INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-521 **Course Title:** Quantum Mechanics – I

L-T-P: 3-1-0 **Credits:** 04 **Subject Area**: PCC

Course Outlines: Foundations of non-relativistic quantum mechanics, Matrix formulation and applications, Harmonic Oscillator, Angular momentum algebra, Quantum scattering theory, Approximate solution methods in Quantum mechanics.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-523 **Course Title:** Advanced Mathematical Physics

L-T-P: 3-1-0 **Credits:** 4 **Subject Area:** PCC

Course Outlines: Review of complex analysis. Fourier and Laplace transforms. Solutions of differential equations: Review of some differential equations relevant to Physics and their solutions (special functions): Legendre, associated Legendre, Hermite, Laguerre, associated Laguerre, Bessel and Hypergeometric equations. Beta and Gamma functions. Solutions of inhomogeneous differential equations and Green's functions. Symmetry and transformations: Tensor calculus. Representation theory of groups and applications in physics.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-525 **Course Title:** Classical Electrodynamics

L-T-P: 3-1-0 **Credits:** 4 **Subject Area:** PCC

Course Outlines: Maxwell's Equations, Scalar and Vector Potentials, Gauge transformations, Poynting theorem; Electromagnetic waves in conducting and non-conducting medium; Multipole expansion of electromagnetic fields, Multipole Moments; Lienard-Wiechert potentials, Fields produced by a charged particle in uniform and arbitrary motion, Radiation from an accelerated charged particle with collinear velocity and acceleration; Synchrotron radiation, Cherenkov radiation, Thomson scattering; Covariant formulation of vacuum electrodynamics: space-time symmetry of the field equations, four-vector potential, Electromagnetic field-tensor and its invariants, Lorentz Force equation in a covariant form.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-527 **Course Title:** Classical Mechanics

L-T-P: 3-1-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Holonomic and nonholonomic constraints, D'Alembert's principle and Lagrange's equation of motion, Calculus of variations, Cyclic coordinates, conservation laws, relativistic and covariant formulation, Hamilton's equation of motion, Principle of least action, Canonical transformations, Sympletic approach, Poisson brackets, Angular momentum, Symmetry groups and Liouville's theorem, Hamilton-Jacobi equations of motion, harmonic oscillations, action-angle variables, Kepler problem, Adiabatic invariants.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-529 **Course Title:** Atomic, Molecular and Laser Physics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Atomic Spectroscopy, Spectra of one and two electron systems, Electron spin and magnetic moment, Fine structure splitting, Lamb shift, hyperfine structure and isotope shifts, exotic atoms, Many-electron atoms, L-S and J-J coupling, Hund's rules, atoms in electric and magnetic fields, X-ray spectra. Molecular spectra of diatomic molecules, Born-Oppenheimer approximation, Raman effect, Characteristics of laser light, Optical amplification, Population inversion, Basic concepts of 2-, 3- and 4-level systems, optical resonator, characteristics of semiconductor and gas lasers.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-531 **Course Title:** Condensed Matter Physics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Free electron theories: Drude and Sommerfeld models, Geometry of solids: crystal structure, X-ray and neutron diffraction, reciprocal lattice, Brillouin zone, Band theory of solids, Bloch's theorem, Lattice dynamics, lattice specific heat, Magnetism: Larmor diamagnetism, Curie paramagnetism, Weiss molecular field theory of ferro and antiferromagnetism, Superconductivity: Meissner effect, heat capacity, isotope effect, type-I and type-II superconductors, London theory, elementary BCS theory.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-533 **Course Title:** Statistical Mechanics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Review of classical statistical mechanics; Quantum statistical mechanics: FD and BE statistics and their applications in physics; Phase transitions and applications: spontaneous symmetry breaking, order parameter, critical phenomena, Landau theory of phase transitions, Ising model; Stochastic processes: random walk and its applications.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-535 **Course Title:** Laboratory Work

L-T-P: 0-0-6 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Hall effect, Four Probe method, PN junction, random nature of nuclear radiation, G.M. tube characteristics, distribution of the size of Aerosol, attenuation of laser radiation in varying atmospheric condition, precipitation rate of water using rain gauge, numerical aperture of a fiber, laser beam characteristics, elliptically and circularly polarized light, flip flop, relaxation oscillator, Schmitt trigger, binary/BCD up-down counter.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-537 **Course Title:** Elements of Nuclear and Particle Physics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outlines: Two nucleon interaction, nuclear models, spin-orbit interaction and magic numbers, Nuclear reactions: conservation laws, angular distributions and cross sections, direct and compound reactions, elementary particles and conservation of baryon number, strangeness, colour, quarks and gluons, SU(2) and SU(3) groups, SU(3) flavour symmetry, V-A theory of β-decay, Klein-Gordon and Dirac equation, Gauge theory: the electromagnetic, weak and strong interactions.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHC-539 **Course Title:** Physics of Earth's Atmosphere

L-T-P: 2-0-0 **Credits:** 2 **Subject Area:** PCC

Course Outlines: Atmospheric Evolution, Solar radiation, present atmospheric constituents, Thermodynamics of Atmosphere, Humidity variables, Moist air, adiabatic expansion of unsaturated air, various lapse rates, Atmospheric absorption and greenhouse effect, Atmospheric aerosols, Plasma, Ionosphere, Chapman theory of layer production, electron, ion and neutral temperatures in the thermosphere, airglow and auroral emissions.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHC-543 **Course Title:** Computational Physics

L-T-P: 2-0-2 **Credits:** 3 **Subject Area:** PCC

Course Outline: Review of computer programming. Linear system of simultaneous equations, nonlinear algebraic equation, curve fitting, roots of transcendental equation, interpolation, data analysis and statistics. Numerical integration and differentiation, Monte-Carlo simulation, Numerical methods for solving ordinary- and partial- differential equations; Applications drawn from various fields of physics.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHC-545 **Course Title:** Semiconductor Devices and Applications

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outline: Energy bands, Intrinsic and extrinsic semiconductors, Density of states, Law of mass action, Direct and indirect band gaps, Carrier transport: Drift, Diffusion, Hall effect, Carrier generation, Recombination, Lifetime, Continuity equation, and Haynes–Shockley experiment, Schottky junctions, Ohmic contacts, p–n junction, Energy band diagram, Junction breakdowns, Diode theory, Tunnel diodes, LEDs, Photodiodes, Solar cells, Heterojunctions, Transistors: BJTs, JFETs, MOSFETs, and Gunn diodes.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHC-547 **Course Title:** Quantum Mechanics-II

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PCC

Course Outline: Time-independent Perturbation Theory: Non-degenerate and degenerate perturbation theory and their applications, Time-dependent Perturbation Theory: harmonic perturbation, Fermi-golden rule, quantization of the electromagnetic field, Identical Particles: Indistinguishability, two-particle system: Helium atom, Hartree and Hartree-Fock methods. Relativistic Quantum Mechanics: Klein-Gordon equation and its applications, Dirac theory of electron, spin of the electron, Dirac equation for free particles and Hydrogen atom.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHL-504 **Course Title:** Fiber and Nonlinear Optics

L-T-P: 3-1-0 **Credits:** 4 **Subject Area:** PEC

Course Outline: Salient features of an optical fiber, modes of a waveguide, scalar modes of an optical fiber, attenuation, pulse dispersion, splice loss, fiber fabrication, fused fiber coupler, fiber- based components, 2nd order nonlinear effects, second harmonic generation, parametric down conversion, sum frequency generation, 3rd order nonlinear effects, self-focusing, 4-wave mixing, optical phase conjugation.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHL-534 **Course Title:** Nuclear Astrophysics

L-T-P: 3-0-0 **Credits:** 3 **Subject Area**: PEC

Course Outline: General characteristics of thermonuclear reactions, cross sections, stellar reaction rates, S-factor, rates at elevated temperatures, non-resonant and resonant rates, neutron, charged particle, and photon induced reactions, pp chain, CNO cycle, Helium burning, Creation and survival of ^{12}C, other stellar cycles, abundance calculations, Nucleosynthesis in massive stars, s – process, r – process, Indirect methods in nuclear astrophysics, Nuclear Astrophysics databases, and experimental facilities worldwide.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHL-540 **Course Title:** Quantum Theory of Solids

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** PEC

Course Outline: Quantum many body techniques: second quantization, many body Hamiltonian in second quantized form, Hartree-Fock Theory, Green's function, Magnetism (using second quantized notation): Heisenberg model, spin waves, ferromagnetic and antiferromagnetic magnon, Superconductivity (using second quantized notation): BCS theory, Bogoliubov transformation, Plasma oscillations in free electron gas.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Physics

Subject Code: PHL-564 **Course Title:** Atmospheric Turbulence

L-T-P: 3-1-0 **Credits:** 4 **Subject Area:** PEC

Course Outline: Conservation laws and governing equations of fluid dynamics, Symmetries and invariance of Navier-Stokes equation, Random nature of turbulence, Equations of the mean flow, Homogeneous and isotropic turbulence, Energy cascade and Kolmogorov hypotheses, Intermittency and multiscaling, Two-dimensional turbulence, Atmospheric turbulence, Turbulence in atmospheric boundary layer, Convective turbulence in the interior of the Sun and planetary atmospheres, Geostrophic turbulence.

Department of Physics: Proposed STAR Courses

FOR PG

Subject Code: PH-xxx PHT-501 Course Title: **Advanced Materials for Energy Harvesting and Storage**
L-T-P: **3-0-0** Credits: 3 Subject Area: STAR Course

Outline: Basics of energy conversion processes (thermoelectric, piezoelectric, photovoltaic, hydroelectric, etc.), Materials for energy harvesting and storage, covering synthesis, characterization. Hydroelectric cells, dielectrics, quantum dots, perovskite solar cells, and supercapacitors, batteries. Role of nanostructures in enhancing energy storage performance. Flexible and wearable energy devices

Subject Code: PH-xxx PHT-502 Course Title: **Functional Materials**
L-T-P: **3-0-0** Credits: 3 Subject Area: STAR Course

Outline: Functional materials are materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli (temperature, electric/magnetic field, etc.) and are therefore applied in a broad range of technological devices for example in memories, displays and telecommunication. This course aims to provide students with a detailed understanding of a range of functional materials, including magnetic and superconducting materials, ferroelectric materials, semiconductor materials and 2D materials. These are a rapidly emerging class of materials that exhibit novel physical properties and find applications in a wide range of fields such as catalysis, electronic devices, actuators and sensors.

FOR UG

Subject Code: PH-xxx PHT-503 Course Title: **Fundamentals of Nanoscience and Technology**
L-T-P: **3-0-0** Credits: 3 Subject Area: STAR Course

Outline: Nanoscience, Nanotechnology, Fundamentals, Principles, Applications, Nanostructures, Quantum Mechanics, Materials Science, Characterization Techniques, Fabrication Methods, Nanomaterials, Nanoelectronics, Self-assembly, Surface Science, Nanoengineering, Quantum Dots, Carbon Nanotubes, Nanosensors, Energy Applications, Environmental Implications, Ethical Considerations.

FOR UG/PG

Subject Code: PH-xxx PHT-504 Course Title: **Computational Science with Python**
L-T-P: **2-0-2** Credits: 3 Subject Area: STAR Course

Outline: Programming in Python, Variables and Array, Control structure, basic numerical algorithms covering interpolation, integration, differentiation, ODE and PDE solvers, Dense linear algebra (numpy), Sparse linear algebra (scipy), Plotting, Symbolic computing (sympy), Data processing (pandas), Machine learning basics (Regression)

Subject Code: PH-xxx PHT-505 Course Title: **Quantum Simulations**
L-T-P: **2-0-2** Credits: 3 Subject Area: STAR Course

Outline: Basics of quantum computing applied to simulating physical systems. Coding quantum computers for solving some eigenvalue problems in many-body systems with an adequate introduction to the relevant algorithms, encodings, and transformations.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Physics

Subject Code: PHT-506 **Course Title:** Superconducting Qubits-based Quantum Computing

L-T-P: 3-0-0 **Credits:** 3 **Subject Area:** STAR

Course outlines: Quantum states in Hilbert space, EPR paradox, Schrödinger wave equation and its incompleteness, Superposition, entanglement, Quantum Confinement, Fundamentals of Superconductivity, Cooper pairs, and Josephson tunneling. Bits and Qubits, Josephson Quantum dot-junction-based Superconducting quantum qubits, charge qubits, flux qubits and phase qubits, Transmon qubit, and hybrid qubits. Quantum circuits Quantum gates X-gate (bit flip, Not), Z-gate (phase flip), H-gate and T gate, controlled-NOT, qubits gates and quantum Circuits, Shor's Algorithm, and Grover's Algorithm code, Superconducting qubits-based quantum computers fabrication, advantages based on coherence time, operation fidelities and Error's correction, Di-Vincenzo Criteria, Possible array of Superconducting Quantum Qubits, and Challenges ahead in Quantum computing.