6.	EM Waves and Fields	3-0-0	3	3
7.	Interaction of Radiation with Matter	2-0-2	4	3
8.	Modern Optics	3-0-0	3	3
9.	Fluids and Plasmas	2-0-2	4	3
10.	EM Lab	0-0-3	3	1.5
11.	Applied Optics Lab	0-0-3	3	1.5
12.	Thermal Physics	3-0-0	3	3
13.	Solid State Physics	3-0-2	5	4
14.	Electronics	3-0-0	3	3
15.	Semiconducting and Optoelectronic Devices	3-0-2	5	4
16.	Electronics Lab	0-0-3	3	1.5
17.	Thin Film and Material Characterization Lab	0-0-3	3	1.5
18.	Physics of Atoms, Molecules and Nuclei	3-0-0	3	3
19.	Nuclear Radiation and Energy	2-0-0	2	2
20.	EM and Neutrino Astronomy	3-0-0	3	3
21.	Modern Physics Lab	0-0-2	2	1
22.	Radiation and Particle Detection Lab	0-0-2	2	1
23.	Medical Physics	2-0-0	2	2
24.	Entrepreneurship for Physicists	2-0-0	2	2
25.	BS Project	0-0-6	6	3
			Total	**61**

9. Topic clouds and their mapping with proposed courses

Area	Category	Topics	Course (IE/PC/PE)
Fundamental Physics	Core	Tensor operations, Simple harmonic, Damped, and Forced oscillations, Central force, Dynamics of rigid bodies, Law of gravitation, Constraints and their classification, Lagrange's equations of motion, Hamilton's equations of motion, Poisson brackets, Galilean transformations, Basic principles of STR	Mechanics-I [3-0-0]
		Special Matrices, Eigenvalues and Eigenvectors, Dirac representation, Origin of quantum theory, Schrödinger's equation, Application of Schrödinger's equation, Theory of Angular Momentum, Consequence of quantization	Mechanics-II [3-0-0]
	Techniques	Special Functions such as Dirac-Delta, Beta, Gamma, Legendre, Bessel and their Integral expressions, Classification of PDEs, Laplace and Poisson equations, Diffusion equation, Wave equation, Analytic functions, Cauchy-Riemann conditions, Classification of singularities, Residue theorem, Contour integration, Taylor and Laurent series	Mathematical Methods for Physicists [3-0-0]
		Linux OS, Shell and Python scripting, MATLAB, Sci-lab, Mathematica, gnu-plot, xmgrace, MINUIT, Algorithms, Flowcharts, I/O statements, Logical/Relational/Arithmetic operations, Matrix multiplication, Matrix inverse, Control statements, Subroutines, LaTeX and Overleaf, LaTeX Commands and Environments	Basic Computational Lab [0-0-3]
	Applications	Curve Fitting, Numerical integration, Minimization technique using CG or SD, Solving ODEs and PDEs, Systems of linear and nonlinear equations, Singular Value Decomposition, Thermodynamics and Statistical Physics, Monte Carlo integration, Importance Sampling, Metropolis algorithm, Detailed Balance, Markov	Applied Computational Lab [0-0-3]

		process, Monte Carlo simulation of Area calculation, Random walk problem, Photon gas, Lennard-Jones fluid	
Electrodynamics and Plasma Physics	Core	Green's Function in Electro and Magnetodynamics, Electromagnetic Wave Propagation in Media, Fresnel Coefficients, Geometry of Waveguides and Resonant Cavities, Retarded and Advanced Potentials, Radio Waves and Antennas.	EM Waves and Fields [3-0-0]
		Geometrical Optics: Design of Beam Expanders, collimator, telescope, FSR & spacing of etalon. **Electrodynamics Numerical Solver (Software/VORPAL):** circular and rectangular geometrical structures, rectangular waveguide, V number, Polar pattern & gain of waveguide antenna, Design & Characterization of parabolic dish antenna. (7-9 experiments)	EM Lab [0-0-3]
	Techniques	Radioactive decays and related energy loss mechanisms, Geiger Muller Counter, Nuclear sensors and Radiation Safety, Free-electron Laser, Synchrotron Radiation, Cherenkov, Particle accelerator, Optical Transition and Bremsstrahlung Radiation **Lab Component:** Plateau region of GM tube, Radiation Counters: Gamma-Ray, Beta-Ray counts, Dosimeter calibration, Gamma-ray attenuation, Simulation with GEANT	Interaction of Radiation with Matter [2-0-2]
		Corpuscular and Wave models of light, Wave particle duality, Diffraction and probabilistic interpretation, Fermat's principle, Eikonal equation, Matrix method in paraxial optics, aberrations, origin of refractive index, interference by division of wave-fronts and amplitudes. Coherence, Fresnel and Fraunhofer Diffraction, spatial frequency filtering, Fourier transforming property of thin lens. Production and Analysis of polarized light, Phenomenon of double	Modern Optics [3-0-0]

		refraction, Walston prism,EM wave propagation in anisotropic media, Faraday rotation, Semi-Classical and Quantum approaches for Optics.	
	Applications	Saha equation, Plasma and relevant characteristic parameters, Plasma in nature, Continuity equations, Equations of state, Fluid approximations, Magneto hydrodynamics (MHD), Waves and instabilities, Townsend discharge, Electrical breakdown conditions of gases, Discharge regimes, DC and RF Plasma, Cold plasma, Capacitive & Inductive plasmas, ECR plasma, Tokamak plasma, Laser produced plasma, Plasma deposition, Etching, Plasma applications in health, food, energy and agriculture. **Lab component:** Basics: Plasma Striations, Paschen Curve and Ion-Acoustic Waves Experiments. Plasma Diagnostics: Single Langmuir Probe, Double Langmuir Probe and Plasma Spectroscopy. Applications: Thin film deposition using Magnetron Sputtering, Plasma nitriding for surface hardening, non-equilibrium cold plasma treatments.	Fluids and Plasmas [2-0-2]
		Two-beam interferometer (Michelson & Mach Zehnder), Fresnel Bi-prism, 2D Diffraction experiments, D1 and D2 lines of Sodium light, Polarization study: Brewster Angle measurements, Malus law, Fiber Optics experiments: Numerical Aperture and loss measurements of optical fiber. Light amplification through fiber, Holography, Electro-optic effect.	Applied Optics Lab [0-0-3]
Condensed Matter Physics	Core	Kinetic theory of gasses, Einstein theory and Brownian motion, Specific heat capacity, Virial expansion, Thermodynamic laws and its applications, Maxwell's thermodynamic relations, Gibbs and Helmholtz free energy, Phase transitions, Black body Radiation, Kirchhoff's law, Statistical Physics:	Thermal Physics [3-0-0]

		Concepts of Ensemble, Partition Function and Quantum Statistics	
		Crystal structure, Reciprocal Lattice, Crystal Binding, Phonon dispersion, Electrons in metals, Free electron model, Bloch potential, Kronig-Penny model, Band structure, Metals, Semiconductors and Insulators, Magnetism and Superconductivity **Laboratory:** Phonon dispersion, M-H hysteresis, Magnetic susceptibility, Electron spin resonance, Two probe and Four probe resistivity, Dielectric constant, Thermoluminescence, Temperature dependent ionic conductivity	Solid State Physics [3-0-2]
		Transistors, JFET and MOSFET, frequency analysis of FET, Differential and Operational amplifiers, Characteristics of Amplifier, Feedback loop, Voltage gain and operational modes of amplifier, Linear and Nonlinear Op Amp Circuits, Integration & differentiation Oscillator circuits, Digital logic gates, Data processing circuits, arithmetic circuits, clock and timer circuits, flip-flops	Electronics (PHL6040) [3-0-0]
	Techniques	**Synthesis of thin films:** spin-coating, dip coating, thermal evaporation **Structural properties:** XRD, electron microscopy, AFM and analysis **Physical properties:** (Electronic, magnetic, Thermal and Optical properties of materials) Temperature dependent Resistivity, Thermal conductivity, Thermoelectric properties, heat capacity (DSC), UV-Vis spectroscopy, Raman **Mechanical properties:** Stress-Strain and hardness (with ME and Metallurgy)	Thin film and Material Characterization Lab [0-0-3]
		JFET biasing and amplifier circuit design, Input Output circuit based on Differential amplifier, Voltage-Current output of Op Amps,	Electronics Lab (PHP6010) [0-0-3]

		Mathematical operation using Op Amps, Design of negative feedback loop for signal modification, Low pass, high pass and band pass filter circuit design, Wien bridge and LC oscillator circuit, 555 timer for alarm circuit, Logic gate, Flip-flop circuit, TTL circuits, Use of shift register and binary ripple counter, Multiplexers and generation of Boolean functions, Decoder and D/A converter	
	Applications	Optical Imaging techniques, Polarization microscopy, Fluorescence Microscopy, Confocal Microscopy, Overcoming Diffraction limit in microscopy, X-ray imaging and CT, Positron emission Tomography, Magnetic Resonance Imaging, Image analysis based on ML and AI techniques, Interaction of radiation with tissues, cells and organs, Thomson and Compton scattering, Plasma for Therapeutic and Nuclear Medicine	Medical Physics [2-0-0]
		Intrinsic and Extrinsic semiconductor, Excitons, Stokes' shift, charge carrier mobility, diffusion length. Semiconductor Biasing across pn junction, generation recombination current, Metal semiconductor junctions, Heterojunction, band alignment, MOSFET, Frequency response of MOSFET, High electron mobility transistors, Solar cells, Light emitting diodes, Materials and devices for Spintronics, Valleytronics and Plasmonics, Organic electronics. **Laboratory:** Band gap of semiconductor, Temperature dependent Hall effect, Temperature dependent electrical conductivity of doped semiconductor, Mobility of charge carrier, Capacitance-Voltage measurement, Characterization of solar cell, Quantum efficiency of solar cell, Output characteristic of LED, I-V characteristic of photodetector and phototransistors, Optical absorption and Photoluminescence	Semiconducting and Optoelectronic Devices [3-0-2]

Atomic & Subatomic Physics	Core	Relativistic Energy correction in Hydrogen atom, Zeeman effect, Stark broadening, Hyperfine splitting, Helium Atom, Diatomic molecules, Hartree-Fock method Molecular Orbital and Electronic configuration of Diatomic molecules: H2, C2, O2, NO and CN, Nuclear forces, Models-Liquid Drop model, Shell model, Collective model, abundance, stability	Physics of Atoms, Molecules and Nuclei [3-0-0]
		Measurement of the Planck's Constant, Stark Effect, Zeeman Effect, Dissociation of I2, Rydberg constant, Frank Hertz Expt, ESR Spectroscopy-Solids, Charge of Electron, E/M ratio, Measurement of the speed of light. (8-9 experiments)	Modern Physics Lab [0-0-2]
	Techniques	Nuclear Transition, Multipole expansion of Nuclei, Nuclear Energy levels, Dosimetry, Image plate and Nuclear Calorimeter, MCP (Multichannel plates), Single Channel Analyzer (SCA) & Multi-channel analyzer (MCA), Radiocarbon dating in archaeology, Thorium cycles and Uranium Cycles, Nuclear reactor basics	Nuclear Radiation and Energy [2-0-0]
		Kinematics of particle interactions, Conservation laws, Neutrinos, Hadrons, EM Weak and strong interactions. Classification of stars with Optical observation, Hertzsprung-Russel diagram, Stellar Evolution, Astrophysical objects with Radio emission, X-rays and Gamma-rays, Cosmic Rays, Sky-mapping with neutrinos.	EM and Neutrino Astronomy [3-0-0]
	Applications	Gamma and Alpha Energy resolved measurement, Compton Scattering, Measurement of Dead-time in GM tube, Mass Spectrometric TOF, Detection of Atmospheric Muon with Scintillator detector, Measurement of Muon life-time, Measurement of half-life of radioactive source, Track Detectors (CR-39), Spark Chamber	Radiation and Particle Detection Lab [0-0-2]

10. Specializations

S. No.	Specialization	Description	
1.	**Advanced Energy Materials**	Energy materials encompasses all the aspects of energy harvesting materials and their corresponding devices. Here, various renewable and non-renewable energy sources and their corresponding devices will be studied. The principle behind their operation and how the efficiency of the devices can be optimized to achieve maximum output from the devices would be discussed. This specialization will provide an in-depth understanding of the energy materials and their future applications.	
		Specialization Core (12 credits)	**Specialization Elective (18 credits)**
		1. Materials for Energy Technologies [3-0-0] 2. Advanced Electrochemistry and Applications 3. CHXXXX [3-0-0] 4. Fabrication and Characterization of Devices [0-0-2] 5. Electrical Energy Storage Materials and Devices [3-0-0] 6. Nanomaterials and Nanodevices 7. CHXXXXX [2-0-0]	1. Physics of Solar Cells PHL7390 [3-0-0] 2. Optics for Solar Energy Applications 3. PHL7520 [3-0-0] 4. Nanomaterials for Hydrogen Production and Storage 5. MTL7XXX [3-0-0] 6. Bioenergy 7. BBL4110 [3-0-0] 8. Energy Harvesting 9. PHL7510[3-0-0] 10. Nanoscience and Nanotechnology 11. PHL7440[3-0-0] 12. Hydrogen Generation, Storage & Applications [3-0-0] 13. Solar Resource Assessment and Its Management [3-0-0] 14. Project (6 credits)
2.	**Photonics**	Photonics is the branch of science dealing with light and its devices to transmit, transfer and store information. It is the enabling technology covering broad industrial applications from light harvesting to storage and light modulation to delivery. Photonics specialization enables students to understand principles & the design of optical, photonic and laser systems for various applications, including Health care, communications, defense, safety, security, and entertainment.	
		Specialization Core (12 credits)	**Specialization Elective (18 credits)**
		1. Fundamentals of Photonics [3-0-0] 2. Laser Physics [2-0-0] 3. Terahertz technology [3-0-2] 4. Photonic Devices [2-0-2]	1. Optical fiber technology (PHL7XXX) [3-0-0] 2. Laser Technologies (PHL7330) [3-0-0] 3. Engineering Optics (PHL6310) [3-0-0] 4. Optical Communication Systems (EEXXXX) [3-0-0]

			5. Biophotonics [3-0-0] 6. Plasmonics [3-0-0] 7. Contemporary Optical [3-0-0] 8. LED Technology [3-0-0] 9. Selected topics on Photonics [1-0-0] 10. Selected topics on Photonics [2-0-0] 11. Selected topics on Photonics [3-0-0] 12. Project (6 credits)
3.	**Quantum Technologies**	Quantum Mechanics has emerged as a fundamental ingredient for understanding various facets of nature such as atomic and sub-atomic physics, quantum optics and a plethora of phenomena in condensed matter physics. The amalgamation of quantum physics with computing and information theory could be historically traced from the works of EPR (Einstein, Podolsky and Rosen), followed by that of John Bell and culminating in efforts made by Charles Bennett. Quantum technologies are envisaged to provide unparalleled security, which would be a real booster in future to the country's defense and financial establishments. To provide an overview of the importance and impact of an emerging technological domain, this specialization will enable the students to be well versed with the various challenges on different aspects of quantum technology. This specialization is offered in collaboration with IDRP-QIC.	
		Specialization Core (12 Credits)	**Specialization Elective (18 credits)**
		1. Quantum Communications (QCL4XXX) [3-0-0] 2. Quantum Computing (QCL4XXX) [3-0-0] 3. Quantum Optics and Quantum Information Laboratory (QCP4XXX) [0-0-4] 4. Quantum Communication Laboratory [0-0-2] 5. Quantum Optics and Engineering (PHL7500) [3-0-0]	1. Quantum Cryptography and Coding (QCL7XXX) [3-0-0] 2. Non-classical states for Quantum Information and Computation (QCL6XXX) [3-0-0] 3. Quantum Computational Finance (QCL7XXX) [3-0-0] 4. Quantum Machine Learning (QCL7X10) [3-0-0] 5. Hilbert Space Techniques for Quantum Mechanics (QCL7XXX) [3-0-0] 6. Seminal Features of Quantum Information Processing (QCL7010) [3-0-0] 7. Open Quantum Systems (PHL7480) [3-0-0] 8. Nonlinear Optics and Nonclassical Light Detection Techniques (QCL7XXX) [3-0-0] 9. Quantum Devices and Circuits [3-0-0] 10. Project (6 credits)

11. Specialization topic clouds and mapping with proposed courses

Specialization	Category	Topics	Course (SC/SE/IE)
1. Photonics	Core	Plane wave and Helmholtz equation, Gaussian and Bessel beams, Group velocity and dispersion, pulse spreading, Polarization and representation through Poincare sphere, Coherence, optical Fourier transform, Transmission Grating and Reflection grating, light modulation, Light guiding, Photonic crystals, Optical Resonators, mode stability, ring resonators, micro-resonators, Nonlinear polarization and its implications.	Fundamentals of Photonics [3-0-0]
		Radiation and its quantification, Einstein relations and Planck's Law, Laser Oscillation, principle of Lasers, Laser-matter interaction-Electric Polarization and Susceptibility, electron model-classical oscillator, resonators and Laser design, pumping sources, Lasing mechanisms, optical gain, gain saturation, hole burning, broadening, Laser modes, Gaussian Beam and Gouy phase shift, Beam Quality factor, Solid State Lasers, Semiconductor lasers, Gas Lasers(He-Ne, CO2), Overview on Industrial Application of Lasers including laser inscription and data storage	Laser Physics [2-0-0]
	Techniques	Fundamentals of Terahertz science and basic theory of Terahertz interaction with matter, Terahertz band, components for THz propagation and modulation, THz waveguides, Plastic optical fibers, artificial materials for THz, THz sources and detectors. Photoconductive antennas, Quantum Cascade Lasers, Nonlinear crystals, Difference Frequency Generation, optical rectification, Bolometer, Pyroelectric Detector, Golay Cells. Terahertz spectroscopy, THz imaging, THz sensing, THz frequency security system, Toward 6G Communication Networks, Terahertz communications, Industrial applications.	Terahertz Technology [3-0-2]
		Optical directional coupler, Optical switches, optical amplifiers, wave guides, splicers, couplers, connectors, Acousto-optic devices, Electro-optic devices, Magneto-optic devices, Electro-absorption modulator, optical modulators, SLM.	Photonic Devices [2-0-2]

		Photonic crystal waveguides, Nonlinear optical devices, power limiters, Optics on chip, Direct Laser writing, Lifi, Fiber Bragg grating, Laser Tweezers and scissors.	
	Applications	Laser oscillator and Laser characteristics, modes and mode selection, Laser Line width and Line broadening, Types of lasers, Generation of ultrashort pulses, Q-Switching, Mode locking, Chirping and Pulse compression, YAG Lasers, State-of–art-lasers, Self-phase modulation in fibers, broadband and supercontinuum sources, HOM interferometer, Shearing Interferometer, Michelson Interferometer in the contest of LIGO experiments, Four-wave mixing, Transient absorption	Laser Technologies PHL7330 [3-0-0]
		Single and Multimode, Step index and Graded Index Fibers, mode field diameter, The consequences of attenuation and dispersion in Optical Fibers, pulse band width, refractive index profile, bend loss, Intermodal and Intramodal Dispersion, Fiber Fabrication Methods, Optical amplification, noise in EDFA, WDM, bit-error rate, signal-to-noise ratio, Optical communications, photonic bandgap guiding mechanism, endless single-mode guidance, fiber optic sensors, nonlinear pulse propagation, optical solitons	Optical Fiber Technology PHL7XX0 [3-0-0]
		Wave Optics and applications, interferometer Fresnel diffraction, Babinet's principle, Fraunhofer diffraction, limit of resolution, N-slit diffraction, liquid crystals, holography, waveguides, Lasers and Nonlinear Optical Devices, Optical instruments (telescope, camera microscope)	Engineering Optics PHL6310 [3-0-0]
		Basic building blocks, optical transmitters, optical receivers, optical amplifiers, Optical transmission system, line coding schemes, eye pattern, Noise effects, attenuation and dispersion limited link design, Modulation and Detection Techniques, Tunable optical filters, Optical fiber considerations-Pulse broadening, Free space effects-turbulence models, weather conditions, under-water impairment, BER analysis under channel impairments,	Optical Communication Systems EEL4XX0 [3-0-0]
		Optical properties and dielectric constant, plasmons, volume plasmons, surface plasmons and applications, localized	Plasmonics [3-0-0]

		surface plasmons, field enhancement, damping, dephasing time and line width, combination of SPR and LSPR, arrays, SERS, Meta materials and applications	
		Paraxial Ray Optics, optical aberration, Fresnel-Kirchhoff's diffraction, partially coherent light, Fourier optics; spatial filtering and optical transfer function, point split function ex: microscope, Image formation, Frequency analysis, Introduction to optical instruments: spectrometers, monochromators.	Contemporary Optics [3-0-0]
		Radiative and non-radiative processes, Luminescence decay, LED basics- Diode current–voltage characteristics, Carrier distribution, Electron injection, Radiation pattern, The lambertian emission pattern, LED Design parameters-High internal efficiency designs, Design of current flow, High extraction efficiency structures, Types of LEDs	LED Technology [3-0-0]
		Biophotonics —a new frontier, introductory concepts of biology, cellular processes, protein classification and function, types of tissues and their functions, tumors and cancers Interaction between light and a molecule , fate of excited state, electronic absorption, luminescence, vibrational spectroscopy, fluorescence correlation spectroscopy, interaction of light with cells, interaction of light with tissues , in vivo photoexcitation, optical biopsy, Biomaterials for Photonics, Bioimaging: transmission microscopy, fluorescence microscopy, confocal microscopy, optical coherence tomography, near-field optical microscopy, nonlinear optical imaging, optical biosensors- fiber optic biosensors, planar waveguide biosensor, evanescent wave biosensors, spr biosensor , flow cytometry, photodynamic therapy and applications, tissue engineering with light, laser tissue welding, femtolaser surgery, Lab-on-a-Chip Technology.	Biophotonics [3-0-0]
2. Advanced Energy Materials	Core	Conventional energy systems and related materials challenges, transformer materials, Solar thermal energy systems, materials for concentrator, reflectors, heat transfer and storage, solar photovoltaics, materials for energy conversion, materials for electrical	Materials for Energy Technologies [3-0-0]

		energy storage, wind energy, materials for wind blades, nuclear energy, geothermal energy	
		Historical background, rechargeable and non-rechargeable batteries, primary and secondary battery, lead-acid battery, nickel-cadmium battery, metal ion batteries (Lithium, sodium and potassium), multivalent metal ion batteries (magnesium, aluminum, zinc), metal-air battery, redox-flow battery, photo rechargeable batteries, Technical challenges, liquid, gel, solid and solid polymer electrolytes, supercapacitors, modeling electrode materials and the physics of electrolytes.	Electrical Energy Storage Materials and Devices [3-0-0]
	Techniques	Basics of nanomaterials, nanoparticles, and clusters, quantum confinement and quantum dots, nanotechnology for energy generation and storage: DSSC and QDSSC, fuel cells, hydrogen storage in carbon nanomaterials, nanocatalyst	Nanoscience and Nanotechnology PHL7441 and PHL7442 [2-0-0]
		Quantum efficiency study of photovoltaics, electrochemical characterizations of energy storage devices, electrical characterization of thermoelectric, piezoelectric, and triboelectric devices. Characterization of PV modules, characterization of battery packs/modules.	Characterization of Energy Devices [0-0-2]
		First generation silicon solar cells, thin-film silicon solar cells, CIGS and CdTe solar cells, DSSC, perovskite solar cells, piezoelectric MEMS energy harvester, piezoelectric energy transducers, triboelectric nanogenerator, thermoelectric energy harvesting, pyroelectric energy harvesting	Energy Harvesting [3-0-0]
	Applications	Thermodynamics of solar cells and light, properties of semiconductors, generation and recombination of charge carriers, different types of junctions, understanding the current flow across the junction.	Physics of Solar Cells PHL7390 [3-0-0]
		Ray optics, design of lenses, concentrating systems, sun simulators, field design for solar thermal application, Hydrogen production from biowaste and fossil fuels, Thermochemical, electrochemical and photo-electrochemical process for hydrogen production, Hydrogen storage in	Optics for Solar Energy Applications PHL7520 [3-0-0]

		Metal Hydrides, Non-metal hydride nanomaterials for Hydrogen Storage, Thermodynamics of Hydrogen Storage	
		Introduction, hydrogen production processes, metal hybrid nanomaterials for hydrogen storage, non-metal hydride nanomaterials for hydrogen storage, thermodynamics of hydrogen storage	Nanomaterials for Hydrogen Production and Storage MTL7XX0 [3-0-0]
		Electrochemical dissociation, electrocatalysis, photocatalysis, pressurized hydrogen, liquid hydrogen, metal hydrides, chemisorption materials, fuel cell principles, distributed application for energy generation, electric vehicles	Hydrogen Generation, Storage and Applications [3-0-0]
		High-temperature materials for conventional energy, physics of polymer nanocomposite, liquid electrolytes, damage assessment of the materials, recycling of materials used in power plants, case studies,	Materials Management for Energy Technology [3-0-0]
		History of bioenergy, bio-energy harvesting, thermoelectrics, bio-reactors, bio-piezoelectric materials, light-harvesting biomaterials, bio-fuel cell, artificial leaf, bio-fluorescent materials, bio-phosphorescent, microbial fuel cells, bio-macromolecules and bio-polymers	Bioenergy [3-0-0]
		Solar radiation and measurement, devices for measurement, resource data centers, data assessment, prediction using machine learning and artificial intelligence	Solar Resource Assessment and Its Management [3-0-0]
3. Quantum Technologies	Core	Measures of entanglement and nonlocal correlations, Classical and quantum information, Quantum Communication Protocols, other quantum cryptographic protocols, Eavesdropping and security, Remote State Preparation, Controlled communication protocols, Quantum Operations and Noisy Channels, Quantum Error Correction	Quantum Communications QCL4010
		Quantum-Circuit Model, Clauser-Horne-Shimony-Holt inequality as a nonlocal game, single and multi-qubit operations, Measurements, Quantum Algorithms, Deutsch-Jozsa and Bernstein-Vazirani Algorithms, Simon's Algorithm, Phase	Quantum Computing QCL4020

		estimation and quantum Fourier transform, Quantum cryptography and post quantum cryptography, Scalability issues, Fault tolerant quantum computation	
		Hanbury Brown -Twiss Interferometer, Generation of Entangled photons using BBO crystal, Photon Statistics using Single Photon Detector, Bell-State Analyzer, Random Number Generation using Quantum resources, Experimental demonstration of BB84 protocol	Quantum Optics and Quantum Information Laboratory QCP4XX0
		Test of QNRG with NIST suite, FPGA based symmetric and anti-symmetric QKD generation, Experiments with QKD at components level, Free space quantum communication up to 30 meters with single photon and analysis Experiments with phase-shift key protocol in QKD experiments or quantum communication, Optical simulation module for Satellite based communication	Quantum Communication Laboratory
		Spontaneous Parametric Down-Conversion (SPDC) process, Entangled photon detection, HOM and Franson Interferometer, Hanbury-Twiss Interferometer, Quantum distribution theory: Q, P and W distributions, Photon detection and quantum coherence functions, Atom-field interaction Hamiltonian; density matrix of two-level atom with a single mode field, Lasing without inversion, coherent trapping, electromagnetically induced transparency: Basic concepts of these quantum interference phenomena.	Quantum Optics and Engineering PHL 7500
	Technique	Modern cryptography; number theoretic concepts, Classical Coding Theory: Concepts of entropy, mutual information and related aspects; Shannon's coding theorem, Quantum Key Distribution protocols: BB84, B92, Ekert protocol, Goldenberg-Vaidman, counterfactual quantum cryptography; protocols of quantum dialogue, Shor's factoring algorithm and modern cryptography; Experimental progress in quantum cryptography, Quantum aspects of Shannon coding theorem.	Quantum Cryptography and Coding QCL7XX0 PHL7XX0

		Generation of Single Photon, Heralded Photon and Photon added/subtracted states, NOON State. Photon Statistics and higher-order moments for non-classical states and quantum Metrology, qubits using photons and superconducting quits, modern quantum algorithms, Open Quantum Systems Technological Implementation.	Non-classical states for Quantum Information and Computation PH6XX0
		Hilbert spaces, dual of Hilbert space, separable Hilbert spaces, linear functionals, Adjoint operators, bounded linear operators, unbounded operators, basic postulates, Observables, states, mixed states, qubits, superselection rules, compatible observables, Born's correspondence rule for determinative measurements, General form of the Schrodinger equation, the evolution operator, formalism of matrix mechanics, equivalence of formalisms, Symmetric and antisymmetric tensor products of Hilbert spaces, spin and statistics, Spin and statistics for the n-body problem	Hilbert space methods in Quantum Mechanics PH7XX0
		Foundations of quantum entanglement, Introductory and seminal contributions related to bi-partite and multiqubit entanglement, measures of entanglement, classification and quantification of nonlocal correlations, entanglement versus separability versus nonlocality, multiqubit controlled communication protocols, splitting of information, open destination teleportation, quantum cryptography and post quantum cryptography, Bell-CHSH inequalities and quantum games,	Seminal Features of Quantum Information Processing PH7XX0
		Josephson Effects and Superconducting Electronics, Circuits and resonance; circuit quantization, charge, flux, and phase qubits, Quantum hardware implementation, Qubit readout; dispersive measurement; parametric amplification, variational quantum circuits and its applications, Weak measurement and feedback, decoherence mechanisms, Fluxonium, Positive Operator Value Measure (POVM), Non-demolition measurements and quantum noise, Introduction quantum sensing & Quantum MEMS, Single photon detectors	Quantum Devices and Circuits [3-0-0]

	Applications	Single photon source, NV centers Squeezed Light generation, mode squeezing techniques and other squeezing techniques and Parametric down conversion (PDC) Second and Fourth Intensity correlation, Homodyne (Balanced & Unbalanced) Time-Domain, Radon Transformation and Inverse-Radon Transformation, Quantum state Tomography	Nonlinear Optics and Quantum Light Detection Techniques PH7XX0
		Partition function as a path integral; density matrix evolution as a path integral. Liouville equation; Langevin equation; Fokker-Planck equation; Boltzmann equation; quantum dynamical semigroups and Lindblad equations; projection operator techniques. Role of open systems in quantum information; geometric phase; quantum cryptography.	Open Quantum Systems PHL 7480
		Financial Derivatives, Spot and Forward Rates, Forward and Futures, Options (call and put), European and American Options, Put-call parity, Binomial Tree, Discrete Time Models for Option Pricing, Simon's algorithm, The prime factorization algorithm, Grover's search algorithm, Error correction and fault-tolerant, Quantum Computing, Quantum optimization Algorithms, Quantum machine learning Algorithms (quantum principal component analysis, quantum K-means, quantum hierarchical clustering), Quantum amplitude estimation and Monte Carlo Algorithm, Lagrangian for Stock Price with Stochastic Volatility, Classical Monte Carlo Pricing, Quantum Algorithm for Monte Carlo and European Option Pricing	Quantum Computational Finance PH7XX0

		Futuristic aspects and role of computer science and engineering- Algorithms, machines and their architectures; limitations and prospects of quantum technologies in comparison to their classical counterparts, Quantum computing and machine learning, Quantum-Simulation, Optimization, Algorithms, error correction and cryptography in the new era, Quantum computing and machine learning, Quantum Supremacy, Quantum annealing, Eigenvalue problem and Quantum phase estimation algorithms, Variational eigenvalue solver, Quantum circuit learning, Quantum nodes, hybrid learning algorithms, Quantum Approximate Optimization Algorithm, Discrete optimization, kernel functions, Coherent quantum machine learning protocols	Quantum Machine Learning PH7010

12. Curriculum

Cat	Course	LTP	CH	NC	GC
Semester-I					
IE	Introduction to Electrical Engineering	3-0-2	5	-	4
IE	Introduction to Computer Science	3-0-2	5	-	4
IE	Introduction to Bioengineering	3-0-2	5	-	4
IS	Mathematics I	3-1-0	4	-	4
IE	Engineering Visualization	0-0-2	2	-	1
NE	Engineering Design I	0-0-2	2	1	-
NH	Communication Skill I	0-0-2	2	1	-
NH	Social Connect and responsibilities I	0-0-1	1	0.5	-
NH	Performing Arts I /Sports I	0-0-1	1	0.5	-
	Total	**12-1-14**	**27**	**3**	**17**
Semester-II					
IE	Engineering Mechanics	2-1-0	3	-	3
IS	Chemistry	3-0-0	3	-	3
IS	Physics	3-0-0	3	-	3
IS	Chemistry Lab	0-0-2	2	-	1
IS	Physics Lab	0-0-2	2	-	1
IS	Mathematics II	3-1-0	4	-	4
IE	Engineering Realization	0-0-2	1	-	1
NE	Engineering Design II	0-0-2	2	1	-
NH	Communication Skill II	0-0-2	2	1	-
NH	Social Connect and responsibilities II	0-0-1	1	0.5	-
NH	Performing Arts II/Sports II	0-0-1	1	0.5	-
	Total	**11-2-12**	**25**	**3**	**16**
Semester-III					
IE	Introduction to Machine Learning	3-0-2	5	-	4
IE	Signals and Systems	3-1-0	4	-	4
PC	Mechanics I	3-0-0	3	-	3
PC	Mechanics II	3-0-0	3	-	3
PC	Thermal Physics	3-0-0	3	-	3
PC	Basic Computational Lab	0-0-3	3	-	1.5
NE	Intro. To Profession	0-0-2	2	1	
	Total	**15-1-7**	**23**	**1**	**18.5**

Semester-IV					
IE	Data Structures and Algorithms	3-0-2	5	-	4
PL	Embedded Systems & IoT	3-0-2	5	-	4
PC	Mathematical methods for Physicists	3-0-0	3	-	3
PC	Modern Optics	3-0-0	3	-	3
PC	EM waves and fields	3-0-0	3	-	3
PC	EM Lab	0-0-3	3		1.5
IH	Humanities I	3-0-0	3	-	3
	Total	**18-0-7**	**25**	**-**	**21.5**
Semester-V					
PL	Big Data Management	2-0-2	4	-	3
PL	Communication Systems	3-0-0	3	-	3
PC	Physics of atoms, molecules and nuclei	3-0-0	3	-	3
PC	Electronics	3-0-0	3	-	3
PC	Solid State Physics	3-0-2	5	-	4
PC	Electronics Lab	0-0-3	3	-	1.5
PC	Thin film & Material Characterization Lab	0-0-3	3	-	1.5
PC	Applied Computational Lab	0-0-3	3	-	1.5
IH	Humanities II	3-0-0	3	-	3
NH	Professional Ethics I	0-1-0		1	-
	Total	**17-1-13**	**30**	**1**	**23.5**
Semester-VI					
PC	Medical Physics	2-0-0	2	-	2
PC	Nuclear radiation and Energy	2-0-0	2	-	2
PC	Interaction of radiation with matter	2-0-2	4	-	3
PC	Semiconducting and Optoelectronic Devices	3-0-2	5	-	4
PC	Applied optics Lab	0-0-3	3	-	1.5
PC	Modern physics Lab	0-0-2	2	-	1
PC	Radiation and particle detection Lab	0-0-2	2	-	1
PC	Entrepreneurship for Physicists	2-0-0	2	-	2
SC/SE	Specialization Core/Electives				4
NH	Professional Ethics II	0-0-2	2	1	-
	Total	**11-0-13**	**24**	**1**	**20.5**

Semester-VII					
PC	Fluids & Plasmas	2-0-2	4	-	3
PC	BS project	0-0-6	6	-	3
SC/SE	Specialization Core/Electives	-	-	-	11
IH	Humanities III	3-0-0	3	-	3
IS	Environmental Science	2-0-0	2	-	2
	Total	**7-0-8**	**15**	**-**	**22**
Semester-VIII					
PC	EM and Neutrino Astronomy	3-0-0	3	-	3
SC/SE	Specialization Core/Electives	-	-	-	15
IH	Humanities IV	3-0-0	3	-	3
	Total	**6-0-0**	**6**	**-**	**21**
			Total of Graded Credits	**-**	**160**
			Total of Non-Graded Credits	**9**	**-**
			Non-Graded Design Credits	**6**	**-**
			Grand Total	**175**	

13. Detailed Program Compulsory Course Contents

13.1 Fundamental Physics

Title	Mechanics-I	Number	PHL2XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	BS Physics	Type	Compulsory
Prerequisite	None		

Objectives

The instructor will:

1. Discuss the fundamental principles of particle dynamics.
2. Provide concepts and problem-solving approach related to dynamics of particles and rigid bodies.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basic methodology of particle dynamics.
2. Design and solve problems related to model mechanical systems.

Course Contents

Tensor analysis: Determinants, Spaces of N dimensions, Coordinate transformations, Covariant, contravariant mixed tensor, Kronecker Delta, Tensor algebra, Matrix algebra. [10 Lectures]

Waves and Oscillations: Simple harmonic, Damped, and Forced oscillations, Mechanical and Electrical Oscillators. [4 Lectures]

Newtonian Mechanics: Dynamics of particle: Newton's law of motion, Central force, motion under inverse square law of force, Inertial and non-inertial frames; Dynamics of a system of particles: Linear and angular momentum, Total energy of a system of particles, Two-body problem; Dynamics of rigid bodies: Moments and product of inertia of some symmetrical bodies, Law of gravitation, Gravitational potential. [12 Lectures]

Lagrange's formulation of mechanics:
Constraints and their classification, Principle of least action, D'alembert's principle, Lagrange's equations of motion, Generalized force, Application of Lagrangian formulation. [6 Lectures]

Hamiltonian's formalism of mechanics:
Canonical conjugate momenta, Legendre transformation, Hamilton's equations of motion, applications of Hamilton's equations. [5 Lectures]

Special Theory of Relativity:
The basic principles of special relativity, The Lorentz transformation, Length contraction, Time dilation, Twin paradox, Covariant four-dimensional formulation, The force and energy equations in relativistic mechanics. [5 Lectures]

Textbook

1. A. W. Joshi, Matrices and tensors in Physics, New Age International (1975)
2. Rana & Joag, Classical Mechanics, Tata McGraw-Hill (1991)
3. A. K. Raychaudhuri, Classical Mechanics, OUP India (1983)
4. Kleppner, Daniel; Kolenkow, Robert, An Introduction to Mechanics, Cambridge University Press (2021)

Reference Books

1. Goldstein, H., Classical Mechanics, Pearson India Limited, New Delhi (2011)
2. Jose, J. V., and Saletan, E. J., Classical Dynamics: A Contemporary Approach, Cambridge University Press, (2002).
3. Landau, L. D., and Lifshitz, E. M., Mechanics, Pergamon Press, (1960).

Self -Learning Material

1. Banerjee D., Classical Mechanics, Indian Institute of Technology Kharagpur, Kharagpur, https://nptel.ac.in/syllabus/115105098/.

Title	Mechanics-II	Number	PHL2XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	BS Physics	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Address the limitations of classical mechanics and illustrate how quantum mechanics can overcome them.
2. Illustrate the postulates, basic descriptions of quantum systems, and important applications of quantum mechanics.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the necessity and the domain of applications of the quantum mechanical approach.
2. Solve Schrödinger's equation for model systems.
3. Understand the operator algebra of quantum mechanical angular momentum.

Course Contents

Linear Vector Spaces:
Algebraic Eqns, Matrices, Special Matrices, Special Functions, Eigenvalues and Eigenvectors, Vectors, Operators, Bra and Ket notation for vectors, Representation theory. [12 Lectures]

Origin of Quantum Theory:
Conceptual aspects, The black body radiation, Photoelectric effect, Failure of Rutherford's atomic model, Atomic spectra, Bohr's theory, The mathematical aspects. [3 Lectures]

The Basic Principles:
De Broglie and Schrodinger's matter waves, Double slit experiment, Fundamental Postulates, The uncertainty principle, Density matrix. [3 Lectures]

Quantum Mechanics:
Schrödinger's equation, Particle in a box, Particle in well, Tunneling and resonances, The linear Harmonic oscillator, The hydrogen atom. [12 Lectures]

Theory of Angular Momentum:
The definition, Orbital angular momentum, Addition of angular momentum, Angular momentum and rotation, Consequence of quantization. [12 Lectures]

Textbook

1. A. Beiser, S. Mahajan, and S. R. Choudhury, Concepts of Modern Physics, McGraw-Hill, 7th Ed., 2017.
2. H. C. Verma, Quantum Physics, Surya Publications, 2nd Ed., 2012.
3. D. J. Griffiths and D. F. Shroeter, Introduction to Quantum Mechanics, Cambridge, 3rd Ed., 2018.

Reference Books

1. R. P. Feynman, R. B. Leighton, and M. Sands, The Feynman Lectures On Physics - Vol. 3 - Quantum Mechanics: The New Millennium Edition, Pearson Education, 1st Ed., 2012.
2. J. L. Powell and B. Crasemann, Quantum Mechanics, Dover Publications Inc., 2015.
3. E. Merzbacher, Quantum Mechanics, Wiley, 3rd Ed., 1998.

Self -Learning Material

1. NPTEL Course Material, Balakrishnan, V., Department of Physics, IIT Madras https://nptel.ac.in/courses/ 122106034/.
2. Prof. H. C. Verma, IIT Kanpur, https://hcverma.in/QuantumMechanics
3. V. Vuletic, Quantum Physics I, http://hdl.handle.net/1721.1/90372.

Title	Mathematical Methods for Physicists	Number	PHL2XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	BS Physics	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Enable students with the mathematical skills required to approach problems of interests to physicists in the fundamental and applied research areas.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the properties of special functions and partial differential equations and apply these in various physical problems, for instance, electrostatics and quantum mechanics.
2. Obtain the power series of a function and apply the residue theorem for evaluating contour integrals.

Course Contents

Special Functions and Integrals:

Ordinary and singular points of a linear differential equation, Beta and Gamma functions, Dirac-delta function, Hypergeometric functions, Legendre, Hermite, Laguerre polynomials and their associated polynomials, Bessel and spherical Bessel functions, Recurrence relations, Rodrigues formula, Integral expressions, Applications in potential theory and wave mechanics such as evaluation of wave functions for Quantum harmonic oscillator, Hydrogen atom, etc. [14 Lectures]

Partial Differential Equations (PDEs) and Integral Transforms:

PDEs in natural science, First order PDEs, Classification of second order PDEs and reduction to canonical forms, Laplace and Poisson equations, Application to boundary value problems in potential theory and steady-state thermal conduction, Heat equation and application to molecular diffusion, Wave equation and application to vibrational modes of a string/membrane, Method of separation of variables in different coordinate systems, Method of integral transforms. [14 Lectures]

Complex Analysis:

Review of complex numbers and elementary functions, Analytic functions, Cauchy-Riemann conditions, Harmonic functions, Classification of singularities, Order of poles and zeros, Cauchy's residue theorem, Contour integration and application to solving definite integrals, Jordan's lemma, Evaluation of indefinite integrals, Convergence of a power series, Taylor and Laurent series, Analytic continuation. [14 Lectures]

Textbook

1. G. B. Arfken, H. J. Weber, and F. E. Harris, Mathematical Methods for Physicists, Elsevier, 7th Ed., 2012.
2. S. D. Joglekar, Mathematical Physics: The Basics, Universities Press, 1st Ed., 2005.
3. S. D. Joglekar, Mathematical Physics: Advanced Topics, Universities Press, 1st Ed., 2006.

Reference Books

1. I. Sneddon, Elements of Partial Differential Equations, Dover, 2006.
2. M. L. Boas, Mathematical Methods in the Physical Sciences, John Wiley & Sons, 2005.
3. V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, Ane Books, 2017.
4. M. R. Spiegel, Complex Variables, Schaum's Outline Series, McGraw-Hill, 1999.

Self- Learning Material

1. Selected topics in Mathematical Physics, NPTEL course (by Prof. V. Balakrishnan, Department of Physics, IIT Madras).
2. Linear Partial Differential Equations, MIT OpenCourseWare, Fall 2006, https://ocw.mit.edu/courses/mathematics/18-303-linear-partial-differential-equations-fall-2006/index.htm, (by Dr. Matthew Hancock, Veryst Engineering, LLC)

	3. Complex Variables with Applications, MIT OpenCourseWare, Spring 2018 https://ocw.mit.edu/courses/mathematics/18-04-complex-variables-with-applications-spring-2018/index.htm# (Dr. Jeremy Orloff, Lecturer in Mathematics, MIT)

Title	Basic Computational Lab	Number	PHP2XXX
Department	Physics	L-T-P [C]	0–0–3 [1.5]
Offered for	BS Physics	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Help gaining skills in Linux commands, shell scripting and programming
2. Introduce different tools to visualize and graphically analyze data.

Learning Outcomes

The students are expected to have the ability to:

1. Apply basic computational skills in designing and solving problems.
2. Develop computer programs to solve problems in science and engineering.

Course Contents

Introduction to Linux, Shell Scripting, and Python Scripting:

1) Basic concepts and commands of Linux; text editing using vim editor
2) Shell and Python scripting

Data Analysis and Visualization: MATLAB, Scilab, Mathematica, Gnuplot, xmgrace, MINUIT

3) Data analysis and visualization using MATLAB, Scilab, and Mathematica
4) Scientific plotting and graphical/data analysis using Gnuplot and xmgrace
5) Minimization algorithms and error analysis using MINUIT (CERN program software library)

Scientific Programming:

6) Basic elements of programming: Algorithms and Flowchart development
7) Declaration of constants and variables, Print/Read/Write statements with formatting.
8) Unary and binary operations: Logical, relational, and arithmetic operations
9) Array manipulation and application to matrix multiplication and inversion
10) Control statements: IF loops, DO loops, Nested loops
11) Functions/Subroutines: Solving real physical problems

LaTeX Typesetting:

12) Introduction to LaTeX and Overleaf: Document class, building and compiling a LaTeX file
13) Commands and Environments: Inserting equations, figures, tables, list environments, etc.

Textbook

1. V. Rajaraman, Computer Programming in Fortran 90 and 95, Prentice Hall India, 1997.
2. S. S. Sastry, Introductory Methods of Numerical Analysis, Prentice Hall India, 5th Ed., 2012.
3. S. C. Chapra, Applied numerical methods with MATLAB for engineers and scientists, Tata McGraw-Hill, 2nd Ed., 2008.
4. P. K. Janert, Gnuplot in Action: Understanding Data with Graphs, Manning, 2nd Ed., 2016.

Reference Books

1. J. H. Mathews and K. D. Fink, Numerical methods using MATLAB, PHI Learning, 4th Ed., 2004.
2. R. H. Landau, M. J Paez, and C. C. Bordeianu, Computational Physics: Problem-solving with Python, Wiley-VCH, 3rd Ed. 2015.
3. H. Kopka and P. W. Daly, A Guide to LaTeX: Tools and Technologies for Computer Typesetting, Addison-Wesley Longman, 4th Ed., 2003.

Self -Learning Material

1. Computational Physics, NPTEL course (by A. Chatterji and P. Ghosh, Department of Physics, IISER Pune)
2. MINUIT: Function Minimization and Error Analysis, Reference Manual, https://root.cern.ch/download/minuit.pdf (by F. James, CERN Geneva, Switzerland)

Title	Applied Computational Lab	Number	PHP3XXX
Department	Physics	L-T-P [C]	0–0–3 [1.5]
Offered for	BS Physics	Type	Compulsory
Prerequisite	Basic Computational Lab		

Objectives

The Instructor will:

1. Help implement different numerical techniques and minimization.
2. Introduce Monte Carlo methods to solve real problems in natural sciences.

Learning Outcomes

The students are expected to have the ability to:

1. Apply Monte Carlo techniques in designing and solving scientific problems.
2. Model and simulate real phenomena in physics.

Course Contents

Numerical Techniques:

1. Curve Fitting and Numerical Integration
2. Minimization with CG or SD
3. Solving ODEs and PDEs
4. Systems of Linear and Nonlinear Equations
5. Singular Value Decomposition

Thermodynamics and Statistical Mechanics:

6. Thermodynamic Properties and Ensemble Averages
7. Langevin and Brownian dynamics

Monte Carlo Integration and Sampling Methods:

8. Random Number Generators and Monte Carlo integration
9. Importance Sampling

Metropolis Algorithm:

10. Detailed Balance and Markov process

Monte Carlo Simulations:

11. Calculation of Pi
12. Random walk problem to understand Brownian motion and molecular diffusion
13. Hard sphere model or Ideal gas
14. Photon gas problem
15. The Physics of the Lennard-Jones system

Textbook

1. Chapra, S. C., and Canale, R. P. Numerical Methods for Engineers, 7th Edition, McGraw-Hill Education.
2. Newman, M., Computational Physics, CreateSpace Independent Publishing Platform, 2012.

Reference Books

1. Allen, M. P., and Tildesley, D. J., Computer Simulation of Liquids, Oxford University Press, 2nd ed. 2017.
2. Landau, D. P. and Binder, K., A Guide to Monte Carlo Simulations in Statistical Physics, 3rd Edition, Cambridge University Press 2009.
3. T. Schlick, Molecular Modeling and Simulation: An Interdisciplinary Guide, New York: Springer-Verlag, Second Edition (2010).

Self -Learning Material

1. MIT Open CourseWare, 3.320 "Atomistic Computer Modeling of Materials (SMA 5107)", by Ceder, G. and Marzari, N.; Spring 2005, https://ocw.mit.edu/courses/materials-scienceand-engineering/3-320-atomistic-computer-modeling-of-materials-sma-5107-spring-2005/

13.2 Electrodynamics and Plasma Physics

Title	**EM Waves and Fields**	**Number**	**PHL2XXX**
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will:

1. Provide the concepts regarding boundary value problems in electro and magnetodynamics.
2. Basic understanding of electro-magnetic fields and their applications in applied branches of physical sciences.

Learning Outcomes

The students are expected to have the ability to:

1. Explain and solve problems based on classical electrodynamics
2. To understand retarded and advanced potentials, waveguides, resonant cavities and their applications.

Course Contents

1. Green's Function in Electro- and Magnetodynamics, Boundary value problems in Electrostatics, Uniqueness theorem, Green's Function in Electrostatics, Multipole expansion, Magnetodynamics, Displacement current, Maxwell's equations, Vector potentials, Electromagnetic energy momentum Tensor. [12 Lectures]

2. Electromagnetic Wave Propagation in Media and Fresnel Coefficients: Electromagnetic Waves at a Plane Interface between Dielectrics, Plane Waves in Non-conducting Medium, Group Velocity Dispersion (GVD), Kramers-Kronig Relations, Linear and Circular Polarization, Wave-plates, Stokes Parameter, Fresnel coefficients. [10 Lectures]

3. Geometry of Waveguides and Resonant Cavities: Fields at the surface of and within a Conductor; Cylindrical Cavities and Wave Guides, Resonant Cavities, Power losses in a Cavity and Q of a Cavity. [10 Lectures]

4. Retarded and Advanced Potentials: Radiation by moving Charges, Lienard-Wiechertz Potentials and Fields for a moving Point Charge, Total power Radiated by an Accelerating charge, Larmor's formula. [6 Lectures]

5. Radio Waves and Antennas: Introduction to Radio waves and different types of antennas. [4 Lectures]

Textbook

1. Jackson, J. D., Classical Electrodynamics, Wiley India Pvt. Ltd., 2007.
2. Griffiths, J. David, Introduction to Electrodynamics, Prentice Hall.

Reference Books

1. Lorrain, P. and Corson, D., Electromagnetic Fields and Waves, CBS Publishers, 2003.
2. Panofsky W.K.H. and Philips M., Classical Electricity and Magnetism, Dover Publishers, 1990.

Self-Learning course material

1. Dighe, A., Electrodynamics, Tata Institute of Fundamental Research, Mumbai, https://nptel.ac.in/syllabus/115101004/.
2. Gut, A., Lecture notes on Electromagnetism II, MIT open course ware https://ocw.mit.edu/courses/physics/8-07-electromagnetism-ii-fall-2012/lecture-notes/

Title	**Interaction of Radiation with Matter**	**Number**	**PHL3XXX**
Department	Physics	L-T-P [C]	2–0–2 [3]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will:

1. To provide the basic understanding of interaction of different forms of radiation with matter.
2. Basic scientific processes involving detection of radiation and its applications.

Learning Outcomes

The students are expected to have the ability:

1. To familiarize with fundamental concepts of radioactive and ionizing radiations.
2. To familiarize with the usage of ionizing radiation in the modern technologies.

Course Contents

Theory:

1. Radioactive decays and energy loss mechanisms: Interaction of ionizing and non-ionizing radiation with matter, Energy loss mechanism of charged particle and Radiation, Collisional Stopping power (Bathe's formula), Energy range of alpha and beta particles. Mass spectrometer & Time-of-flight (TOF), Scattering: Differential Cross-section of a nuclei and related experimental techniques, Introduction to Geant. [7 Lectures]

2. Radiation Counters: Principle of radiation counter, Geiger Muller (GM) Counter, Scintillation Counter and other radiation counting techniques, Particle accelerator. [6 Lectures]

3. Nuclear sensors and Radiation Safety: Nuclear detection techniques, Radiation threshold for humans, Radiation Safety and protocols. [6 Lectures]

4. Generation of Radiation and its applications: Synchrotron Radiation, Free-electron Laser, Cherenkov, Optical Transition Radiation (OTR) & Coherent Transition Radiation (CTR) and Bremsstrahlung Radiation. [9 Lectures]

Lab:

1. To measure the plateau region of GM tube
2. To calculate gamma-ray attenuation in a medium using gamma source
3. Dosimeter calibration using different radio-active sources
4. Radiation counter: To measure the gamma-ray counts using gamma-ray counter
5. Radiation counter: To measure the beta-ray counts using beta-ray counter
6. Simulation of GEANT-4: Interaction of high energy positive ions in a medium
7. Simulation of GEANT-4: Interaction of high energy electrons in a medium
8. Simulation of GEANT-4: Interaction of high energy gamma-particles and other neutral in a medium

Textbook

1. Irving Kaplan, Nuclear Physics, Addison -Wesley publication
2. J. D. Jackson, Classical Electrodynamics, Wiley-India Pvt. Ltd., 1999, Third Edition.
3. Manual for GEANT-4 simulation software

Reference Books

1. B. L. Cohen, CONCEPTS OF NUCLEAR PHYSICS, Tata Mcgraw Hill Education Private Limited, 2005, Third Edition.
2. Ghoshal, S. N., Nuclear Physics, S. Chand, 2011.

Self-Learning Material

1. T. Kundu, IIT Bombay, Electromagnetic Radiation – Matter Interactions, https://nptel.ac.in/courses/115101003
2. Jeffrey Coderre, MIT Course Number 22.55J, PRINCIPLES OF RADIATION INTERACTIONS, https://ocw.mit.edu/courses/22-55j-principles-of-radiation-interactions-fall-2004/pages/syllabus/

Title	Modern Optics	Number	PHL3XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will provide:

1. The concepts of fundamental optics.
2. Classical and Semi-Classical approaches to understand the characteristics of light wave.

Learning Outcomes

The students are expected to have the ability:

1. To gain the knowledge of Geometrical and Wave Optics.
2. To understand the role of Polarization and Fourier Optics in optical instruments.

Contents

Geometrical Optics: Light, Corpuscular and Wave models of light, Wave particle duality, Fermat's principle and its applications, Eikonal Equation, reflection and refraction by spherical surfaces, Matrix method in paraxial optics, Thin and thick lens, Optical system (telescope), aberrations. [10 Lectures]

Wave Optics: Simple Harmonic Motion, Forced Vibrations and origin of refractive index, wave propagation, wave equation, Huygens principle and its applications, superposition of waves, interference by division of wave-fronts and division of amplitudes, multiple beam interference, Coherence. [10 Lectures]

Fourier Optics: Overview of Diffraction, Diffraction Integral: Fresnel Diffraction, Fraunhofer approximation. Fraunhofer Diffraction by long narrow slit, rectangular aperture, circular aperture, Working principle and application of telescope, spatial frequency filtering, Fourier transforming property of a thin lens, Fresnel diffraction. [8 Lectures]

Polarization: Malus Law, Production of polarized light, Brewster angle, Phenomenon of double refraction, interference of polarized light, Analysis of polarized light, Walston prism, EM Wave propagation in a anisotropic media, Ray velocity, Ray refractive index, Faraday rotation. [8 Lectures]

Semi-Classical and Quantum approaches. [6 Lectures]

Textbook

1. Ghatak A, Optics, 7th Edition Mc-graw Hill Publisher, 2021.
2. Hecht E., Optics, 4th Edition, Pearson Publisher, 2007.

Reference Book:

1. Born & Wolf, Optics (7th edition)
2. K K Sharma, Optics: Principles and Applications, Academic Press 2006.

Self-Learning Material

1. Barbastathis, G. and Sheppard C., Optics, https://ocw.mit.edu/courses/mechanical-engineering/2-71-optics-spring-2009/

Title	**Fluids and Plasmas**	**Number**	**PHL4XXX**
Department	Physics	L-T-P [C]	2–0–2 [3]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will:

1. Provide a basic understanding of contemporary developments in the plasma technology area through concept building of plasma science.
2. Familiarize students to the broad range of plasma environments and plasma applications and provide experience in the handling of basic equipment.

Learning Outcomes

The students are expected to have the ability to:

1. Solve basic plasma physics problems and be familiar with important scientific approaches of Fluids and Plasmas.
2. Acquire a broad knowledge base of plasma science and its technological applications.
3. See plasma as an enabling technology and understand where applying plasmas can lead to new or improved technology.

Course Contents

The Name Plasma: Relevant concepts from gas (kinetic) theory, Saha equation, Definition of plasma and relevant characteristic parameters (e.g., Mean free path, Debye length, Debye shielding, plasma temperature, plasma oscillations, degree of ionisation, plasma sheath), Plasmas in nature. [6 Lectures]

Fluid Theory: Two fluid model, Continuity equation, Momentum conservation, Convective derivative, Equations of state, Single fluid approximation: MHD, MHD equilibria, Generalised Ohm's Law, Waves and instabilities in plasmas. [7 Lectures]

Breakdown Conditions and Man-Made Plasmas: Townsend discharge and electrical breakdown conditions of gases, Discharge regimes (Glow Discharge, Abnormal Glow Discharge, Arc Discharge), Concepts of DC plasma, DC-pulsed plasma, RF plasma, Atmospheric pressure Cold plasma, Capacitive and Inductive plasmas, Electron Cyclotron Resonance (ECR) plasma, Tokamak plasma, Laser produced Plasma. [9 Lectures]

Laboratory Plasma Applications: Plasma treatment of surfaces, Plasma deposition, Plasma Etching, Plasma Lightning devices, Cold plasma applications in health, food, energy and agriculture, Nanoscale fabrications and plasma for biomedicines. [6 Lectures]

Lab:

1. To study the conditions of occurrence of plasma striations.
2. To study the dependence of break-down voltage on pressure and inter-electrode gap for a given gas using Paschen Curve.
3. To launch and detect ion-acoustic waves and demonstrate collective behaviour of plasma.
4. Measurement of plasma parameters (floating potential, electron temperature and plasma density) by Langmuir probe.
5. To measure plasma parameters using a double Langmuir Probe where there is no reference point.
6. To identify the plasma species and their concentrations using plasma spectroscopy.
7. To demonstrate thin film deposition on glass substrate using Magnetron Sputtering System.
8. To demonstrate Plasma Nitriding Process for surface hardening of different alloyed steels.
9. To demonstrate surface treatment using non-equilibrium Cold Plasma.

Textbooks

1. F.F. Chen, Introduction to Plasma Physics and Controlled Fusion, Volume 1: Plasma Physics, NY, Plenum Press, 1984
2. Yuri P. Raizer, Gas Discharge Physics, Springer-Verlag Berlin Heidelberg, 1991
3. J. Reece Roth, Industrial Plasma Engineering, Vol. 1 & 2, Institute of Physics Publishing, 2003
4. P.I John, Plasma Sciences and the Creation of Wealth, Tata McGraw-Hill Education Company Pvt. Ltd., New Delhi, 2005

Reference Books

1. R.J Goldston and Paul H. Rutherford, Introduction to Plasma Physics, Institute of Physics Publishing, Bristol 1995.
2. Michael Lieberman and Allan J. Lichtenberg, Principles of Plasma Discharges and Materials Processing, John Wiley, 2005
3. John Wesson, Tokamaks, Clarendon Press- Oxford, 2004

Self-Learning course material

https://nptel.ac.in/courses/115102020/

Title	**Applied Optics Lab**	**Number**	**PHP3XXX**
Department	Physics	L-T-P [C]	0–0–3 [1.5]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will:

1. Provide the experimental understanding regarding the fundamental concepts of Optics using different measurement techniques.

Learning Outcomes

The students are expected to have the ability to:

1. Apply the concepts and become familiar with the fundamental optical processes.
2. Understand the working principles of various optical measurement techniques.

Course Contents

1. Measurement of the wavelength of He-Ne Laser and Na lamp using Michelson’s Interferometer. Study of fringes of equal inclination and equal thickness using Na lamp.
2. To measure the (a) optical path difference and (b) refractive index of transparent material using Mach Zehnder’s interferometer.
3. To measure the spacing between the tracks on a CD using Diffraction of laser light.
4. To determine the wavelength of Sodium light using Fresnel bi-prism. To find out the angle of bi-prism.
5. To find out the difference in wavelength of D1 and D2 lines of sodium light. To determine the wavelength of monochromatic light.
6. Verification of Malus' law. Measurement of reflection coefficient of a glass plate for p- and s-polarizations. Determination of Brewster angle.
7. To determine the (a) Numerical aperture, (b) splice loss and bending loss of a multi-mode optical fiber.
8. Demonstration of light amplification process through optical fiber as a gain media.
9. To generate Holographic images used laser based Holography.
10. To study electro-optic effect using Non-linear Optical Crystal.

Textbook

1. Ghatak A, Optics, 7th Edition Mc-graw Hill Publisher, 2021
2. F.L. Pedrotti, L. M. Pedrotti, L.S. Pedrotti, Introduction to Optics 3rd Edition, Pearsons, 2014.

Self-Learning Material

1. Barbastathis, G. and Sheppard C., Optics, https://ocw.mit.edu/courses/mechanical-engineering/2-71-optics-spring-2009/

Title	**EM Lab**	**Number**	**PHP2XXX**
Department	Physics	L-T-P [C]	0–0–3 [1.5]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite	None		

Objectives

The Instructor will:

1. Provide an experimental understanding of Electromagnetic Waves and Fields and their significance in various equipment's.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basics related to the EM waves, working principles of various measurement techniques.
2. Experimentally establish the theoretical concepts of EM.

Contents

1. To construct a Collimator and a Beam Expander using required optical components and measure the expansion in the laser beam spot size.
2. To construct a Telescope using required optical components and obtain a magnification of 20X.
3. To measure the FSR (free spectral range) and spacing of the etalon using Fabry-Perot etalon.
4. Electrodynamics Numerical Solver: Electrostatic field distribution and its characterization for circular geometrical structures.
5. Electrodynamics Numerical Solver: Electrostatic field distribution and its characterization for rectangular geometrical structures
6. (a) To determine the frequency and wavelength in a rectangular waveguide working on TE 01 mode. (b) Determination of V number.
7. To measure polar pattern and gain of a waveguide antenna.
8. Characterization of parabolic dish antenna, Effect of Impedance measurement for different coaxial cables and their frequency dependence.

Textbook

1. Jackson, J. D., Classical Electrodynamics, Wiley India Pvt. Ltd., 2007.
2. Griffiths, J. David, Introduction to Electrodynamics, Prentice Hall.

Reference Books

1. Lorrain, P. and Corson, D., Electromagnetic Fields and Waves, CBS Publishers, 2003.
2. Panofsky W.K.H. and Philips M., Classical Electricity and Magnetism, Dover Publishers, 1990.

Self-Learning course material

1. Dighe, A., Electrodynamics, Tata Institute of Fundamental Research, Mumbai, https://nptel.ac.in/syllabus/115101004/.
2. Gut, A., Lecture notes on Electromagnetism II, MIT open course ware https://ocw.mit.edu/courses/physics/8-07-electromagnetism-ii-fall-2012/lecture-notes/

13.3 Condensed Matter Physics

Title	**Thermal Physics**	**Number**	**PHL2XXX**
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite			

Objectives

The Instructor will:

1. Provide basic understanding and knowledge to thermal physics including both fundamental as well as applied aspects.

Learning Outcomes

The Students are expected to have the ability to:

1. Understand the fundamental laws of thermodynamics and statistical physics and applications.
2. Develop the ability and skill to apply the thermal physics principles to various thermo-dynamical systems and processes in different domains of physics and technology including condensed matter and semiconductor materials and devices.

Course Contents

Kinetic theory of gasses: Maxwell-Boltzmann speed distribution law, Mean free path, collision probability, Fundamentals of transport phenomena, Brownian motion and its significance, Einstein's theory of molecular diffusion, Perrin's experiment, random walk, Viscosity, diffusion, effusion, thermal conductivity in gas. [10 Lectures]

Principle of equipartition of energy: Specific heat of monoatomic, diatomic and polyatomic gasses, Specific heat of solids, Dulong-petit law, Virial expansion. [4 Lectures]

Thermodynamic laws and potentials: zeroth, 1st, 2nd, and 3rd laws of thermodynamics, Cyclic process, Carnot's theorem, Entropy and the concept of unavailable energy, T-S diagram thermodynamic potentials, Equation of state for Real gasses, deviation from ideal gas equation, The Van-der Waals equation of state, Clausius–Clapeyron relation, Gibbs- Helmholtz and energy equations, Enthalpy, Helmholtz and Gibbs free energies, general condition for thermodynamic equilibrium, thermodynamics of chemical reactions. [12 Lectures]

Phase Transitions: 1st and 2nd order phase transitions, Phase diagram and Triple point, Ehrenfest equations, Gibbs phase rule and simple applications. [6 Lectures]

Radiation: Energy density and pressure of radiation, Blackbody radiation and Kirchhoff's law, Blackbody (Cavity). [4 Lectures]

Statistical Physics: Principle of statistical physics, Concept of ensemble and introduction to different statistics. [6 Lectures]

Textbook

1. Schroeder D, An Introduction to Thermal Phsyics, Oxford University Press, 2021
2. Zemansky M W and Dittman R H, Heat and Thermodynamics, McGraw Hill, 2017

Reference Books

1. Kittel C and Kroemer H, Thermal Physics, W. H. Freeman Publication, 1980
2. Rief, F., Fundamental of Statistical and Thermal Physics, Waveland Press, 2009
3. Blundell S. J. and Blundell, K. M., Concepts in Thermal Physics, Oxford University Press, 2009
4. Saha Meghnad, Srivastava, A Treatise on Heat, Indian Press Ltd, 1935

Self-Learning course material

1. Banerji D., Thermal Physics, NPTEL course material, Department of Physics, IIT Kharagpur https://onlinecourses.nptel.ac.in/noc22_ph21/preview
2. Anand, T. N. C., Thermodynamics, NPTEL course material, Department of Mechnical Engineering, IIT Madras https://onlinecourses.nptel.ac.in/noc20_ce27/preview

Title	**Solid State Physics**	**Number**	**PHL3XXX**
Department	Physics	L-T-P [C]	3–0–2 [4]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite			

Objectives

The Instructor will:

1. Provide an introduction to crystals and their representation in physics.
2. Provide the concepts of thermal, electronic, magnetic and dielectric properties due to the periodic nature of crystals.

Learning Outcomes:

The Students are expected to have the ability to:

1. Understand the physical properties of crystalline materials using simple models and approximations.
2. Develop the understanding how many body interactions at quantum scale manifests into measurable and observable physical effects.

Course Contents

Crystal Structure and Crystal Binding: Solids and Liquids, Symmetry, Periodic Lattice, Unit Cell, Miller indices, Reciprocal Lattice, Brillouin Zone, X-ray diffraction and extinction rules. [11 Lectures]
Crystal Binding: Crystals of inert gasses, Van der Waals London interaction, Cohesive energy, Ionic, Covalent and Metallic bonding, Hydrogen bonds. [3 Lectures]

Phonons and Electrons in Solid: Phonon dispersion for mono and diatomic systems, Phonon heat capacity, Density of states, Einstein and Debye model of specific heat capacity, Thermal expansion and Thermal conductivity. [6 Lectures]

Electron in Periodic potential: Free Electron model, Density of states, Heat capacity, Electrical conductivity, Motion in magnetic field, Thermal conductivity and Lorentz number, Energy Bands, Bloch function, Kronig-Penney model, metals, semiconductors and insulators. [11 Lectures]

Magnetism and Superconductivity: Types of Magnetism, Quantum theory of dia and paramagnetism, Weiss model of Ferro and Antiferromagnetism, Domains and hysteresis, Meissner effect, Theoretical Models of Superconductivity, BCS theory, Josephson effect, Flux quantization. [11 Lectures]

Laboratory Experiments: Phonon dispersion, M-H hysteresis, Magnetic susceptibility, Electron spin resonance, Two probe and four probe resistivity, Dielectric constant and curie temperature, thermoluminescence, temperature dependent ionic conductivity; Report and/or presentation on Advanced topics in solid state physics selected by the instructor (Lab manuals will be provided)

Textbook

1. Kittel, C., Introduction to Solid State Physics, Wiley, 8th Edition, 2008.
2. Omar, M. A., Elementary Solid State Physics, Pearson, 2009.

Reference Books

1. Ashcroft, N., W. and Mermin, N., D., Solid State Physics, Cengage Learning, 1976
2. Simon, S., The Oxford Solid State Basics, Oxford University Press, 2013
3. Dekker, A. J., Solid State Physics, Springer, 1981

Self-Learning course material

1. Rangarajan, G., Condensed Matter Physics, NPTEL Course Material, Department of Physics, Indian Institute of Technology Madras, https://nptel.ac.in/courses/115106061/.
2. Wen, X-G., Physics of Solids I, MIT open course, https://ocw.mit.edu/courses/physics/8- 231-physics-of-solids-i-fall-2006/

Title	**Thin film and Material Characterization Lab**	**Number**	**PHP3XXX**
Department	Physics	L-T-P [C]	0–0–3 [1.5]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite			

Objectives

The Instructor will:

1. Describe techniques to deposit thin films on a substrate.
2. Demonstrate the structural, electrical, magnetic, thermal and mechanical characterization techniques for bulk and thin film materials.

Learning Outcomes

The students are expected to have the ability to:

1. Deposit thin films by simple techniques.
2. Measure the structural and physical properties viz, electronic, magnetic, optical and mechanical properties of bulk and thin film samples.
3. Perform Analysis and interpretation of the measured data.

Course Contents

1. Thin film deposition by spin-coating and dip-coating
2. Thin film deposition by thermal evaporation
3. X-Ray diffraction of bulk and thin film materials and analysis
4. Electron microscopy and or AFM to find the morphology and surface topography
5. Temperature dependent Resistivity and Magnetoresistance by four probe
6. Van der Pauw method for electrical resistivity and Hall bar geometry
7. Thermal conductivity measurement by Lee's disc method
8. Heat capacity (DSC/TGA)
9. Thermoelectric properties/ Seebeck coefficient of semiconductors
10. UV-Vis spectroscopy to find absorption edges of materials
11. Raman Spectra of solid sample
12. Stress-Strain and hardness measurement of bulk samples

Textbook

1. Kaufmann, E. N., Characterization of Materials, Wiley, 2012
2. Laboratory Manuals of equipment

Reference books

1. Ohring, M., Materials science of thin films, Elsevire, 2nd Edition, 2002
2. Maissel, L. I. and Glang, R., Handbook of Thin Film Technology, McGraw-Hill, 1970

Self-Learning course material

1. Alagarsam, P., Characterization of Materials, NPTEL course material, Department of Physics, IIT Guwahati, https://nptel.ac.in/courses/115103030
2. Review papers and Technical reports

Title	**Semiconducting and Optoelectronic Devices**	**Number**	**PHL3XXX**
Department	Physics	L-T-P [C]	3–0–2 [4]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite			

Objectives

The Instructor will:

1. Provide concepts on semiconducting and optoelectronic devices.
2. Show the approach to analyze and understand the physics of semiconducting device operation.

Learning Outcomes

The students are expected to have the ability to:

1. Know the operational principles of semiconducting and optoelectronic device.
2. Design a device for the desired application.

Course Contents

Basic Overview: Crystal Structure, quantum mechanics, solid state physics. [2 lectures]

Semiconductor in Equilibrium: Intrinsic carrier concentration, dopants, extrinsic semiconductor, distribution of carriers, location of Fermi level; charge transport, drift-diffusion equation; non-equilibrium semiconductor-generation and recombination, ambipolar transport, quasi-Fermi energy. [10 lectures]

Semiconductor Device: PN-junction diode, zero bias, reverse bias, junction breakdown, junction current, generation-recombination current, charge storage and diode transient, zener diode. [10 lectures]

Device Interface: Metal semiconductor barrier, Schottky contact, Ohmic contact, heterojunctions, MOSFET-C-V characteristics, I-V characteristics, frequency limitation, non-ideal conduction, MOSFET scaling, channel effects. [7 lectures]

Three terminal devices: Junction field effect transistor, device characteristics, non-deal effects, frequency limitation, high electron mobility transistor. [3 lectures]

Optoelectronic devices: Solar cells, photodetectors, light emitting diode, laser diodes. [5 lectures]

Next Generation Electronic devices: Materials and devices for Spintronics, Valleytronics and Plasmonics, Organic electronic. [5 lectures]

Laboratory: Band gap of semiconductor, Temperature dependent Hall effect, Temperature dependent electrical conductivity of doped semiconductor, Mobility of charge carrier, Capacitance-Voltage measurement, Characterization of solar cell, Quantum efficiency of solar cell, Output characteristic of LED, I-V characteristic of photodetector and phototransistors, Optical absorption and Photoluminescence, Report and/or presentation on Advanced topics in Semiconducting and Optoelectronic devices selected by the instructor.

Textbook

1. Semiconductor Physics and Devices, Donals A. Neamen
2. Solid State Electronic Devices, Ben G. Streetman, S. K. Banerjee

Reference Books

1. Physics of Semiconductor Devices, S. M. Sze

Self-Learning Material

1. Prof. M. R. Shenoy, Semiconductor Optoelectronics, NPTEL course material, Department of Physics, IIT Delhi, https://nptel.ac.in/courses/115102026

Title	Medical Physics	Number	PHL3XXX
Department	Physics	L-T-P [C]	2–0–0 [2]
Offered for	B.S. Physics	Type	Compulsory (PC)
Prerequisite			

Objectives

The Instructor will:

1. Introduce physics concepts and principles relevant for medicine and health.
2. Provide the introduction to physics driven modern diagnostic tools and various technology in the healthcare arena.

Learning Outcomes

The students are expected to have the ability to:

1. Get deeper insights into impact of physics in medical applications.
2. Apply physics based principles in the development of medical diagnostics and therapeutic.

Course Contents

Imaging techniques and Image analysis [PHL3XX1]:

(a) Optical and Radiological Imaging: Polarization Microscopy, Confocal Microscopy, Fluorescence Microscopy and Phase Contrast Microscopy, Breaking the diffraction limit in microscopy, Scanning near-field optical microscopy (SNOM), X-ray imaging and computerized Tomography (CT), Radioisotope imaging, Positron–emission Tomography, Hybrid imaging techniques (SPECT/CT, PET/CT).

(b) Resonance imaging and Image analysis: Principle of Nuclear Magnetic resonance and Magnetic Resonance Imaging, functional MRI, Principles of Image analysis including Advanced ML and AI techniques. [14 lectures]

Physics in Medical research and Therapeutic applications [PHL3XX2]:

(a) Interaction of radiation with matter, Interaction of photons with tissues, molecules, cells and organs, Bragg's Curve, Elastic and inelastic scattering, Thomson and Compton Scattering, Techniques of delivering radiation to human body.

(b) Plasma for Medicine and Nuclear Medicine: Low temperature plasma technology for medical research, Cold plasma applications in Therapeutic, Fundamentals of Nuclear Medicine, Radioactivity, Production of radionuclides, Radiation therapy for cancer treatment. [14 lectures]

Textbook

1. Cho, Z-H., Jones, J. and Singh, M. (1993), Foundations of Medical Imaging, 1st Edition Wiley Interscience
2. Pryma, D. A. (2015), Nuclear Medicine, 1st Edition, Oxford University Press
3. Murphy, D. B. and Davidson, M. W. (2012), Fundamental of Light Microscopy and Electronic Imaging, 2nd Edition, Wiley-Blackwell
4. Cherry, S. R., Sorenson, S. A. and Phelps M.E. (2012), Physics of Nuclear Medicine, Elsevier Inc.

Reference Books

1. Bushberg, J. T., J. Anthony S., Edwin M. L., and Boone, j., The Essential Physics of Medical Imaging. 2nd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2001.

Self-Learning Material

1. Sheet, D., Medical Image Analysis, Department of Electrical Engineering, IIT Kharagpur, https://nptel.ac.in/courses/108105091/
2. Jasanoff, A., MIT Opencourseware, Noninvasive Imaging in Biology and Medicine, https://ocw.mit.edu/courses/nuclear-engineering/22-56j-noninvasive-imaging-in-biology-and medicine-fall-2005/index.htm

13.4 Atomic and Subatomic Physics

Title	Physics of Atoms, Molecules and Nuclei	Number	PHL3XXX
Department	Physics	L-T-P [C]	0–0–3 [3]
Offered for	BS in PH	Type	Compulsory
Prerequisite	Mechanics II		

Objectives

1. To learn Atomic Physics with a problem solving approach towards atomic physics and spectroscopy.
2. To understand the stability of nucleus with nucleon interactions.

Learning Outcomes

1. The students will have an understanding of quantum behavior of atoms in external electric and magnetic fields.

Course Content

Hydrogen atom: Review of time-independent perturbation theory. Fine structure of the hydrogen atom spectra: Relativistic correction to the kinetic energy and spin-orbit coupling for one electrons systems. Review of the Dirac equation. Dirac equation in the non-relativistic limit. Effect of one electron system in electric and magnetic fields, introduction to Landau quantization. Spectroscopy Hyperfine interaction in atomic Hydrogen. Spectroscopy with the 21 cm emission line. [10 Lectures]

Line broadening mechanics and Interaction of electromagnetic radiation with a two-level atom: Line broadening mechanisms. Spontaneous and stimulated emissions and Einstein coefficients. Rabi flopping. Selection rules and transition probability. Transition probabilities and intensity of spectral lines. masers and lasers. [10 Lectures]

Many electron systems and Molecular Physics: Two-electron systems Electron configurations and spectroscopic notation, equivalent and non-equivalent electrons and Hund's rules. Hartree-Fock SCF method, Total Hamiltonian of a molecule. Born -Oppenheimer approximation. Rotational and Vibrational Spectra of molecules. Infrared and Raman Spectra analysis. The quantum treatment of Raman effect. Molecular Orbital and Electronic configuration of Diatomic molecules: H2, C2 and O2; Vibrational structure and vibrational analysis, Dissociation Energy of diatomic molecules. [10 Lectures]

Nuclear Models and Nucleon-nucleon interactions: Magic Number, Shell model, Nucleon mean potential, Deuteron nuclei potential and dipole moment. Low energy neutron-proton scattering, Spin dependence of neutron-proton interaction, Non-central force, Low energy proton-proton scattering, High-energy neutron-proton & proton-proton scattering, Meson theory of nuclear force, Nature of two nucleon potential. [10 Lectures]

Textbook

1. Bransden, B.H. and Joachain, C.J., (2004), Physics of Atoms and Molecules, Prentice Hall, 2nd Edition, Pearson Education, Delhi
2. B. L. Cohen, Concepts of Nuclear Physics, Tata Mcgraw Hill Education Private Limited, 2005, Third Edition.

References

1. Condon, E. U. and Shortley, G. H., (1951), The Theory of Atomic spectra, Cambridge University Press

Self-Learning Material

NPTEL : NOC:Atomic and Molecular Physics (Physics) (digimat.in)

1. NPTEL: by H.C. Verma Nuclear and Particle Physics https://nptel.ac.in/courses/115104043

Title	**Modern Physics lab**	**Number**	**PHP3XXX**
Department	Physics	L-T-P [C]	0–0–2 [1]
Offered for	BS in PH	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Provide the experimental techniques regarding the fundamental concepts of Modern physics using different measurement techniques.

Learning Outcomes

The students are expected to have the ability to:

2. Apply the concepts and become familiar with experimental aspects of Modern Physics.

Contents:

S. No. Name of the Experiment

1. Recording of Hydrogen Spectra - Rydberg Constant
2. Zeeman effect- Atom in a magnetic field
3. Speed of light
4. Stark effect- Hydrogen atom in an electric field
5. Dissociation Energy of Iodine molecule (I2) using Rowland Grating
6. Frank-Hertz Experiment
7. Charge of Electron- Millikan Oil drop method
8. Measurement of charge to mass ratio of an electron (e/m ratio)
9. Measurement of Planck's Constant
10. ESR Spectroscopy- Solids

Textbook

1. Melissinos Adrian C. and Napolitano J. Experiments in Modern Physics 2003, Academic Press

Self-Learning Material

1. Manuals of the Experiment.

Title	Nuclear radiation and energy	Number	PHL3XXX
Department	Physics	L-T-P [C]	2–0–0 [2]
Offered for	BS in PH	Type	Compulsory
Prerequisite	Mechanics II		

Objectives

The Instructor will:

1. Provide the basic physics of nuclear energy and radiation.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the applications of Nuclear radiations.

Course Contents

Introduction to Nuclear Radiation: Nuclear Transition, Multipole expansion of Nuclei, Nuclear Energy levels, Transition Selection Rules, Nuclear Interactions with matter. [8 Lectures]

Nuclear detection and measurements: Dosimetry, Image plate and Nuclear Calorimeter, MCP (Multichannel plates), Single Channel Analyzer (SCA) & Multi-channel analyzer (MCA), Coincidence counter (CC) and Anti-Coincidence counter (ACC). [5 Lectures]

Nuclear archaeology: Radiocarbon dating in archaeology, Calibration technique and estimation of archaeological artifacts. [8 Lectures]

Fission and Fusion reactors: Thorium cycles and Uranium Cycles, Nuclear reactor basics. [7 Lectures]

Textbook

1. Cohen B. L., Concepts of Nuclear Physics, McGraw-Hill Publisher, 1971.
2. Knoll. G., Radiation Detection and Measurement, John Wiley & Sons, Inc., 2000.

Self-Learning Material

1. Nuclear Engineering Science, MIT Opencourseware

Title	**Radiation and Particle Detection Lab**	**Number**	**PHP3XXX**
Department	Physics	L-T-P [C]	0–0–2 [1]
Offered for	BS in PH	Type	Compulsory
Prerequisite	None		

Objectives

The Instructor will:

1. Provide the experimental techniques regarding the concepts of radiation and particle detection techniques.

Learning Outcomes

The students are expected to have the ability to:

1. Apply the concepts and become familiar with experimental aspects of Radiations and Particles.

Course Contents:

S. No. Name of the Experiment

1. Gamma and Alpha Energy resolved measurement
2. Compton Scattering
3. Measurement of Dead-time in GM tube
4. Mass Spectroscopic TOF
5. Detection of Atmospheric Muon with Scintillator detector
6. Measurement of muon lifetime
7. Measurement of half-life of radioactive source
8. Track Detectors (CR-39)
9. Spark Chamber

Textbook

1. Melissinos Adrian C. and Napolitano J. Experiments in Modern Physics 2003, Academic Press

Self-Learning Material

1. Manuals of the Experiment.

Title	EM and Neutrino astronomy	Number	PHL4XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	BS in PH	Type	Compulsory
Prerequisite	Mechanics II		

Objectives

The Instructor will:

1. Provide basics of elementary particles and different interactions.
2. Describe observation techniques in astrophysics and its interpretation.

Learning Outcomes

The students are expected to have the ability to:

1. Understand the interactions of elementary particles.
2. Understand details about multi-wavelength astronomy.

Course Contents

Elementary particles:
Kinematics of high energy collisions, Pi mesons, Muons and their properties, Strange mesons, Hyperons, Resonance particles, Fundamental interactions in nature, Quark hypothesis of elementary particles, Classification of elementary particles, Neutrino oscillation, Conservation laws. [10 Lectures]

Basics of Astronomy:
Celestial coordinates, brightness, absolute and relative magnitude. Properties of stars with optical radiations: Hertzsprung-Russel (HR) diagram, size, mass and temperature of stars. Reading Hipparcus catalogue for stars and making the HR diagram for open and closed clusters. [10 Lectures]

Radio, X-ray and gamma-ray Astronomy:
Radio emission from astrophysical objects, Radio HR-diagram, Radio emission from Pulsars, H1 emission from Galaxies, Quasars.
X-ray and Gamma-ray radiations from high energy astrophysics phenomena: cataclysmic variable, Neutron Stars, Active Galactic nucleus, Gamma ray Bursts, Starburst Galaxies etc. X-ray and gamma-ray satellite detectors. [10 Lectures]

Cosmic Rays:
CR spectrum, Direct and Indirect detection of CRs, Origin of Galactic and Extragalactic CR sources. [10 Lectures]

Sky-mapping with neutrinos:
Dynamics of expansion, The cosmic neutrino background, Neutrino temperature, Solar neutrinos, Supernova neutrinos, Neutrinos as dark matter. Ultra-high energy Neutrinos, Neutrino Telescopes. [10 Lectures]

Textbook

1. Peskin M. E., (2019), Concepts of Elementary Particle Physics, Oxford Master Series.
2. Unsöld A., and Baschek B., (2002) The New Cosmos - Introduction to Astronomy and Astrophysics, Addison-Wesley Press.

Reference Books

1. Zeilik, Michael, and Stephen A. Gregory. Introductory Astronomy and Astrophysics. 4th ed. Fort Worth, TX: Saunders College Publishing, 1997.

Self-Learning Material

1. Saul Rappaport. 8.282J Introduction to Astronomy. Spring 2006. Massachusetts Institute of Technology: MIT OpenCourseWare
2. https://ocw.mit.edu.

Title	Entrepreneurship for Physicists	Number	PHLXXX
Department	Physics	L-T-P [C]	2-0-0 [2]
offered for		Type	SC
Prerequisite			

Objectives

The Instructor will:

1. Provide students the knowledge about the charms of being an entrepreneur.
2. Provide the information about entrepreneurship and important theories, models, tools and usage that could help students transform an idea into business.

Learning Outcomes

The students are expected to:

1. Clear the doubts and perplexities that physicists have towards everything that is related to business.
2. Understand the exciting aspects of the entrepreneurial process that brings ideas to market.

Course Contents

Invention and Innovation: Introduction to research, Variables and definitions, Invention and Innovation, Process and product innovation, Innovation driven entrepreneurship, Technology intelligence with case studies, Entrepreneurship mind set and culture. [8 Lectures]

Intellectual Property and Early Business Processes: Introduction to IPRs, Patent search & Analytics, Patent and copyright drafting, Techno-economic feasibility analysis, Understanding business plan and funding opportunities for entrepreneurs, Characteristics of entrepreneur, Risk factors in entrepreneurship, Technology business incubation, Venture capital. [10 Lectures]

Entrepreneurship Tools and Techniques: Ideation based on available resources, Market demands and societal needs, Hackathon, Pitching, Market push and pull, Project Management Tools & Techniques, Scheduling of Project Plan, Project risk management, Effectuation theory, Business canvas, Introduction to detailed project report (DPR). [10 Lectures]

Textbook

1. Davide Iannuzzi "Entrepreneurship for Physicists" Morgan & Claypool Publishers, ISBN: 978-1-6817-4669-2 (2017).
2. K Nagarajan "Project Management" New Age International Publishers, ISBN-13:978-9386286024 (2017).
3. David Bainbridge "Intellectual Property" Pearson 10th edition, ISBN-13: 978-1292002644 (2018).

Reference Book

1. Kunal Upadhyay "Hand book on Non Profit incubator Manager' Handbook for Incubator Managers.pdf (niti.gov.in)
2. The Innovator's Toolkit: 10 Practical Strategies to Help You Develop and Implement Innovation (Harvard Business Essentials): ISBN-13 978-1-4221-990-9 (2019).

13.5 Specialization: Photonics

Title	Fundamentals of Photonics	Number	PHL7XX0
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	(SC)
Prerequisite			

Objectives

1. To understand the fundamental aspects of light wave, its propagation in the medium and concepts of polarization & image formation.
2. To understand the principle of light confinement, Wave guiding and propagation through photonic systems
3. To provide the foundation of Nonlinear Optics.

Learning Outcomes

1. The students will become familiar with the interesting concepts of photonics including principles of polarizers, waveguides, resonators and fibers; Also, provides a roadmap to develop specialized knowledge in the field of photonics.
2. Understanding of the Light propagation and guidance in photonic crystals and optical fibers.
3. Understanding of the basic concepts of Nonlinear Optics

Course Contents

Wave propagation in dielectric: group velocity and dispersion, pulse spreading, plane wave and Helmholtz equation, Gaussian and Bessel beams. [5 Lectures]

Polarization states and representation: Jones vector, Stokes parameters for polarized and unpolarized light, Poincare sphere, Coherence- linewidth, spatial coherence, interference and applications. [6 Lectures]

Fourier optics: free space light propagation, optical Fourier transform, introduction to diffraction of light, concept of image formation. [5 Lectures]

Optical Resonators: mode and mode density, losses and spectral width, quality factor, light modulation, mode stability, Fabry-Perot etalon, ring resonators, micro-resonators. [5 Lectures]

waveguides and Photonic crystals: TIR guidance, Modes, conventional wave guides, periodic media and Bloch waves, concept of photonic bandgap, 1D, 2D and 3D crystals, dispersion relation, PhC wave-guidance, basics of optical fibers, types of the fibers, Photnic crystal fibers. [12 Lectures]

Nonlinear Optics: Description of Nonlinear optical processes: Second Harmonic Generation, Sum frequency generation, Difference frequency generation, optical parametric oscillation, Third harmonic generation, Intensity-Dependent Refractive Index, Saturable absorption, two-photon absorption, stimulated Raman scattering, Kramers–Kronig Relations in Linear and Nonlinear Optics, four-wave mixing, concept of soliton. [9 Lectures]

Textbook

1. Yariv, A., and Yeh, P., Photonics, Oxford University Press, 2007.
2. Saleh, B. E. A. and Teich, M. C., Fundamentals of Photonics, Wiley, 2018.
3. Boyd, R., Introduction to Nonlinear Optics, Third Edition, AP publishing, 2008.

Self-Learning Material

1. Srinivasan, B., Introduction to Photonics, https://onlinecourses.nptel.ac.in/noc19_ee20/preview

Reference Course Material

1. Ghatak, A. K., and Thyagarajan, K., Optical Electronics, Cambridge University Press, 2002.

Title	**Laser Physics**	**Number**	**PHL7XX0**
Department	Physics	L-T-P [C]	2–0–0 [2]
Offered for	B.S. Physics	Type	(SC)
Prerequisite			

Objectives

1. This course aims to introduce the basics of Lasers and laser design.
2. Introducing the state-of-the art laser systems and their industrial applications

Learning Outcomes

1. Provides students with basic knowledge of laser physics.
2. Understanding the light-matter interactions
3. Gain the required knowledge to design advanced lasers.

Course Contents

Introduction: EM Wave equation, Radiation and its quantification, Atomic transitions and radiative process, Einstein relations and Planck's Law, principle of Lasers, Laser Oscillation, Optical amplification, Characteristics of Laser light. [6 Lectures]

Light-matter interactions: Atomic Polarizability, Dielectric constant, Electric Polarization and Susceptibility, electron model-classical oscillator, dispersion and complex refractive index [5 Lectures]

Laser Design: Optical resonators, sources of light and pump sources, Lasing mechanisms in 3 and 4 level systems and rate equations, operation of Lasers, Coherence, Laser Line width, optical gain, gain saturation, hole burning, Line broadening, laser modes, Gaussian Beam and Gouy phase shift, Beam Quality factor and laser output beam properties. [10 Lectures]

Practical Lasers and applications: concept of CW lasers and Pulsed Lasers, Solid State Lasers, Semiconductor lasers, Gas Lasers (He-Ne, CO_2), Overview on Industrial Application of Lasers including laser inscription and data storage [7 Lectures]

Textbook

1. Siegman, A., Lasers, Mill Valley, Calif. University Science Books, 1986
2. Yariv A. & Pochi Yeh, Photonics, Oxford University Press, 2006.
3. Ghatak, A. & Thyagarajan, K., Optical electronics, Cambridge University Press, 2011.

Self-Learning Material

1. Introduction to Laser by Prof. M. R. Shenoy, IITD. https://nptel.ac.in/courses/115102124

Reference Course Material

1. Orazio Svelto, Principles of Lasers, Springer, 2010

Title	**Terahertz Technology**	**Number**	**PHL7XX0**
Department	Physics	L-T-P [C]	3–0–2 [4]
Offered for	B. S. Physics	Type	(SC)
Prerequisite			

Objectives

1. This course aims to introduce the science and technologies of Terhertz radiation.
2. To provide comprehensive knowledge on THz generation, delivery and detection.
3. To provide the overview of the state-of-the art Terahertz technologies and applications.

Learning Outcomes

1. The students will be familiar with the foundation of Terahertz science and Technology.
2. Understanding of the current THz technologies and appreciate the scope and the challenges for future development THz technology.

Course Contents

Fundamentals of Terahertz science: Terahertz band, basic theory of Terahertz interaction with matter, Electromagnetic Waves in Matter, Electric Dipole Radiation, Terahertz Radiation and Elementary Excitations. [5 Lectures]

THz Optics: Dielectric Properties of Solids in the Terahertz Region, Materials for Terahertz Optics, Optical components for THz propagation and modulation, Terahertz Waveguides, Theory of Rectangular Waveguides, Dielectric/plastic Fibers, Artificial Materials at Terahertz Frequencies: Metamaterials, Photonic Crystals, Plasmonics. [12 Lectures]

THz sources and detectors: BWO (backward wave oscillator), klystron, gyrotron, Difference Frequency Generation and Parametric Amplification, Frequency Multiplication of Microwaves, Quantum Cascade Lasers, Generation of Terahertz Pulses from Biased Photoconductive Antennas, Optical Rectification, Free-Space Electro-Optic Sampling, Bolometer, Pyroelectric Detector, Golay Cells. [14 Lectures]

THz Technologies: Terahertz spectroscopy, THz imaging, THz sensing, THz frequency security system, Toward 6G Communication Networks, Atmospheric THz propagation and Terahertz communications, Industrial applications. [11 Lectures]

Lab component:

1. THz generation using femtosecond pulses
2. THz detection through electro-optical sampling
3. THz bandwidth measurement
4. THz absorption spectrum for air and Nitrogen

Textbook

1. Yun-Shik Lee, Principles of Terahertz Science and Technology, Springer, 2009.
2. Daryoosh Saeedkia, Handbook of terahertz technology for imaging, sensing and communications, Woodhead Publishing Limited, 2013.

Reference Course Material

1. Ho-Jin Song, Tadao Nagatsuma, Handbook of Terahertz Technologies: Devices and Applications, Taylor and Francis Group, 2015.

Title	**Photonic Devices**	**Number**	**PHL7XX0**
Department	Physics	L-T-P [C]	2–0–2 [3]
Offered for	B.S. Physics	Type	(SC)
Prerequisite			

Objectives

1. This course aims to introduce working principles and applications of Photonic devices.
2. To provide a comprehensive overview of the state-of-the art photonic components and devices.

Learning Outcomes

1. The course provides students with basic knowledge of components for light based technologies.
2. Students will be familiar with necessary knowledge of working principles on future All Photonic devices.

Course Contents

Lightwave components and devices: Optical directional coupler-coupling length, coefficient's, applications: photonic switches; optical routers, optical amplifiers-Er doped fiber amplifier, Dielectric waveguides, Planar waveguide and strip waveguide, splicers, connectors. [10 Lectures]

Light modulation components and devices: Birefringence, Acousto-optic effect, Raman-Nath AO modulator, Bragg Modulator, Electro-optic effect, Electro-optic crystals, Kerr modulator, Magneto-optic effect, Isolators, Electro-absorption modulator, optical modulators, SLM, Quantum Modulators. [10 Lectures]

Advanced Photonic components and devices: Photonic crystal fibers, Fiber optic sensors, Optical detectors, Nonlinear optical devices, power limiters, Optics on chip, ultrafast laser and direct laser writing, Lifi, Fiber Bragg grating, Laser Tweezers and scissors. [10 Lectures]

Lab Component:

1. Optical coupler and characterization
2. Fiber Bragg grating and characterization
3. Study of Electro-optic effect (Kerr effect)
4. Light modulation with SLM
5. Birefringence/beat length measurement of a polarization maintaining optical fiber
6. Splicing optical fiber and studying splice loss
7. Optical power limiting by nonlinear optical material

Textbook

1. Ghatak, A. & Thyagarajan, K., Optical electronics, Cambridge University Press, 2011.
2. Shun Lien Chuang, Physics of Photonic Devices, Wiley publisher, Second edition, 2009.

Self-Learning Material

1. Integrated Photonics Devices and Circuits by Prof. Bijoy Krishna Das, IITM
   https://archive.nptel.ac.in/courses/108/106/108106180/#

Reference Course Material

1. Saleh, B. E. A. and Teich, M. C., Fundamentals of Photonics, Wiley, 2018.
2. John Wilson and John Hawkes, Optoelectronics, Pearson, Third edition, 2019.

Title	**Contemporary Optics**	**Number**	**PHL7XXX**
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	SE
Prerequisite			

Objectives

The Instructor will provide:

1. The concepts regarding optical aberrations and theory of diffraction.
2. Basic understanding of optical instruments using Fourier Optics and their common applications.

Learning Outcomes

The students are expected to have the ability:

1. To gain the knowledge to correct optical aberrations in the optical instruments.
2. To evaluate and estimate the processes involving the Incoherent and partial coherent light.

Contents

Geometrical Optics and Diffraction: Paraxial Ray Optics, optical aberrations, Fresnel-Kirchhoff's diffraction, Scalar theory of diffraction Diffraction of Aperture: Square, Rectangle, Circular, Fresnel and Fraunhofer diffraction. [14 Lectures]

Partially coherent light: Mutual Coherence and Degree of Coherence, Propagation of Partially Coherent Light, Cross-Spectral Density Function, van cittert -Zernike theorem. [8 Lectures]

Fourier Optics: Convolution, spatial correlation, optical filtering, spatial filtering and optical transfer function (OTF), point split function (PSF), ex: microscope, Image Formation, Frequency Analysis.
[14 Lectures]

Introduction to optical instruments: Spectrometers, monochromators, Polarimeters and detectors. [6 Lectures]

Textbook

1. Contemporary Optics, Ghatak and Thyagarajan

Reference Book:

1. Optics by Born & Wolf (7th edition)
2. K K Sharma, Optics: Principles and Applications, Academic Press 2006.

Title	BioPhotonics	Number	PHL7XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	SE
Prerequisite			

Objectives

The Instructor will provide:

1. This course aims to introduce the concept of light interaction with biological matter.
2. To provide comprehensive knowledge on existing tissue and cell engineering through photonic techniques.
3. To provide the overview of the state-of-the art Bio-imaging and Bio-sensing techniques.

Learning Outcomes

The students are expected to have the ability:

1. The students will be familiar with the foundation of Biophotonics.
2. Understanding of the Biophotonic tools and techniques for interdisciplinary applications.

Course Contents

Introduction: Biophotonics a new frontier, nature of light, quantized states of matter, introductory concepts of biology, various types of cells, cellular structure, interactions determining three-dimensional structures of biopolymers, cellular processes, protein classification and function, organization of cells into tissues, types of tissues and their functions, tumors and cancers. [5 Lectures]

Fundamentals of Light–Matter Interactions: Interactions between light and a molecule, interaction of light with a bulk matter, fate of excited state, the various spectroscopies useful for biophotonics: electronic absorption spectroscopy, electronic luminescence spectroscopy, vibrational spectroscopy, spectroscopy utilizing optical activity of chiral media, fluorescence correlation spectroscopy. [6 Lectures]

Photobiology: interaction of light with cells, interaction of light with tissues, in vivo photoexcitation, methods of light delivery for in vivo photoexcitation, optical biopsy. [4 Lectures]

Biomaterials for Photonics: Bioderived materials, bioinspired materials, biotemplates, bacteria as biosynthesizers for photonic polymer. [4 Lectures]

Bioimaging: Principles and techniques for optical methods of imaging: transmission microscopy, fluorescence microscopy, scanning microscopy, confocal microscopy, multiphoton microscopy, optical coherence tomography, low coherence interferometry, Angle resolved interferometry for biological tissue imaging, near-field optical microscopy, fluorescence lifetime imaging microscopy (film), nonlinear optical imaging. [11 Lectures]

Biophotonics Applications: Optical biosensors- fiber optic biosensors, planar waveguide biosensor, evanescent wave biosensors, spr biosensor, flow cytometry: basic steps, the components, optical response, photodynamic therapy and applications, tissue engineering with light: tissue engineering and light activation, laser tissue contouring and restructuring, laser tissue welding, femtolaser surgery, Lab-on-a-Chip Technology. [12 Lectures]

Textbook

1. Paras N. Prasad, Introduction to BioPhotonics Wiley, 2003.
2. Gerd Keiser, Biophotonics Concepts to Applications, Springer, 2016.

Reference Book:

1. Jürgen Popp, Valery V. Tuchin, Arthur Chiou, Stefan H. Heinemann, Hand book of Biophotonics, Wiley, 2012.

Self-Learning Material

1. Biophotonics by Prof Basudev Lahiri https://nptel.ac.in/courses/127105225

Title	Plasmonics	Number	PHL7XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	SE
Prerequisite			

Objectives

The Instructor will provide:

1. This course aims to introduce light interaction with metals.
2. To provide comprehensive knowledge on Surface plasmon polaritons, localized surface plasmons and plasmon waveguides.
3. To provide the overview of the state-of-the art SERS based techniques and other plasmonic applications.

Learning Outcomes

The students are expected to have the ability:

1. The students will be familiar with the foundation of Plasmonics and functional devices.
2. Understanding the plasmonic enabled technologies including sensing and imaging.

Course Contents

Electromagnetics of Metals: Maxwell's Equations and Electromagnetic Wave Propagation, Drude model, The Dielectric Function of the Free Electron Gas, The Dispersion of the Free Electron Gas and Volume Plasmons, Mie theory, Drude–Sommerfeld Model, Drude–Lorentz Model, Real Metals and Interband Transitions, The Energy of the Electromagnetic Field in Metals. [8 Lectures]

Surface Plasmon Polaritons: Surface Plasmon Polaritons at a Single Interface, Multilayer Systems, Energy Confinement and the Effective Mode Length, excitation of surface plasmon polaritons, Prism Coupling, Grating Coupling, Near-Field Excitation, other coupling schemes, imaging surface plasmon polariton propagation. [10 Lectures]

Localized surface Plasmons: Normal Modes of Sub-Wavelength Metal Particles, Mie Theory, Beyond the Quasi-Static Approximation and Plasmon Lifetime, Observations of Particle Plasmons, Coupling Between Localized Plasmons. [6 Lectures]

Plasmon waveguides: Rectangular Hollow Metallic Waveguides and Resonators, Waveguide Modes, behaviors of TE and TM Modes, Solutions for TEmn and TMmn Modes, Attenuation in Rectangular Waveguides, Excitation of Waveguides by Probes, Loops, and Slots , Rectangular Cavity Resonators, Transverse Magnetic TMmnp Resonator Modes, Quality Factor, Planar Elements for Surface Plasmon Polariton Propagation, Surface Plasmon Polariton Band Gap Structures, Surface Plasmon Polariton Propagation Along Metal Stripes, Localized Modes in Gaps and Grooves, Metal Nanoparticle Waveguides. [10 Lectures]

Plasmonics Applications: enhancement of emissive processes SERS basics, SERS in the Picture of Cavity Field Enhancement, SERS Geometries, Enhancement of Fluorescence, Luminescence of Metal Nanostructures and bioimaging applications, Spectroscopy, sensing and metamaterials, photodynamic therapy. [8 Lectures]

Textbook

1. Stefan Alexander Maier, Plasmonics: Fundamentals and Applications, Springer, 2007.
2. Liudmila Nickelson, Electromagnetic Theory and Plasmonics for Engineers, Springer, 2019.

Reference Book:

1. Sabine Szunerits, Rabah Boukherroub, Introduction to Plasmonics, Pan Stanford Publishing, 2015.

Title	**LED Technology**	**Number**	**PHL7XXX**
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.S. Physics	Type	SE
Prerequisite			

Objectives

The Instructor will provide:

1. This course aims to introduce fundamentals and working mechanisms of light emitting diodes.
2. To provide comprehensive knowledge on LED device structure and their classifications.
3. To provide the overview of the state-of-the art and advanced LEDs for various applications.

Learning Outcomes

The students are expected to have the ability:

1. The students will be familiar with the materials for LED devices and their characteristics.
2. Understanding the various existing LEDs and their speciality applications.
3. They will acquire knowledge on design and development of advanced LEDs for future applications.

Course Contents

Radiative and non-radiative processes: Electroluminescence, Radiative electron−hole recombination, Radiative recombination for low-level and high-level excitations, Luminescence decay, Non-radiative recombination in the bulk and surfaces, Competition between radiative and non-radiative recombination, Theory of radiative recombination. [7 Lectures]

LED basics-Electrical and Optical: Diode current–voltage characteristic, Carrier distribution in p-n homojunctions and heterojunctions, Electron injection and blocking layers, EL spectrum, Radiation pattern, internal and external quantum efficiency measurements, The lambertian emission pattern, Temperature dependence of emission intensity. [12 Lectures]

LED Design parameters: Device structure, Junction and carrier temperatures, High internal efficiency designs, Doping of the confinement regions, Design of current flow, High extraction efficiency structures, Light Output per LED, Reflectors. [6 Lectures]

Types of LEDs: Flashing LEDs, Visible-spectrum LEDs (GaAsP, GaP, GaAsP:N, and GaP:N, AlGaAs /GaAs, AlGaInP /GaAs and GaInN material systems), Organic LEDs, polymer LEDs, UV LEDs, LED lasers-Spontaneous emission from resonant cavities, Resonant-cavity light-emitting diodes, White-light sources based on LEDs. [7 Lectures]

Advanced LEDs and Applications: LEDs and Lighting - LED Light bulbs, High-Brightness (HB) LEDs, LEDs in communications-IR Remote Operation (TV Remote Control, Remote Control LEDs), LEDs for fiber-optic communication, Ethernet Networking, LED Displays, UV LED applications in Health care and water treatment. [10 Lectures]

Textbook

1. E. Fred Schubert, Light-Emitting Diodes, Cambridge University Press, Second edition, 2006.
2. Gilbert Held, Introduction to Light Emitting Diode Technology and Applications, CRC Press, 2009.

Self-Learning Material

1. Semiconductor optoelectronics (Lecture 27 to 31) by Prof. Shenoy, IITD.
   http://www.nitttrc.edu.in/nptel/courses/video/115102103/L27.html

13.6 Specialization: Advanced Energy Materials

Title	**Materials for Energy Technologies**	**Number**	**PHL6XX0**
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for		Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce different energy/power generation systems and emphasize on the need of materials and its engineering for these systems/sub-systems.

Learning Outcomes

The students are expected to have the ability to:

1. Get aware of different energy generation systems and their functioning.
2. Materials related issues and challenges in such energy technologies and engineering pathways towards their mitigation.

Course Contents

PHL6XX1 (Conventional Energy systems) [1-0-0]

1. Building blocks of conventional energy systems (Coal and Hydro- energy power plants), working mechanism of different components and thermodynamics of these system. [5 lectures]
2. Need of materials with specific characteristics, Generation block, transmission block, Materials for high voltage transformers, Turbine materials. [9 lectures]

PHL6XX2 (Solar thermal and solar photovoltaic systems) [1-0-0]

1. Solar thermal system/sub-systems as a power generation unit. Need of materials in solar-thermal subsystems: Issues and Challenges, Materials for collectors, reflectors, thermal fluid, storage materials, and structure [7 lectures]
2. Solar photovoltaic system/sub-systems as a power generation unit, Need of materials for photovoltaic cells, issues and challenges, Materials for electrical storage, Structure. [7 lectures]

PHL6XX3 (Wind, Geothermal and Nuclear Energy systems) [1-0-0]

1. Wind and Geothermal energy generation sub-systems/systems, need of materials for designing wind blades for different environmental conditions, and geothermal systems. [8 lectures]
2. Nuclear power generations systems/sub-systems, mechanism and materials requirement for source, safety materials issues and challenges, high temperature materials for thermal management, materials for managing nuclear reactions. [6 lectures]

Textbook

1. Sukhatme S. P. and Nayak J. K., Solar Energy: Principles of Thermal Collection and Storage, McGraw-Hill, 2008
2. Duffie J. A. and Beckmann W. A, Solar Engineering of Thermal Processes, 3rd Ed John Wiley 2006

Self-Learning Material

1. Online review papers in various journals.

Preparatory Course Material

1. Online NPTL and MIT courses.

Title	Fabrication and Characterization of Devices	Number	PHLXXX
Department	Physics	L-T-P [C]	0-0-2 [1]
offered for		Type	SC
Prerequisite			

Objectives

The Instructor will:

1. Provide the knowledge to recognize an energy harvesting device.
2. Provide the information about the tools to characterize the energy harvesting devices.

Learning Outcomes

The students are expected to:

1. To fabricate nanomaterials based devices.
2. To characterize the device.

Course Contents

1. Synthesis and characterization of metal nanomaterials
2. Synthesis and characterization of semiconducting nanomaterials
3. Fabrication of micropatterns by lithographic techniques
4. Fabrication and characterization of solar cells
5. fabrication and characterization of batteries
6. Fabrication and characterization of supercapacitors

Textbook

T. Pradeep, A Textbook of Nanoscience and Nanotechnology, 2012, Tata McGraw Hill Education Private Limited

Title	Hydrogen Generation, Storage and Applications	Number	PHLXXX
Department	Physics	L-T-P [C]	3-0-0 [3]
Offered for		Type	SC
Prerequisite			

Objectives

The Instructor will:

1. Provide knowledge about hydrogen energy, various ways of its production and storage.
2. Provide the role of materials in hydrogen generation, storage and uses of different hydrogen technologies.

Learning Outcomes

The students are expected to:

1. Understand the fundamentals of hydrogen technology, using it as a way to store energy.
2. Gain a better understanding of thermodynamics, electrochemistry and their applications to energy conversion and storage.
3. Learn how various materials can be exploited to realize the production of green hydrogen and its storage for various applications.
4. Understand theoretical and practical limits of hydrogen energy conversion among various forms and corresponding efficiencies.

Course Contents

Introduction: Renewable Energy Sources, Fundamentals of hydrogen energy, Relevance of hydrogen in relation to depletion of fossil fuels and environmental considerations, Various types of hydrogen based on its ways of production. Various factors relevant to safety, use of Hydrogen as Fuel. [6 Lectures]

Hydrogen Generation: Methods for sustainable hydrogen generation, electrochemical and photoelectrochemical water splitting, working mechanism of electrochemical water splitting, HER mechanism, OER mechanism, Physics of material characteristics for production of hydrogen, electrochemical potential, artificial photosynthesis, Parameters for assessing the electrochemical performance: Tafel slope, electrochemical active surface area, turnover frequency, Faradaic efficiency. [12 Lectures]

Hydrogen Storage: Hydrogen storage methods, compressed hydrogen, liquid hydrogen, Cryogenic hydrogen storage, Physical and Chemical storage of hydrogen, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials, Carbon storage materials, Metallic and complex hydrides, New Storage Modes. [12 Lectures]

Hydrogen Applications: Hydrogen in industry, Hydrogen for Electricity Generation, Introduction and overview of Fuel Cells, Various type of Fuel Cells, Working Mechanism of Fuel Cells, Thermodynamics and reaction kinetics of fuel cells, Fuel cell characterization, Applications of Fuel Cell, Voltage generation in a fuel cell, Fuel cell modeling and system integration, Elementary concepts of other Hydrogen Based devices such as Hydride Batteries. [12 Lectures]

Textbook

1. Hydrogen as an Energy Carrier Technologies Systems Economy: Winter, C. J. and Joachim Nitsch.
2. Hydrogen Fuel Production, Transport, and Storage Edited by Ram B . Gupta CRC Press 2008.

Reference Book

1. Fuel Cells and Hydrogen Production 2 Vol Set 2nd Edt. by Lipman TE, Springer.
2. Hydrogen as a Future Energy Carrier: Andreas Zuttel, Andreas Borgschulte and Louis Schlapbach.
3. Fuel Cells Principles, Design, and Analysis By Shripad T. Revankar, Pradip Majumdar, CRC Press 2014.

Online Course Materials

1. NPTEL Course on Fuel Cell Technology by Prof. S. Basu, Dr. Anil Verma. https://nptel.ac.in/courses/103102015

2. Prof. Pal K., NPTEL Course Material, Hydrogen Production from Electrolysis, Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, https://www.youtube.com/watch?v=Nf3r2mphRPI
3. Prof. Pal K., NPTEL Course Material, Hydrogen Storage, Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, https://www.youtube.com/watch?v=6EOVaK2Pn9c

Self-Learning Material
to be added here

Preparatory Course Material

NPTEL Course on Fuel Cell Technology by Prof. S. Basu, Dr. Anil Verma. https://nptel.ac.in/courses/103102015

Title	Electrical Energy Storage Materials and Devices	Number	PHLXXX
Department	Physics	L-T-P [C]	3-0-0 [3]
offered for		Type	SC
Prerequisite			

Objectives

The Instructor will:

1. Provide the knowledge about the principles and configurations of conventional and advanced electrical energy storage devices.
2. Provide the role of materials in electrical energy storage and conversion technologies.

Learning Outcomes

The students are expected to:

1. Understand how the fundamental properties of materials can be exploited to realize an electrical energy storage device.
2. Understand the working mechanisms of various existing electrical energy storage technologies as well as emerging technologies of the field.

Course Contents

Introduction: Historical background, Overview of Electrical Energy Storage Materials and Devices, Ragone Plot, Chemical and Electrochemical reactions, primary and secondary batteries, Applications of Batteries and Supercapacitors. [6 Lectures]

Batteries: Battery Components, Working Mechanism, Gibbs Free Energy, electrochemical potential, Battery Parameters: Charge Capacity, Specific Energy, Specific Power, Energy density, Amp hour efficiency, C-rate, Columbic efficiency, Operating Voltage, Self-discharge. Theoretical capacity of battery, Intercalation and Conversion Materials. [9 Lectures]

Battery Technologies: Lead-Acid battery, Nickel-Cadmium battery, Metal-ion batteries: Lithium, Sodium and Potassium, Li-Polymer batteries, Multivalent metal-ion batteries: Magnesium, Aluminum, Zinc. Metal-air battery, Redox-flow battery, Photo rechargeable battery. [12 Lectures]

Supercapacitors: Difference between Supercapacitor and Battery, Working Mechanism, Electrolyte and Electrode materials, Characterization of Supercapacitors, Types of Supercapacitor: Electric double layer capacitor, Pseudo supercapacitor and Hybrid Supercapacitor. Technical Challenges. [9 Lectures]

Technical Challenges: Thermal runaway, Dendrite formation, Voltage limits. Electrolytes: Liquid, Polymer gel, Solid, Solid-polymer, Physics of electrolytes, Electrode material modeling, Future trends. [6 Lectures]

Textbook

1. Reiner Korthauer (Ed), Lithium-Ion Batteries: Basics and Applications, Springer (2013).
2. Cheong,K.Y., Impellizzeri,G., and Fraga, M.A. Emerging Materials for Energy Conversion and Storage 1st Edition, Elsevier (2018)

Reference Book

1. Rosen M. A. Energy Storage, Nova (2012)
2. Robert A. Huggins, Advanced Batteries, Springer (2009)

Online Course Materials

1. Prof. Bazant M., MITopencourseware: Electrochemical Energy Systems, MIT Course Number 10.626 / 10.426, https://ocw.mit.edu/courses/chemical-engineering/10-626-electrochemical-energy-systems-spring-2014/
2. Prof. Pal K., Selection Of Nanomaterials For Energy Harvesting And Storage Application, NPTEL Course Material, Mechanical Engineering, Indian Institute of Technology Roorkee, https://nptel.ac.in/courses/112/107/112107283/

Self-Learning Material

1. Tester W.J., et al., Fundamentals of Advanced Energy Conversion, MIT open course, https://ocw.mit.edu/courses/mechanical-engineering/2-60-fundamentals-of-advanced-energy-conversion-spring-2004/

Preparatory Course Material

1. Maiti, H.S., Lithium Ion Battery, NPTEL Video Lecture https://www.youtube.com/watch?v=no4vRKvKxcU

Title	Solar Resource Assessment and Its Management	Number	PHL6XX0
Department	Physics	L-T-P [C]	3–0–0 [3]
offered for	B.S./ B.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Introduce physics of solar radiation covering the blackbody radiation and UV catastrophe, Sun-Earth realtions, Sun observer raltions and collector orientation and shading effects with resource data and measurements, its analysis, and prediction using ML and AI.

Learning Outcomes

The students are expected to have the ability to:

1. Obtain a flavor of solar resource data, its measurement with its utility for solar thermal and photovoltaic power plant applications.
2. Management of data, handling and use of ML/AI for its prediction.

Course Contents

PHL6XX1 (Basics of Sun-Earth Relationship and solar radiation) [1-0-0]

a) Meteorology explaining the angular relations between Sun-Earth system, Sun observable angles, collector-Sun angles, Earth's tilted axis and cosine projection effect, Conversion of solar time to angle to watch time, Making and Reading of a Sun chart Orientation of collector/PV modules, Air-Masses. [5 lectures]
b) Laws of light, spectral reflectance or Albedo, Irradiance principles, Global/diffuse irradiation, DNI, DHI, GHI, radiation resources for energy conversion. [9 lectures]

PHL6XX2 (Measurement of solar radiation and data analysis) [1-0-0]

a) Principles of irradiance measurements, Instruments for solar radiation measurements: pyranometers, pyrheliometers, calibration of these measurement units, other instruments, Measurement uncertainty. [7 lectures]
b) Measurement station design consideration, location in India, Data acquisition, data communication, Data quality control, data correction, data quality assessment. [7 lectures]

PHL6XX3 (Modeling/prediction of Solar Radiation) [1-0-0]

a) Modeling clear sky solar radiation, physics based models, empirical models, parameterization models, modeling global irradiance under all sky conditions, correlation models, cloud observations, empirical all sky radiation models. [6 lectures]
b) Missing component modeling, estimation of diffuse irradiance from GHI, direct irradiance from GNI. Application of ML and AI in solar radiation prediction. [8 lectures]

Textbook

1. Daryl M Myers, Solar Radiation, CRC-Press, 2013
2. Lucien Wald, Fundamentals of Solar Radiation, CRC Press, 2020
3. Jan Kleissl, Solar Energy Forecasting and Resource Assessment, 2013

Self-Learning Material

1. Sengupta et al Best Fractices Handbook for the collection and use of solar resource data for solar energy applictions, NREL Report.
2. Online review papers in various journals.

Preparatory Course Material

1. Online NPTL Courses.

13.7 Specialization: Quantum Technologies

Title	Quantum Communication Laboratory	Number	PH4XX0
Department	IDRP-QIC	L-T-P [C]	0–0–2[1]
Offered for	B.Tech./ Ph.D.	Type	Compulsory
Prerequisite			

Objectives

The Instructor will:

1. Introduce the students to quantum communication and quantum key distribution experiments.

Learning Outcomes

The students are expected to have the ability to:

1. Understand and appreciate the experimental aspects of quantum optics and quantum communication.

Course Contents

Is List of Experiments (related to quantum effects, Bell state measurement, Entanglement generation etc.)

1. Test of QNRG with NIST suite (2 lab sessions, 6-8 tests)
2. FPGA based symmetric and anti-symmetric QKD generation
3. Experiments with QKD at components levels
4. Free space quantum communication up to 30 meters with single photon and analysis
5. Experiments with phase-shift key protocol in QKD experiments or quantum communication
6. Unbalanced homodyne detection and Wigner distribution of an given coherent light and its analysis
7. Optical simulation module for Satellite based communication

Textbook:

1. Beck, M., (2012) Quantum Mechanics: Theory and Experiment, Oxford Univ. Press

Reference Books

Alber, G., Beth, Th., Horodecki, M., Horodecki, P., Horodecki, R., Rötteler, M., Weinfurter, H., Werner, R., Zeilinger, A., (2001) Quantum Information, An Introduction to Basic Theoretical Concepts and Experiments, Springer-Verlag

Self-Learning Materials:

Title	Quantum Devices and Circuits	Number	PHL7XXX
Department	Physics	L-T-P [C]	3–0–0 [3]
Offered for	B.Tech.	Type	Elective
Prerequisite			

Objectives

The Instructor will:

1. Provide background in Quantum Devices and Circuits

Learning Outcomes

The students are expected to have the ability to:

1. Understand the basic concepts in quantum devices and circuits and apply these concepts to solve the related problems.

Course Contents

Quantum hardware review and Circuit implementation:
Introduction to Quantum hardware implementation based on atoms/ions/molecules, superconducting junctions, Superconductivity, Josephson Effects and Superconducting Electronics, Circuits and resonance; circuit quantization, charge, flux, and phase qubits; transmons, Single-qubit and two-qubit gate theory experimental implementation, gate errors; Qubit readout; dispersive measurement; parametric amplification, variational quantum circuits and its applications , optical analog of quantum circuits and implementation. [20 Lectures]

Weak Measurements and Decoherence: Weak measurement and feedback, decoherence mechanisms, Fluxonium, c-shunt flux qubits and Novel architectures, POVM, Non-demolition measurements and quantum noise. [12 Lectures]

Spin systems, Spin Defects: NV centers, other color centers, optical readout, sensing & magnetometry and introduction quantum sensing & Quantum MEMS, Single photon detectors. [10 Lectures]

Textbook

1. Chen Goong, Church David A., Englert Berthold-Georg, Carsten Henkel, Rohwedder Bernd Scully Marlan O., (2006) Principles, Designs and Analysis of Quantum Computing Devices, Chapman & Hall/CRC, London.

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