AME 404 – Computational Solutions to Engineering Problems, Fall 2020

Lecture: MW 9:30-10:50 am (class # 28755D) ONLINE
MW 2:00-3:50 pm (class #28754R) ONLINE
MW 9:30-10:50 am (class # 29005D) DEN
Instructor: Takahiro Sakai, Ph.D.
Email: tsakai@usc.edu, **Office:** OHE430H
Office Hours: Mondays 4-6pm ONLINE (start from the 2nd week)
Textbook: Not required.
Supplemental book: Gilat and Subramaniam, *Numerical Methods for Engineers and Scientists*, Wiley
Teaching Assistant / TA Office hours :
Haotian Hang (haotianh@usc.edu): Grading & Piazza
Chan-Ye (Chris) Ohh (ohh@usc.edu): Tue 7-9pm; Thu 4-6pm; Fri 9-11am ONLINE (start from the 2nd week)

Online Course Portal: This course is managed by D2L learning management system. Google "usc den" and click the first hit or go to https://courses.uscden.net/d2l/login and login using your FULL USC email address. Access links for lectures are set up in D2L and are delivered through **WebEx** (similar to Zoom). All the assignments are to be submitted to Dropbox set up in D2L.

Catalogue Data: Mathematical aspects of the solutions to typical advanced mechanical engineering problems. Modeling, simulation, computational aspects, computer solutions, and computational tools.

Course Objective: This course introduces numerical methods in solving typical advanced problems that arise in aerospace and mechanical engineering, including dynamical systems, solid/fluid mechanics, vibrations and heat transfer. Mathematical modeling of governing physics, analytical solutions to ideal problems and numerical error analysis will be also provided. Many computer assignments provide the students the opportunities in solving problems by writing computer programs.
Recommended Preparation: Math245, ITP168 (MATLAB), Senior standing

Selected Topics (some topics may change):

1. Numerical Simulations of Dynamical Systems
   - Modeling of the 1st order, the 2nd or higher order ODEs and the 1st order systems
   - Integration methods of Ordinary Differential Equations
   - Stability of dynamical responses
   - Fourier spectral analysis, Frequency Power Spectrum
2. Numerical Solutions to Two-point Boundary Value Problems (BVP)
   - Iterative method (the shooting method)
   - Direct method
   - Modal solutions (Eigenvalues and Eigenfunctions)
3. Numerical Solutions to Partial Differential Equations (PDEs)
   - Finite differences
   - Solution methods of linear system equations
   - 1D heat conduction problems
   - 2D steady state heat conduction problems
   - Transport equations
   - Introductory computational fluid dynamics problems

Grading Plan: Homework 25% and three projects, 25% each.

Computer Programming Language: MATLAB programming language is required for this course. Students are assumed to have a beginner-level MATLAB programing skill, which includes <u>Matrix and vector computations, whole-array (dot) operations, array element definitions and manipulations, if-constructs, for-loop, while-loop, user-defined functions and subfunctions, structure/cell arrays and basic 1-D plotting.</u> MATLAB is freely available from USC ITS at https://itservices.usc.edu/software/. You can use any version of MATLAB. Recommended MATLAB tutorials: Attaway, *Matlab: Practical Introduction to Programming and Problem Solving*, Butterworth-Heinemann.

General Assignment Policy (read carefully):

- Students are expected to work on assignments independently. Discussion with peer students is not discouraged. However, students must write computer programs <u>independently</u>. Your work will be carefully monitored for academic integrity throughout the semester. If graders determined that academic plagiarism is highly likely, then the work will receive a score of zero. If the plagiarism persists, then such a case will be filed to Student Judicial Affairs & Community Standards (http://www.usc.edu/student-affairs/SJACS) with a recommended course grade of F.

- Your questions on grading will be accepted for ONE-WEEK counting from the day the homework is returned (one week after the due date), and the grade will not be changed thereafter (even the answer is correct) and no appeal or excuse will be accepted. It is your responsibility to track all your credit record up to date.
- Due date will never be compromised. Please note that late submission is NEVER accepted (NO EXCEPTION). This includes a post-due supplemental submission. You are responsible to make sure your online submission is successful.
- In general, submitted work must include computer program (REQUIRED) and results (REQUIRED) other than that required by the assignment. Do NOT forget attaching the computer code for full credit. It is strongly recommended to type all your work and paste results and codes in the same document and save it as a **pdf-file**.
- Grading is based on ACCURACY of the results and QUALITY of presentation. Computational work would be valuable, only if correct results were produced timely and presented in clear way. Students are responsible for every line of their code and must be *careful* because even one incorrect line will produce entirely incorrect results which can cost substantial amount of the score. If the presentation of your results is unclear, you will not be able to receive full credit even you obtained correct results. But *some* partial credit will be given, even if the program does not output correct results, as long as your code is presented.
- **All assignments must be submitted electronically to a Dropbox set up in D2L.** Submitted document must be **a single PDF file** in which ALL required work (e.g., results and codes) are included (NO .zip, .tar, .rar., .docx, etc., unless as otherwise required by the assignment). The Dropbox can accept multiple submissions, but the most recent submission will be graded. If you submit a revised file, you MUST write a note to the grader in the submission menu box. Please DO NOT directly email your work to us. NO EXCEPTION. All informal, non-conformable submissions will be ignored.
- Please refrain from emailing your code to the instructor or TAs and simply ask for debugging it, because it usually takes a while in bug identification plus when we receive many codes at a time (this actually happened before), we won't be able to respond timely to each of you. Therefore, students are rather encouraged to directly consult us during our office hour.
- We will STRICTLY and CONSISTENTLY follow these policies throughout the semester.

Project Assignment Policy:

- Project is considered as a "take-home exam". Instructors will assist you in clarifying the problems but NOT in technical details of computer programming, including DEBUGGING and in "clarifying CORRECTNESS" of your answers.

Piazza: This course adopts piazza online discussion system (https://piazza.com). During the first week of the semester students will be notified to set up your piazza account for this course. Please post your question in public mode. Please refrain from posting your code and answer to avoid their improper use by others.

Academic Integrity: The Department of Aerospace and Mechanical Engineering adheres to the University's policies concerning Academic Integrity as described in SCampus. All faculty, staff and students share the responsibility for maintaining an environment of integrity. Students are expected to be aware of, and to observe, the academic integrity standards set forth in SCampus. We will collectively follow these standards in this section of AME 404.

Homework Grade Scale: Homework grade is scaled into quintile based on the level of correctness. **5:** 90% or more; **4:** 80-90%; **3:** 60-70%; **2:** 40-60%; **1:** less than 40%

Course Letter Grade Scale: The course final grade is determined automatically based on the following numerical scale applied to the total weighted score. Number under the decimal point is rounded to a nearest integer.

A	93-100	C	73-77
A-	90-92	C-	70-72
B+	88-89	D+	68-69
B	83-87	D	63-67
B-	80-82	D-	60-62
C+	78-79	F	59 and below

Tentative Schedule and Assignments

week	Day	Topics	Assignment	Due date
1	17-Aug	Intro to the 1st order models, Numerical solution of the 1st order ODE, Euler's method		
	19-Aug	Numerical accuracy, Runge-Kutta method, ode45 built-in function, integration error control, Stiff ODEs and Matlab family of ODE solvers (ode113, ode23, ode15s, ode23s, etc.)	Hw 1	Fri 8/28
2	24-Aug	Numerical simulation of the 2nd-order model (spring-mass-damper system)		
	26-Aug	Simple pendulum model; Optionally intro to higher order model (multi-degree of freedom problem, application of Lagrange's equation of motion)	Hw 2	Fri 9/04
3	31-Aug	Numerical simulation of high order model - Heat exchanger system		
	2-Sep	Airplane longitudinal dynamics; system matrix, eigenvalue/vectors, stability	Hw 3	Fri 9/11
4	7-Sep	**Labor Day (Holiday)**		
	9-Sep	Fourier series - Review: periodic functions, Fourier modes, convergence, Gibbs phenomenon		
5	14-Sep	Fourier spectral analysis - complex Fourier series, Discrete Fourier Transform (DFT), Inverse DFT, Nyquist frequency, Frequency Power spectrum	Project 1	Fri 10/09
	16-Sep	Fast Fourier Transform (FFT), numerical treatment of non-uniformly sampled signals & non-periodic signals, aliasing error	Hw 4	Fri 9/25
6	21-Sep	2pt Boundary Value Problem (BVP) - the shooting method, numerical solution to the laminar boundary layer (Blasius) equation		
	23-Sep	Modal solutions of 2pt BVP - Torsional vibration of a shaft: modal shapes, modal frequencies	Hw 5	Fri 10/02
7	28-Sep	Torsional vibration of a shaft (cont.) - Implementation of shooting method; Project 1 - Review		
	30-Sep	Intro to PDE: classification, derivation of the heat conduction equation, boundary conditions		
8	5-Oct	1D steady heat equation: Dirichlet problem - Finite differences, tridiagonal system	Project 2	Fri 10/30
	7-Oct	1D steady heat equation: Neumann problem, consistency, numerical accuracy, convergence	Hw 6	Fri 10/16
9	12-Oct	Steady heat conduction in a circular rod submerged in water, numerical treatment of the pole		
	14-Oct	Steady heat conduction in a gas turbine blade, variable shape, convection boundary condition	Hw 7	Fri 10/23
10	19-Oct	2D steady heat conduction: Fourier series representation of solution, scalar/vector field plotting		
	21-Oct	2D steady heat conduction: numerical implementation of direct method		
11	26-Oct	2D steady heat conduction: iterative solution approach - Jacobi, Gauss-Seidel, SOR methods	Hw 8	Fri 11/06
	28-Oct	1D unsteady heat conduction: Fourier series representation of solutions, making computer animation of time-dependent solutions by using Matlab		
12	2-Nov	1D unsteady heat conduction: Explicit scheme (FTCS scheme), Numerical stability		
	4-Nov	1D unsteady heat conduction: Implicit scheme I (Fully Implicit method), Neumann BC	Project 3	**Mon 11/23**
13	9-Nov	1D transport equation (linear advection-diffusion), upwind scheme, MacCormak's scheme		
	11-Nov	Project 3 - Review		

Disclaimer: This syllabus is tentative and subject to change as needed during the semester. Any changes will be announced in class in advance.