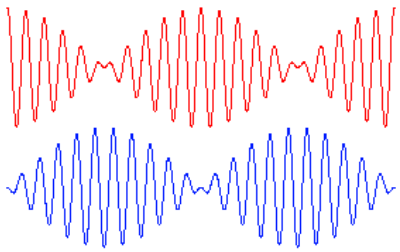
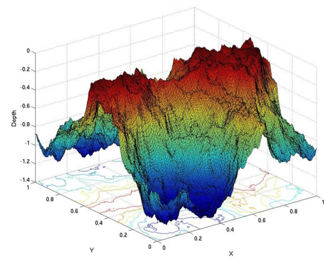
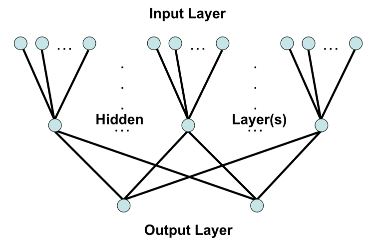
Technical Elective







ECE 411/511 - Numeric Modeling of Physics & Biological Systems

Course Offering - Fall 2017

Tuesdays, Thursdays: 9:30 AM – 10:45 AM
Room: Harvill #115

Course Description: This course combines themes from mechanics, electromagnetics, thermal physics, and neural networks 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 oscillators; electric fields of electric lenses; geo-thermal power station; and artificial neural networks), derive the necessary mathematical equations describing these systems, learn the necessary numerical methods to solve the underlying equations, and implement the system equations and numerical methods in MATLAB to simulate these systems. As a result, students will be prepared to formulate problems or model systems in physics, biology, and related disciplines, and to solve them numerically or in simulation.

Course Prerequisites: ECE 330, ECE 381, Math 254, PHYS 141, PHYS 143, PHYS 241, ECE 175 (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 undergraduate enrollment contact Sydney B. Donaldson: undergradadvisor@ece.arizona.edu

For graduate enrollment contact Tami Whelan: gradadvisor@ece.arizona.edu

Instructor and Contact Information:

Instructor: Dr. Wolfgang Fink
Associate Professor
Edward & Maria Keonjian Endowed Chair
ECE Dept./BME Dept./SIE Dept./AME Dept.
Dept. of Ophthalmology and Vision Science
Email: wfink@email.arizona.edu
Phone: 520-621-8734
Office Hours: Wed 10:00 AM – 12:00 PM
Office Location: ECE Room #521
http://ece.arizona.edu/wolfgang-fink
Course homepage: https://d2l.arizona.edu/
Instructor homepage: http://ece.arizona.edu/wolfgang-fink
D2L information: https://d2l.arizona.edu/

Teaching Assistant: Siteng "Star" Chen
Email: sitengchen@email.arizona.edu

Course Objectives and Expected Learning Outcomes:

Envisioned Detailed Course Description:

- **Basic introduction to Matlab**
  Students will become familiar with the *Matlab environment* and learn how to edit, compile, and run programs in Matlab.
- **Numerical differentiation**
  Students will become familiar with *numerical differentiation (Two-Point formula and Three-point formula)*.
- **Numerical integration**
  Students will become familiar with numerical integration techniques, such as: *Trapezoidal Rule, Simpson rule, Newton-Cotes Integration, Gauss-Legendre Integration*.
- **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.
- **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.
- **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.
- **Artificial Neural Networks**
  Students will be familiar with *Multi-layer Feedforward Networks, Perceptron Learning Rule; Error-Backpropagation algorithm; Hopfield Attractor Networks, Hebb-learning*, and other training algorithms, especially in the presence of noisy input patterns.
- **Computation of Electric Fields**
  Students will become familiar with the numerical formulation of the *electric field* within a plate condenser, *discretization of second order differential equation (i.e., Laplace's equation)*, and the *Method of Successive Over-Relaxation (Liebmann Method)* for solving the numerical equations.
- **Geo-Thermal Power Station**
  Students will be familiar with solving the *Fourier Heat Conduction equation* describing the performance of a geo-thermal power station using the *Fourier method* for solving partial differential equations.

Specific Outcomes of Instruction: *By the end of this course, the student will be able to*:

1. Use MATLAB for data manipulation, data plotting, and programming (411: basic; 511: advanced).
2. Numerically differentiate and integrate functions with several techniques of different accuracy and efficiency.
3. Transform systems of differential equations and solve them numerically with several techniques of increasing numerical accuracy.
4. Solve systems of linear equations efficiently.
5. Understand the underlying theory for a variety of systems in physics and biology, model these systems by deriving the necessary mathematical equations describing these systems, understand and apply the necessary numerical methods to solve the underlying equations, and program the system equations and numerical methods in MATLAB to simulate the systems.
6. Formulate problems or model systems in physics, biology, and related disciplines, and solve them numerically or in simulation.
7. Know and assess the validity, limits, and pitfalls of numerical simulations.

Relationship to Student Outcomes: *ECE 411/511 contributes directly to the following specific Electrical and Computer Engineering Student Outcomes of the ECE Department (H=HIGH, M=MEDIUM, L=LOW):*

(a) an ability to apply knowledge of mathematics, science, and engineering (H)
(b) an ability to design and conduct experiments, as well as to analyze and interpret data (M)
(d) an ability to function on multidisciplinary teams (L)
(e) an ability to identify, formulate, and solve engineering problems (H)
(f) an understanding of professional and ethical responsibility (M)
(i) a recognition of the need for, and an ability to engage in life-long learning (L)
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (H).

Absence and Class Participation Policy: The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/2015-16/policies/classatten.htm.

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored.
See: http://uhap.web.arizona.edu/policy/appointed-personnel/7.04.02

Participating in course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their healthcare provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

Course Communications: Homework assignments and important course announcements will be posted on D2L.

Required and Recommended Books:

1. **Required:**
   Wolfgang Fink
   ECE 411/511 "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"
   2nd Edition, Springer
   ISBN-10: 3540522433
   ISBN-13: 978-3540522430

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

Assignments and Examinations: Schedule/Due Dates:

Homework: 20% of final course grade *(Homework assignments will be posted on D2L).*

Midterm and Final Exams: Two written midterm exams will be given during the semester. Each is worth 20% of the final course grade. There will be one final exam at the end of the semester worth 40%.

FINAL EXAM DATE: *TUESDAY, DECEMBER 12, 8:00 AM – 10:00 AM*

Final Examination Information: The final exam will be held on Tuesday, December 12, 8:00 AM – 10:00 AM.
Final exam schedules for the University may be found at:
http://www.registrar.arizona.edu/students/courses/final-exams

Grading Scale and Policies:

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).

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%

Difference in Requirements for Graduate versus Undergraduate Students: Undergraduate and Graduate Students alike will be subject to the same two Midterm Exams and the same Final Exam. However, Graduate Students in contrast to Undergraduate Students will have additional, much more challenging homework assignments: Whereas Undergraduate Students will only engage in minor MATLAB programming exercises limited to existing code manipulations and execution, Graduate Students will have to program simulations for various physics and biological systems, including numerical and graphical outputs, entirely from scratch (e.g., harmonic, anharmonic and coupled oscillators; electric fields of electric lenses; geo-thermal power station; and artificial neural networks).

The respective scoring schemes for the Midterms Exams, the Final Exam, the Homework Assignments, as well as the overall scoring scheme for the class will be the same for Undergraduate and Graduate Students.

Requests for incompletes (I) and withdrawal (W) must be made in accordance with University policies which are available at http://catalog.arizona.edu/2015-16/policies/grade.htm#I and http://catalog.arizona.edu/2015-16/policies/grade.htm#W respectively.

Scheduled Topics/Activities:

Below is the tentative weekly schedule for the class. Assignment due dates and midterm exam dates are TBD and will be announced via D2L throughout the semester.

Week	Topic	Assignment Due Date (if applicable)
Week 1	First Day of Class, Wednesday, January 11 – Introduction to Course; Introduction to Matlab	TBD
Week 2	Introduction to Matlab; Introduction to Numerical Recipes; Numerical differentiation (two-point formula, improved two-point formula, three-point formula)	TBD
Week 3	Numerical integration: Trapezoidal Rule, Simpson Rule, Gauss-Legendre	TBD
Week 4	Harmonic Oscillations with Sliding and Static Friction; Transformation of differential equations; Euler Method	TBD
Week 5	Anharmonic Free and Forced Oscillations; Improved Euler Method; Runge-Kutta Method	TBD
Week 6	Coupled Harmonic Oscillations; Runge-Kutta Method	TBD
Week 7	Q&A for 1st Midterm Exam; First Midterm Exam	TBD
Week 8	Artificial Neural Networks (ANN): General Introduction to Neural Networks; Multi-Layer Feedforward Networks	TBD
Week 9	ANN: Multi-Layer Feedforward Networks; Perceptron Learning Rule; Gradient Learning; Error-Backpropagation algorithm	TBD

Week 10	ANN: Multi-Layer Feedforward Networks; Error-Backpropagation algorithm; Hopfield Attractor Networks; Hebb-learning	TBD
Week 11	ANN: Hopfield Attractor Networks; Projection Rule for noisy input patterns; Storage Capacities	TBD
Week 12	Q&A for 2nd Midterm Exam; Second Midterm Exam	TBD
Week 13	Electric Lens study system; Discretization of Second Order Differential Equation (i.e., Laplace's equation); Solving of Linear Equations; Method of Successive Over-Relaxation (Liebmann Method)	TBD
Week 14	No class – November 23, Thanksgiving observance – no class	TBD
Week 15	Geo-Thermal Power Station; Fourier Heat Conduction equation; Fourier method	TBD
Week 16	Q&A for Final Exam; Last day of Class, Tuesday, December 5	
FINAL EXAM	***TUESDAY, December 12, 8:00 AM – 10:00 AM***	

Classroom Behavior Policy: To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (i.e. texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Students are asked to refrain from disruptive conversations with people sitting around them during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Threatening Behavior Policy: The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to one's self.
See: http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations: Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact Disability Resources (520-621-3268) to establish reasonable accommodations. For additional information on Disability Resources and reasonable accommodations, please visit http://drc.arizona.edu/.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity: Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism available at:
http://www.library.arizona.edu/help/tutorials/plagiarism/index.html.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA email to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student email addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy: The University is committed to creating and maintaining an environment free of discrimination, http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy.

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.