Back by Popular Demand

ECE 401: Numeric Modeling of Physics & Biological Systems

Course Offering – Fall Semester

Tuesday, Thursday: 9:30am – 10:45am

Room: TBD

Instructor: Dr. Wolfgang Fink

Contact Information:

Instructor: Dr. Wolfgang Fink
Associate Professor
Edward & Maria Keonjian Endowed Chair
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Office Hours: Wed 10am – Noon
Location: ECE Room #521
Course Description: This course combines themes from mechanics, electromagnetics, thermal physics, neural networks, and multi-dimensional optimization techniques with an introduction to numerical methods as well as the use of MATLAB. Students will become familiar with the underlying theory for a variety of systems in physics and biology (e.g., harmonic, anharmonic and coupled oscillations; computation of electric fields; geo-thermal power station; artificial neural networks; and multi-dimensional optimization techniques), derive the necessary mathematical framework describing these systems, learn the necessary numerical methods to simulate the systems and to solve the underlying equations, and actually implement these methods in MATLAB as a hands-on experience. As a result, students will be prepared to formulate problems in physics and related disciplines, and will have acquired a tool set that enables them to solve these problems numerically or in simulation.

Course Prerequisites: ECE 330, ECE 381, Math 254, PHYS 141, PHYS 143, PHYS 241 (if you do not meet the prerequisites criteria you may still be able to register after consulting with the instructor).

Course Requirements: Books and note readings, weekly homework assignments (20% of final course grade), 2 written midterm exams (each 20% of final course grade), and one written final exam (40% of final course grade).

For enrollment contact Marisa Pope-Malings: undergradadvisor@ece.arizona.edu
Required and Recommended Books:

1. **Required:**
   Wolfgang Fink  
   ECE 401 “Numeric Modeling of Physics & Biological Systems”  
   Class Notes @ Bookstore

2. **Required:**
   WH Press, BP Flannery, SA Teukolsky, and WT Vetterling  
   "Numerical Recipes in C: The Art of Scientific Computing"  
   Cambridge University Press, Cambridge, NY

3. **Required:**
   Holly Moore  
   “MATLAB for Engineers”, 3rd Edition  
   Pearson

4. **Recommended:**
   EW Schmid, G Spitz, W Loesch  
   "Theoretical Physics on the Personal Computer" (hardcover)  
   Springer, 2nd edition  
   ISBN-10: 3540522433  

5. **Recommended:**
   B Mueller, J Reinhardt  
   "Neural Networks: An Introduction"  
   Berlin: Springer

6. **Recommended:**
   J Hertz, A Krogh, RG Palmer  
   "Introduction to the Theory of Neural Computation (Lecture Notes vol 1)"  
   Reading, MA: Addison-Wesley

7. **Recommended:**
   DE Goldberg  
   "Genetic Algorithms in Search, Optimization and Machine Learning"  
   Addison-Wesley, 1989
Envisioned Detailed Course Description:

- **Module 1 (week 1): Basic introduction to Matlab**
  Students will become familiar with the *Matlab environment* and learn how to edit, compile, and run programs in Matlab.

- **Module 2 (week 2): Numerical differentiation**
  Students will become familiar with *numerical differentiation*.

- **Module 3 (week 3): Numerical integration**
  Students will become familiar with numerical integration techniques, such as: *Trapezoidal Rule, Simpson rule, Newton-Cotes Integration, Gauss-Legendre Integration*.

- **Module 4 (week 4): Harmonic Oscillations with Sliding and Static Friction**
  Students will become familiar with the numerical formulation of the harmonic oscillation problem, the *transformation of differential equations*, and the *Euler Method* for solving the differential equations.

- **Module 5 (week 5): Anharmonic Free and Forced Oscillations**
  Students will become familiar with the numerical formulation of anharmonic oscillations, the numerical treatment, an *improved Euler Method*, and the *Runge-Kutta Method* for solving the differential equations.

- **Module 6 (week 6): Coupled Harmonic Oscillations**
  Students will become familiar with the numerical formulation of coupled harmonic oscillations, the numerical treatment, and further application of the *Runge-Kutta Method* for solving the differential equations.

- **Module 7 (week 7-10): Artificial Neural Networks**
  Students will be familiar with *multi-layer feedforward networks, Hopfield Attractor Networks, Hebb-learning, Error-Backpropagation algorithm*, and other training algorithms.

- **Module 8 (week 11): Computation of Electric Fields**
  Students will become familiar with the numerical formulation of the electric field within a plate condenser, *discretisation of Laplace’s equation*, and the *Method of Successive Over-Relaxation (Liebmann Method)* for solving the numerical equations.

- **Module 9 (week 12): Geo-Thermal Power Station**
  Students will be familiar with solving the Fourier Heat Conduction equation describing the performance of a geo-thermal power station.

- **Module 10 (week 13-14): Multi-Dimensional Optimization Techniques**
  Students will be familiar with *heuristic optimization methods such as Simulated Annealing and Genetic Algorithms* for solving/optimizing multi-dimensional optimization problems that exhibit multiple local minima.
**Homework:** 20% of final course grade

**Midterm and Final Exams:**
Two written midterm exams (each 20% of final course grade) will be interspersed in the above schedule, followed by a written final exam (40% of final course grade) at the end of the semester.

**Grade Distribution:**
A: 85 – 100%
B: 70 – 84%
C: 55 – 69%
D: 40 – 54%
E: < 40%