Computational Science Program for Ohio Community and Technical Colleges

Draft Competencies for Introduction to Computational Physics
March 2008

Competency/Descriptors
Identify the forces impacting the motion of a projectile and translate these forces into a mathematical model: **Descriptors:** Forces include the force due to gravity and drag. Effects upon these forces include air movement, variable mass, and variations due to temperature and altitude. Using Newton's Second Law develop differential equations and translate them into difference equations. Develop a computational model from these difference equations and solve them using a computational tool (e.g. Matlab, Excel, STELLA, Berkeley Madonna, Vensim, Mathematica, Maple). Compare the model results with analytic results and experimental data, identifying the sources of errors. Visualize the results of the model with the appropriate graphics. Example: Model of a baseball, golf ball or rain droplet having a variable mass.
Identify the forces associated with simple, damped and forced harmonic motion: **Descriptors:** Explain the principles associated with a dynamical system. Using Newton's Second Law develop and solve a system of differential equations that describe the system. Identify the critical parameters associated with each system type. Identify approaches that lead to a stable solution. Example: Model of a single mass on a spring and coupled masses on springs.
Analyze electrical circuits containing resistors, inductors, and capacitors: **Descriptors:** Utilize Kirchhoff's Rules to develop a system of differential equations that accurately model the dynamics of different types of circuits. Develop a simulation that will permit the study of steady state and transient characteristics of these circuits. Visualize the results of the simulation. Example: Model an LRC circuit (inductor, resistor, and capacitor) to display the frequency response and phase relationships.
Assess the numerical techniques utilized in a computational model and determine the impact of the techniques and algorithms on the appropriate solution to the

problem:

Descriptors:

Utilize Newton's Gravitational Force Law to calculate the motion and path of objects.
Model the orbital behavior of two astronomical objects in space.
Model an orbital transfer of a satellite using the Hohmann orbit transfer criteria.
Compare different algorithms for solving the problem.

Example: Model of a satellite orbiting the earth including orbit transfers.

Demonstrate the ability to model empirical data with mathematical representations:

Descriptors:

Determine unknown coefficients in a theoretical mathematical model using empirical data.
Analyze the appropriateness of a fitting function.
Transform curved graphs of empirical data using semi-logarithmic and logarithmic graphs to obtain fitting functions.
Identify trends in empirical data using regressions.

Example: Least squares fit of spectral data.

Describe Monte Carlo Methods and their application:

Descriptors:

Describe applications of Monte Carlo models
Discuss algorithms for Monte Carlo methods
Use a Monte Carlo simulation to generate an output distribution for a given distribution

Examples: Calculate the area, volume, mass and moment of inertia of an irregular shaped object. Model a physical material with variations in properties. Use cellular automata techniques to model a system with embedded uncertainties.

Conduct a Fourier analysis of linear and nonlinear signals:

Descriptors:

Decompose a periodic motion into a Fourier series.
Decompose a non-periodic motion into Fourier series.
Utilize the Discrete Fourier Transform algorithm.

Example: Obtain a Fourier transform of a highly nonlinear oscillator.