PHY-381 Computational Physics

Credit Hours: 2-1

Pre-requisite: CS-114 Fundamentals of Programming

Course Objectives: This course treats an important topic for physicists – computational physics. In this course first the programming skills learnt by students are revised and then numerical methods are used to solve important problems in Physics. The students would apply the numerical methods of solving first and second order differential equations including Euler Method, Euler Cromer Method, Range-Kutta method, Fast Fourier transform, Method of least squares, Monte-Carlo integration.

Core Contents: Numerical methods used to solve important problems in Physics.

Detailed Course Contents: The numerical methods learnt and applied are: Euler Method, Euler-Cromer Method, Method of Least Squares, Jacobi Method, Monte Carlo Integration, Fast Fourier Transform. The problems solved numerically are: First numerical problem: radioactive decay, Realistic projectile motion – air resistance, trajectory of a canon shell, motion of a batted ball, Throwing a baseball: effect of spin, golf; Simple harmonic motion with dissipation, chaos, period doubling, Logistic map, the Lorenz Model, the billiard problem, behavior in the frequency domain, Kepler's Laws, the inverse square law and stability of planetary orbits, precession of the perihelion of mercury, the three body problem and the effect of Jupitar on Earth, Resonance in the solar system, chaotic tumbling of Hyperion, Electric potential and fields, potentials and fields near electric charges, Magnetic field produced by a current, magnetic field of a solenoid, Why perform simulation of random process, random walks, self-avoiding walks, random walks and diffusion, Diffusion and entropy, cluster growth models, fractal dimensionalities of curves, Statistical Mechanics, phase transitions and Ising model or Quantum Mechanics: time independent and time dependent Schrodinger equation.

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

- learn and apply numerical methods like Euler method, Euler-Cromer method, Range-Kutta method, fast Fourier transform, method of least squares, Jacobi Method, Monte-Carlo simulations
- solve physical problems numerically based on first and second order differential equations
- apply numerical methods to solve random processes
- apply numerical methods to solve some problems in statistical and quantum mechanics.

Textbook: Nicholas J. Giordano, Hisao Nakanishi, Computational Physics, 2nd ed. Prentice Hall, 2005.

Reference Books:

Mark Newman, Computational Physics, CreateSpace Independent Publishing Platform, 2012.

Weekly Breakdown		
Week	Section	Topics
1	Handouts	Revision of programming
2	Handouts	Revision of programming
3	GN 1	Euler Method: First numerical problem: radioactive decay
4	GN 2.1-2.3	Euler Method: Realistic projectile motion – air resistance, trajectory of a canon shell, motion of a batted ball
5	GN 2.4-2.5	Range-Kutta Method: Throwing a baseball: effect of spin, golf
6	GN 3.1-3.4	Euler-Cromer Method: Simple harmonic motion with dissipation, chaos, period doubling
7	GN 3.5-3.8	Euler-Cromer Method: Logistic map, the Lorenz Model, the billiard problem, behavior in the frequency domain
8	GN 4.1-4.4	Euler-Cromer Method, Method of Least Squares, Range-Kutta Method: Kepler's Laws, the inverse square law and stability of planetary orbits, precession of the perihelion of mercury, the three-body problem and the effect of Jupitar

		on Earth
		Midterm Exam
9	GN 4.5-4.6	Euler-Cromer Method, Method of least squares, Range-Kutta Method: Resonance in the solar system, chaotic tumbling of Hyperion
10	GN 5.1-5.2	Jacobi Method: Electric potential and fields, potentials and fields near electric charges
11	GN 5.3-5.4	Jacobi Method: Magnetic field produced by a current, magnetic field of a solenoid
12	GN 7.1-7.4	Method of Least squares, Monte Carlo Integration: Why perform simulation of random process, random walks, self-avoiding walks, random walks and diffusion
13	GN 7.5-7.7	Method of Least squares, Monte Carlo Integration: Diffusion and entropy, cluster growth models, fractal dimensionalities of curves
14	GN one of Chap. 8 or 10	Statistical Mechanics, phase transitions and Ising model or Quantum Mechanics: time independent and time dependent Schrodinger equation.
15		Revision