INSTRUCTOR: Professor Richard Regueiro, richard.regueiro@colorado.edu
Office Hours: ECOT 421, TBD

DESIRABLE PREREQUISITES: Undergraduate Engineering Calculus sequence through Differential Equations and Linear Algebra.

OBJECTIVES: To introduce you to scientific computing for ordinary and partial differential equations (ODEs and PDEs) with applications to engineering/scientific problems. This course will provide you with a set of tools (numerical methods, proficiency with MATLAB) that you will use in other graduate courses, and potentially also in your thesis research. You will also gain a general awareness of computational approaches to problems in engineering, which will enable you to approach other classes of problems that we will not cover in this course, but may be pertinent to your research.

SYLLABUS: Rather than take the classical route to numerical analysis, which focuses on approximation and interpolation theory, numerical integration, solving systems of equations and finally ODEs and PDEs (APPM teaches a 3-course sequence along these lines), we have chosen to focus mainly on ODEs and PDEs; with some coverage of solving systems of equations. This is mainly because one of the most basic skills needed in subsequent graduate courses is to model systems described by ODEs and PDEs. There are other sub-branches in Numerical Methods, including Optimization and Statistics, which we will not cover in this course – these topics are covered in other courses (e.g., CVEN 5454).

We begin with an overview of MATLAB, which we have needed to fit into the course because most entering graduate students have limited previous experience with scientific programming beyond EXCEL (we may introduce a short Python tutorial as well). The numerical methods for PDEs we will cover are finite-difference methods. Again, this is in the interest of time. We have chosen to stay within the framework of finite-difference methods and cover a broader range of PDEs and boundary value problems, so you can see how a single approach applies to a variety of problems. Several other introductory courses on finite element methods are offered in the college (e.g., CVEN 5511).

Class notes will be handed out for all topics (see webpage on canvas.colorado.edu).

SUPPLEMENTARY READING: (You may purchase one of these books if you wish)
Introductory books/resources on MATLAB:
- Getting Started with MATLAB, R. Pratap (Oxford University Press)
- MATLAB - An Introduction with Applications, A. Gilat, (John Wiley and Sons)
- Engineering and Scientific Computations Using MATLAB, S. Lyshevski (Wiley)
- MATLAB’s help and documentation are very useful, see www.mathworks.com/help/matlab/getting-started-with-matlab.html

Useful References on Numerical Methods for ODEs and PDEs:
- Finite difference methods for ordinary and partial differential equations: steady-state and time-dependent problems, R.J. LeVeque (SIAM)
- Numerical Solution of Partial Differential Equations, Morton and Mayers (Cambridge)
- Numerical Recipes in (FORTRAN or C or C++), W. H. Press and others (Cambridge)
You may download Matlab for free from OIT: oit.colorado.edu/software-hardware/software-downloads-and-licensing/matlab.

SEQUENCE OF TOPICS

1. MATLAB programming overview and exercises:
   Project I - MATLAB codes for simple problems (e.g., root-finding, series summation).

2. Numerical methods for systems of ODEs (initial value problems):
   Project II - Writing your own ODE solver in MATLAB and using it to solve some ODE systems, comparison to MATLAB’s ODE solvers.

3. Heat/Diffusion equation and numerical methods:
   Project III - MATLAB codes for explicit and implicit finite-difference solutions to the one-dimensional heat/diffusion equation with applications.

4. Elliptic PDEs – Laplace’s and Poisson’s equations:
   Finite-difference discretization for 2D problems, matrix assembly and structure, sparse matrices, direct and iterative solution.

5. Basic Iterative solution of systems of linear equations arising from Laplace’s equation:
   Project IV - MATLAB code for iterative solvers applied to the Laplace/Poisson equation with examples from groundwater flow, membrane deflection, heat conduction.

6. Nonlinear boundary value problems and time-dependent PDEs – finite-difference discretization and solution using Newton’s method and Picard iteration:
   Project V - MATLAB code for a nonlinear PDE in one dimension (nonlinear diffusion-reaction or heat transfer with phase change).

7. Hyperbolic PDEs - first-order advection and wave equation – no project, but codes will be presented in class and discussed (time permitting).

GRADING:
10%: weekly problem sets during earlier part of course
10%: in-class midterm exam (open book, open notes)
65%: 5 programming projects at 13% each
15%: individual final programming project of your choosing (5 minute presentations during final exam period; final report due by end of final exam week)

One assignment (problem set or project, but NOT the final project) may be submitted 1 week late.
Otherwise, no late assignments will be accepted.

Zoom Meeting Information: TBD
   - Meeting ID: ??
   - Join via web browser: ??
   - Join via Zoom app (using meeting ID)
   - Join via One tap mobile: ??
   - Join via telephone: ??
For more information, visit the OIT Zoom website:
oit.colorado.edu/services/conferencing-services/web-conferencing-zoom/help/getting-started