DEPARTMENT OF PHYSICS

EP Syllabus at a Glance

EP1128: Basic Electric Circuits **Credits: 2**

Circuit Concept, Circuit laws, Circuit Analysis concept, Amplifier and Operational Amplifier Circuits, Waveform Signal, EM, EM Induction, Hysteresis, Power sources, Electrical Instruments and Measurements.

References:

- Electrical Technology by Theraja and Theraja
- Theory and Problems of Electric Circuits by Mehmood Nahvi and Joseph A Edminister

EP2041: EP Lab-II **Credits: 2**

List of experiments:

1.Applications of Diode
2.Applications of Transistor
3.Arduino Experiments
4.Boolean Logic Operations using Digital ICs
5.Characteristics of SCR and DIAC.
6.Characteristics of MOSFET
7.Code Conversion
8.Opamp
9.Study of Latches and Flip-flops
10.Amplitude Modulation And Demodulation

EP2108: Special Relativity **Credits: 2**

Galilean transformations, Postulates of Special theory of Relativity, Lorentz transformations, Length contraction, time dilation,Space-time, and space-time diagrams,Relativistic dynamics, mass, momenta,Mass-energy equivalence,Relativistic electrodynamics,Tensor analysis,Brief introduction to General Relativity, Equivalence Principle

Reading References:

- “Introduction to Special Relativity” by Robert Resnick

Additional reading

- Mathematical Physics by Arfken
- Electrodynamics by D J Griffiths
- “General Relativity” by Robert M. Wald

EP2130:Mathematical Physics **Credits:2**

Harmonic and Analytic Functions,Series Representation of Analytic Functions,Contour Integrals and Residue Calculus,Evaluation of Definite Integrals,Analytic Continuation,Conformal Mapping,Fourier Series.Fourier Transforms.Discrete Fourier Transform (DFT),Laplace Transforms,Applications of Fourier and Laplace Transforms.

References.

1. P. Dennery and A. Krzywicki, Mathematics for Physicists, Dover Publications.
2. G. Arfken and H. Weber, Mathematical Methods for Physicists, Academic Press.
3. R. J. Beerends, H. G. ter Morsche, J. C. van den Berg, E. M. van de Vrie, Fourier and Laplace Transforms.

EP3100: Quantum Mechanics-1 **Credits: 3**

Classical to quantum cross-over, basic principles of quantum mechanics, wave function and uncertainty principle, Schrodinger formalism, time-independent and time-dependent Schrodinger equations, Dirac formulation of quantum mechanics, completeness and orthonormalization of basis vectors, basis sets, eigenstate and eigenvalues, Schrodinger Equation in one dimension, probability current density, equation of continuity, Free particle solution of Schrodinger equation, box and delta function normalisation of free particle solution, potential step, potential barrier, particle in an infinite potential box, square well potential and tunnelling, linear harmonic oscillator. Orbital and spin angular momentum operators, angular momentum algebra, eigenstates and eigenvalues of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients, spin-orbit interaction and applications, central potential, solutions of schrodinger equation in a central potential, Hydrogen-like atom, 3 dimensional harmonic oscillator.

References:

- Quantum Mechanics by Stephen Gasiorowicz
- Principles of Quantum Mechanics by R. Shankar
- Quantum Mechanics by Bransden and Joachain
- Quantum Mechanics I, II by JJ Sakurai

EP3110:Electrodynamics **Credits: 3**

Electric field, Divergence and curl of electrostatic fields, electric potential, work and energy in electrostatics,conductors, Special techniques to solve Laplace’s equations, separation of variables and Multiple expansion, Polarization, Field of a polarized object, Electric displacement and linear dielectrics, Lorentz force law, Biot-Savart Law, magnetic vector potential, magnetization, field of a magnetized object, linear and nonlinear media. Electromotive force, Electromagnetic induction, Maxwell’s equations, conservation laws, Poynting theorem, Maxwell’s stress tensor, conservation of momentum, Electromagnetic waves,Electromagnetic waves in vacuum and matter, Absorption and Dispersion, Wave Guides, Potentials and fields, Gauge transformations, Dipole radiation, Power radiated by point charge, Maxwell’s equations in matter, Boundary conditions, Poynting’s theorem, Newton’s third law in Electrodynamics, Maxwell’s stress tensor, Conservation of Momentum, Electromagnetic waves in vacuum, and matter, absorption and dispersion, Guided waves.

References:
David Griffiths: Introduction to Electrodynamics 4th edition

Prerequisites:EP1208

EP3120:Statistical Mechanics **Credits: 3**

Thermodynamics, phase space of classical ideal gas, Boltzmann’s H-theorem, Maxwell-Boltzmann distribution, microcanonical ensemble, Gibbs paradox, Sackur-Tetrode entropy of ideal gas, canonical and grand-canonical ensembles, thermodynamics from partition function, statistical mechanics of simple harmonic oscillators (classical and quantum), equipartition theorem, para-magnetism, solid-gas equilibrium, quantum statistics (fermions and bosons), Fermi gas, Chandrasekhar mass limit, Bose gas, Planck’s radiation law, Debye model of heat capacity, Bose-Einstein condensation, Ising model in 1D and 2D.

References:
Kerson Huang, Statistical Mechanics 2 nd ed. (Wiley 2021)
R. K. Pathria & Paul D. Beale, Statistical Mechanics, 4 th ed. (Elsevier 2021)
F. Reif, Fundamentals of Statistical and Thermal Physics (Waveland Pr Inc, 2008)

EP3208:Advanced Mathematical Physics **Credits: 2**

Series solution of differential equations, separation of variables, Green's function and non-homogeneous differential equation, Bessel equation and function, Legendre equation and function, Hermite equation and function, Laguerre equation and function, Beta and Gamma functions, Group theory ,Discrete groups , Z_n group, cyclic group, permutation group, dihedral group etc. class, cosets, factor group, character table, reducible and irreducible representations,factor group, Lie group, Application of group theory in physics.

Rererence:
Mathematical methods for physicists” by Arfken and Weber
Group theory in physics” by Wu-Ki Tung

EP4071: EP-Lab 3

Credits: 2

List of Experiments

1. Millikan oil drop method
2. e/m method to determine electron charge to mass ratio
3. Maxwell’s velocity distribution
4. Study of magnetic hysteresis
5. Uniform and Non-uniform bending to determine the Young’s modulus of a beam
6. Study of Hall effect
7. Ultrasonic Interferometer
8. Determination of magnetic mass susceptibility of a liquid by Quincke’s method
9. Faraday effect
10. Determination of Curie temperature of ferroelectric sample.

EP4108: Nuclear Physics **Credits: 2**

Discovery of Nuclei, Rutherford scattering, Nuclear radii and charge distributions, nuclear binding energy, semi-empirical mass formula; nuclear models; radioactivity, nuclear reactions, Elementary ideas of alpha, beta, and gamma decays.

References:

1. Nuclear Physics: Principles and Applications (Manchester Physics Series Book 44); John Lilley 1st Edition Wiley
2. KS Krane; Introductory Nuclear Physics 3rd John Wiley & Sons Inc
3. John R. Lamarsh, Anthony J. Baratta Introduction to Nuclear Engineering 3rd Pearson
4. Frank Close NUCLEAR PHYSICS: A VERY SHORT INTRODUCTION Illustrated Oxford University Press.

EP4210:Computational Physics **Credits: 3**

Introduction to Python programming, root finding, numerical differentiation and integration, Euler method, Verlet method, shooting method, Runge-Kutta methods, finite difference technique, numerical solution of Poisson equation in two and three dimensions, heat equation, time-dependent initial value problems, solution of Schrodinger equation, Burgers equation, nonlinear PDEs, Monte Carlo methods and integration, Metropolis algorithm, probability distribution sampling, Fourier spectral method, neural networks, physics informed neural networks.

References:

Joel Franklin, Computational Methods for Physics (Cambridge University Press, 2013)
Nicholas Giordano & Hisao Nakanishi, Computational Physics (Pearson Addison Wesley, 2005)

EP4350:Gravitation and Cosmology **Credits: 3**

• Review of Newton's non-relativistic theory of gravitation: Inverse square law, the notion of gravi-tation field intensity vector, Newton's scalar potential, the Poisson equation for Newton's gravity,Uniqueness, mean value, Earnshaw's theorems, and Multipole expansion of the Scalar potential.Principles of Equivalence of Galileo and Newton, Tidal Forces on extended objects due to gravity.

• Review of Special Relativity: Inertial frames, Lorentz/Poincar´e transformations, Invariant space-time interval (Minkowski metric), Minkowski spacetime, timelike, spacelike, and lightlike separated events, lightcones, Lorentz group & its generators.
• Review of Special Relativity (Continued): Relativistic index notation (4-vector notation), Scalars,Vectors, Tensors, etc., Invariant tensors, Differential Forms and Exterior Calculus.
• Special relativistic formulations of point particles (free) and Newton's laws of motion, Covariant equations for fluid mechanics.
• Fluid mechanics (Continued): Stress-Energy-Momentum Tensor, fluid mechanics, Maxwell theory,Alternative derivation of Maxwell's equations (in terms of potentials) purely from Lorentz symmetry and conservation of charge.
• Lorentz covariant equations for gravity ala Maxwell's equations: Fierz-Pauli field (symmetric tensor potential) and Fierz-Pauli equation, Gauge symmetry of Fierz-Pauli field. Coupling to matter: From Minkowski metric to curved metric, gauge invariance as general coordinate transformation symmetry.
• Mathematical Preliminaries I: Elements of point set topology: topological spaces, homeomorphisms, Topological manifolds, Differentiable manifolds, Differential geometry: Charts & Atlases, Tangent space, cotangent space, functions (tensor fields), Pseudotensors and curves on manifolds, smooth maps, pushforward and pullbacks, flows, Lie derivatives.
• Mathematical Preliminaries II: Riemannian manifolds: metric and geodesic equation, Parallel trans-port and affine connections, Levi-Civita connection (Christoffel symbols), Covariant derivatives,Killing vector and Conservation laws, Geodesic deviation equation & the Riemann Curvature ten-sor, Ricci tensor, Ricci scalar and the Einstein field equation, Properties of the Riemann tensor,Newtonian limit.
• Linear approximation of Einstein field equations: Recovering Fierz-Pauli equation, Lorenz gauge,gravitational waves: polarization and detection, and gravitational radiation.
• Non-linear vacuum solution: Deriving the Schwarzschild Solution for metric outside a spherical mass distribution, Uniqueness theorem, Thin shell, and Newton's theorem. Coordinate and curvature Singularities.Timelike and lightlike geodesics in the Schwarzschild spacetime: ISCO, Photon Sphere, Precession of the perihelion of planets, Deflection of light, Gravitational redshifting and time-dilation,Shapiro's radar-echo delay.
• Optional topics: Homogeneous & Isotropic Cosmological Models: FLRW universes, Friedmann and Acceleration Equation, Cosmological constant, De Sitter universe, Hubble expansion and galactic redshifts. The Hot Big-Bang: From Planck era to Baryogenesis, The Cosmic microwave background, Dark Matter and Dark energy, Origin of Structure.

References:

• Schutz, Bernard F. "A first course in General Relativity", Cambridge University Press; 2nd edition(14 May 2009) (Advanced Undergraduate/ Postgraduate level)
• Carroll, Sean M.. "Spacetime and Geometry: An Introduction to General Relativity", Cambridge University Press, 2019. (Advanced Undergraduate/Postgraduate level)
• Ohanian, Hans C., Ruffini, Remo. "Gravitation and Spacetime", Cambridge University Press, 2013.(Advanced Undergraduate/ Postgraduate level)
• Hartle, James: "Gravity: An Introduction to Einstein's General Relativity", Cambridge Univ. Pr

(2 September 2021) (Advanced Undergraduate/Postgraduate level)
• Weinberg, Steven. “Gravitation and cosmology: principles and applications of the general theory of relativity”, Wiley, 1972. (Postgraduate/ PhD level)

• Stephani, Hans. “Relativity: An Introduction to Special and General Relativity”, Cambridge University Press, 2004. (Postgraduate/ PhD level)

• D’Inverno, Ray. “Introducing Einstein’s Relativity”, Oxford University Press, Oxford University Press, U.S.A. (9 Aug. 1990) (Advanced Undergraduate/ Postgraduate level)
• Misner, Charles W.., Thorne, Kip S.., Wheeler, John Archibald. “Gravitation”, United Kingdom: Princeton University Press, 2017. (Postgraduate/ PhD level)
• Nakahara, Mikio. “Geometry, Topology, and Physics”, United Kingdom: Taylor & Francis, 2003. (Postgraduate/PhD level)

Prerequisites
• Analytical Mechanics
• Electrodynamics
• Special Relativity
• Mathematical Methods (Vector calculus, Linear Algebra, ODEs, PDEs)

EP4510:Introduction to Nanomagnetism with Lab **Credits: 3**

Basics of magnetism, Magnetism at nanoscale (thin films and nanostructures), Magnetic interactions, Magnetic anisotropies,Magnetic domains, Spin textures at nanoscale (nanodisk, nanorings, nanowires), Interfacial physics in thin film multilayers, Techniques in nanomagnetism and applications (magnetic recording). Experimental (SEM, MOKE, MFM, VSM, Lithography etc.) and virtual (micromagnetic simulations) Lab for nanomagnetism.

References:
1. Principles of nanomagnetism: Alberto P. Guimaraes
2. Introduction to magnetic materials: B.D. Cullity
3. Magnetic materials: Fundamentals and Applications:
Nicola A. Spaldin
4. Magnetic domains: Alex Hubert and Rudolf Schafer

EP4710: Particle Physics **Credits: 3**

Basic constituents of matter, Fundamental forces in nature, Accelerators:Cosmic and Manmade, Detectors. Classification of particles, Quark contents of Hadrons, Particle quantum numbers, Gell-Mann Nishijima formula, Relativistic kinematics, scattering amplitudes, Cross sections, decay rate and life-time. Breit-Wigner formula, continuous symmetries and conservation laws. Discrete symmetries. CPT theorem, Weak processes, pion decay, GIM mechanism, Parity violation, Quark mixing,CKM matrix, Neutrino Physics, Elements of Quantum Chromodynamics, Electroweak interaction, Symmetry breaking and Higgs mechanism, Standard Model of Particle Physics and Physics beyond the standard model

Pre-requisite:
Should have already taken courses on Quantum Mechanics (I & II),
Mathematical Physics and Relativity

References:
1. Introduction to Elementary Particles, D. J. Griffiths;
2. Quarks and Leptons, F. Halzen and A. Martin;
3. Collider Physics, R. Phillips and V Barger
4. Gauge theory of elementary Particles, Cheng and Li;
5. Introduction to High Energy Physics, D. H. Perkins.

EP47150:Open Quantum Systems **Credits: 3**

Part 1: Irreversibility in quantum systems from noise and dissipation
i) General concepts and techniques:
a) Concepts of density matrix, mixed state, von-Neumann entropy and quantum master equation,
b) Born-Markov approximation and Redfield quantum master equation,
c) Nakajima-Zwanzig projection operator method, general quantum master equation, and quantum
regression.
d) Quantum and classical noises in a quantum system, and description via Redfield quantum master
equation.
ii) Examples:
a) Qubit under noises, the concept of T1 and T2 times.
b) Modeling an ideal photon detector and finding the spectrum of light detected from a qubit driven
by classical noise.
c) A two-level molecular junction, coupled to two baths at different temperatures.
Part 2: Irreversibility in quantum systems from quantum measurements
i) General concepts and techniques:
a) Completely positive trace preserving (CPTP) maps, Kraus operators
b) CPTP maps as a generalized measurement, and concept of positive-operator valued measure
(POVM).
c) Collisional or repeated interaction model, and continuous measurement.
d) Lindblad quantum master equation as a limit of repeated interaction model.
e) Stochastic unraveling of Lindblad equation, and concept of quantum trajectory.
ii) Examples:
a) Modeling an ideal photon counter at a quantum trajectory level as a single probe qubit.

Prerequisite:
At least one previous course on Quantum Mechanics.

Reference books:
Theory of open quantum systems: Breuer and Petruccione
Quantum computation and quantum information: Neilsen and Chuang
Statistical methods in quantum optics: Carmichael

EP5201: EP-Lab 5 **Credits: 2**

List of Experiments

1.Zeeman Effect
2.Constant Deviation Spectrometer
3.XRD-1
4.XRD-2
5.Magnetoristriction
6.Microwave
7.Electron Diffraction
8. Four Probe Method
9.ESR and NMR
10.Solar cell Characteristics