Central University of Himachal Pradesh

Department of Physics and Astronomical Science

Department Model Curriculum for M. Sc. Physics Programme

2019

M. SC. PHYSICS
4th Semester

Computational Physics

Course Code: PAS 428 A **Course Type: Core Compulsory Course**
Credit: 4

Course Contents:

Unit 1: Ordinary Differential Equations: **(8 hours)**

- Euler method, Application to Radioactivity, Air drag and Projectile motion
- Euler-Cromet Method, Application to SHO
- Predictor-corrector method (Heun's) method, Application to Damped Harmonic Osicllator
- Second order Runge-Kutta method, Application to Forced Oscillations
- Study of Panetary motion
- Higher-order Runge-Kutta method; Application to Coupled Oscillations

Unit 2: Partial Differential Equations: **(8 hours)**

- Finite Difference methods: Elliptic Equations- Laplace equation, solution techniques and boundary conditions;
- Parabolic Equations- Heat Conduction Equation, explicit and implicit methods
- Crank-Nicholson Method; Application to Schrodinger equation.
- Finite Element Method: General approach and applications in One-dimension;
- Application to problems in Electromagnetics.

Unit 3: Random Variables and Random Processes: **(4 hours)**

- Random variables, several random variables; Statistical averages, function of a random variable, moments, characteristic function, joint moments; Transformation of random variables; Sequences of random variables; central limit theorem (without proof);
- Random processes; Stationarity; Mean, correlation and covariance functions; autocorrelation function and properties , cross-correlation functions; Ergodicity; Power spectral density; Gaussian process and its properties;

Unit 4: Random Processes and Monte-Carlo Methods: **(6 hours)**

- Random number generation-uniform and non-uniform distributions;
- Monte Carlo Integration- Hit and miss, Sample mean integration,
- Metropolis Method;
- Computer "Experiments" - applications of Monte-Carlo methods to problems in physics;
- Variational Monte-Carlo tecnique: Application to solving for the ground state of quantum mechanical systems in 1D and 2D

Unit 5: Fast Fourier Transforms and Spectral Methods: **(6 hours)**

- Discrete Fourier Transform,
- Fast Fourier Transform,
- Sande Tukey Algorithm
- Pseudospectral technique to solve the Schroedinger equation

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Computational Physics Laboratory

Course Code: PAS 427 **Course Type: Core Open**
Course Credit: 2

Statistical Mechanics Simulations:

Worksheet based Simulations:

Lab 1: Microstates, Macrostates and Steady-state equllibrium
Lab 2: Ergodic Hypothesis Demonstration

Simulations in Scilab:

Lab 3: Boltzmann Distibution: P(E) vs E
Lab 4: Boltzmann Speed Distribution and Maxwell's velocity distribution
Lab 5: Joule's Expansion and Entropy

Quantum Mechanics Simulations:

Lab 6: Solving the Time-Dependent Schrodinger Equation and obtaining the spreading of Gaussian wavepacket
Lab 7: Studying the Scattering of Gaussian wavepacket
Lab 8: Scattering from a step potential and a barrier

Theoretical Nuclear Physics

Course Code: PAS 527 **Course Type: Elective Specialization**

Course Credits: 4

Course Objectives:

The course is designed to study the following, Interaction of nuclear radiation like charged particles, neutrons, gamma and positron with matter and how these radiations are detected. Study of decay laws, theory and use in the structure exploration of nuclei. Nuclear reactions, kinematics, reaction cross-sections, different types and theories developed. Nuclear Fission, characteristics and applications. Basic fusion process it characteristics, solar fusion etc.

Course Contents

Unit 1: Interaction of nuclear radiation with matter (10 hours)

- Interaction of charged particles with matter
- Interaction of neutrons with matter: energy loss and energy distribution after collision
- Interaction of gamma radiation with matter: attenuation of gamma rays, Compton Effect, photoelectric effect and pair production.
- Interaction of positron with matter
- Detection of nuclear radiation

Unit 2: Radioactive Decay (10 hours)

- Radioactive decay law, Quantum theory of radiative decays, production and decay of radioactivity, Growth of Daughter activities.
- Alpha decay: energetic, decay constant, hindrance factors, alpha particle spectra
- Fermi theory of β-decay, Electron and positron energy spectra, electron capture decay, parity non conservation in β-decay, nuclear structure information from β-decay.
- Theory of γ-decay and internal conversion and nuclear structure information from γ-decay

Unit 3: Nuclear reactions (12 hours)

- Cross-sections, reciprocity theorem, Elastic scattering and method of partial waves, relationship between differential and scattering amplitude.
- Free particle, turning the potential on, scattering amplitude and elastic scattering cross-section, reaction cross-section.
- Scattering by simple potential, square well potential.
- Theory of resonance: General aspects, logarithmic derivative and cross-section, Breit-Wigner formula, R-Matrix theory.

Unit 4: Nuclear Fissionand Fusion (8 hours)

- Fission: Characteristics of Fission, Energy In Fission, Fission and Nuclear Structure, Controlled Fission Reactions, Fission Reactors, Radioactive Fission Products, Fission Explosives.
- Basic fusion processes, characteristics of fusion and solar fusion.

Prescribed Text Books:

1. Introductory Nuclear Physics, K. S. Krane, John Wiley& Sons Ltd
2. An Introduction to Nuclear Physics, W. N. Cottingham, D. A. Greenwood, Cambridge University Pres

Other Resources/Reference books:

1. Fundamentals In Nuclear Physics from Nuclear Structure to Cosmology Jean-Louis Basdevant, James Rich, Michel Spiro, Springer
2. B.R. Martin, Nuclear and Particle Physics, John Wiley& Sons Ltd.
3. R.R. Roy and B.P. Nigam, Nuclear Physics: Theory andexperiment, New age International (P) limited, Publishers.

Elementary Particles & Interactions

Course Code: PAS 549 **Course Type: Elective Specialization Course**
Credits: 4

Course Objectives:

An Overview of Elementary particle physics, Symmetry Principles, conservation laws and Quark Model, Feynman Calculus, QED, and Renormalization, QCD, Weak Interactions and Electroweak Standard Model, Physics Beyond the Standard Model

Course Contents

Unit-1: Introduction and Dirac Equation (5 hours)

- Historical Introduction of Elementary particles, Classification, Quantum numbers & Conservation laws
- Four Forces, Range of Forces, Yukawa Potential, Zero Range Approximation
- Dirac Equation: High energy units, Antiparticles and Bilinear covariants

Unit-2: Symmetriesand Quarks (5 hours)

- Symmetry, Group and Conservation laws, Parity, Charge conjugation, Time reversal
- Combining Representations, Young's Tableaux, SU(2), SU(3) groups
- Quark Model

Unit-3: S- Matrix, Wick's Theorem and QED (10 hours)

- The S-Matrix expansion, Wick's theorem
- Electrodynamics of spin 0, ½ particles, Lifetimes and cross-sections, The Golden rule, The Feynman rules for a toy theory, Lifetime of the A, Feynman Rules for QED, Inelastic electron and muon scattering
- Loops, Renormalization and Running coupling constants.

Unit-4: QCD and Weak Interactions (8 hours)

- Structure of Hadrons, Partons and QCD
- Parity Violation and the V-A Form of the weak current, Interpretation of the Coupling G, Trace theorems, Muon decay, Charged current neutrino-electron scattering, Neutrino-quark scattering, First observation of weak neutral currents, Neutral current, Neutrino-quark scattering
- The Cabibbo Angle, Weak Mixing Angles, CP Violation: The Neutral Kaon System.

Unit-5: Electroweak Interactions, Standard Model and Beyond (12 hours)

- Electroweak theory, Lagrangian in particle physics, Weak spin, Gauge invariance, Standard Model Largrangian, U(1) terms, SU(2) terms, Neutral currents, Charged currents, Quark Lagrangian, Fermion gauge boson Lagrangian
- Standard model masses, Spontaneous symmetry breaking, Abelian Higgs mechanism, Higgs mechanism in the Standard Model
- Grand Unified Theories, Supersymmetry, Strings, etc...

Prescribed Textbooks:

1. Halzen, F. and Martin A.D.: Quarks and Leptons, John Wiley & Sons, 1984.
2. Griffiths, D.: Introduction to Elementary particles, John Wiley & Sons.

Other Resources/Reference books:

1. Martin, B.R. and Shaw, G: Particle Physics, John Wiley & Sons Ltd. 2009.
2. A. Lahiri and P.B. Pal: A First book of quantum field theory, 2nd edn, Narosa publ. house.
3. Gordon, Kane, Modern Elementary Particle Physics, Addison-Wesley Pub. Co. Inc. 1987.
4. Donald, H. Perkins: Introduction to High Energy Physics, Cambridge University Press.
5. Khanna, M.P.: Introduction to Particle Physics, PHI Learning Pvt. Ltd., New Delhi 1999.
6. Tayal, D.C.: Nuclear Physics, Himalaya Publishing House Pvt. Ltd.

Nano Materials & Technology

Course Code: PAS 516 **Course Type: Elective Open**
Course Credit: 2

Course Objectives:

Applications in solving problems of interest to physicists. Explore the potential application of physics at nanoscale regime.

Course Content

Unit 1: Nanoscale Systems **(8 hours)**

- Nanostructures and Nanoscale Devices
- Quantization in Nanostrctures
- Quantization in Heterojunction Systems (Quantum Well)
- Lateral Confinement (Quantum Wires and Quantum Dots)
- Electronic States in Quantum Wires and Dots
- Magnetic Field Effects in Quantum Confined Systems
- Transmission in Nanostructures
- Tunnelling in Planar Barrier Structures
- Current in Resonant Tunnelling Diodes
- Landauer Formula &The Multi-channel Case

Unit 2: Synthesis of Nanomaterials **(6 hours)**

- Top-down and Bottom-up Approach
- Zero-dimensional nanostructures (nanoparticles)
- One-dimensional nanostructures (nanowires)
- Two-dimensional nanostructures (thin films)
- Special nanomaterials (fullerene, carbon nanotube, graphene)
- Physical Vapour Deposition (PVD)
- Pulsed Laser Deposition
- Thermal Evaporation
- E-beam Evaporation
- DC & RF Sputtering
- Molecular Beam Epitaxy (MBE)
- Chemical vapour deposition (CVD)
- Lithography
- Photolithography
- Electron Beam Lithography (EBL)
- Focussed Ion Beam