University of Sri Jayewardenepura

Department of Physics

PHY 308 1.0 - Computational Physics Practical

Lecturer in charge: **Dr. M. M. P. M. Fernando**

Number of lecture hours: **15**

Number of practical hours: **30 (or 45)**

Course Description:

The use of computers in Physics has grown enormously in the twentieth and twenty-first centuries, to the point where computers play a central role in virtually every new physics discovery. Assuming no previous computer programming experience, the course will introduce the basic ideas and programming skills of computational physics and students will develop their own computer software to solve problems in quantum physics, electromagnetism, biophysics, mechanics, chaos, nonlinear dynamics, mathematical methods in physics, geophysics, spectral analysis and other areas.

This course gives a modern introduction to the basic methods in computational Physics and an overview of the recent progress in scientific computing. Many examples from recent research in Physics and related areas are given with the Mathematica and other computer packages and computer languages. Basic computational tools and routines, including the ones for numerical integrations, differential equations, mathematical modeling, data visualization, spectral analysis, and matrix operations, are dealt with through relevant examples, and more advanced topics, such as quantum mechanics, mathematical methods in physics, geophysics, wavelet analysis, molecular dynamics, Monte Carlo simulations and quantum computing are also treated.

Objectives of the course:

- To familiarize the student with the multitude of applications available in Computational Physics using Mathematica.
- To make the student confident in writing programs to solve problems in Physics.
- To provide skills in extracting useful information in a set of given data related to a systems or phenomena in Physics and predict its future behavior.
- To provide the student with the confidence needed to solve advanced problems in Physics and Engineering, Medicine, Economics, … etc by the appropriate the use of Mathematica Computing Algebraic Package.

- To provide the student with the confidence to do self learning in advanced computer technology related packages such as GIS, AutoCad, ….etc.

Course Content:

1) Introduction to computational Physics using Mathematica as the computational tool.

2) Uses of Mathematica

   Mathematica as a calculator, as Software package and as a Programming Language
   Basic programming using Mathematica
   Animations
   Mathematical Manipulations
   Numerical Integration
   Handling Functions
   Simultaneous equations and Nonlinear equations
   Data visualization using Plotting Functions
   Conditionals and Loops
   List and Table Manipulation for data sets and Matrices
   Interpolation and Extrapolation
   Complex Numbers
   File Handling
   Input Box & Objects
   Animations

3) Mathematical & Computational Modeling - A method used to forecast on time dependent variables using discrete data arrays. (Weather Forecasting, Stock Market, … etc)

4) Solving Differential Equations in Mathematical Physics

   Newton's Law of motion and Molecular dynamics, Schrödinger equation, Electronic structure of atoms, …
   Maxwell's Equations in Matter, 1D and 2D Wave Equations, Laplace Equation, …
   Bi-Harmonic Equation for the Physics Problems

5) Introducing Signal Processing Techniques

   Simple Harmonic Motion and Damping Motion
   Real Physics Applications of Fourier Transforms (Forward and Inverse), Noise Elimination from Signals using FT, Fast Fourier Transform (FFT), Monte Carlo integration, Monte Carlo simulations, …
   Introduce Wavelet analysis and solving simple applications in Physics using *Haa* Wavelet

6) Miscellaneous Problems

   LRC Network handling in AC Theory, solution of Schrödinger Equation in Quantum Mechanics, Problems of Gravity and Magnetism in Geophysics, 3D Gravity problem (Forward & Inverse problems), Mathematical and Computational modeling in Multivalve

Functions in Physics (Variation of the Average Temperature of Atmosphere with Time, Variation of Atmospheric CO_2 percentage with Time, … etc)

Learning Outcomes:

At the end of this course, the student will be able to,

- Write programs for different tasks related to Physics and allied areas.
- Represent data in different forms such as 1D Plots, 2D Plots, 3D Plots, Contour Plot, Density Plot, Pie charts, Scatter Plots, Histograms, … etc.
- Write programs related in Physics and allied areas using simple and advanced commands/keywords in Mathematica.
- Illustrate behavior of a process through computer animation.
- Solve certain forward problems and some inverse problems related to Physics and allied areas.

Method of Evaluation:

Attendance	20%
Continuous Assessments	40%
Final Examination	40%

Recommended Readings:

1) A First Course in Computational Physics - Paul L. DeVries, John Wiley & Sons, Inc.
2) Numerical Recipes : The Art of Scientific Computing - William H. Press, Brian P. Flannery, Saul A. Teukolsky, and William T. Vetterling, Cambridge University Press.
3) Numerical Methods for Physics - Alejandro L. Garcia
4) Computer Simulation Methods, Applications to Physical Systems, Part 1 and Part 2 - Harvey Gould and Jan Tobochnik,
5) The Mathematica Book, Fifth Edition, 2003 by Stephen Wolfram
6) Programming with Mathematica, An Introduction. by Paul R. Wellin, 2013
7) An Introduction to Modern Mathematical Computing with Mathematica.
   by Jonathan Borwein, Matthew P. Skerritt, 2012