Detailed Course Description: Introduction to Computational Physics (PHYS 441)

Course Number PHYS 441

Course Title Introduction to Computational Physics

Target Audience Junior and senior level physics majors and minors, and majors in some engineering programs.

Prerequisites PHYS 136 or PHYS 138 or PHYS231 or PHYS251 with a C or better and COCS 101 or COCS 102 or COCS 111 with a C or better.

Catalog Description Explores modern scientific computational techniques needed by undergraduate physics majors and minors. Topics covered include applications in physics involving: numerical integration, numerical differentiation, special functions, Monte Carlo simulations, ordinary differential equations, chaos theory, machine learning, and other selected methods. This course incorporates an individual student semester project in computational physics and requires access to an appropriate computer for homework and the project.

Expected Previous Knowledge

Concepts Conservation of energy, conservation of linear and angular momentum, Newton's laws, Maxwell's equations, wave equation, central limit theorem, uncertainty principle.

Skills Able to calculate derivatives and integrals in 1-D, manipulate trigonometric functions, solve equations with logs and exponents, diagonalize matrices.

Course Objectives

After successfully completing this course, students should be able to: 1) Use computational techniques from this class to solve and explore topics addressed through the undergraduate physics program; 2) Develop and use elementary computational methods to solve physics problems; 3) Develop experience to assess the appropriate computational technique and necessary precision for the particular physics application; 4) Explain computational approach and methods used for selected homework to class; 5) Develop an individual semester-long computational physics project with advice of instructor; 6) Present computational physics project to class at end of semester with write-up.

Sample Text

"Computational Physics: Problem solving with Python", R.H. Landau with:

http://sites.science.oregonstate.edu/~landaur/Books/CPbook/eBook/index.html

or
"Computational Physics", M. Newman.

Minimum Material Covered
Python integrated development environment – PyCharm and Jupyter notebooks.
Numerical derivatives and integrals – ballistic motion, waves on a string, non-linear applications. Special functions – Higher-order Bessel's functions, Legendre polynomials, and spherical harmonics.

Monte Carlo simulations – Simulation of applications in elementary mechanics, solutions via random sampling.

Ordinary differential equations – Van der Pol's Equation and other nonlinear ordinary differential equations.

Chaos – Explore chaotic behavior for three-body problem, sensitivity to initial conditions, nonlinear systems.

Machine learning – Noisy data, improved accuracy of physical observables.