PHY-930 Computational Physics

Credit Hours: 3-0
Prerequisite: None

Objectives and Goals: This course treats an important topic of computational physics for physicists. In the first part, revision of programming skills will be done, and then numerical methods will be introduced 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. Furthermore, in this course, we will also discuss computational part of research topics in theoretical physics such as High Energy Physics, Quantum Information, Quantum Optics, Theoretical Condensed Matter Physics and Plasma Physics.

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

Detailed Course Contents: The numerical methods learnt and applied include, 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, Statistical Mechanics, phase transitions and Ising model or Quantum Mechanics: time independent and time dependent Schrodinger equation, Research problems in the field of High Energy Physics, Quantum Information and Quantum Optics, Theoretical Condensed Matter Physics and Plasma Physics

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

- 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.
- apply numerical techniques in different research areas

Textbook: Nicholas J. Giordano, Hisao Nakanishi, *Computational Physics, 2nd ed.* Prentice Hall, 2005.
Reference Book: Mark Newman, *Computational Physics,* CreateSpace Independent Publishing Platform, 2012.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Handouts	Revision of Programming
2	GN 1, 2.1-2.3	Euler Method: First numerical problem: radioactive decay,Euler Method: Realistic projectile motion – air resistance, trajectory of a canon shell, motion of a batted ball
3	GN 2.4-2.5, 3.1	Range-Kutta Method: Throwing a baseball: effect of spin, golf, Euler-Cromer Method: Simple harmonic motion with dissipation, chaos, period doubling.
4	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.
5	GN 5.1-5.2	Jacobi Method: Electric potential and fields, potentials, and fields near electric charges
6	GN 7.1-7.4	Monte Carlo Integration: Why perform simulation of random process, random walks, self-avoiding walks, random walks and diffusion
7	GN 7.5-7.7	Monte Carlo Integration: Diffusion and entropy, cluster growth models.
8	GN 8.1-8.3	Statistical Mechanics, phase transitions and Ising Model
9	GN 10.1-10.3	Time independent Schrodinger equation, Shooting and Matching methods, Matrix approach
10	GN 10.4, 10.6	Variational approach, Time dependent Schrodinger Equation.
11		Special Topic
12		Project I
13		Project I
14		Project II
15		Project II